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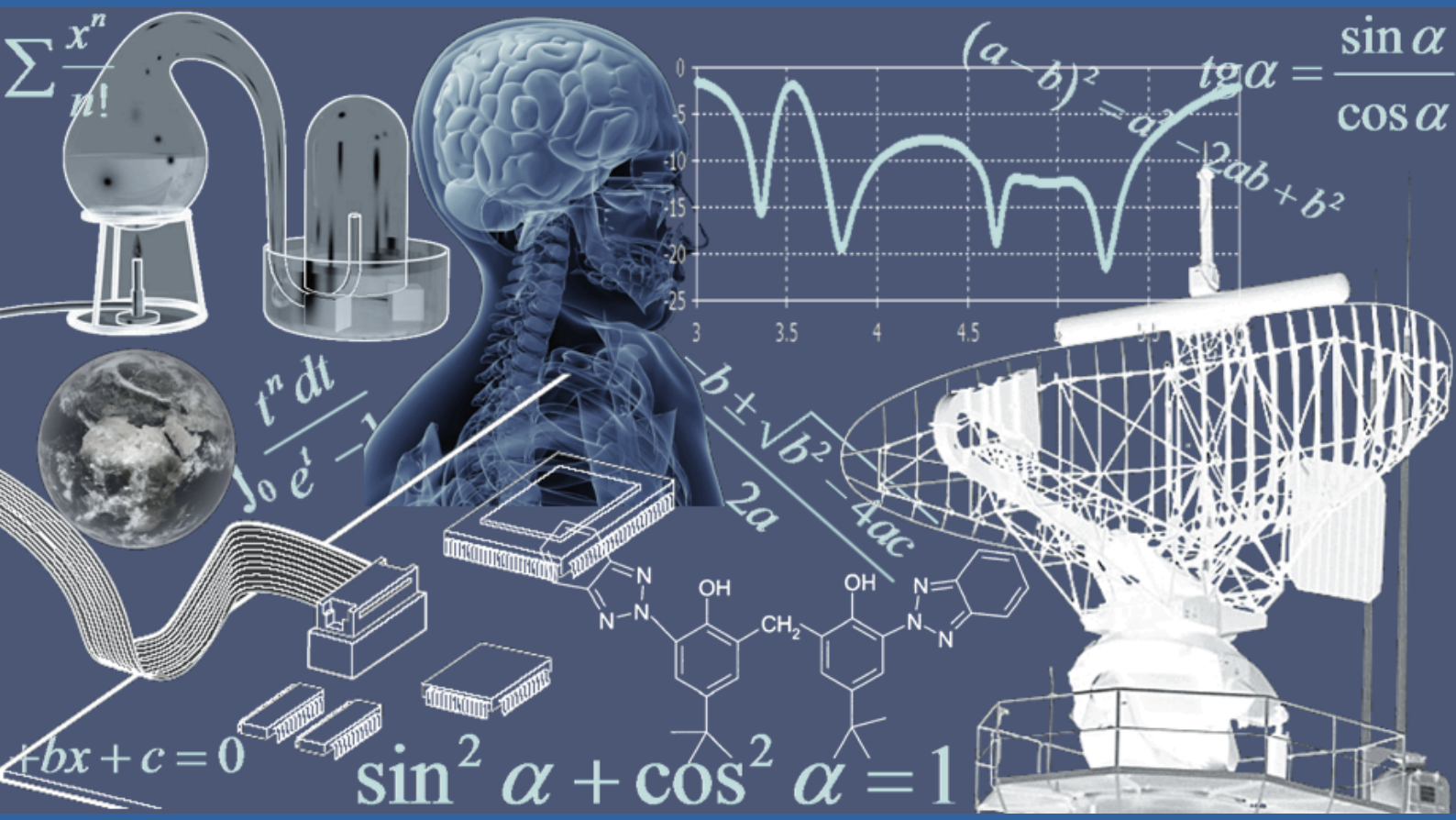

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A Review assessing the "used in the art" Intellectual Property Search Methods and the Innovation Impact therewith

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ABSTRACT: Is Intellectual property (IP) central to innovation or is innovation central to IP? Univocally, patent valuation starts before drafting. Then IP is a valuation step such as innovation is. Equally "innovation is not the idea, but what you do with it". Then can ideation be engendered by artificial means?

Nearly 60 years have passed since the birth of artificial intelligence and the initial dream of a machine possessing the full-range of human cognitive skills still belongs to science-fiction. However software using artificial intelligence are more and more present in our daily life. This is particularly true in the domain of information retrieval. Today's amounts of data one can access through diverse media necessitate the use of "clever algorithms" to find relevant material. This applies even more to the domain of IP.

Companies' whole innovation strategy relies significantly on the analysis of patents, scientific publications and other IP documents. It is therefore crucial for them to extract in the most efficient way the best of the available information. The purpose of this paper is to give strategists, researchers, business analysts… the possibility to understand what is behind the tools they use.

Furthermore we demonstrate that the current dominant search technologies cannot fully support today's economic challenges and that better solutions are at reach. We also review the transferable technologies and methodologies. This inventory has also for objective to draw attention to some promising directions to follow and advocate for.

For example the semantic and image combined mining, comprising interpretation, ideation and reinvention, is a tremendous opportunity to boost the innovation process via the exploration and exploitation of the IP and NPL (non-patent literature); especially when performed by enlarged teams comprising the engineer, scientist, IP strategist, business model expert…

A significant literature base is reviewed along with examples probing the reality and revealing innovation opportunities.

KEYWORDS: Innovation, collaborative, Collaboratory™, adjacent technology analysis, ATA©, IP strategy, semantic analysis, image analysis, artificial intelligence, reverse engineering, reinvention, neo-retro-innovation, iPad®.

Disclaimer: This article is primarily for educational purposes. Selected cases are strictly illustrative. Neither the author nor the illustrator assumes any liability for any errors or oversights, or for how this article or its contents are utilized or interpreted, or for any consequences resulting directly or indirectly from the usage of it.

This assessment is intended to educate and raise awareness of some of the complex issues that surround the intellectual property in the field of knowledge extraction from the about 80 million patent documents available, and to assist in the development of practical skills for dealing with inventions and innovation in general. It does not seek to provide legal, managerial or technical advice on intellectual property related law as such. For any guidance, legal or any other, seek advice from the appropriate professionals; this study can by no mean substitute for expert legal, technical and managerial advice.

The opinions expressed by the writers in this article do not necessarily represent the viewpoints of the companies the author are employed by.

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1 INTRODUCTION AND MOTIVATIONS

Innovation is a growth engine

This study combines and complements elements of the presentation at the Geneva Corporate Innovation Forum of October 6th, 2011 and the plenary lecture given at the International Symposium on Green Chemistry held in La Rochelle on May 21-24th, 2013. It also constitutes a logical continuation of the latest work by Rebouillat [1] (Rebouillat, 2013) untitled "A Science & Business Equation for Collaborative Corporate Innovation" whereby "Business Strategy, IP Strategy and R&D Strategy are the base of an all-in-one Business Model".

In the frequently cited open-innovation context, the business engineer would have to be a Creative-Connoisseur and a Competent-Communicator. But also should conform to almost any profile corresponding to any combinatorial arrangements of the four word roots, 4C©, as depicted on Figure 1.

This reality is taking place and requires the implementation of specific agreements and tools, which can help the sharing of confidential data and the exploitation of public data available by the 100's of million. IP in general and more specifically patents are seen as a monopoly, thanks to a legal situation, which at some point of time became a deterrent; patent is evolving as a mean to boost innovation, thanks to easier access to the 80 some millions of patents reachable by the engineer, scientist, IP strategist, business model expert.

Therefore it might be useful to separate the legal aspect of patent and the technology part; grossly distinguishing the specifications part of the patent document, being a technology and science rich arena for the IP technology strategy expert, and, the claims being the fertile area exploited by the patent lawyer performing the freedom to operate exercise for example.

The appraisal of the patent adjacent technology content via adjacent technology analysis, ATA© [1] (Rebouillat, 2013), led the way to a better characterization of the patent strength. The recent introduction, on top of the patent count per year, of several trademarked, although already existing criteria, such as "Science Strength™" and "Technology Strength™", is a logical step.

The further adoption by patent specialized boards and "patent mining" companies of such criteria led to the recognition of scientifically and technology driven companies such as the one performing business for more than 212 years with a real growth engine based on innovation [2] (www.prweb.com/releases/2012/3/prweb9280362.htm).

Concerning classifications, the world number one company in terms of portfolio count in 2012 is ranked number 3 in the brand value classification; the company ranked number 6 in the brand value classification in 2012 is also ranked number 6 in terms of the portfolio count ranking. Three of the 6 first patent portfolio counts are part of the 10 first valued brands.

Brand and patent count classification seem to get closer as patent portfolio average quality improves with time, i.e. a better alignment of patent strategy with business strategy. The race for "patent count" might be in obsolescence. But the race is still on, slowly shifting towards a "quality rather than quantity" based race.

Undoubtedly patent, IP in general, science and technology in an open innovation context are to lead growth as long as integrated in a larger business model frame of work.

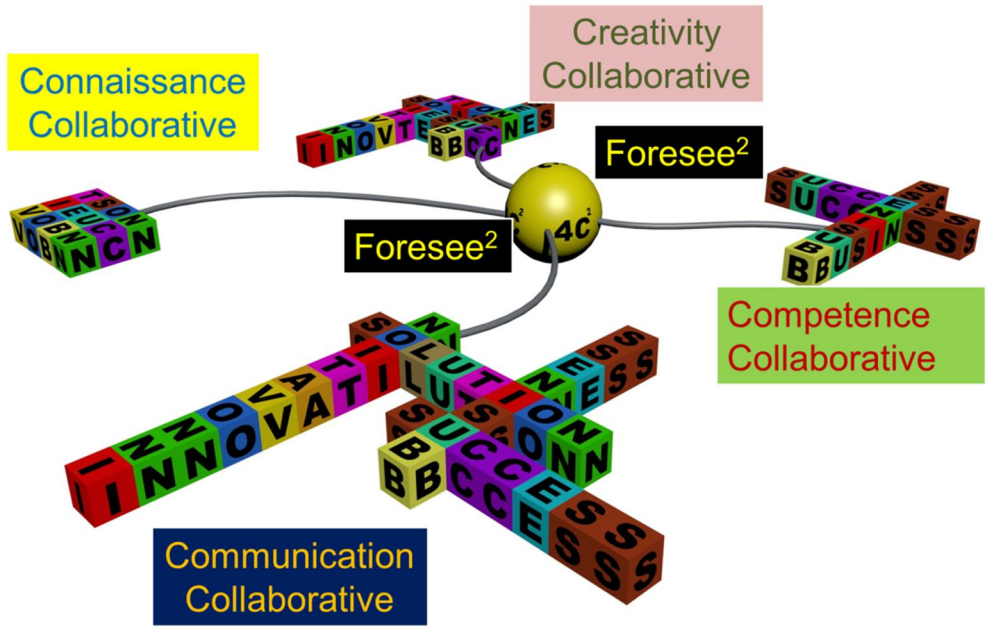

Fig. 1. Foresee Square, 4C²©

In parallel an explosion of applications and publications of various kinds via traditional and e-media is taking place.

From 2008 to 2010 WIPO received about exactly 5,000 new patent applications per day, and Medline received about 110 new articles per day in 2010.

The explosion of design patents in China, more than 500,000 in 2012, i.e. 10x the USPTO or the EPO numbers, has been reported at several occasions by the specialized press. Also described is an "All-time high for activities of the European Patent Office in 2012" which tend to put patent growth in a worldwide context [3] (www.epo.org/about-us/annual-reports-statistics/annual-report/2012/statistics-trends.html).

Within the patent context of novelty, specialized search engines are being made available to provide links to older archived versions of a webpage such as the "way back in time" machines dedicated to electronic archive detection. This is a welcome initiative as underlined below.

To the complexity of finding the right information on time is added the complexity of interpreting; the two are for obvious reason closely linked.

Starting from History review… What's next?

The concept of "information retrieval" as we know it today was introduced by Calvin Mooers from the MIT in 1950 following the birth of digital computers [4] (Garfield, 1997). The potential benefit of these machines as automated searching systems was evident from the beginning and scientists started developing retrieval and indexing algorithms early on. First applied to scientific and medical literature for military purposes, information retrieval has become nowadays an essential activity of our modern life style. The incredibly large amount of data one can access for example on the web, necessitates the use of more sophisticated tools. According to a survey from netcraft.com in October 2013 the web contained over 189,176,770 active websites, a 942 % increase in 10 years [5] (Netcraft.com, 2013). Companies such as Google Inc., Yahoo! Inc. and others have built their core expertise and reputations on indexing and retrieving information.

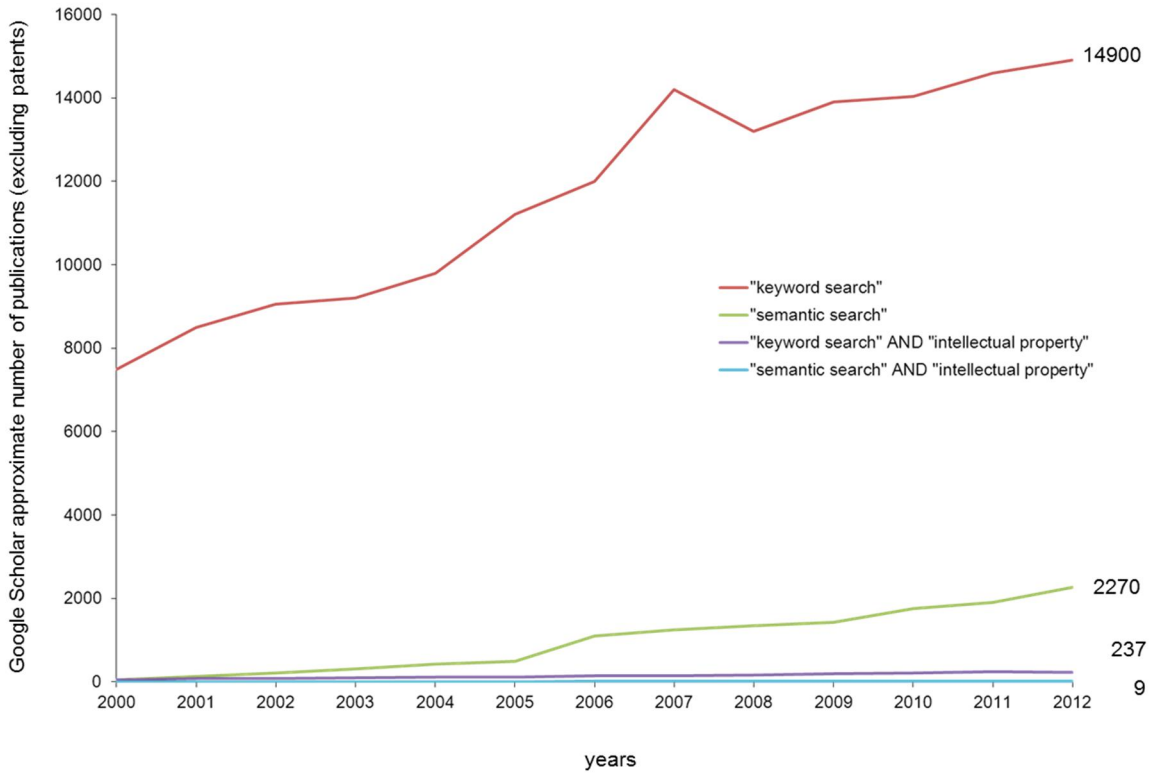

Fig. 2. Search Trends

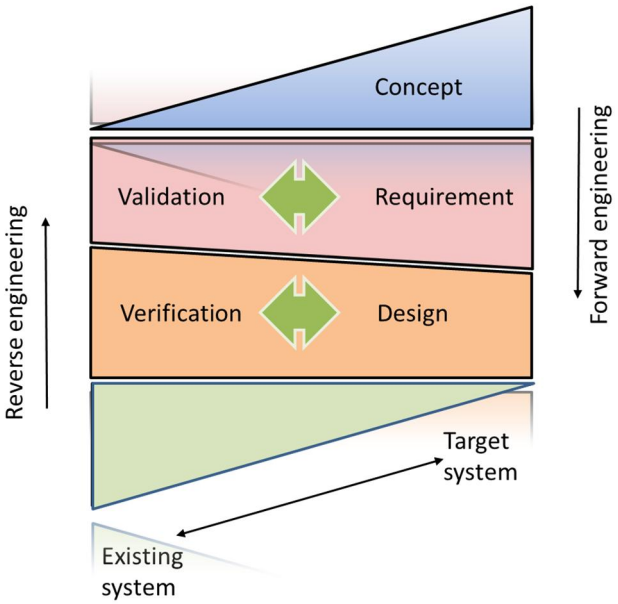

Fig. 3. Reverse Engineering & Reinvention

If the accuracy of search technologies is important for daily requests, it becomes critical when the result directly impacts the chances of survival of a company against an ever growing competition. IP is at the centre of the economical battle and its global analysis through patents, publications, reports, is essential for technological developments and strategic planning. Data have grown enormously in the past few years and traditional search methods may struggle to further cope with the amount and complexity of the documents to be treated. In 2012, the US Patent and Trademark Office granted more than

275,000 patents and Elsevier, the biggest scientific and medical publisher, accepted more than 250,000 articles [6] (Elsevier, 2013); (Figure 2) with more details in section 3.1.. Infringements are also strongly dependent on the ability of search engines to give the right answers to users' queries. In 2012 the number of patent lawsuits filed in US increased by almost 30% compared to 2011 to over 5,000 [7] (PwC, 2013). It is therefore not surprising to see that IP search and companies behind these services are the centre of a lot of attention.

One shall not exclude the perfectly legitimate reinvention methods, as shown on Figure 3. The House-of Quality, the Quality Function deployment (QFD), the Voice-of-Customer (VOC), the Theory-of-Constraints (TOC), the integrated Theory of Inventive Problem Solving (TRIZ), Six Sigma, the 4A method (Accountability-Accreditation-Assessment-Articulation), the Resource-Activity-Results Method (RAR), etc. have paved the way to promote best practices, to boost and to secure the innovation processes and routes to market of multigenerational products and processes.

Most of these approaches, individually or integrated in innovation management processes, have now got Wall Street's attention and became prerequisite to a good design of a portfolio of products. Those methods rely heavily on integrating the most pertinent knowledge.

However there seem to be some expectations divergences between users, software developers and lawyers regarding the finality of IP search. Search companies have for many years favoured a form of search based on keywords, something we practice every day when using Google. Despite some advantages that will be discussed in this review, this technology is not necessary appropriate for patent search and rely mainly on searchers' expertise and on the size and quality of databases.

A particularity of patents text is the jargon used to describe objects making it extremely difficult to write accurate queries. In fact, the word "computer" can easily be replaced by "a system having a storage for storing data, an output device to display information, a terminal for entering information, and a component that modifies the input data and controls flow of data between different parts" [8] (Lupu, 2011). The human brain on the contrary to machines is perfectly able to understand that this latter list of words is in fact a computer without the presence of the actual keyword "computer". In order to do so it uses semantics, i.e. each word has a meaning and is used in a context giving only one or a very limited number of possible interpretations. Semantic technologies take their roots in linguistic where each word is more than just a string of letters. Because the human brain is not able to treat the amount of information necessary to perform an exhaustive search, powerful algorithms using artificial intelligence (AI) have to be used [9] (WIPO, 1991). AI is the key to potentially mimic what the brain can do effortlessly but on a much bigger and faster scale. These solutions exist already in search software but their implementation to professional IP search engines has been delayed. Despite numerous publications and attempts by scientists to bring this technology to the application level [10], [11] (Magerman, Looy, & Song, 2009; Spyropoulos & Botsivaly, 2009) only few companies implemented these solutions.

Another activity mastered by humans is image detection. It takes no more than 170ms for the brain to go through the whole process of face recognition [12] (Liu , Harris, & Kanwisher, 2002), one of the most difficult visual tasks to perform. This complex procedure is not trivial to achieve with a computer and has been barely touched in IP search. Because patents and publications are full of diagrams and technical drawings, image recognition technology which exists and is used in other fields [13] (Zhao & Chellappa, 2003), is a necessary step for a search to be complete. The semantic and image combined mining, comprising interpretation, ideation and reinvention, is a tremendous opportunity to boost the innovation process via the exploration and exploitation of the IP and NPL (non-patent literature); especially when performed by enlarged teams comprising the engineer, scientist, IP strategist, business model expert…

The legal aspect of intellectual property is another limitation for a global, collaborative system. Learning is a necessary process if one wants to acquire knowledge and this also applies to AI technologies. However in an open innovation scenario, the absence of interactions between the queries made by one strategist in company A and one in company B make it even more complex to develop the ultimate *in silico* researcher "driven" by an engineer, a scientist, an IP strategist, a business model expert.

One aim of this review is to make it easier for IP search technology users to understand what is behind the black box they use every day; to give an overview of the new tools available inside and outside the field; to assess where we stand and where we go; and to highlight some of the most needed developments and possible future directions.

From an open innovation perspective and framework

Another aim of this review is then to promote and boost innovation beyond the fear associated with the paradigm connected to the word "open" innovation and the ever increasing and contrasting need for trade secret management. Let's

underline some principles that may alleviate part of this archetype and help the reader through an appeasing journey, along the proposed review trail.

The IP protection insurance and the innovation strategy are of evergreen vital importance. Close coaching and consultancy beyond administration and legal attention, is ideally performed by the innovation strategist well versed in IP matters, with a broad experience and knowledge of business and technology functions – a rather new and emerging role requiring strong mediation skills. In a joint development the exploration phase is likely, in most case, the most decisive and premonitory one for the future overall success. The exploration phase can be defined as per following [1] (Rebouillat, 2013).

The parties explore the possibility of working together, a mutual one-way or two-way confidentiality agreement being in place. Sample and/or material transfer agreements may be used in this incubation phase.

- Identification of interest areas, business and cultural fit is necessary;

- A clear understanding of what each party brings, such as technology expertise and areas of interest shall be established;

- An open discussion mind-set,

- and an agreement on vision for success shall be reached.

2 INTELLECTUAL PROPERTY SEARCH

2.1 IP MATERIAL: THE FIRST CHALLENGE

Some of the most apparent benefits of patent documentation include:

- description of inventions in a way that is aimed at facilitating their reproduction in practice;
- coverage of material which is, by definition, genuinely new and not earlier available to the public;
- the matter of interest is almost universally categorized by a single international cooperative classification system;
- the documentation access is free of charge;
- the patent document appears in a common format; and
- cross-referencing between documents is generally handy;

Patent information is appreciated for a multitude of purposes. This can rank from a foremost study on technological advances in a particular area (e.g. current status of research into AIDS therapy), or a very specific single examination (e.g. is a patent still in force in a given country?). The strategies and methods used for searching patent information therefore vary extensively, contingent on what the information is to be looked for.

The International Patents Classification, IPC, and its cooperative version CPC, are the universal patents classification systems, which are administered by WIPO, EPO and USPTO. Those classifications can therefore form the foundation of a search of the patent literature and quite a few databases may be explored using them.

Frequently made comments include the following drawbacks:

1. “the IPC has insufficient subdivisions and some of the specific subdivisions are already full;
2. IPC revisions are slow and sometimes incomplete in technological fields of rapid changes;
3. it is not specialized for biotechnology inventions;
4. classification into the IPC is not consistently applied in different Patent Offices;
5. use of the IPC for searching requires detailed understanding of technology and the IPC; and
6. the information classified into the IPC is, of course, limited to patent documents.”

We think it is then important here to clarify what IP search is or should be if one wants to use it not only for document retrieval purposes but as a generator of innovative ideas. Furthermore there seems to be discrepancies between the material uses by professional searchers and what is used for the development of new techniques. When reviewing the literature one quickly notices that a great number of publications [14], [15], [16], [17], [18], [19], [20], [21], [22], [23] (Wang et al., 2011; Yoon et al., 2011a, 2011b and 2012; Trappey et al., 2009; Tang et al., 2012; Jessop et al., 2011; Archibugi et al., 1996; Wanner et al., 2008; Wu et al., 2012) or patents [24], [25] (US5,774,833; US8,161,049B2) related to the development of search tools on IP limit their field of application to patents. There are several good reasons for that. Whatever search one performs the

availability of documents is the key factor and patents are freely available through the web. They do also have the advantage of a certain uniformity of format which facilitates some aspects of a search. However the IP domain would suffer a lot if patents, despite their crucial role, would be the exclusive source of inspiration. IP search should incorporate scientific publications, websites, conferences, technical disclosures, defensive filings, brochures and all information that can describe the subject of interest [8], [26] (Lupu, 2011; Codina et al., 2008). Here start the problems, e.g. the total lack of uniformity and sometime the difficulty of accessing such documents. Scientific publications contain a great deal of precious information fundamental for designing future innovations. However scientists and public institutions rarely consider the patenting of knowledge as a natural research step. Moreover, a big part of these publications belongs to publishing companies which, for most, do not provide free access to the manuscripts and their cost can often be a limitation. Even if all these documents would be freely available their retrieval would still be a challenge due to the absence of a global homogeneous indexing system. Some open source search engines, such as FPO, do have a NPL interface that provides scientific articles; this deserves to be underlined. This idea was proposed at the end of the 90s as the semantic web [27] (Greenbaum & Gerstein, 2007), this issue will be discussed later in chapter 7.2. Because of the aforementioned difficulties in broadening the field of IP search, a large part of this review will deal with technologies developed for patent analysis. But we believe that this information apply to all IP documents.

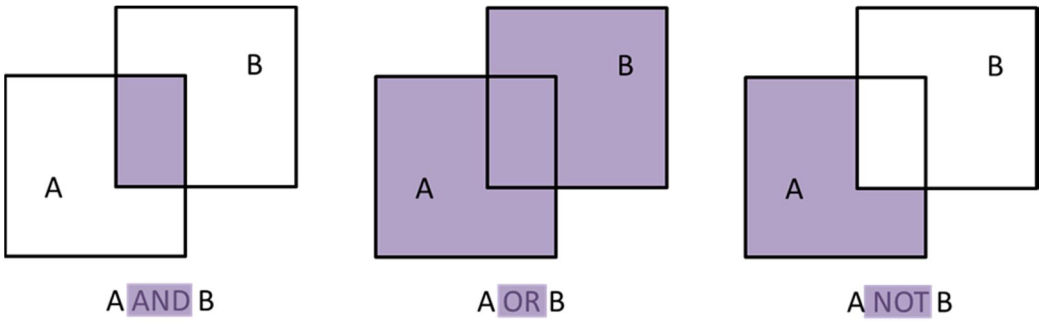

Fig. 4. Boolean Search

2.2 AVAILABLE TOOLS

Before going further into the technical details of IP search it seems important to give an overview of the available technologies. The list provided below does not pretend to be exhaustive but intends to give a broad vision of the current market.

We can divide IP search engines into two broad categories: the free and the paid ones. The free solutions can as well be subdivided into two subcategories which are the systems focusing almost exclusively on patents and those combining it with scientific publications and conference reports. The first category includes the five main institutions granting patents namely the United States Patent and Trademark Office (USPTO), the European Patent Office (EPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the Korean Intellectual Property Office (KIPO) and the Japanese Patent Office (JPO) as well as the World Intellectual Property Organization (WIPO) and data miner engines such as Google Patent Search, The Lens [28] (Jefferson et al., 2013), and Free Patent Online. They are all based on keyword search technologies. The strength of these systems relies on their huge indexed databases, the possibility to look for patent applications and documents are updated regularly. These are interesting tools when one wants to explore quickly a topic or search for a specific patent. The main drawbacks of these software are the restriction of search to patents mostly and the lack of other functionality than the basic Boolean keyword-search and associated tools, with some exceptions, for example The Lens (Figure 4). They can be assimilated to public libraries which offer a logical indexing and search system if one knows what he is looking for. In the category of free solutions, the second subcategory would include engines such as Google Scholar and are pretty similar to the first subcategory in terms of design and functionalities. They do have access to scientific publications, however it is often restricted to their metadata and abstracts and the patent database is much smaller than what the other free technologies offer.

Similar to the free solutions, paid ones can be subdivided into two main subcategories. The first one includes the free-like technologies. Keyword search based, they differ from the free software only from what they offer after the initial search. They are more strategy based, providing statistical tools, similarity measurements and the possibility to visualise in a more friendly way the results of a search. In this subcategory we find software such as DiscoverIP or Delphion. Some software from

this subcategory integrate interesting options such as the Examiner's Application Search Tool (EAST) with an image search. However this latter is not available for users.

The second subcategory of paid technologies is based on linguistic tools to search through patents, scientific publications and other relevant documents. We can cite software such as IHS Goldfire, Pantros IP, IPCentury AG, SemIP.com, LexisNexis TotalPatent and TextWise IP.com. They have the big advantage to combine semantic and keyword searches, many statistical tools, innovation oriented analysis trees, clustering and so on. Some of them propose free patent search solutions such as Pantros IP with freepatentsearchsite.com. Despite their relative youth and not yet proven full capabilities they might soon become essential.

To date no global solution exists that would carry the researcher from the initial question up to an answer not requiring users to inconveniently juggle with several tools.

2.3 THE SEARCH SEQUENCE

2.3.1 TEXTUAL INFORMATION

Analysing textual data from IP documents follows the same sequence as any other text mining.

Advanced search tools for patent professionals being still in their infancy [19] (Tang et al., 2012) the first step of the retrieve sequence is very often followed by long and tedious manual experts' analysis. Emerging technologies are becoming available that could change this process.

The first step corresponds to the selection of relevant documents using an information retrieval engine [29] (Rzhetsky, Seringhaus, & Gerstein, 2009). This step is absolutely critical in the field of IP were being exhaustive is one of the key for success. The rest of the analysis depends almost entirely on it and is, as it will be developed below, still one weak point of the whole process. This is exclusively done using keyword-based search tools. It is important to notice here that most of free technologies do not propose anything after that particular point.

The second step is the named-entity recognition [29] (Rzhetsky, Seringhaus, & Gerstein, 2009). The aim is to scan the text using specialised software and extract various entities (objects, concepts, and symbols) in each sentence. The ideal system would consistently identify an individual entity even though it may have different names and acronyms using machine-learning tools, and dictionaries. This step already necessitates the use of linguistic tools able to catch the meaning of words or use mathematical abstractions. This will be developed in chapter 4.

The third step is information extraction which creates relationships between the extracted entities [29] (Rzhetsky, Seringhaus, & Gerstein, 2009). This step is field oriented; it matches specific requirements and problem of the user using, for example, domain specific ontologies (e.g. genomic, nanotechnologies, chemistry …). An Ontology being: ''a taxonomy with multiple, precisely defined links between the items, that represents knowledge as a set of concepts and their relationships'' [8] (Lupu, 2011). There exists no global ontology; every field has to generate its own. The importance of developing ontologies will be discussed in the chapter 4.2.

The fourth and last step of a search structure is linking a user query and the extracted information. This is where mapping results become relevant to simplify the lecture of the data for a better outcome.

2.3.2 PATENTS METADATA AND CLASSIFICATION CODES

Textual information from the main document is not the only parameter allowing IP analysis. So-called patents' metadata such as title, abstract, publication date, applicants are often used in IP information retrieval. These information are useful to narrow a search to a specific time period, to follow a specific company or inventor or to find prior art documents. In addition patent offices allocate some classification coding to each patent such as the International Patent Classification (IPC), the European Classification (ECLA), the United States patent classification (USPC), the Japanese File Index and F-Term (FI/F-Term) classification and some other minor systems. The IPC is a hierarchical system that replaces or supplements national classification systems since 1971 [8] (Lupu, 2011). Each patent application is allocated a label by the patent examiner based on their technological area. Today it is composed of 8 sections, 129 classes, 639 subclasses, 7,314 main groups, and 61,397 subgroups. It has some potential advantages for information retrieval purposes. It could provide a solution to overcome the problem of heterogeneous terminologies used to describe similar concepts. It is already in a machine-readable format and allows for fast retrieval of patent independently of the language [30] (Lupu, 2013). This code is often used to narrow a search to a homogeneous technical categories, for mapping and collecting prior art publications [31], [32], [33] (Chiu, Hong, & Chiu,

2011; Dirnberger, 2011; Leydesdorff, Kushnir, & Rafols, 2012). Though this seems a very useful piece of information it carries some deadly issues. First of all it has been created by patent institutions for patent examiners to rapidly find if there are similar inventions to the patent under consideration. It is therefore tuned to the need of patent examiners that are not necessary compatible with those of professional search users. Furthermore some examiners might lack sufficient knowledge to appropriately assign a proper IPC code to the patent under consideration. In addition the rapid evolution of technologies and technological terminologies would require a similar evolution speed of classification labels [34] (www.intellogist.com/wiki/IPC_Classification_System). The assignment of the code is subject to human errors that could be potentially overcome by the use of automated patent classification. However these automated methods meet the same challenges as the IP search engines due to the unstructured nature of the data [30] (Lupu, 2013). Finally not every country use the IPC system, and from those using it, such as the US and Japan, they rely more on their own classification codes.

The issues associated with a search using classification codes illustrate once more obvious expectations divergence between the different actors of the IP field and this is detrimental to the overall quality of IP search.

2.3.3 DIGITAL MAPS: VISUALIZATION AND ANALYSIS TOOLS

Information retrieval is not complete without the visualization tools that allow to intuitively understand the large amount of extracted data and to be the foundation of further analysis. It is the topic of a research field called visual analytics [8] (Lupu, 2011). "Appropriate display of clusters points can give the analyst an insight that it is impossible to get from reading tables of outputs or simple summary statistics" [35] (Polanco, François, & Lamirel, 2001). Visualization techniques are numerous and vary depending on the type of data to be displayed [36] (Keim, 2002). Clustering methods are the most extensively studied and have been applied in many scientific fields [37] (Jain, 2010). Clustering techniques are used in neurosciences [38], [39], [40] (Dupret, O'Neill, & Csicsvari, 2013; Kadir, Goodman, & Harris, 2013; Mańko, Geracitano, & Capogna, 2011), bioinformatics [41], [42] (Frijters et al., 2010; Khalid, Yunus, & Adnan, 2010), patent mapping [43] (Woon & Madnick, 2011), face recognition [13] (Zhao & Chellappa, 2003), prosodic modelling [44] (Escudero-Mancebo & Cardeñoso-Payo, 2007) and many others. These techniques can be supervised or unsupervised depending on the presence or absence of initial knowledge injected into the clustering algorithm [35] (Polanco, François, & Lamirel, 2001). Unsupervised methods present more interesting potentials for problem solving or solution finding by grouping data in statistically distinct groups without *a priori* knowledge. There are as many cluster models as algorithms and so far none can be said superior because there are always many possible and correct ways to group data together [37] (Jain, 2010) (Figure 5). Distance and similarity measurements are the typical values used to compare different clusters of data [43], [45], [46] (Choi, Yoon, Kim, Lee, & Kim, 2011; Rodriguez-Esteban, 2009; Woon & Madnick, 2011). In the IP domain these tools have been used in business analytics to visualize citation relationships or patent collections [30] (Lupu, 2013). The expansion of semantic tools in IP search is asking for more visualization and visual analysis techniques to be used to simplify professionals' task.

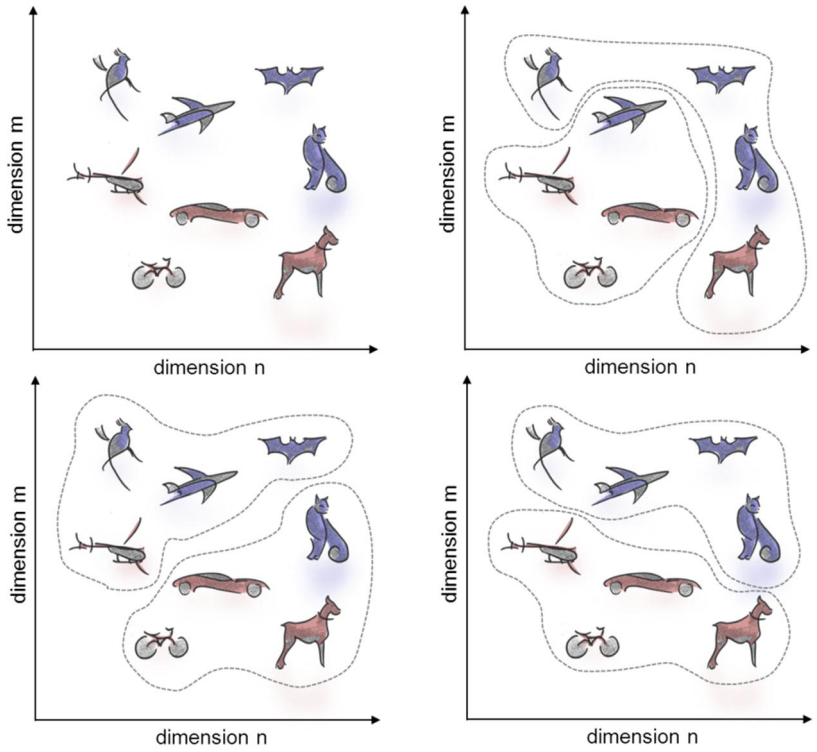

Fig. 5. Multiple Ways of Clustering, with electable parameters such as m,n…

2.4 SEARCH TOOLS EVALUATION ISSUES

The aim of this section is not to detail all possible evaluation methods (a more exhaustive reading can be find in [8] (Lupu, 2011)) but some aspects necessitate our attention. The first one is that IP search engines despite many publications and campaigns on the topic do not come with satisfactory evaluation methods. There are currently two main ways to evaluate the results of a search.

The first one uses “quality measurements” or “effectiveness measurements” which all derived from the initial Cranfield collection tests based on two factors: precision[1] and recall[2] [47] (Bonino, Ciaramella, & Corno, 2010) (Figure 6). Individual attempts have been made to evaluate the effectiveness of keyword search strategies [48] (Xie & Miyazaki, 2013). Despite some methodological discrepancies to obtain these measures, the traditional process is to use a set of predefined queries presented to a search engine using a manufactured corpus of documents. The number of relevant document for each query being known. This generates values for each factor which can then be both summarized in one single value, the F-measure. Many values then derived from this such as the R-precision, the break-even point, as well as the discounted cumulative gain and rank-biased precision family measures, if ranking efficiency is considered. In order to boost the whole field of information retrieval system evaluations campaigns such as the NTCIR, TREC and CLEF have been organised to bring together the experts of the field in order to generate accessible corpus and queries to evaluate any search technology [49] (Piroi et al., 2012) (NTCIR: NII Test Collection for IR systems - NII: National Institute of Informatics (Japan) - TREC: Text Retrieval Conference - CLEF : Conference and Labs of the Evaluation Forum). Though these results might be interesting for keyword-based searches they do not shine any light on more advanced systems using semantic [50] (Hempelmann & Raskin, 2008). The F-measure is also questionable when comparing different applications since a low value might simply reveal a harder task. Moreover, different engines may accomplish different results on different types of text meaning that a high F-measure value might simply be due to a specific entry data format [46] (Rodriguez-Esteban, 2009). The proposed corpuses are also

[1] Precision corresponds to the number of relevant documents present among those retrieved.
[2] Recall is the number of relevant documents retrieved among all relevant documents present in the initial collection.

completely artificial and it is difficult to relate these evaluations to any reality. The assumption that if a system performs well on tests evaluation it will perform well [8] (Lupu, 2011) appears oversimplified considering the complexity of the problem at hand.

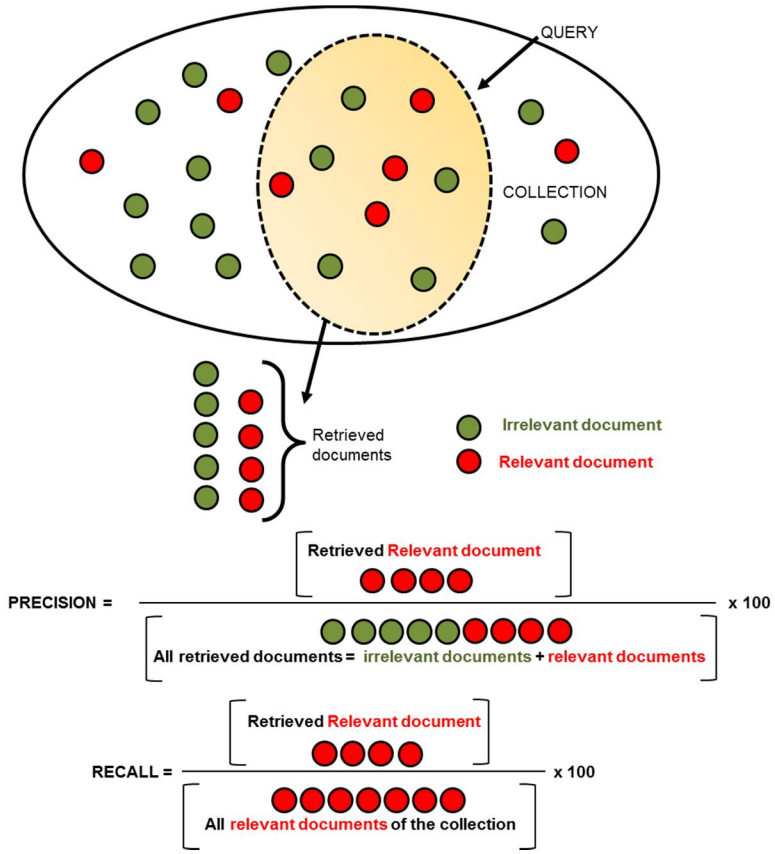

Fig. 6. Precision and Recall Effectiveness Measurement of a Search

The second possibility when evaluating a search system is the expert panel [10], [17], [51] (Magerman et al., 2009; Yoon, Park, & Kim, 2012; Hawizy, Jessop, Adams, & Murray-Rust, 2011). The retrieved results following a query are controlled by experts who validate the relevance of each document. This has several drawbacks such as the relative limited amount of documents that can be assessed as well as the diverging opinions on what is considered to be relevant.

As we mentioned at the beginning of this chapter, there are no satisfactory method and it is often the empirical experience of search professionals that will guide them to use the tool that can provide the more appropriate answers.

3 KEYWORD SEARCH

3.1 THE DOMINANT BOOLEAN SEARCH TECHNOLOGY IN THE IP DOMAIN

The reader can find a detailed description of the Boolean search in 'An introduction to information retrieval' [52] (Manning, Prabhakar, & Schuetze, 2009).

Keyword-based search and in particular Boolean search have dominated for decades free and commercial information retrieval tools including IP search. This information retrieval model is based on queries combining the Boolean operators AND, OR, NOR and NOT (Figure 4 & Figure 2). The model views each document as a set of tokens which for most of the cases correspond to words. In order to query a corpus, documents need first to be indexed. The Boolean inverted index associates each term of the collection with the documents in which they appear. A query such as *Romeo* AND *Juliette* would be process as follow: locate in the inverted index dictionary the term 'romeo' (most of keyword search systems are case insensitive); identify what documents the term 'romeo' points to and create a posting list; do the same steps for the term 'juliette'; merge

both posting lists; extract the documents that includes both terms. In this kind of index a word does not have any associated meaning even when synonyms are used to improve the performance. Other options have been added to the original Boolean search such as truncation to find words sharing common structures (e.g. word-words-wording); wildcards are expressions that can replace characters or digits; proximity looks for documents where two or more terms occur within a certain distance; fuzzy search helps with misspelling using approximate string matching methods; and synonyms.

Boolean search has been shown to be the fastest technology to search through multiple documents. On the contrary to other technologies it gives clear and fast results, e.g. a document matches or not a query. Nowadays the majority of keyword search engines use ranked technologies to balance the absence of weight for each document in a Boolean search. The ranking of relevant documents is done using tools such as the vector space model [10] (Magerman et al., 2009), probabilistic models and term weighting (tf-idf: term frequency–inverse document frequency) [8] (Lupu, 2011).

3.2 A LEGITIMATE DOMINATION?

Free text query solutions, which have been shown to perform with higher effectiveness [53] (Turtle, 1994), exist since the beginning of the 90s. However as seen above, Boolean search is still the main technology in use nowadays [8] (Lupu, 2011). Despite some obvious advantages for software developers Boolean search is overall not satisfactory. Keyword searches often generate irrelevant results because one term can have different meaning in different contexts and relationship between words is lost in inverted index dictionaries [18] (Trappey, Trappey, & Wu, 2009). Another intrinsic issue of Boolean search is that using AND operators increases precision and lower recall, while using OR operators decreases precision and increases recall, and it is nearly impossible to find the right balance [52] (Manning et al., 2009).

Keyword search engines are for most of them not using any dictionary making the system intolerant to spelling mistakes and will not help the user with inappropriate choice of words as would do Google Search for example. Many patenting organization search engines offer neither case sensitivity technologies nor term proximity. A Boolean system when used alone only reports term presence or absence and display results with nothing more than a chronological ranking [52] (Manning et al., 2009). Keyword searches are adequate for getting information about entities, which are typically nouns or noun phrases. They fail on queries that are looking for relationships between entities. For example, if one wants to retrieve documents containing text of the form “Company X acquired Company Y”, then keywords alone are extremely inadequate [54] (Sarawagi, 2007). Not only these technologies alone are inefficient in finding the right documents, they also rely almost entirely on users’ expertise and databases’ size.

3.3 USER-FRIENDLY OR AN ILLUSION OF SIMPLICITY

At first sight, a search using Boolean operators might looks straightforward but anyone who has used this type of queries knows that the reality is different. First of all it nearly entirely relies on the users’ skills acquired during years of trials and errors [47] (Bonino et al., 2010). Furthermore “regardless of how well the indexer manages to process the patent collection, the ultimate results will also depend on asking the right questions, or, in this case, on generating the most effective queries” [30] (Lupu, 2013) and this is not an easy task.

Here is a query from Yoon and Kim [17] (Yoon et al., 2012) in order to collect granted patents from the USPTO since 2000 about organic photovoltaic cells:

((((((photovoltaic* solar*) adj (cell* batter* device*)) and ((bulk* adjheterojunc*) ppv* phenylenevinylen* tandem* (dye* adj sensitiz*)fluoren* fulleren* PTCBI* PTCDA* PTCDI* H2PC* ZnPc* CuPc*TPyP* TFD* NPD* CBP* PCBM* (conjugat* adj polymer*))) or(((organic* plastic* polymer* (dye* adj sensitiz*)) adj3 (photovoltaic*solar*) adj (cell* batter* device*)) DSSC*))) and (B32B* C07* H01*H05B-033*).IPC.) AND @RD[=20000101\=20101231

This query illustrates two things. First the person who wrote it is an expert in this particular field and second he is accustomed to the USPTO query syntax. Syntaxes between search engines can be very different. For example if one is looking for the word “graphene” in patents’ title, the correct syntax for EspaceNet would be “ti=graphene” whereas for USPTO that would look like “TTL/graphene”. No need to give more examples if such simple query is already that different. It requires the user to be properly trained for one particular engine, and one can only learn few of them if efficiency is the goal. This ultimately impacts knowledge availability with only big corporations able to have the necessary human resources.

Another interesting concept for our present discussion is the principle of ‘query optimization’ [52] (Manning et al., 2009). This is the process of selecting a query that will ease the search process for the system. One way of doing it is to call the different posting lists in a specific order. This is the perfect illustration that to be efficient the system needs the user to

formulate expert queries to find the relevant set of documents. Nevertheless it raises an interesting point that the system can be improved since the user can optimize it.

It is then quite understandable that this technology is still the most used one in the IP search domain. It is more convenient and easier to develop and manage to the detriment of the users community.

The keyword based query system demands from the users to formulate their objectives in a very complex and unnatural way. In a society where everything is made to ease the life of users this technology seems pretty obsolete.

In an attempt to summarize for the non-trained in the art, - more details being aforementioned -, the main disadvantages of the overwhelmingly used keywords approach, can be summarized as follow:

- some practical knowledge of the field is necessary including jargon and synonyms;
- some knowledge of how the search engine operates is necessary to yield reliable results. The more flexible and performing-powerful the search engine used, the more essential is the knowledge and experience acquired; and
- acquaintance of the relevant databases, including abstracting and organized-controlled language, is essential to produce a dependable result.

4 SEMANTIC SEARCH

4.1 NATURAL LANGUAGE PROCESSING

Semantic technology is often presented in the literature as a solution developed to overcome the limitations of keyword centred search and to address complex information needs [55], [56] (Dreyfus, 1972; Minsky, 1969). Not only this information is wrong but it gives the false impression that there slow progress is due to the youth of the project. Semantic search is not a novel concept and has been a main branch of AI research since its beginning. The reader might want to read about the early attempts in the semantic treatment of information [55] (Minsky, 1969). The foundation of semantic search is the simulation of human language processing. Linguistic being one of its main field of study. Natural language processing (NLP) is the original component of semantic but nowadays many other theories have emerged. The goal of these tools is to automatically decompose unstructured text data into smaller parts, identifying their elements and relations and putting them into a machine-readable structure for analysis. As opposed to keyword based tools the meaning of each word as well as their relationships is at the centre of the algorithms. The strength of semantic is the ability of the system to perform a search by interpreting the meaning of keywords and extracting object, concepts, symbols and their relationships. NLP uses different tools to break/parse the textual information into meaningful elements such as sentence extraction, tokenisation[3], word stemming[4], part-of-speech tagging[5], lemmatization[6] and named entity recognition[7] [16], [51], [57] (Yoon & Kim, 2011a; Hawizy et al., 2011; Spinakis & Chatzimakri, 2005). In order to "understand" the meaning of a word the system needs specific knowledge regrouped into ontologies. An ontology is "a taxonomy with multiple, precisely defined links between the items that represents knowledge as a set of concepts and their relationships" [8] (Lupu, 2011). The human language has many properties such as synonymy and polysemy that are a challenge for search engines. When using keyword based solutions one would have to enter all possible synonyms and all different meaning of one word in order to grasp the whole information. Semantic is doing that naturally using the context in which a word appears, as a human would do when reading a document. Ontologies are domain-specific because one keyword in a domain might have a different meaning in another one. We think it is important here to highlight the fact that most of the published documents are written in English with a lot of authors using English as a foreign language, which might add confusion around the meaning of a keyword. A French person is for example

[3] Tokenisation is the process of cutting character strings into pieces called *tokens*. These elements can be words, symbols or other meaningful elements [52] (Manning et al., 2009).

[4] Stemming is used to gather certain words under the same *stem* and reduce the number of indexed elements. The stem 'search' is the root word for 'searching', 'searcher' [10] (Magerman et al., 2009).

[5] Part-of-speech taggers classify words as nouns, verbs and others [52] (Manning et al., 2009).

[6] Lemmatization groups all grammatical inflections of a word under a common *lemma*. The lemma 'have' includes 'has' and 'had' [52] (Manning et al., 2009).

[7] Named-entity recognition techniques are used to find and classify domain specific *terms*. A term can be a medical disease, chemical name, person, and others [29], [46] (Rodriguez-Esteban, 2009; Rzhetsky et al., 2009).

profusely using “eventually” instead of “possibly” because “possibly” corresponds to “éventuellement” in French. The context is therefore crucial to understand textual information.

Despite its relatively long history, semantic has only been recently introduced in search engines. Other conceptual models are available instead of NLP such as object or entity relationship modelling [58] (Wen, Zeng, Li, & Lin, 2011). The notion of function, defined as the action changing the features of any object, is another part of semantic research from TRIZ. The functions are also associated with Subject-Action-Object (SAO) models [15], [16], [17] (Yoon & Kim, 2011a, 2011b; Yoon et al., 2012).

According to Eetu Mäkelä [59] (Mäkelä, 2005) semantic search has five main research directions: “augmenting traditional keyword search with semantic techniques, basic concept location, complex constraint queries, problem solving and connecting path discovery”. The efficacy of semantic search has been demonstrated for keyword search increase performance [59] (Mäkelä, 2005), new technological opportunities detection [15] (Yoon & Kim, 2011b), technology landscape visualization [43] (Woon & Madnick, 2011), similarity measurements [60], [61] (Moehrle & Gerken, 2012; Moehrle, 2010), technological trends identification [16], [17], [45] (Yoon & Kim, 2011a; Yoon et al., 2012; Choi et al., 2011), distance analysis [15] (Yoon & Kim, 2011b) and novelty monitoring [62] (Gerken & Moehrle, 2012) among others.

4.2 ONTOLOGY: GENERAL CHALLENGES AND IP SPECIFICITIES

A machine needs specialized knowledge to “understand” textual information. Ontologies are the knowledge base of semantic technologies and are domain specific as seen previously. It is therefore critical to create ontologies for all existing domains including IP [63] (Hare, 1998). Biomedical and chemistry domains are both ahead of many others in term of semantic search and therefore available ontologies [20], [46], [51], [64] (Jessop, Adams, & Murray-Rust, 2011; Rodriguez-Esteban, 2009; Hawizy et al., 2011; Gurulingappa, Müller, & Hofmann-Apitius, 2011). The fact that some ontologies are provided by organisations such as the Royal Society of Chemistry demonstrates that a community effort is necessary to develop such dictionaries. Only domain experts are qualified to generate such databases and this ground work is one major limitation for semantic search to be used more broadly. The IP domain and in particular patent documents propose an even greater challenge. “It is well settled that a patentee can act as his own lexicographer by choosing his own definition of a term and using it as he wishes so long as he remains consistent in its use and makes the meaning clear” [65] (Wetherell & Mehok, 2005). Not only this makes the whole ontological process a nightmare but it does generate irrational activities in the course of a patent’s life. It is important to remind the reader that during infringement analysis the claims of the patents under examination are compare to one another using similarity measurements. This aberration is analogous to the measure of similarity between a French written document and a German one using an English dictionary.

A collaborative ground work from domain experts is a necessity if we want ontologies to ever become the foundation of search engines. It is important to notice here that they might not be the appropriate response to the current issues in data mining.

4.3 LATENT SEMANTIC ANALYSIS

An alternative to NLP is Latent Semantic Analysis (LSA) also called Latent Semantic Indexing. “This is a method for extracting and representing the contextual-usage meaning of words by statistical computations applied to a large corpus of text” [66] (Landauer, Foltz, & Laham, 1998). This method does not rely on ontological knowledge to find and assimilate new concepts. Using artificial neural networks it creates its own conceptual lexicon using algebraic methods based on word frequency. The corpus of documents is the only knowledge necessary for the system to work. This unsupervised learning method produces concepts that “do not have any textual or intuitive expression of their own, but they are defined by vectors that relate them to words of the initial vocabulary”. Concepts are mathematical abstractions obtained by different sets of comparisons [67] (Fernández Sánchez, 2009).

LSA is used to do semantic with a non-semantic tool, avoiding many inherent problems but reducing the potential power of its application [50] (Hempelmann & Raskin, 2008). The aim is to deduce meaning from non-meaningful language properties using statistical tools such as co-occurrence of words or other structural aspects [43] (Woon & Madnick, 2011). LSA is employed in language processing to help with text categorization, indexing, essay grading, image auto-annotation, auto-annotation, and automatic cross-language retrieval. Google recently implemented semantic in its search engine with the hummingbird update. Though it is difficult to find the information on what is exactly behind this improvement the patent title suggests the use of LSA [68] (US 8,538,984). Such technology has been shown to outclass Boolean models and seems to give an interesting alternative to the complexity of NLP [69] (Chen, Martin, Daimon, & Maudsley, 2013). However it has not been yet proven that LSA concepts correspond to any reality [67] (Fernández Sánchez, 2009).

4.4 INADEQUATE INITIAL DOCUMENTS SELECTION

It is of common use to run semantic analysis on pre-selected set of documents. The selection process is often done using keywords centred search systems. We cannot stress enough that one purpose of semantic solutions is to get rid of the inadequate use of keywords to build a better understanding of specific fields of research. By pre-selecting documents using inappropriate tools researchers greatly reduce the usefulness of semantic to a simple analytical instrument. In the IP domain, considering everything that has been discussed so far in this review, keyword search engine should be used only when searching for a specific patent or publication. If the goal is bigger it is then a necessity to use the full potential of linguistic to generate innovative paths, map existing domains, compare technologies and so on. Human communication, and more importantly, problem formulation is made using natural language and not a list of keywords. It is therefore natural to question a system using queries written in natural language. The technology to process such queries exists and is already used but the IP industry is slow to make the change. The relatively low number of existing ontologies or thesaurus is obviously a limitation as described in the previous chapter.

There are processes in place [1] (Rebouillat, 2013) that request ideation to start with a 300 word expression, defining the problem to solve, the proposed solution and a path to practice. The 300 count is not a magic number but corresponds to a size that avoids distraction and temptation to express several rather intricate ideas with some googling intrusions; possibly removing the idea from its original inception. Such ideation expression is then used as natural language inputs in ad hoc engines.

4.5 PROBING THE VARIOUS APPROACHES

In an illustrative attempt, of very limited scope, amplitude and depth, to compare some of the various search approaches (Figure 7) and to underline their complementary and/or usefulness, three cases were studied and are reported here.

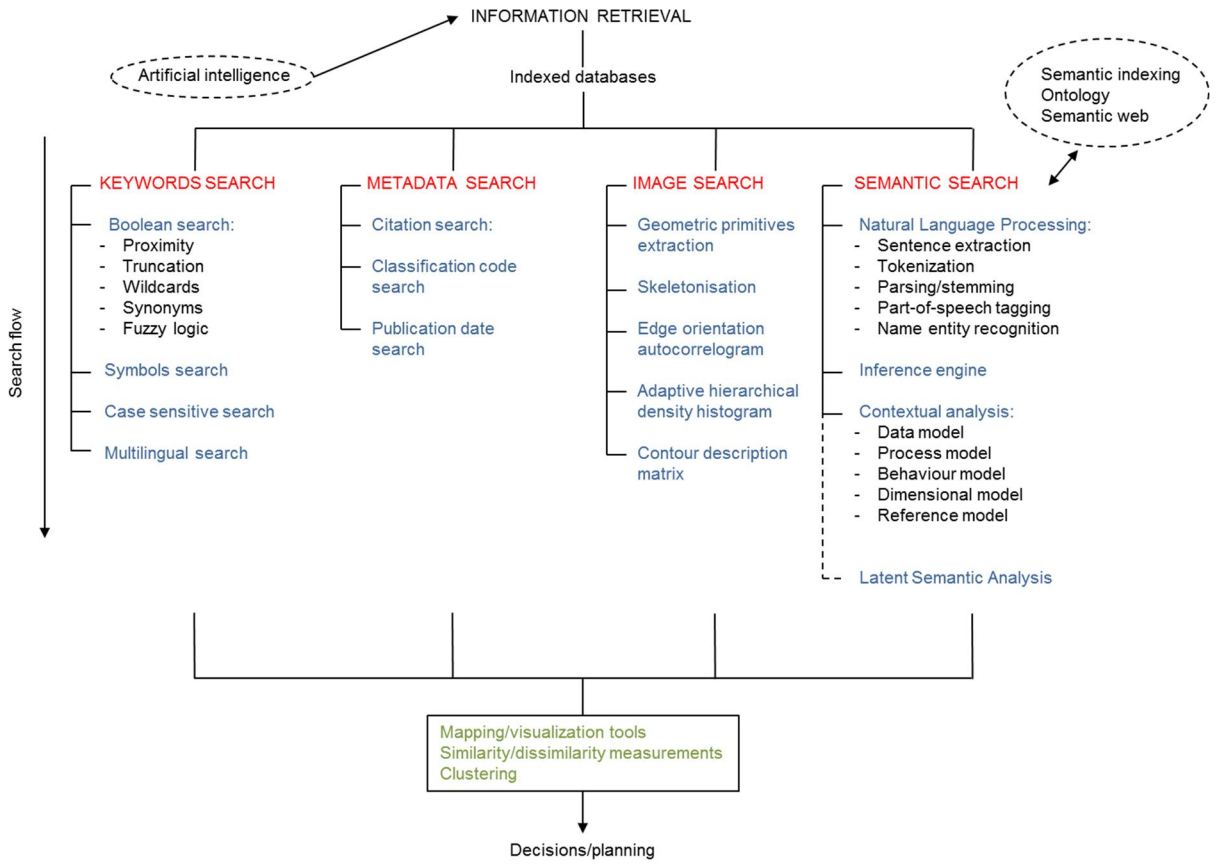

Fig. 7. Various Search Approaches

During the course of a patent examination, a preliminary patent search report on patentability will be coordinated by the ad hoc patent office, at the national level or at the international level. For example in the case of a broader (PCT) application via the WIPO, or in the case of a European application via the European Patent Office. The PCT is an international Patent Cooperation Treaty, directed by the World Intellectual Property Organization (WIPO), involving more than 140 Paris Convention countries; therewith enabling broader and simpler patent application procedure with a well-defined priority date applicable across the member states.

The patent search report on patentability provides, earlier on, to the assignee, often referred to as the applicant, the list of relevant documents that may affect the patentability of the considered patent applications.

Two categories of cited documents in the search report have special and critical relevance. The X category covers the document of particular relevance against which the claimed invention can neither be considered novel nor inventive. The Y category classifies documents which are of particular relevance against the claimed invention which cannot be considered to involve an inventive step when the document is combined with one or more such classified documents, such combination being obvious to the person skilled in the art.

The search report is performed by a series of structured patent preliminary examination steps involving patent examiners who rate the application against the above classification criteria. The related patent examiner hierarchy is very specialized and experienced in the domain and is believed to operate via IPC/keyword searches mostly. The expert in the field examiner has means to cross check her/his findings and corroborate with various adjacent cases.

First case study: "Continuous flow biodiesel processor, US20070175092"

The search report on patentability, available via the Patenscope® dedicated patent database, cites two X references dated 1928 and 1973, and 4 Y documents dated between 1987 and 2000.

The search was performed on the 4th of February 2008. We chose to conduct a semantic search using the entire patent document and limiting documents output to those appearing prior to that date.

The semantic search yielded no X references but only two Y references, one classified in 3rd position, of all relevant documents found, with a relevance of 88 over 100 (100 being the maximum relevance achievable, generally meaning the exact same document) and one ranked 19 with a relevance of 80 over 100. Worth observing that the X documents are all available in the selected database; included the one dating back to 1928. The semantic analysis did not found those X documents as being relevant.

We clearly outline here the importance of the field expertise favourable to the human expert examination and co-involvement in any automated computerize process. The latter can also misjudge. The bioscience domain of concern being in its establishment phase may also suffer from the lack of coverage and classification in the IPC current version.

Second case study: "US20130317853 - WO/2013/177493A1 - Device selectively storing and presenting critical medical information."

For that particular case the "recordation" of the PCT search history is provided with a completion date of 20/8/2013.

As listed below 6 patent classes, 2 patent databases, 4 NPL databases, 21 keywords have been used for that search; this is hardly conceivable by non-patent search experts.

"Field of Search/Classification Information:

IPC(8) Classification(s): G06Q 50/00, G08B 23/00 (2013.01) USPC Classification(s): 705/3; 128/903; 600/300,340/573.1

Database(s) Searched (Patent and Non-Patent Literature (NPL), Including SubDatabases and Files Searched) and Search Terms Used: MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C.B, DE-A, DE-T, DE-U, GB-A, FR-A); DialogPRO; Google; Google Scholar; Medline/PubMed: worn, wearable, wristwatch, pendant, broach, bolo, wristband, bracelet, jewelry, medical, drugs, allergies, diseases, illnesses, microprocessor, cpu, microchip, rom, ram, portable, hand-held."

Performed on the 23rd of August 2013 the search report available in the Patenscope® database cites 2 X classified documents and 4 Y classified ones.

A semantic analysis using the entire patent document was conducted limiting the output to a date prior to the completion of the international search. In rather unfavourable positions 69 and 73, were identified the two X classified documents with a relevance of 75 and 74 over 100, being the maximum relevance obtainable. No Y cited documents were found within a

reasonable relevance level, which is generally set at a maximum 70-75 by experts in the field. Below that level of 70-75, documents are generally considered as non-relevant but only of documentary value representing the general state of the art.

The above demonstrates the complexity of the search in the patent field and the rather distant results obtained from a semantic search versus the human expert approach interacting with multiple databases.

Nonetheless, in both cases some significant references were found, which would have been unlikely, probably impossible, based on a single keyword approach or sole patent class search methodology.

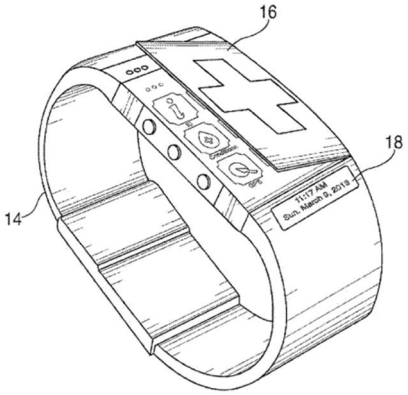

Fig. 8. Device Selectively Storing and Presenting Critical Medical Information

Figure 8 above provides a good representation of the article subject of the second case. One would wonder whether an image based search, possibly combined with some interactive semantic, would have not provided a faster and more precise recall; at least the searcher would have an already quite inspiring idea of the competitive adjacent article to look for and/or to compare with.

Third case study: Neo-Retro-Innovation, way back to future innovation?

We propose to further test the information retrieval means at disposal to the trained in the art of searching, non-expert in the field.

Using a recent definition of a PC-Tablet, provided by Henderson [70] (Henderson, 2009), this third case study aims at finding whether with the information available back within a selected period of time, such as 1975-1995, references corresponding to that definition were available at that time. The definition of interest is formulated in the following fashion:

"As the name suggests, a tablet PC is a small computer about the size of a notebook (not to be confused with a "notebook PC," which is a small, light laptop). The user can write on the screen with a stylus to take notes (for similar functionality, see graphics tablet), draw, and make selections with stylus or fingertip. If the user writes on the screen, software converts the writing to the appropriate characters and stores them in a file (see handwriting recognition). As with some PDAs, there may also be a system of shorthand "gestures" that can be used to write more quickly. Alternatively, the user can type with stylus or fingertips on a "virtual keyboard" displayed on the screen (see touchscreen). A more versatile and natural interface is becoming available: "multitouch," pioneered by the Apple iPhone and Microsoft Surface, can recognize multiple motions and pressure points simultaneously. This allows the user to, for example, flick the finger to "turn a page" or use a pinching motion to "pick up" an object. Applications for tablet PCs include many PDA-type applications (see personal information management and PDA), field note taking, inventory, and other tasks that require a device that is not encumbering. Because of its compactness, a tablet PC can also be a good reader for ebooks (see e-books and digital libraries). Tablet PCs generally follow common specifications developed by Microsoft, and often use Windows XP Tablet PC Edition or, later, Windows Vista, which has built-in support for tablet PCs. These operating systems include support for sophisticated handwriting recognition that can be "trained" by the user and that can store handwritten input in special data formats. Voice recognition is also supported. A "convertible" tablet PC is a hybrid in which the tablet is attached to a base containing a keyboard. The display can be used vertically (laptop style) or rotated and folded down over the keyboard for tablet use."

Using commercial tools with a semantic analysis feature, a search using the above PC tablet definition yields a list of related references, appearing within the selected period of 1975 to 1995, and classified from most to least relevance level. We leave other details for a paper more focused on those search criteria.

18 references were found ranking from an acceptable relevance level of 76 to a moderate relevance level of 67.

In position 2 of the 18 reference list appears the Agulnick, Todd patent dated 13 September 1994, (Application Date: 31.10.1990), untitled "Control of a computer through a position-sensed stylus" published under United States Patent 5,347,295.

A glance at one of the patent drawing, Figure 9, would draw the attention of the observer towards a tablet of nowadays; visually an iPad® like almost.

Additionally a Google keyword search using the word sequence "wiki tablet history" provide the link, "http://en.wikipedia.org/wiki/History_of_tablet_computers", which relates to the development history of the tablet computers. The proposed Wikipedia article cites, in position 82 out of 103 references, the exact patent by Agulnick and Todd mentioned above.

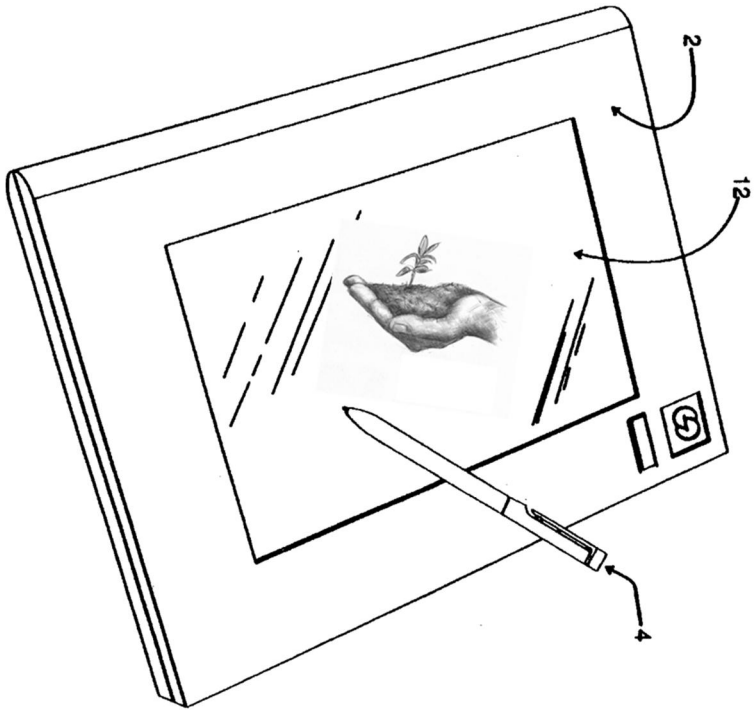

Fig. 9. Control of a Computer through a Position-sensed Stylus with Application Date: 31.10.1990

Wikipedia list of references comprises only 4 patents, all retrievable in free databases as long as the number is known. Only one of those references was found from the semantic analysis, although the most pertinent one by far; especially given its inspiring picture that may have led to earlier discoveries in the field, should the image be findable beyond a pure IP context and the examination of the specific entire document.

The "Telautograph" was subject to patents dated back in 1888 and 1942, which are referred to in the Wikipedia reference list and clearly state the object of the two inventions. For the latter, 1942, "My invention relates to improved means and systems whereby writing or tracing movements of a body such as a pen, pencil or stylus in tracing a picture or design may be reproduced at a distance.". And for the first one, 1888, "The invention relates… to the act of writing at a sending-station operates to reproduce it at the receiving-station".

The dawning (Figure 10) associated with that latter invention, 1888, United States Patent 386,815, is eye-popping given the clear interpretation by drawing of the fact that the movement of a pen is reproduced at distance via electro-magnetic components; this back in 1888.

- The above study shows that semantic is a quick and a valuable improvement to patent searching, requiring minimum training. There are improvements which would be welcome as indicated in the rest of the paper.
- The current case study also underlines that retro-innovation is conceivable, using contemporary information. The possibly most inspiring information are discoverable back 20 years before a breakthrough technology is appearing on the market. The 1994 patent could have been or has been inspirational to current tablets, ipad® and the likes. The 1888 Telautograph drawings are premonitory, prophetic or clairvoyant provocateurs to many remote actionable devices of today.
- Finally, image analysis combined with semantic support is definitely a promising route to enhance innovation pace. The proliferation of camera life video recording such as dashcams could promote the development of *in silico* IP image interpretation and semantic ideations and/or reverse.

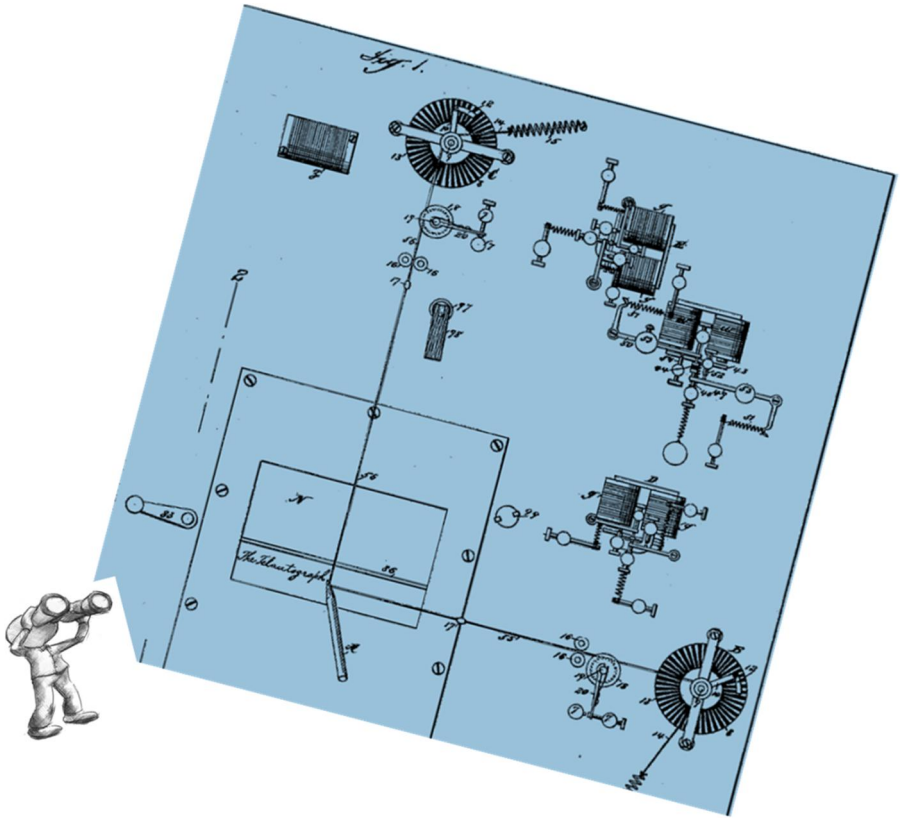

Fig. 10. The Telautograph (1888)

5 IMAGE RETRIEVAL SYSTEMS

5.1 A MISSING LINK

The adage "a picture is worth a thousand words" suits particularly well to the IP domain. In a patent; also true for scientific publications; drawings, diagrams, plots convey an often critical amount of information that is largely ignored by IP search engines [71] (Bhatti & Hanbury, 2012). Considering the terminology problems inherent to patent, image retrieval technologies seem a natural and crucial step in IP search. It is thus surprising that it did not yet reach a satisfactory level. However some tools exist and have been used on patents for image retrieval. The Optical Structure Recognition Software (OSRA) was applied to recover chemical information [20] (Jessop et al., 2011) and the Content-Based Image Retrieval (CBIR) for drawing retrieval [30] (Lupu, 2013). In addition some rare attempts have been made to associate several techniques including image search in the IP domain [26] (Codina et al., 2008). This is obviously not a trivial task but some other domains seem to have done better in this matter.

Semantic Image Analysis, SIA

There is no need to further insist on this aspect and the necessity to add it to the patent/IP search toolbox; the sooner the better at the condition to take care of its harmonization with legal aspects. The lawyer's "shyness", vis-à-vis the interpretation of drawings and the claimable matter related to those, is well-recognized.

It could be the subject matter of an entire chapter. Let's first make sure that the principle is clearer than the title, semantic image analysis (SIA), may pretend, and let's use for that purpose a very simple analogy associated with children recognition and learning process.

The SIA, using a symbolic neural architecture, is schematically associated with Figure 11; one of the key references on the matter has been proposed by Kollia [72] (Kollia, 2010).

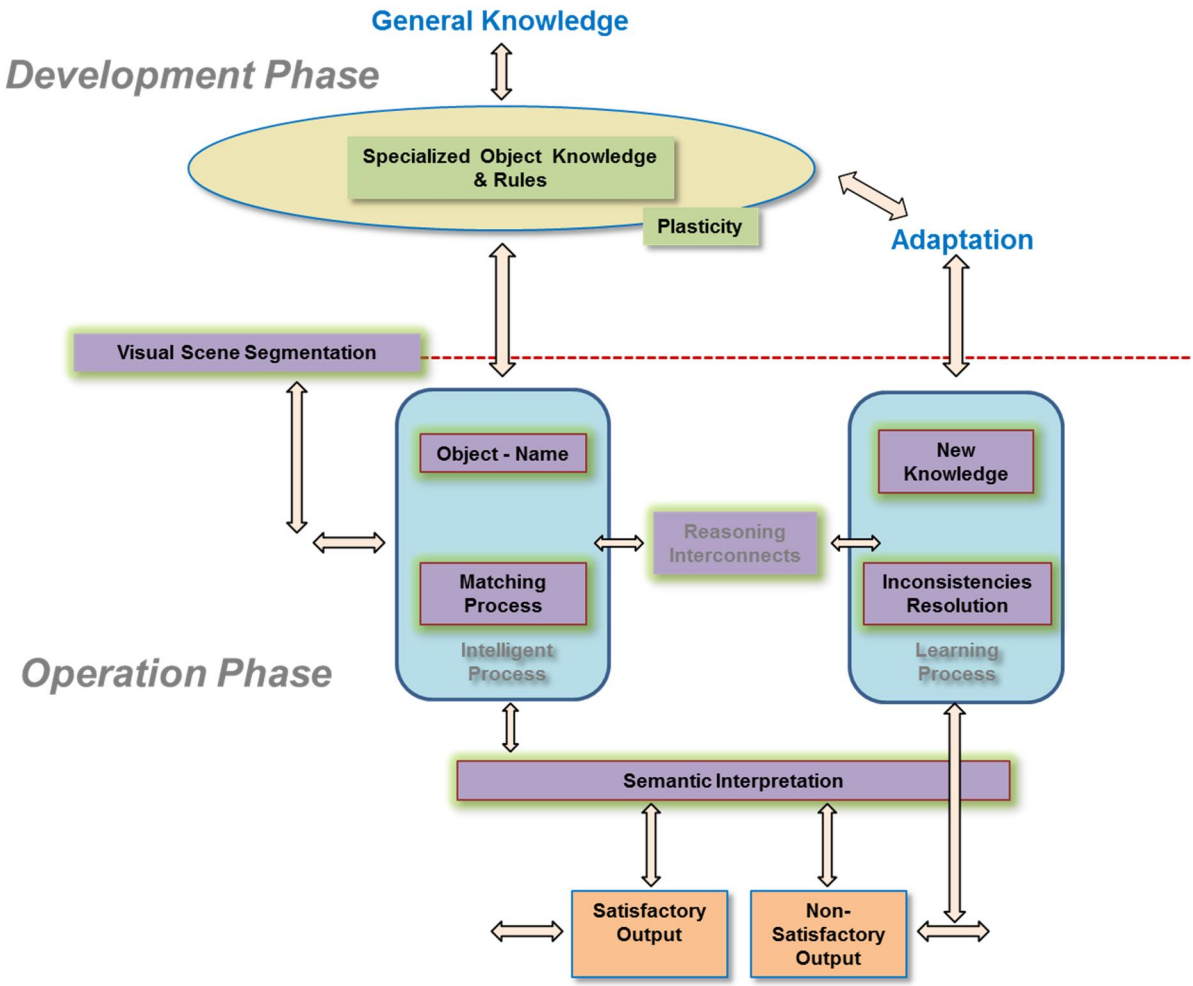

Fig. 11. The Semantic Image Analysis, using a Symbolic Neural Architecture

In order to understand the whole process let's describe what could be the way a child is visually interpreting its environment. The first step would be to segment what he sees into objects depending on colours, intensity, depth, size, etc. (= feature extraction and classification). The next step would be to associate a name to each detected object (= semantic interpretation) using the knowledge he gained from his parents (= formal knowledge). However not every shape an object can take has been previously encountered and explained. The formal knowledge therefore contains some conflicting information (e.g. a lamp does not always possess a lampshade). His brain (= reasoning engine) will use the new information (connectionist learning) to adapt and modify (= knowledge extraction) his general knowledge. Using this strategy and new inputs from his parents, the child will slowly become expert in the interpretation of his surroundings. By similar means the semantic image analyser segments and classifies pictures using a formal knowledge. This latter contains inconsistencies that

will be corrected by the knowledge adaptation through the reasoning engine. Follows a correct or improved interpretation of new pictures presented to the analyser.

It shouldn't be of any surprise if the child chooses to put a hat on a lamp that is missing a shade by design, or by some sort of necessity. The child will, by this token, appreciate the fuller purpose of a shade when the recreated object fails to meet its primitive observable function. A lot more can be learned from Chomsky's paramount contribution [73] (Chomsky, 2013) in the language-cognition field.

5.2 WHAT CAN WE LEARN FROM OTHER DOMAINS?

Image retrieval is not restricted to the IP domain and has made huge progresses in other fields of research [71] (Bhatti & Hanbury, 2012). One field in particular, which shares several elements with information retrieval as defined here, has been really successful during the past few years. Face recognition technology necessitates a high level of image analysis and encounter many challenges. Similar to IP image search, face recognition using AI needs to analyse an image and compare it with a database. However the analysis has to be often done online while screening live and poor video signals. The success of these techniques might be attributed to the large number of applications for this technology. They are present in the field of advanced video surveillance and passport controls, but also TV parental control, video games, human-computer-interactions and many others [13] (Zhao & Chellappa, 2003). Face recognition sequence follows a similar path than image search, namely face detection, feature extraction and face recognition. Though they do not confront exactly the same issues, there are no reasons for image search technologies to be behind if a process as complex as facial identification is possible. Other technologies are used for hand-drawn sketches recognition [74], [75], [76] (Brieler & Minas, 2010; Fernández-Pacheco, Albert, Aleixos, & Conesa, 2012; Sezgin & Davis, 2008), to identify children who are at risk of handwriting difficulties [41] (Khalid et al., 2010), to create a 3D model from a sketch [77] (Olsen et al., 2009) among others. These various successes illustrate well the feasibility of image search in the IP domain.

6 WHAT IS BEHIND THE AI BLACK BOX: I WISH I KNEW!!

Before going deeper in the subject of this paragraph we think it is important to clarify one concept, e.g. artificial intelligence is *artificial*. It might sound obvious to the reader but it is in fact an important aspect of a search engine or AI in general. Despite a lot of publications that claim otherwise for many years now [55], [78] (Davies, 2011; Minsky, 1969), the abilities of AI is very far from performing the full range of human brain cognitive skills [79] (Schlinger, 2012). The purpose of this declaration is not to minimize the progresses done since the birth of AI but to highlight the gap that still needs to be crossed to have a human brain *in silico*, if required. Neuroscience is still a juvenile discipline and the mysteries of the human brain have been barely explored and even less understood. This is why this intelligence is artificial, e.g. based on brain activity theories that might only partially reflect reality [56], [80] (Dreyfus, 1972; Schlinger, 1992).

Artificial intelligence is the core of search engines [81] (Liao, Chu, & Hsiao, 2012) but what we would like to assess in this section is how clever these algorithms really are and how much they simplify users' task.

According to the Oxford English dictionary intelligence is "the ability to acquire and apply knowledge and skills". Intelligence is rational, a goal-driven behaviour. A child will develop and learn from its interaction with the environment as well as other individuals. Search engines such as those using LSA technology are self-learning through documents ingestion. George, the AI from Pantros IP, gets around 40,000 new documents per week but what about its interaction with other intelligent entities. The ultimate goal is to have a machine able to reason with the user. However this can only be achieved if there is the output results are understood and will receive feedbacks to improve the whole process. Users need to assess AI judgements reliability. Tait and Diallo proposed the concept of *searcher trust* that "would require explanations of the internal processing mechanism leading the displayed results to be accessible and comprehensible to the searcher" (chapter 20 [8] (Lupu, 2011)). This interaction does not exist and professionals have to blindly trust results and analysis. It is well known that when comparing relevant documents from two professionals only 40% will overlap [8] (Lupu, 2011). But how is it with search engines? What are those relevant documents that I am presented with? Should I use them like that or would it be reasonable to reformulate a query and start again? These are logical question one can expect from two professionals questioning each other's judgements. What about this new player that is AI? Is it to assume that its judgments are not to be questioned?

7 MOST NEEDED EVOLUTIONS AND FUTURE DIRECTIONS

7.1 POSITIONING USERS AT THE CENTRE OF THE SEARCH PROCESS

One apparent but striking aspect of IP search is the appearing lack of common efforts to facilitate the professional searchers' task. As seen in the previous chapters, professionals generally have to juggle with multiple search engines, interfaces, document collections, query syntaxes, patent institution classification, languages in an ever growing competitive industry. Nothing seems to be done to simplify the different steps of the whole process.

The counter argument is that this is probably a perfectly justified position coming from the non-expert in the field. The professional, as the Doctor with the "antediluvian" stethoscope, needs that proximity and wants to develop a feeling for where she/he is heading to. The number of steps to reach a never predictable objective is a joy for most of the professionals who constantly learn from a journey during which they don't want to be GPS guided at the risk and anxiety therewith of no longer been able to read a map.

The often heard "don't worry about your engine selection, pick one and go" illustrates how the field is organised. Innovation is the foundation of industry progress with IP laws to protect and propagate knowledge. The industrial applicability erected as the third patentability pillar and the associated requirement is not negotiable. In order to help companies and communities at large to use their maximum creative potential, efforts must be made to simplify the access, retrieval, analysis and use of all available information.

We believe that positioning the user at the centre of the IP search development is critical to promote innovative ideas. It is then decisive to favour the adoption of automated *in silico* search to assure that the professional "by no means" feels at the merci of her/his GPS and ends-up in a dead-end of a dirt bike road; just at a few 100's yards from the final destination.

7.2 THE SEMANTIC WEB INITIATIVE: OTHERS FAILURES CAN BE INSPIRING

Semantic Web was proposed in 2001 by Tim Berners-Lee, inventor of World Wide Web. His motivation was to index semantically the whole information present on the Web and make it meaningful for computer programs [82] (Berners-Lee, Hendler, & Lassila, 2001). Unfortunately, more than 10 years later it still did not happen. Nevertheless it is still active with a collective effort under the lead of the World Wide Web Consortium (W3C) which encourages the inclusion of semantic content to web pages. The idea of indexing the whole knowledge following standardized rules is of great interest for the IP domain. Every web document would have its attached machine-readable description. There would be no need to process text anymore; knowledge would be the entity machines would work with. This brilliantly simple idea is far from being a reality for many reasons but one raised issue merits all our attention. "The Semantic Web will never work because *it depends on businesses working together, on them cooperating*" [83] (Downes, 2007). This simple fact illustrates a fundamental issue that also needs to be addressed by the IP community.

Only a collaborative and standardized movement will make today's developments worth the efforts. What is needed is what misses for the Semantic Web to succeed, meaning "simple, well-defined, measurable, widely understood tasks; specific practices and approaches for performing them; tools, resources, and industry support" [84] (Kiryakov et al., 2004). The initiative may not come from relatively independent scientists working in their labs, rather remote from the business and industry prime objectives in that field. Industry and business support may be necessary to boost the initiative wherever it comes from. IP search entities might lead the way to a real evolution, if not a revolution, in the treatment of relevant information. One should not stop at a high-level vision but it should be combined with high-level standards with legal approval and integration, of course.

7.3 NEW SEARCH TECHNOLOGIES REQUIRE NEW EVALUATION TOOLS

The whole field of IP search is slowly moving away from keyword only based technologies and the evaluation has to progress towards new ways of measuring a search engine ability. Effectiveness has been for many years the main value evaluations would take into account as seen in chapter 2.4. This might be a useful thing to consider when retrieving "relevant documents" is the main goal but is of poor value when one wants to go further into the potential of this technology. IP search users want more from their software than simply finding results, they want answers. Professionals use these tools to help them planning and generating innovative ideas. There is therefore a need for a new appropriate way of evaluating search tools.

One major potential of search technologies especially in the IP domain is the ability to predict technological trends [16], [17], [45] (Yoon & Kim, 2011a; Yoon et al., 2012; Choi et al., 2011). We propose here a new evaluation test based on a simple idea: if the software would have been used at a particular moment in the past, could the technological breakthrough of that time period have been anticipated?

Here the test corpus would contain all available prior art documents from a major technological event. It should not only focus on documents' relevance but on being exhaustive and should include any kind of data and not only patents. The main idea is to move away from a first keyword-based selection of data that reduces the collection size only to "relevant documents". Such large collection already exists for patents but the tests are usually done on a small subset. CLEF-IP 2010 had 2.6 million patents in XML format but tests were only done on subsets of 500 to 2,000 documents. Considering storage and computing abilities of modern super-computers, handling big corpus is not anymore a technical limitation. This type of test corpus would have, to our opinion, several major advantages. The first one is the possibility to finally create what the Semantic Web intends to do but on a smaller scale than the whole web. Coordinating efforts on these data would be useful to come up with standardized index parameters for the IP domain. On the other hand working on very large dataset might implicate different algorithms since it is known that the behaviour of AI programs vary when acting on small or big collections. In the proposed model there would be no pre-selection of documents but the system would work on everything available in the corpus. The idea here is that new innovative concepts and breakthrough might not be detectable using only topic related data. The final measurement of this kind of evaluation would be prediction abilities and visualization capability.

Of course this rather broadly conceptualized idea would be perfected using noise reduction technology involving measurement of the noise impact and its value, possibly. One may "soundboard" the idea by referring to the work published by Nature in February 2009 on the "Detection of influenza epidemics using search engine query data".

7.4 AUTONOMY THROUGH DYNAMIC AND INTERACTIVE SYSTEMS

The currently available tools in the field of information retrieval even when using technologies more solution-oriented stick to a unidirectional kind of user-machine interaction. The user enters its query, the machine retrieves, processes and gives a result. IP domain is in need of adaptive software able through interactions with the users to learn and evolve to more autonomous entities. Once more it is not necessary to go very far to see examples of technologies that could be the future of IP search. Recently Apple launched a new application named Siri. Siri is the first commercially available AI that uses human-like ways of interaction [85] (Weaver, 2012). Unlike traditional search engines that necessitate screen and keyboard, Siri interacts with spoken language. It is then possible to query a system using natural language instead of lists of keywords. Ambient intelligence is a new evolution of AI that "refers to a digital environment that proactively, but sensibly, supports people in their daily lives" [86] (Ramos, Augusto, & Shapiro, 2008). Here the AI interprets its environment through sensorial sources, retrieves and represents the associated knowledge then plans, takes actions and learns from it. Its applications spread from smart homes to health monitoring and assistance [87] (Cook, Augusto, & Jakkula, 2009).

"Although these systems tend to be currently used as classification assistants, the ultimate goal for researchers in the field is to provide fully unsupervised systems, for instance to build pre-classification tools or to classify large volumes of patents in batch mode" (chapter 20 [8] (Lupu, 2011)). If one goes even further, automated systems will be able to plan, act, adapt, and be autonomous. This is already a reality in some field of research in biology. King and colleagues published in 2009 an article describing a robot scientist named Adam [88] (King et al., 2009). Adam formulates and tests hypothesis without human intellectual intervention. The IP domain would benefit from automated hypothesis particularly considering the multi-domain literature and concepts to manipulate [89] (Evans & Rzhetsky, 2010). The whole methodology of innovation is in need of a revolution and tools are available, one needs to put them together.

7.5 WHAT CAN WE LEARN FROM TRIZ?

The "theory of inventive problem solving" (from Russian TRIZ) has been developed by a Russian patent examiner Genrich Altshuller. The concept on which lie this theory is the following: "existing methods of inventing are so bad that they should be replaced" [90] (Altshuller, 1999). The innovative process tends to follow the same trial and errors schema throughout the ages. Despite people making some great inventions this is neither efficient nor satisfactory. Most of the time this rather limits the chances to solve "inventive" problems. Nowadays trial and errors remains a method which is still rather extensively used for scientific research, although most of the time accompanied by a design of experiments (DOE) which improves convergence. To overcome these issues the industry introduced, for a long time already, methods to enhance creativity and networking such as brainstorming. Yet the outcome still leaves some room for improvement. TRIZ, already in place for some time, tries to go further and proposes to define a methodology for invention based on knowledge. Because TRIZ approaches

problems from an algorithm point of view, it is more repeatable, more predictable and more reliable as opposed to other methods [91] (http://www.triz-journal.com/archives/what_is_triz/). The purpose of this section is not to praise TRIZ in particular but to attract the attention of the reader on the afterwards of information retrieval and analysis. TRIZ is one of the first "real" attempts to rationalize the innovation procedure. Innovation methodology needs to remain subject to careful scientific examination. It is now part of few search engines such as IHS Goldfire. We believe that these tools are a necessary evolution for the whole industry to continue its mutation to the next level of creativity in an open collaborative environment making use of the tremendous information available in various forms, such as images in patent literature and problem solving motivations at disposal in such literature and in patent specifications in particular.

From an academic stand point the above is even more legitimate and has to be mentioned in a review; additional what is more natural from a researcher standpoint to dream of a research recipe? To the tribute of TRIZ creators, the genesis of that method started from a clear understanding that problem solvers are good creators. Several successful business entrepreneurs developed computerized social networks from a problem solving approach; most of the time "improving and transferring" rather than discovering.

Opposite to some academic research framework, keeping a honeycomb search approach with lack of adjacent communication networks between the cells, industry and corporate research more specifically, have developed some level of hierarchy in their organization; leaving all research results more or less accessible to the researcher at large.

Some of those structures have naturally or by design evolved towards research crews with well identifiable profiles such as:

- The legendary **gate-keeper** focusing year after year on the maintenance and evolution of trade secrets and patent fortress therewith.
- The **coaching style technology master** (CSTM), capable of creating year after year evolving generational technology packages with awareness of the routes to market and the business models. The CSTM is well versed to communication, nurturing and empowerment of less experienced innovator generations or to help redirect already in place more experienced researchers.
- **Freelance profiles**, sometime perceived as "unmanageable" intrapreneurs (conversely entrepreneurs), take part to such controlling organization and are likely to bring non-core innovative solutions. They come generally from the problem solver side of the research organization; generally originating from the sometime less appreciated problem spotters, i.e. "trouble makers".

Earlier on, back in the 1990 [1] (Rebouillat, 2013), was developed and further adapted the Z-process, as a business development process, which starts from the VOC (Voice Of the Customer) analysis. Such VOCs rarely yield lack of clarity regarding product improvement opportunities from a customer standpoint; the latter is generally eager to sell the best products then requiring the best solutions from her/his suppliers and her/his research approach.

The Z-process includes the following steps:

- Market Survey
- Target Definition – Research and market Targets
- Speculative Research and Discovery Process
- Process Development
- Pilot Scale Manufacture
- Full Scale Manufacture
- Launch Phase
- Establishment Phase

The details of that process is out of the scope of this article, nonetheless one would wonder how a trial-and-error defiance would survive in such an organized research and business development, with rigorous time table, critical objective tasks, and CTQs; i.e. Critical To Quality parameters representing the product or service characteristics as defined by the customer/ user.

Rebouillat advocates the discipline of adopting an ATA© [1] (Rebouillat, 2013) as a process yielding the integration of IP and NPL in the business model and roadmaps therewith. The key ATA© associated "search" phases imply to:

- Conduct an Xpress inventory of science and technology portfolio at disposal, being core or adjacent;

- Reconsider Unexploited assets;

- Identify Unexplored areas;

- Formulate Ideal and dreamed approaches;

- Express Perceived Limitations & Frustrations;

Sequences, which involve 8 to 12 participants, 4 hour session repeated 4 times with a convergence mind-set, generally insure awareness and cross team interactions without being over time consuming.

Once more this approach will unlikely tolerate a lack of knowledge of the available prior art, core or adjacent. One may as well reconsider, in an open innovation perspective, the need to avoid giving dominancy to internal vs. external comparative analysis in favour of an external vs. internal focus; having the advantage of promoting a modest profile more permeable to others' contributions.

This does not mean that the information search, retrieval and exploitation, is handy, since improvement is definitely needed in this area as seen all along this work.

8 LEGAL ISSUES

IP is a legal concept and issues will naturally rise from a global use of intelligent search technologies. Two main points merit our immediate attention. The first one is related to the manipulation of data. The biggest challenge is to accompany the move of IP search from an internal task where confidentiality stays under a certain level of control, to external entities that would need a full access of in-house information (Chapter 20 [8] (Lupu, 2011)). Outsourcing data processing to businesses that most likely will manipulate information coming from direct competitors is a serious problem.

The second issue is AI itself and the creation of IP through human-machine partnership. Already in 1991 the WIPO had a symposium entitled "The intellectual property aspect of artificial intelligence" [9] (WIPO, 1991). The issue of ownership of IP from AI work has been recently raised again with the launch of Siri from Apple. This software is the first of many and will necessitate a re-examination of how we grant IP rights of AI creations as well as how we determine and assign liability [85] (Weaver, 2012). In anticipation of such events people have proposed to give a new legal status to AI and recognised them as individuals [78] (Davies, 2011). Law has to be part of the whole process not to restrict creativity or innovation but to accompany it to another level.

In this review we have clearly identified the key improvement in the information retrieval related to patent literature and NPL. The semantic image analysis (SIA) is necessary and has also to be adopted from a legal standpoint. There is no secret about the discomfort of some patent agents when dealing with images and drawings in patents; this in spite of guidance strongly encouraging applicants to include drawings and the risk of rejection for incompleteness.

Furthermore the guide for the preparation of patent drawings, available on the USPTO site, is a 135 page document with series of rules, which add to the complexity for the non-represented applicant at least.

The reluctance may be also attributed to the misinterpretation potential and the creation of new jurisprudential boundaries with the proliferation of images, versus annotated drawings, in patent applications.

"The Eye Alone Is the Judge" in the address of Rebecca Tushnet at Georgetown University Law Centre Conference in 2012, summarizes the most recent view on the matter in the following terms:

"But what does it mean for the eye to be the judge in a legal system organized around words? How can the report of an eye be turned into a verdict, and further into a reviewable judgment?"

A picture is worth a thousand words, which refers to the notion that a complex idea can be conveyed with just a single still image, is by far not yet the adage of the patent legal environment.

9 CONCLUSION

Being an IP researcher is becoming more and more complex with the explosion of data that need to be reviewed. Not only it is necessary to be an expert in different domains, to be aware of the diversity of the available literature, there is also a need to find the best strategy to retrieve the information. This later being at the centre of the whole process and is not an easy task.

Many obstacles, some of them depicted in this review, face strategists and IP researchers. Nevertheless companies are still able to generate new patents and move always forward the limits of innovation. Furthermore using automated search tools is still relatively young and needs to find its own pace. New technologies are becoming available and soon will become an essential part of any corporation that desires to grow and protect its interests at the same time. These new developments to be fully beneficial need to be more user-friendly and focused on slowly transferring the burden of data gathering to *in silico* researchers. And this will have to go through a simplification of the human-machine interactions. An exciting revolution faces the whole industry and IP search using AI is a key component.

We have underlined two elements that may be central to a near future success in the field.

One is the adjacent technology analysis, ATA©, which means that the position or distribution of patents (or IP in general) in an enlarged business environment may be more important than the value of the core technology indicators. Recurrent Xpress inventories of the core technology offering and reflection on unexplored, unexploited and ideal solutions, well balanced by the honest recognition of the frustrations and missing new capabilities, constitute the essence of the method. ATA© is the opportunity to stay in touch with the IP world from a technology standpoint as well as from a legal one without excessive lawyering.

The second element outlined in this review is the urgent need for SIA, in other words put the image at a central place in the IP search process and promote the IP via pictorial description. This in order to harmonize information and get closer to the non IP world made of pictures and motions rather than 1000's of words. The legal dimension is to be integrated naturally.

There is a tremendous opportunity to remove the fear associated with the open-innovation concept. The IP and NPL search harmonization can be enabling via semantic and image analysis. Finally, why not adopting a more holistic approach of data usage in the context of IP by integrating larger amount of data without doing screening from keywords and relevance standpoint? Instead elect for a well proportionated Semantic Web like approach. *A long way to go and an exciting journey onward!* And more papers to come on the influence of such approaches on the process of innovation.

We highly recommend the additional reading, of about 56 references, provided at the end of the reference list. More details on related specific matters are available in those.

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REFERENCES

[1] S. Rebouillat, "A Science & Business Equation for Collaborative Corporate Innovation . Business Strategy, IP Strategy, R&D Strategy: an all-in-one Business Model. A review with a Bio-Technology & Green Chemistry Focus." *Int. J. Innov. Appl. Stud.*, vol. 4, no. 1, pp. 1–19, 2013.

[2] D. (PRWEB) WILMINGTON, "A Record Year for DuPont Innovation," 2012. [Online] Available: http://www.prweb.com/releases/2012/3/prweb9280362.htm (2012).

[3] "Statistics and trends." [Online] Available: http://www.epo.org/about-us/annual-reports-statistics/annual-report/2012/statistics-trends.html.

[4] E. Garfield, "A tribute to Calvin N. Mooers, a pioneer of information retrieval," *Sci.*, 1997.

[5] Netcraft.com, "October 2013 Web Server Survey," 2013. [Online] Available: http://news.netcraft.com/archives/2013/10/02/october-2013-web-server-survey.html (2013).

[6] Elsevier, "Elsevier for authors," 2013. [Online] Available: http://www.elsevier.com/journal-authors/home (2013).

[7] PwC, "2013 patent litigation study," 2013. [Online] Available: http://www.pwc.com/en_US/us/forensic-services/publications/assets/2013-patent-litigation-study.pdf (2013).

[8] M. Lupu, *Current challenges in patent information retrieval*, ISBN: 978-3-642-19230-2, vol. 29. 2011.

[9] WIPO, "The intellectual property aspect of artificial intelligence," in *WIPO worldwide symposium*, 1991.

[10] T. Magerman, B. Looy, and X. Song, "Exploring the feasibility and accuracy of Latent Semantic Analysis based text mining techniques to detect similarity between patent documents and scientific publications," *Scientometrics*, vol. 82, no. 2, pp. 289–306, Jun. 2009.

[11] B. Spyropoulos and M. Botsivaly, "Improving the interpretation of Patent Data by the employment of the Semantic-Web formalism in the specific context of Biomedical Technology," *IFMBE Proc.*, pp. 257–260, 2009.

[12] J. Liu, A. Harris, and N. Kanwisher, "Stages of processing in face perception: an MEG study.," *Nat. Neurosci.*, vol. 5, no. 9, pp. 910–6, Sep. 2002.

[13] W. Zhao and R. Chellappa, "Face recognition: A literature survey," *Acm Comput. Surv.*, vol. 35, no. 4, pp. 399–458, 2003.

[14] W. M. Wang and C. F. Cheung, "A Semantic-based Intellectual Property Management System (SIPMS) for supporting patent analysis," *Eng. Appl. Artif. Intell.*, vol. 24, no. 8, pp. 1510–1520, Dec. 2011.

[15] J. Yoon and K. Kim, "Detecting signals of new technological opportunities using semantic patent analysis and outlier detection," *Scientometrics*, vol. 90, no. 2, pp. 445–461, Oct. 2011.

[16] J. Yoon and K. Kim, "Identifying rapidly evolving technological trends for R&D planning using SAO-based semantic patent networks," *Scientometrics*, vol. 88, no. 1, pp. 213–228, Apr. 2011.

[17] J. Yoon, H. Park, and K. Kim, "Identifying technological competition trends for R&D planning using dynamic patent maps: SAO-based content analysis," *Scientometrics*, vol. 94, no. 1, pp. 313–331, Sep. 2012.

[18] A. J. C. Trappey, C. V. Trappey, and C.-Y. Wu, "Automatic patent document summarization for collaborative knowledge systems and services," *J. Syst. Sci. Syst. Eng.*, vol. 18, no. 1, pp. 71–94, Mar. 2009.

[19] J. Tang, B. Wang, Y. Yang, P. Hu, and Y. Zhao, "Patentminer: Topic-driven patent analysis and mining," *KDD'12*, 2012.

[20] D. M. Jessop, S. E. Adams, and P. Murray-Rust, "Mining chemical information from open patents.," *J. Cheminform.*, vol. 3, no. 1, p. 40, Jan. 2011.

[21] D. Archibugi and M. Planta, "Measuring technological change through patents and innovation surveys," *Technovation*, vol. 16, no. 9, pp. 451–468, 1996.

[22] L. Wanner, R. Baeza-Yates, S. Brügmann, J. Codina, B. Diallo, E. Escorsa, M. Giereth, Y. Kompatsiaris, S. Papadopoulos, E. Pianta, G. Piella, I. Puhlmann, G. Rao, M. Rotard, P. Schoester, L. Serafini, and V. Zervaki, "Towards content-oriented patent document processing," *World Pat. Inf.*, vol. 30, no. 1, pp. 21–33, Mar. 2008.

[23] C. Wu and C. Yao, "Constructing an Intelligent Patent Network Analysis Method," *Data Sci. J.*, vol. 11, no. November, pp. 110–125, 2012.

[24] M. A. Newman and T. L. Works, "Method for syntactic and semantic analysis of patent text and drawings," US 5,774,833 (1998).

[25] A. Williams, "System and method for patent evaluation using artificial intelligence," US 8,161,049 B2 (2012).

[26] J. Codina, E. Pianta, S. Vrochidis, and S. Papadopoulos, "Integration of Semantic, Metadata and Image Search Engines with a Text Search Engine for Patent Retrieval.," *SemSearch*, vol. 334, 2008.

[27] D. Greenbaum and M. Gerstein, "Semantic web standards: Legal and social issues and implications," in in *Revolutionizing Knowledge Discovery in the Life Sciences*, 2007, pp. 413–433.

[28] O. a Jefferson, D. Köllhofer, T. H. Ehrich, and R. a Jefferson, "Transparency tools in gene patenting for informing policy and practice.," *Nat. Biotechnol.*, vol. 31, no. 12, pp. 1086–93, Dec. 2013.

[29] A. Rzhetsky, M. Seringhaus, and M. B. Gerstein, “Getting started in text mining: part two.,” *PLoS Comput. Biol.*, vol. 5, no. 7, p. e1000411, Jul. 2009.
[30] M. Lupu, *Patent Retrieval*, ISBN 978-1-60198-648-1, vol. 7, no. 1. 2013, pp. 1–97.
[31] L. Leydesdorff, D. Kushnir, and I. Rafols, “Interactive overlay maps for US patent (USPTO) data based on International Patent Classification (IPC),” *Scientometrics*, pp. 1–23, 2012.
[32] T. Chiu, C. Hong, and Y. Chiu, “Using IPC-Based Clustering and Link Analysis to Observe the Technological Directions,” in in *Semantic Methods*, 2011, pp. 183–197.
[33] D. Dirnberger, “A guide to efficient keyword, sequence and classification search strategies for biopharmaceutical drug-centric patent landscape searches - A human recombinant insulin patent landscape case study,” *World Pat. Inf.*, vol. 33, no. 2, pp. 128–143, Jun. 2011.
[34] Intellogist, “IPC classification system.” [Online] Available: http://www.intellogist.com/wiki/IPC_Classification_System.
[35] X. Polanco, C. François, and J. Lamirel, “Using artificial neural networks for mapping of scienceand technology: A multi-self-organizing-maps approach,” *Scientometrics*, vol. 51, no. 1, pp. 267–292, 2001.
[36] D. a. Keim, “Information visualization and visual data mining,” *IEEE Trans. Vis. Comput. Graph.*, vol. 8, no. 1, pp. 1–8, 2002.
[37] A. K. Jain, “Data clustering: 50 years beyond K-means,” *Pattern Recognit. Lett.*, vol. 31, no. 8, pp. 651–666, Jun. 2010.
[38] M. Mańko, R. Geracitano, and M. Capogna, “Functional connectivity of the main intercalated nucleus of the mouse amygdala.,” *J. Physiol.*, vol. 589, no. Pt 8, pp. 1911–25, Apr. 2011.
[39] D. Dupret, J. O’Neill, and J. Csicsvari, “Dynamic reconfiguration of hippocampal interneuron circuits during spatial learning.,” *Neuron*, vol. 78, no. 1, pp. 166–80, Apr. 2013.
[40] S. Kadir, D. Goodman, and K. Harris, “High-dimensional cluster analysis with the Masked EM Algorithm,” *arXiv.org*, pp. 1–10, 2013.
[41] P. I. Khalid, J. Yunus, and R. Adnan, “Extraction of dynamic features from hand drawn data for the identification of children with handwriting difficulty.,” *Res. Dev. Disabil.*, vol. 31, no. 1, pp. 256–62, 2010.
[42] R. Frijters, M. van Vugt, R. Smeets, R. van Schaik, J. de Vlieg, and W. Alkema, “Literature mining for the discovery of hidden connections between drugs, genes and diseases.,” *PLoS Comput. Biol.*, vol. 6, no. 9, pp. 1–11, Jan. 2010.
[43] W. L. Woon and S. Madnick, “Semantic distances for technology landscape visualization,” *J. Intell. Inf. Syst.*, vol. 39, no. 1, pp. 29–58, Oct. 2011.
[44] D. Escudero-Mancebo and V. Cardeñoso-Payo, “Applying data mining techniques to corpus based prosodic modeling,” *Speech Commun.*, vol. 49, no. 3, pp. 213–229, Mar. 2007.
[45] S. Choi, J. Yoon, K. Kim, J. Y. Lee, and C.-H. Kim, “SAO network analysis of patents for technology trends identification: a case study of polymer electrolyte membrane technology in proton exchange membrane fuel cells,” *Scientometrics*, vol. 88, no. 3, pp. 863–883, Jun. 2011.
[46] R. Rodriguez-Esteban, “Biomedical text mining and its applications.,” *PLoS Comput. Biol.*, vol. 5, no. 12, p. e1000597, Dec. 2009.
[47] D. Bonino, A. Ciaramella, and F. Corno, “Review of the state-of-the-art in patent information and forthcoming evolutions in intelligent patent informatics,” *World Pat. Inf.*, vol. 32, no. 1, pp. 30–38, Mar. 2010.
[48] Z. Xie and K. Miyazaki, “Evaluating the effectiveness of keyword search strategy for patent identification,” *World Pat. Inf.*, vol. 35, no. 1, pp. 20–30, Mar. 2013.
[49] F. Piroi, M. Lupu, A. Hanbury, W. Magdy, A. P. Sexton, and I. Filippov, “CLEF-IP 2012: Retrieval Experiments in the Intellectual Property Domain,” *CLEF-IP Initiat. EU*, 2012.
[50] C. Hempelmann and V. Raskin, “Semantic Search: Content vs. Formalism,” 2008.
[51] L. Hawizy, D. M. Jessop, N. Adams, and P. Murray-Rust, “ChemicalTagger: A tool for semantic text-mining in chemistry.,” *J. Cheminform.*, vol. 3, no. 1, p. 17, Jan. 2011.
[52] C. D. Manning, R. Prabhakar, and H. Schuetze, *An introduction to information retrieval*, no. c. 2009.
[53] H. Turtle, “Natural language vs. Boolean query evaluation: A comparison of retrieval performance,” *West Publ. Co.*, 1994.
[54] S. Sarawagi, “Information extraction,” *Found. Trends Databases*, vol. 1, no. 3, pp. 261–377, 2007.
[55] M. Minsky, *Semantic Information Processing*. 1969.
[56] H. L. Dreyfus, *What computer can’t do - The limits of artificial intelligence*. 1972.
[57] A. Spinakis and A. Chatzimakri, “Analysis of Biotechnology Patents,” *Knowl. Min.*, vol. 290, no. 2005, pp. 281–290, 2005.
[58] K. Wen, Y. Zeng, R. Li, and J. Lin, “Modeling semantic information in engineering applications: a review,” *Artif. Intell. Rev.*, vol. 37, no. 2, pp. 97–117, May 2011.
[59] E. Mäkelä, “Survey of semantic search research,” pp. 1–18, 2005.
[60] M. G. Moehrle, “Measures for textual patent similarities: a guided way to select appropriate approaches,” *Scientometrics*, vol. 85, no. 1, pp. 95–109, May 2010.

[61] M. G. Moehrle and J. M. Gerken, "Measuring textual patent similarity on the basis of combined concepts: design decisions and their consequences," *Scientometrics*, vol. 91, no. 3, pp. 805–826, Mar. 2012.
[62] J. M. Gerken and M. G. Moehrle, "A new instrument for technology monitoring: novelty in patents measured by semantic patent analysis," *Scientometrics*, vol. 91, no. 3, pp. 645–670, Jan. 2012.
[63] C. Hare, "Towards an Ontology of Intellectual Property," *Am. J. Econ. Sociol.*, 1998.
[64] H. Gurulingappa, B. Müller, and M. Hofmann-Apitius, "Information Retrieval Framework for Technology Survey in Biomedical and Chemistry Literature.," *TREC*, no. Xml, pp. 1–4, 2011.
[65] J. R. Wetherell and M. Mehok, "United States: Claim Construction: The Dictionary/Specification Dichotomy," 2005. [Online] Available: http://www.mondaq.com/unitedstates/x/32125/Patent/Claim+Construction+The+DictionarySpecification+Dichotomy (2005)
[66] T. Landauer, P. Foltz, and D. Laham, "An introduction to latent semantic analysis," *Discourse Process.*, vol. 25, no. 2, pp. 259–284, 1998.
[67] M. Fernández Sánchez, "Semantically enhanced Information Retrieval: an ontology-based approach," 2009.
[68] A. Mahabal, N. Takahiro, Z. Garrett, and K. Inoue, "Synonym identification based on co-occurring terms," US 8,538,984 (2013).
[69] H. Chen, B. Martin, C. M. Daimon, and S. Maudsley, "Effective use of latent semantic indexing and computational linguistics in biological and biomedical applications.," *Front. Physiol.*, vol. 4, no. January, p. 8, Jan. 2013.
[70] H. Henderson, *Encyclopedia of Computer Science and Technology*, vol. 17, no. 8. 2009, pp. 38–39.
[71] N. Bhatti and A. Hanbury, "Image search in patents: a review," *Int. J. Doc. Anal. Recognit.*, Dec. 2012.
[72] I. Kollia, N. Simou, A. Stafylopatis, and S. Kollias, "Semantic Image Analysis Using a Symbolic Neural Architecture," *Image Anal. Stereol.*, vol. 29, no. 3, pp. 159–172, Nov. 2010.
[73] N. Chomsky, Lecture at the University of Geneva Grandes Conferences. "The Language-Cognition Interface", International Congress of Linguists, Geneva July 2013.
[74] T. M. Sezgin and R. Davis, "Sketch recognition in interspersed drawings using time-based graphical models," *Comput. Graph.*, vol. 32, no. 5, pp. 500–510, Oct. 2008.
[75] D. G. Fernández-Pacheco, F. Albert, N. Aleixos, and J. Conesa, "A new paradigm based on agents applied to free-hand sketch recognition," *Expert Syst. Appl.*, vol. 39, no. 8, pp. 7181–7195, Jun. 2012.
[76] F. Brieler and M. Minas, "A model-based recognition engine for sketched diagrams," *J. Vis. Lang. Comput.*, vol. 21, no. 2, pp. 81–97, Apr. 2010.
[77] L. Olsen, F. F. Samavati, M. C. Sousa, and J. a. Jorge, "Sketch-based modeling: A survey," *Comput. Graph.*, vol. 33, no. 1, pp. 85–103, Feb. 2009.
[78] C. R. Davies, "An evolutionary step in intellectual property rights – Artificial intelligence and intellectual property," *Comput. Law Secur. Rev.*, vol. 27, no. 6, pp. 601–619, Dec. 2011.
[79] H. D. Schlinger, "What Would It Be Like to Be IBM's Computer, Watson?," *Behav. Anal.*, vol. 1, no. 1, pp. 37–44, 2012.
[80] H. D. Schlinger, "Intelligence: Real or artificial?," *Anal. Verbal Behav.*, vol. 10, no. 1985, pp. 125–33, Jan. 1992.
[81] S.-H. Liao, P. Chu, and P. Hsiao, "Data mining techniques and applications–A decade review from 2000 to 2011," *Expert Syst. Appl.*, vol. 39, no. 12, pp. 11303–11311, Sep. 2012.
[82] T. Berners-Lee, J. Hendler, and O. Lassila, "The Semantic Web," *Sci. Am.*, 2001.
[83] S. Downes, "Why the Semantic Web Will Fail," 2007. [Online] Available: http://halfanhour.blogspot.ch/2007/03/why-semantic-web-will-fail.html (2007).
[84] A. Kiryakov, B. Popov, I. Terziev, D. Manov, and D. Ognyanoff, "Semantic annotation, indexing, and retrieval," *Web Semant. Sci. Serv. Agents World Wide Web 2*, vol. 2, no. 1, pp. 49–79, Dec. 2004.
[85] J. Weaver, "Siri Is My Client: A First Look At Artificial Intelligence And Legal Issues," *Mondaq*, 2012. [Online] Available: http://www.mondaq.com/unitedstates/x/176106/Telecommunications+Mobile+Cable+Communications/SIRI+Is+My+Client+A+First+Look+At+Artificial+Intelligence+And+Legal+Issues (2012).
[86] C. Ramos, J. C. Augusto, and D. Shapiro, "Ambient Intelligence—the Next Step for Artificial Intelligence," *IEEE Intell. Syst.*, vol. 23, no. 2, pp. 15–18, Mar. 2008.
[87] D. J. Cook, J. C. Augusto, and V. R. Jakkula, "Ambient intelligence: Technologies, applications, and opportunities," *Pervasive Mob. Comput.*, vol. 5, no. 4, pp. 277–298, Aug. 2009.
[88] R. D. King, J. Rowland, S. G. Oliver, M. Young, W. Aubrey, E. Byrne, M. Liakata, M. Markham, P. Pir, L. N. Soldatova, A. Sparkes, K. E. Whelan, and A. Clare, "The automation of science.," *Science (80-.).*, vol. 324, no. 5923, pp. 85–9, Apr. 2009.
[89] J. Evans and A. Rzhetsky, "Philosophy of science. Machine science.," *Science (80-.).*, vol. 329, no. 5990, pp. 399–400, Jul. 2010.

[90] G. Altshuller, *The Innovation Algorithm*. MassachusettsTechnical Innovation Center, Inc. ISBN-10: 0964074044, ISBN-13: 978-0964074040, 1999.

[91] K. Barry, E. Domb, and M. S. Slocum, "TRIZ - What Is TRIZ?," *The TRIZ Journal*. [Online] Available: http://www.triz-journal.com/archives/what_is_triz/

RECOMMENDED ADDITIONAL READING

Anonymous. (n.d.). Patent Search Strategies : Keywords or Classifications ? http://patex.ca/pdf/publications/Patent Search Strategies.pdf

Archibugi, D., & Planta, M. (1996). Measuring technological change through patents and innovation surveys. *Technovation*, *16*(9), 451–468.

Bekmambetov, T. (2013). Visualisation of natural language text. Patent WO 2013/032354 A1

Benson, C. L., & Magee, C. L. (2012). A hybrid keyword and patent class methodology for selecting relevant sets of patents for a technological field. *Scientometrics*, *96*(1), 69–82. doi:10.1007/s11192-012-0930-3

Bogal-Allbritten, E. (2013). Decomposing notions of adjectival transitivity in Navajo. *Natural Language Semantics*, *21*(3), 277–314. doi:10.1007/s11050-012-9093-2

Cable, S. (2013). Beyond the past, present, and future: towards the semantics of "graded tense" in Gĩkũyũ. *Natural Language Semantics*, *21*(3), 219–276. doi:10.1007/s11050-012-9092-3

Cohen, K., & Hunter, L. (2008). Getting started in text mining. *PLoS computational biology*, *4*(1), 1. doi:10.1371/journal.pcbi.0040020

Corporation, F. F. (2013). New Patent For Decision Making Using Artificial Intelligence Issues With Financial Firebird Corporation Ready To Launch The First Public Use To Help People In Debt.

Deerwester, S., & Dumais, S. (1989). Computer information retrieval using latent semantic structure. *US Patent …*.

Fattori, M., Pedrazzi, G., & Turra, R. (2003). Text mining applied to patent mapping: a practical business case. *World Patent Information*, *25*(4), 335–342. doi:10.1016/S0172-2190(03)00113-3

George, B. R. (2013). Which judgments show weak exhaustivity? (And which don't?). *Natural Language Semantics*. doi:10.1007/s11050-013-9098-5

Ginsberg J. et al., Detecting influenza epidemics using search engine query data. Nature 457, 1012-1014 (19 February 2009). doi:10.1038/nature07634

Govada, S., & Kandekar, S. (2008). Patent analysis of RFID technology. In *MIS 580 – Knowledge Management Project*.

Greenbaum, D., & Gerstein, M. (2007). Semantic web standards: Legal and social issues and implications. In *Revolutionizing Knowledge Discovery in the Life Sciences* (pp. 413–433).

Guha, R., McCool, R., & Miller, E. (2008). Semsearch. *5th European Semantic Web Conference*.

He, J., Jifeng, X., Zhilei, R. E. N., Youxi, W. U., & Xindong, W. U. (2012). Misleading Classification. *Sci China Inf Sci*, *55*(12), 1–16.

Hehenberger, M., Ph, D., & Coupet, P. (1998). Text mining applied to patent analysis, 1–13.

Hersh, W. R., & Hickam, D. H. (1995). An evaluation of interactive Boolean and natural language searching with an online medical textbook. *Journal of the American Society for Information Science*, *46*(9), 719–719.

Isa, D., Blanchfield, P., & Chen, Z. (2009). Intellectual Property Management System for the Super-Capacitor Pilot Plant. *IC-AI*, 37–42.

Jiang, Y. (2014). analysis on the application of artificial intelligence technology in modern physical education. *Information Technology Journal*.

Lahm, A., & de Rinaldis, E. (2007). PatentMatrix: an automated tool to survey patents related to large sets of genes or proteins. *Source code for biology and medicine*, *2*, 4. doi:10.1186/1751-0473-2-4

Lamirel, J., & Shehabi, S. Al. (2003). Intelligent patent analysis through the use of a neural network: experiment of multi-viewpoint analysis with the MultiSOM model. *Proceedings of the ACL-2003 Workshop on Patent Corpus Processing*, 7–23.

Lange, N., Bishop, C. M., & Ripley, B. D. (1997). Neural Networks for Pattern Recognition. *Journal of the American Statistical Association*, *92*(440), 1642. doi:10.2307/2965437

Lucio-Arias, D., & Leydesdorff, L. (2007). Knowledge emergence in scientific communication: from "fullerenes" to "nanotubes." *Scientometrics*, *70*(3), 603–632. doi:10.1007/s11192-007-0304-4

Meżyk, E., & Unold, O. (2011). Machine learning approach to model sport training. *Computers in Human Behavior*, *27*(5), 1499–1506. doi:10.1016/j.chb.2010.10.014

Mende, M. (2010). Method for semantic processing of natural language using graphical interlingua. *WO Patent 2,010,051,966*.

Mika, P., Elfring, T., & Groenewegen, P. (2006). Application of semantic technology for social network analysis in the sciences. *Scientometrics*, *68*(1), 3–27.

Miron, A., Gensel, J., & Villanova-Oliver, M. (2010). Semantic Analysis for the Geospatial Semantic Web. In *Advances in Knowledge Discovery and Management* (pp. 287–306).

Mustafa, J., Khan, S., & Latif, K. (2008). Ontology based semantic information retrieval. *2008 4th International IEEE Conference Intelligent Systems*, 22–14–22–19. doi:10.1109/IS.2008.4670473

Newman, M. A., & Works, T. L. (1998). Method for syntactic and semantic analysis of patent text and drawings.

Osborne, G., & Chin, S. (2002). Artificial intelligence system for genetic analysis. *US Patent 2012/0177261 A1*

Palangkaraya, A., Webster, E., & Jensen, P. (2011). Misclassification between patent offices: Evidence from a matched sample of patent applications. *Review of Economics and Statistics*, *93*(August), 1063–1075.

Papić, V., Rogulj, N., & Pleština, V. (2009). Identification of sport talents using a web-oriented expert system with a fuzzy module. *Expert Systems with Applications*, *36*(5), 8830–8838. doi:10.1016/j.eswa.2008.11.031

Patinkin, S. (2009). Method, apparatus, and system for clustering and classification. *US Patent 7,574,409*.

Poltorak, A. (2007). Apparatus and method for identifying and/or for analyzing potential patent infringement. *US Patent 7,296,015*.

Pyle, D. (2003). Data Mining, 273–273. doi:10.1016/B978-155860653-1/50011-7

Russo, D. (2011). Global Product Development. (A. Bernard, Ed.). doi:10.1007/978-3-642-15973-2

Rzhetsky, A, Seringhaus, M., & Gerstein, M. (2008). Seeking a new biology through text mining. *Cell*, *134*(1), 9–13. doi:10.1016/j.cell.2008.06.029.Seeking

Scellato, G., Calderini, M., Caviggioli, F., Franzoni, C., & Ughetto, E. (2011). *Study on the quality of the patent system in Europe* (pp. 1–194).

Smucker, M. D., Allan, J., & Carterette, B. (2007). A Comparison of Statistical Significance Tests for Information Retrieval Evaluation. In *CIKM'07*.

Srikrishna, D., & Coram, M. (2013). Finding relevant documents. *US Patent 20,130,031,088*.

Sternitzke, C. (2009). Patents and publications as sources of novel and inventive knowledge. *Scientometrics*, *79*(3), 551–561. doi:10.1007/s11192-007-2041-0

Trappey, Amy J C, Trappey, C. V, & Wu, C. (n.d.). A Semantic Based Approach for Automatic Patent Document Summarization, (10608).

Trappey, Amy J.C., Trappey, C. V., & Wu, C.-Y. (2009). Automatic patent document summarization for collaborative knowledge systems and services. *Journal of Systems Science and Systems Engineering*, *18*(1), 71–94. doi:10.1007/s11518-009-5100-7

Vermeir, D., Laenens, E., & Dierick, J. (1988). Applying AI techniques for patent information retrieval. *World Patent Information*, *10*(1), 26–36.

Wang, W. M., & Cheung, C. F. (2011). A Semantic-based Intellectual Property Management System (SIPMS) for supporting patent analysis. *Engineering Applications of Artificial Intelligence*, *24*(8), 1510–1520. doi:10.1016/j.engappai.2011.05.009

Wanner, L., Baeza-Yates, R., Brügmann, S., Codina, J., Diallo, B., Escorsa, E., … Zervaki, V. (2008). Towards content-oriented patent document processing. *World Patent Information*, *30*(1), 21–33. doi:10.1016/j.wpi.2007.03.008

Weaver, J. (2012). Siri Is My Client: A First Look At Artificial Intelligence And Legal Issues. *Mondaq*. Retrieved from http://www.mondaq.com/unitedstates/x/176106/Telecommunications+Mobile+Cable+Communications/SIRI+Is+My+Client+A+First+Look+At+Artificial+Intelligence+And+Legal+Issues

Wen, K., Zeng, Y., Li, R., & Lin, J. (2011). Modeling semantic information in engineering applications: a review. *Artificial Intelligence Review*, *37*(2), 97–117. doi:10.1007/s10462-011-9221-2

Williams, A. (2012). System and method for patent evaluation using artificial intelligence. *US Patent 8,161,049*.

Wilson, J. (2010). Ontology and the regulation of intellectual property. *The Monist*, *93*(3), 450–463.

Wu, CC, & Yao, C. (2012). Constructing an Intelligent Patent Network Analysis Method. *Data Science Journal*, *11*(November), 110–125.

Wu, Chun-yi, Trappey, A. J. C., & Trappey, C. V. (2013). Concurrent Engineering Approaches for Sustainable Product Development in a Multi-Disciplinary Environment. In J. Stjepandić, G. Rock, & C. Bil (Eds.), *Concurrent Engineering Approaches for Sustainable Product Development in a Multi-Disciplinary Environment*. London: Springer London. doi:10.1007/978-1-4471-4426-7

Wyner, A., & Mochales-Palau, R. (2010). Approaches to text mining arguments from legal cases. In Semantic Processing of Legal Texts. Springer.

Zhang, Y., Zhou, X., Porter, A., Gomila, J., & Yan, A. (n.d.). Triple Helix innovation in China's dye-sensitized solar cell industry: hybrid methods with semantic TRIZ and technology roadmapping. *Scientometrics*.

Zhou, X., Han, H., Chankai, I., Prestrud, A., & Brooks, A. (2006). Approaches to text mining for clinical medical records. *Proceedings of the 2006 ACM symposium on Applied computing - SAC '06*, 235. doi:10.1145/1141277.1141330

Zhuhadar, L., & Nasraoui, O. (2010). Multi-language ontology-based search engine. In proceeding of: ACHI 2010, The Third International Conference on Advances in Computer-Human Interactions, Saint Maarten, Netherlands, Antilles, February 10-16, 2010.

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In-vitro cytotoxicity of Polyethyleneimine on HeLa and Vero Cells

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ABSTRACT: The success of gene therapy depends on the choice of a suitable vector that is biocompatible and efficient in delivering therapeutic DNA into disease cells. After more than two decades, such an ideal vector is still a wish. Viral vectors though naturally evolved to transfect cells are immunogenic. As alternatives, non-viral vectors such as polyethyleneimine have been exploited. We decided to investigate the *in-vitro* cytotoxicity of branched polyethyleneimine 800D, 25kD and linear 20kD on HeLa and Vero cells. At exponential phase, cells were exposed to polymers at concentration range of 0.5 to 1000mg/ml. Cells were MTT assayed after 24, 48 and 72hours for viability (IC_{50}). Linear PEI was less toxic than the branched PEI in both cells. The IC_{50} (mg/ml) values (Mean±SEM, n=6) post 72hours of PEI800D, 25kD and PEI20kD on HeLa cells were 2.42±0.22, 2.92±0.59, and 3.03±0.11 and for Vero cells, 7.42±0.29, 7.26±0.12, and 6.89±0.53 respectively. Two tailed t-test ($P<0.05$) of each polymer on both cells 72hours post dosing gave a significant P value of <0.0001. The results indicate that branched PEI800D, PEI25kD and linear PEI20kD are differently apoptotic to HeLa and Vero cells. The toxicity also time, cell line and concentration dependent. More research aimed at improving biocompatibility and transfection efficiency is needed.

KEYWORDS: HeLa, Vero, Polyethyleneimine, Poly L-lysine, Cytotoxicity, Dextran.

1 INTRODUCTION

The success of gene therapy depends on the choice of a suitable vector and there is no perfect vector. There are basically two privileged groups of vector commonly used in gene therapy clinical trials: viral and non-viral vectors [1]. Viral vectors have evolved over millions of years the capability to naturally infect all kinds of cells [3]. Despite the successes of viral vectors as seen recently with Glybera in 2012, there still exist limitations to the use of viral vectors in gene therapy. These include immunogenicity, insertional mutagenesis, safety profile of the vector in humans, difficult to produce viral titres, oncogenicity, and fear of germline line alteration which could be inheritable, low insert size and high cost [1], [2], [3], [4]. These ethical and safety concerns have led some investigators to consider non-viral vectors as alternative nano-delivery system.

1.1 NON-VIRAL VECTORS

Commonly used non-viral vectors are cationic lipids and polymers. Their use is based on their ability to interact with negatively charged DNA through electrostatic interaction. This leads to the formation of lipoplexes and polyplexes, respectively with a net positive charge which allows them to interact with the negative charge on the target membranes [1], [4]. They have outstanding ability to condense plasmid DNA and interact with cells [5]. Unlike their viral counterparts, they are easier to produce on a large scale, lower immunogenicity, larger insert up to 52 kilobases, possibility of selected modification to enhance vector carrying capacity, reduce toxicity, less ethical issues and acceptable cost[1], [4], [6]. Other classes include inorganic particles such as calcium phosphate, silica, gold particles and also physical methods such as electropororation and magnetofection [7].

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1.2 POLYETHYLENEIMINE

First introduced in 1995, polyethyleneimine (PEI) is a versatile non-viral vehicle that is widely studied [6]. It has a privilege place in gene therapy when compared to other polymers due to its potential for endosomal escape by proton sponge effect and higher transfection efficiency in a broad range of cell types [8]. PEI is a polymer of ethylene imine monomers that exists in mainly two forms: linear and branched molecule [6]. It can be synthesized in different lengths and also undergo functional group addition or substitution. Its polycationic nature enables it to complex DNA and form polyplexes at the appropriate nitrogen to phosphate ratios [6], [8]. However, it is also toxic like other cationic polymers. Its condensation with plasmid DNA or RNA is also believed to be majorly by electrostatic interaction between the negative phosphates on nucleic acids and positive groups of the amines [4], [6], [8].

Many factors have been shown to affect their degree of transfection and toxicity and they include degree of branching, molecular weight, ionic strength, zeta potential, concentration used and particle size [9], [10], [11]. Low molecular weight and moderately branched PEI has been shown by studies to be less toxic to cells and also have good transfection [12], [13]. Two types of toxicities have been reported in the use of PEI-mediated transfection: immediate toxicity associated with free PEI and delayed cytotoxicity associated with the PEI/DNA complexes [14]. Generally, it is assumed that the backbone linkages (carbon-carbon or carbon-amide bonds) are non-degradable at physiological pH and are resistant to systemic clearance, and accumulate in cells leading to further toxicity [15]. PEI has shown relatively low cytotoxicity when complexed with DNA and also higher transfection efficiencies significantly better than those observed with PLL and naked DNA [13].

The aim of this study was to establish the *in-vitro* cytotoxicity of branched polyethyleneimine (Br-PEI) molecular weight 800D and 25kD and linear polyethyleneimine (L-PEI) molecular weight 20kD on HeLa and Vero cells using poly L-lysine (PLL) and dextran as positive and negative controls respectively.

2 MATERIAL AND METHODS

2.1 MATERIALS

Multiskan EK plate reader and HERA cell 150i CO_2 incubator were supplied by Thermo Scientific Loughborough UK. Class II microbiological safety cabinet supplied by Envair, Lancashire UK. Sterile and non-pyrogenic tissue culture multi-well plates and 75cm^2 culture flasks obtained from Corning Incorporated, New York USA. Minimum Essential Media Eagle (MEM) and Dulbecco Modified eagle Medium (DMEM) were purchased from Life technologies Paisley, UK. Both media were supplemented by adding 10% Fetal Bovine Serum (FBS) and 1% penicillin streptomycin and glutamine (P/S/G). The HeLa (NR1 CRL-13011™) and Vero (CCL-81™) cells were obtained from ATCC, Middlesex, UK. Thiazoyl blue tetrazolium with 98.5% bromide with CAS 298-93-1 were supplied by Sigma Aldrich USA. Dimethyl sulfoxide with CAS 6768-5 was supplied by Fisher Scientific Loughborough UK. PEI branched MW 25,000 with CAS 9002-98-6, PEI branched MW 800 with CAS 25987-06-8 and PEI linear MW 20,000 with CAS 764965-1G, Dextran molecular weight 35,000-45,000 with CAS 9004-54-0, and PLL MW > 30,000 with CAS 26124-78-7 were equally obtained from Sigma Aldrich, St. Louis USA. Industrial Methylated Spirit was obtained from Fisher Scientific, Loughborough, UK.

2.2 CELL CULTURE AND SEEDING OF PLATES

The HeLa and Vero cells were cultured using corning culture flasks with vented caps. The HeLa cells were grown on MEM and the Vero cells on DMEM both supplemented with 10%FBS and 1% penicillin, streptomycin and glutamine. The culturing and seeding were aseptically done in a class II safety cabinet. The flasks were kept at 37^{o}C in 5% CO_2 and the cells passaged every 2 to 3 days in order to keep the cells alive.

2.3 DOSING OF CELLS

Following the seeding of the well plates with both HeLa and Vero cell at density of 1x10^4, the plates were incubated at 37^{o}C in 5% CO_2 overnight. Serial dilutions of concentrations 1mg/ml, 0.5mg/ml, 0.1mg/ml, 0.05mg/ml, 0.01mg/ml, 0.005mg/ml, 0.001mg/ml, and 0.0005mg/ml were prepared with Br-PEI 800D, Br-25kD and L-PEI20kD, PLL and dextran respectively. The cell lines were then incubated with these dilutions for 24, 48 and 72hours for branched PEI 25kDa and dextran. While with Br-PEI800, L-PEI 20kDa and PLL, the cells were incubated for 24 and 48hours. Post 24, 48 and 72hours of dosing, MTT assay as briefly described below was then carried out.

2.4 MTT ASSAY

The MTT toxicity assay was then carried out on both HeLa and Vero cells after 24hours for testing the toxicity of PLL, dextran and the PEI both linear and branched. The first and last wells on each labelled columns and rows were left out since they are labile to evaporation. To each of the remaining 6 wells, 10□l of MTT was added and the mixture mixed by gently tapping. This was repeated to each of the culture well plates. The plates were then incubated at 37^{o}C and 5% CO_2 for 4 hours. After incubation, the MTT and the media were aspirated out completely, and 100□l of DSMO was added to the same wells to ensure the dissolution of the formed insoluble formazan crystals, and incubated for 30 minutes. After incubation, absorbance (OD_{540}) were taken and recorded.

2.5 STATISTICAL ANALYSIS

All readings for the toxicity were converted to cell viability and expressed as a percentage using an excel template. The cell viability graphs and analysis of IC_{50} values were done using Graphpad Prism6.0.

3 RESULTS

The toxicity recorded for both cells were plotted and analysed as shown in figures 1 -4 and tables 1-3. As shown in the graphs, our positive control dextran did not result in any significant toxicity to our cell lines. However, abnormal spikes were seen in figures 2, 4 and 5 for positive control dextran, and also in figures 1, 4 and 5 for the test polymers. We included them in our graphs because F-test did not result in any significance. The error bars in the graphs correspond to Mean±SEM. Generally, concentrations ≥ 2mg/ml of both negative control and our study test polymers were toxic to the cells.

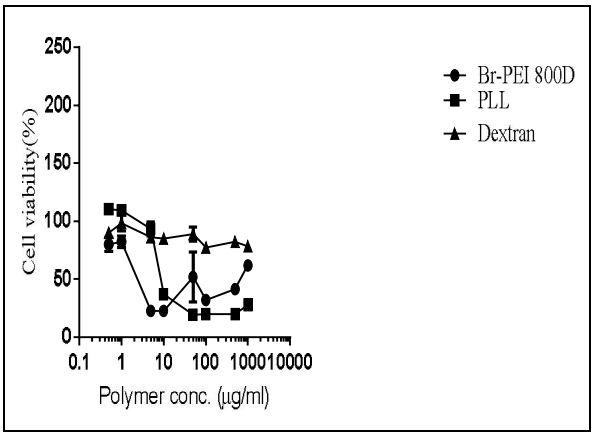

Fig. 1. HeLa cell viability after 72hours with Br- PEI 800D, dextran and PLL

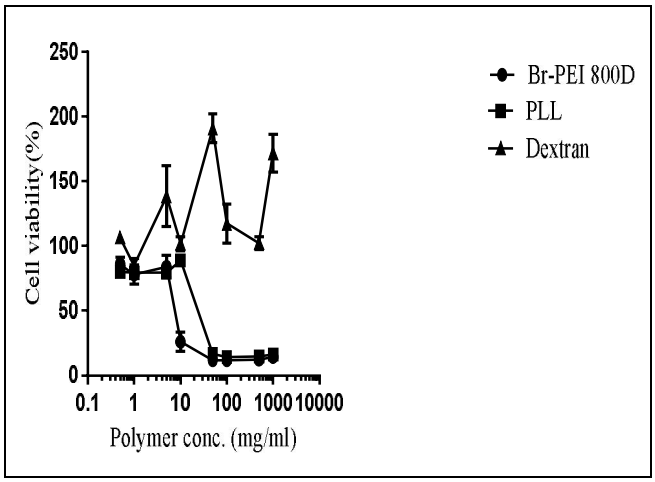

Fig. 2. Vero cell viability after 72 hours with Br- PEI 800D, dextran and PLL

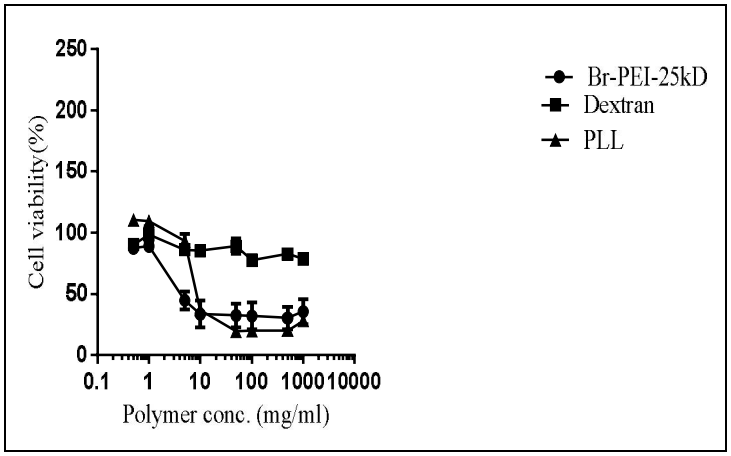

Fig. 3. HeLa cell viability after 72 hours with Br- PEI 25kD, dextran and PLL

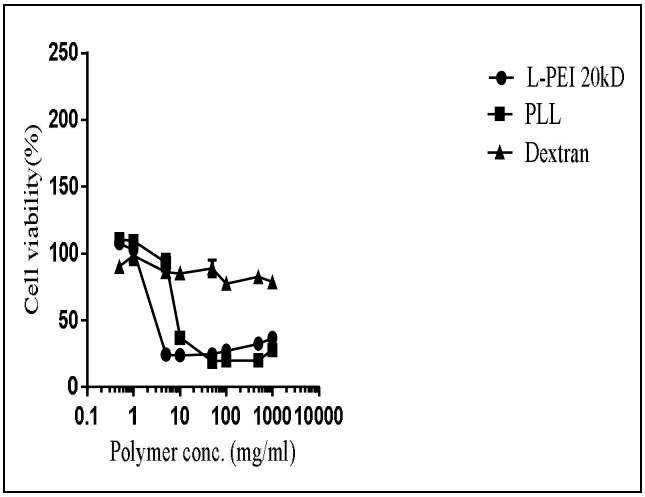

Fig. 4. HeLa cell viability after 72 hours with L-PEI 20kD, dextran and PLL

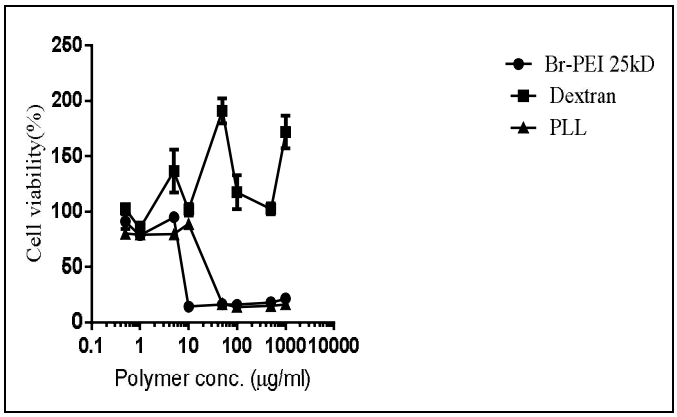

Fig. 5. Vero cell viability after 72 hours with Br- PEI 25kD, dextran and PLL

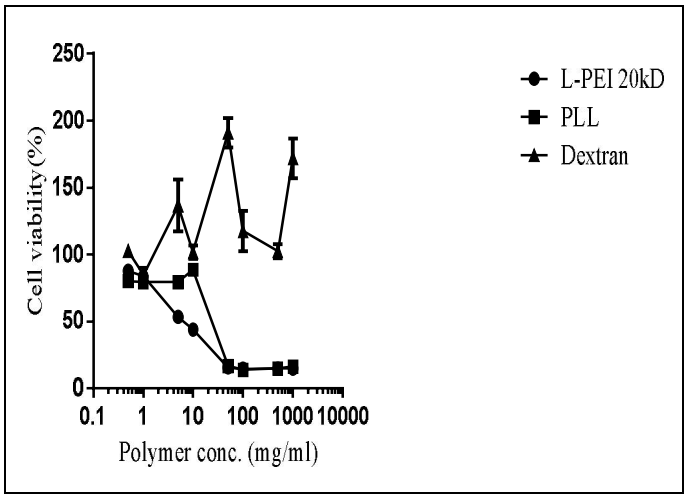

Fig. 6. Vero cell viability after 72 hours with L-PEI 20kDa, dextran and PLL

Table 1. T-test analysis of IC_{50} values for test and control polymers at various incubation times on HeLa and Vero cells

Cell line	Br-PEI800D	L-PEI20kD	Br-PEI25kD	Dextran	PLL
HeLa 24h	*3.957±0.219	29.70±1.910	9.930±0.416	> 1000	29.400±6.981
HeLa 48h	-	-	1.993±0.281	> 1000	-
HeLa 72h	2.422±0.216	3.033±0.110	2.917±0.590	> 1000	8.780±0.206
Vero 24h	2.762±0.157	66.830±3.707	26.850±9.763	> 1000	29.230±2.116
Vero 48h	-	-	7.325±0.2646	> 1000	-
Vero 72h	7.425±0.290	6.887±0.530	7.258±0.122	> 1000	24.350±0.917

**Cytotoxicity is expressed as an IC_{50} (g/ml) Mean±SEM, n=6.*

Table 2. T- test analysis of test polymers IC_{50} (µg/ml) at various incubation times on Vero and HeLa cells

Type of Polymer /Incubation time	Cell type	Difference of Mean±SEM	Significance At P<0.05	R^2	P Value
L-PEI 20KD 24 Vs 72hours	Vero	-59.950±3.745	Yes	0.962	<0.0001
L-PEI 20KD 24 Vs 72 hours	HeLa	-26.670±1.914	Yes	0.951	<0.0001
Br-PEI 800D 24 Vs 72hours	Vero	4.663±0.290	Yes	0.963	<0.0001
Br-PEI 800D 24 Vs 72hours	HeLa	-1.535±0.308	Yes	0.977	0.0006
Br-PEI 25kD 48 Vs 72hours	Vero	-0.067±0.291	No	0.005	0.8236
Br-PEI 25KD 24 Vs 72hours	Vero	19.590±9.764	No	0.287	0.0735
Br-PEI 25KD 24 Vs 48hours	Vero	19.530±9.767	No	0.286	0.0735
Br-PEI 25KD 24 Vs 72hours	HeLa	-7.013±0.719	Yes	0.905	<0.0001
Br-PEI 25KD 48 Vs 72hours	HeLa	0.9242±0.650	No	0.168	0.185
Br-PEI 25KD 24 Vs 48hours	HeLa	7.938±0.5017	Yes	0.967	<0.0001

Table 3. T- test analysis of test polymers on Vero and HeLa cells after 72hours of incubation

Types of Polymers	Cell types	Incubation time(hours)	R^2	*Diff in Mean±SEM	Significance at P<0.05	P Value
L-PEI20kD	HeLa Vs Vero	72	0.840	-3.853 ±0.539	Yes	< 0.0001
Br-PEI 800D	HeLa Vs Vero	72	0.960	5.003 ± 0.326	Yes	< 0.0001
Br-PEI 25kD	HeLa Vs Vero	72	0.840	-4.342 ± 0.599	Yes	< 0.0001

*n=6, degree of freedom = 10. * Represents the resulting IC_{50} (Difference in Mean±SEM) values in (µg/ml).*

Table 1 shows the IC_{50} values of the polymers for HeLa and Vero cells post 24, 48 and 72hours post dosing for test polymers, positive and negative controls. Dextrans gave a high IC_{50} values as our negative control. All three of our test polymers showed toxicity values much lower than that the negative control PLL in both cell lines meaning the test polymers were more toxic to than the positive and negative controls at concentrations and dosing duration used for this study. In table 2, t-test analysis of IC_{50} values (24 and 72 hours) after dosing for linear PEI, was significant (P<0.0001) with R^2 values of 0.962 and 0.951, respectively for Vero and HeLa cells. In the same vein, the branched PEI800D was also significant (P values = <0.0001, 0.0006) and (R^2 values = 0.963, 0.977) for Vero and HeLa cells respectively. On the other hand, our branched PEI25kD was not significant (P= 0.0735, R^2= 0.287) for Vero cell but was significant for HeLa cell (P<0.0001, R^2=0.905). For PEI800 also gave a significant value (P<0.0001, R^2= 0.967) for 48 and 72 hours post dosing, while others did not (see table 2).

A comparison of the IC_{50} values for both cells using only 72hours post dosing gave an significant value (P<0.0001, R^2 = 0.840, 0.960, and 0.840) for our PEI 20kD, 800D and 25kD respectively. This indicates that 72hours post dosing was consistently toxic to both cells as opposed to 24 and 48hours.

4 DISCUSSION

4.1 IN VITRO CYTOTOXICITY OF BRANCHED AND LINEAR PEI

Gene therapy it is thought will make the world a better place by helping treat and cure diseases as far as they have a molecular basis [16]. It has even been named as medicine of the future [17]. Since the characteristic of the coding and non-coding sequences of the human genome is different, there is no single effective vector that can be used to deliver all therapeutic DNAs into cells and tissues [1].

Immunological, safety and toxicity concerns limits the use of viral vectors despite their high natural transfection abilities in various cells [18], [19], [20], [21]. On this backdrop, safer alternatives have been investigated including PEI, PLL, and poly amidoamine and so on [22], [23]. PEI is one of the most promising non-viral vectors that have been widely studied since first introduced in 1995 by Boussif [6]. The main challenge still remains its high toxicity to cells [6], [23], [24], [25].

Branched PEI 25kD has been regarded as the gold standard but its transfection efficiency is marred by high toxicity to different cell lines [5], [18], [24], [25]. Linear PEI has been shown to be less toxic to cell but less efficient in delivering DNA to cells when compared to their branched counterparts [13], [18]. Studies have confirmed that the high charge density in the methylene ($-CH_2(CH_2)N(X)-$) backbone of branched PEI is proportional to their toxicity [26], [27]. Studies have also shown that PEI25kD branched is more toxic than linear PEI25kD in epidermal cell A431 [18] and this conforms to our values as represented in table 2 even though our linear PEI was 20kD and incubation time 72hours, the toxicity was roughly similar. PEI800 branched have been shown to cause unacceptable massive necrosis compared to linear 25kD, branched PEI1.8, PEI2 and PEI11 which showed more acceptable toxicity [28].

Our study confirms that Br-PEI800D, L-PEI20kD and Br-PEI25kD are indeed apoptotic agents as previously reported [6], [29]. The toxicity was however time, dose and cell line dependent. Br-PEI 800D and 25kD gave an IC_{50} values lower than the linear PEI 20kD in our study in both HeLa and Vero cells and this was consistent with that know fact that PEI toxicity depends on cell type and degree of branching[13], [18]. Omidi *et al* 2011 reported IC_{50} values of 37□g and 74□g for PEI25kD branched and linear on A431 cells. These were higher than our findings of post 24, 48 and 72 hours of dosing as shown in table 1. Roughly same IC_{50} values of 10□g have been reported for HeLa and 293T cells by Huang *et al*, 2010. The difference in toxicity seen in both cells in this study is probably due to the difference in physiology of both cells. HeLa cells are derived from

human cervical cancer cell and Vero gotten from normal kidney cell of African Green Monkey. The difference in toxicity in both cell lines and in different polymers indicates a high significance post 72hours for each polymer for both cells with $P<0.0001$ (table 3)

The toxicity of L-PEI20kD, Br-PEI 800D and 25kD is also dependent on time. For HeLa cell, all the polymers gave a significant increased toxicity post 24 and 72 hours incubation with polymers. On the other hand, Vero cells did show increased but insignificant toxicity with PEI25kD, significant increased toxicity with PEI800D and a significant reduced toxicity with linear PEI20kD.

5 CONCLUSION

The success of gene therapy is highly dependent on the choice of a suitable vector. An ideal vector should have high transfection and no toxicity to the target cells. So far these essential requirements have not been meet in both viral and non-viral vectors studied thus far. There may never be an ideal vector for shuttling all genes by gene therapy given the different biological behaviour of viruses and physicochemical properties of non-viral vectors. Our studies have shown that polyethyleneimine branched 800D and 25kD, and linear polyethyleneimine 20kD are indeed cytotoxic to HeLa and Vero cell lines. This toxicity was seen to be cell type, concentration, polymer and time dependent. Post doing time of 72hours appeared to be the most toxic duration with significant difference in both cell lines and all three polymers employed for this study. All three polymers appeared to be more toxic to HeLa than Vero cells with time.

Given the higher cytotoxicity seen in our study for Br-PEI800 and 25KD and the lower toxicity for L-PEI 20kD, their transfection efficiencies also needs to be studied properly in not just HeLa and Vero cell but also other clinically important cell lines. Studies have shown that polyethyleneimine can be made more biocompatibility with copolymers. Therefore, it is equally important to look at the toxicity profiles and transfection efficiencies with such copolymers such as poly ethylene glycol, chitosan and dextran.

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REFERENCES

[1] S. N. Uddin, Cationic lipids in non-viral gene delivery systems. *Biotechnology and Molecular Biology Review*, 2(3): 058-067, 2007.

[2] Panno, J. (2010). Viruses: Cornerstones of Gene Therapy. Gene Therapy, In: Gene Therapy Treatments and Cures for Genetic Disease. Rev. Ed. Bang Printing USA. pp. 55-71, 2010.

[3] T. W. Writh and Y. H. Seppo, History of gene therapy. *Journal of Gene***,** 525(2):162-169, 2013.

[4] M. Morille, C. Passirani, A, Vonarbourg, A. Clavreul and J. P. Benoit, Progress in developing cationic vectors for non-viral system gene therapy against cancer, *Biomaterials,* 29:3477-3496, 2008.

[5] F. W. Huang, H. Y. Wang, C. Li, H. F., Wang, Y. X. Sun and J. Feng, PEGylated PEI-based biodegradable polymers as non-viral gene vector, *Acta Biomaterialia,* 6:4285-4295, 2010.

[6] H. Lv, S. Zhang, B. Wang, S. Cui, and J, Yan, Toxicity of cationic lipids and cationic polymers in gene delivery, *Journal of Control Release*, 114:100-109, 2006.

[7] Gascón, Pozo-Rodríguez and Solinís,2013 Non-Viral Delivery Systems in Gene Therapy, Gene Therapy - Tools and Potential Applications, F. Martin (Ed.), ISBN: 978-953-51-1014-9, InTech, DOI: 10.5772/52704. Available: http://www.intechopen.com/books/gene-therapy-tools-and-potential-applications/non-viral-delivery-systems-in-gene-therapy, (July 7, 2013).

[8] C. Tros de Ilarduya, Y. Sun, and N. Duzgunes, Gene delivery by lipoplexes and polyplexes. *European Journal of Pharmaceutical Sciences*. 40:159-170.

[9] K. Kunath, D. von Harpe, H. Fisher, U. Petersen, K. Bickel, T. Voight and T. Kissel, Low molecular weight polyethyleneimine as a non-viral vector for DNA delivery: comparison of physicochemical properties, transfection efficiency and in vivo distribution with high-molecular polyethyleneimine, *Journal of Control Release*, 89:113-125, 2003.

[10] M. Lungwitz, M. Breunig, T. Blunk, and A. Go-pferich, Polyethylene mine based non-viral gene delivery systems, *Eur. J. Pharm. Bio pharm*, 60:247-266, 2005.
[11] Y. H. Kim, J. H. Park, M. Lee, Y. H. Kim, T. G. Park, and S. W. Kim, Polyethyleneimine with acid-labile linkages as a biodegradable gene carries, *Journal of Control Release,* 103:209-219, 2005.
[12] M. Breunig, U. Lungwitz, R. Liebl, C. Fontanari, J. Klar, and Kurtz A, et al,. Gene delivery with low molecular weight linear polyethyleneimine, *J. Gene Med*, 7(10):1287-98, 2005.
[13] W. T. Godbey, K. K. Wu, A.G. Mikos and G. J. Hirasaki, Improved packing of polyethyleneimine/DNA complexes increases transfection efficiency, *Gene Therapy,* 6:1380-1388, 1999.
[14] W. T. Godbey, K. K. Wu and A.G. Mikos, Size matter: molecular weight affects the efficiency of polyethyleneimine as a gene delivery vehicle, *J. Biomed. Mater.*R*es,* 45:268-275, 2001
[15] M. R. Park, K. O. Han, I. K. Han, M .H. Cho, J. W. Nah, Y. J. Choi, and C. S Cho, Degradable polyethyleneimine-alt-poly (ethylene glycol) copolymers as novel gene carriers, *Journal of Controlled Release,* 105:367-380, 2005.
[16] A. F. Vargas, The Human Genome Project and its importance in clinical medicine, *International Congress Series,* 1237: 3 –13, 2002.
[17] K. Lundstrom and T. Boulikas, Viral and Non-viral Vectors in Gene Therapy: Technology Development and Clinical Trials, *Technology in Cancer Research and Treatment*, 2(5): 471-485, 2003.
[18] O. Kafil and Y. Omidi, Cytotoxic Impact of Linear and Branched Polyethleneimine Nanostructures in A431 cells, *Bioimpacts,* 1(1):23-30, 2011.
[19] J. R. Goss, W. F. Goins, D. Lacomis, M. Mata, J. C. Gloriso, and D. J. Fink, Herpes simplex-mediated gene transfer of the nerve growth factor protects against peripheral neuropathy in streptozotocin-induced diabetes in the mouse, *Diabetes*, 51:2227-2232, 2002.
[20] M. Giacca and S. Zacchigna, Virus-mediated gene delivery for human gene therapy, *Journal of Controlled Release*, 161**:**377-388, 2012.
[21] S. Yla-Herttuala, Endgame: Glybera finally recommended for approval as the first therapy drug in the European Union, *Molecular Therapy,* 20: 1831-1832, 2012
[22] S. C.W. Richardosn, N. G. Pattrick, N. Lavignac, P, Ferruti and R. Ducan, Intracellular fate of bioresponsive poly(amidoamine) *in vitro* and *in vivo, Journal of Controlled Release*, 142**:**78-88, 2010.
[23] Y. J. Choi, S. J. Kang, Y. J. Kim, Y.B. Lim and H.W. Chung, Comparative studies on the genotoxicity and cytotoxicity of polymeric gene carriers polyethyleneimine (PEI) and polyamidoamine (PAMAM) dendrimers in Jurkat T-cells, *Drug and Chemical Toxicology*, 33(4):357-366, 2010.
[24] B.I. Florea, C. Meaney, H. E. Junginger, and G. Borchard, Transfection efficiency and toxicity of polyethyleneimine in differentiated Calu-3 and non-differentiated COS-1 cell culture, *AAPS Pharm. Sci.*, 4(3):E12, 2002.
[25] M. Turk, S. Dincer, I.G. Yulug and E. Piskin, In vitro transfection of HeLa cells with temperature sensitive polycationic copolymers, *Journal of Controlled Release,* 96:325-340, 2004.
[26] J. H. Jeong, S. H. Song, D.W. Lim, H. Lee, and T.G. Park, DNA transfection using linear poly(ethyleneimine) prepared by concentration acid hydrolysis of poly(2-ethyl-2-oxazoline), *Journal of controlled Release,* 73:391-399, 2001.
[27] M.P. Xiong, M.L. Forrest, G. Ton, A. Zhao, N.M. Davies and G.S, Kwon, ,Poly(aspartate-g-PEI800), a polyethyleneimine analogue of low toxicity and high transfection efficiency for gene delivery, *Biomaterials,* 28(32): 4889-4990,2007
[28] D. Fischer, T. Bieber, Y. Li, and H.P. Elasser, (1999). A novel non-viral vector for DNA delivery for DNA delivery based on low molecular weight, branched polyethyleneimine: effect of molecular weight on transfection efficiency and cytotoxicity, *Pharma. Res*., 16:1273-1279, 1999
[29] A.C. Hunter, Molecular hurdles in polyfectin design and mechanistic background to polycation induced cytotoxicity. *Adv. Drug Del. Rev.,* 58:1523-1531, 2006.

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Diagenesis and reservoir quality in continental fault-block reservoirs: Evidence from the Second Member of Shahejie Formation, Dongying Sag, Eastern China

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ABSTRACT: Continental fault-block reservoirs in the Second Member of Shahejie Formation in Dongying Sag of Eastern China are difficult to achieve efficient exploration and development due to the complex geological conditions. This study relates to the in-depth analysis on diagenesis and reservoir quality in such deposits. These deposited sandstones have a wide range of porosity and permeability, which indicate both depositional facies and diagenesis control. Diagenetic processes that influenced the reservoir quality of the study area mainly insist of the formation of carbonate cements, and clay minerals, mechanical compaction, quartz cementation, and dissolution of framework grains. The distribution patterns and mineralogy of cements vary spatially, being relevant to reservoir evaluation. Among the diagenetic menerals, carbonate cements occur as the predominant components in the Shahejie sandstones of the study area. In such settings, the quality-destruction processes include mechanical compaction and carbonate cementation, whereas the quality-generation process is dissolution of detrital grains and calcite cements. The major sequence is eodiagenesis with the types and extent of eogenetic alterations related to the near-surface geological conditions. This study demonstrates diagenesis and related reservoir quality evolution can be linked to fine reservoir characterization, and thereby has an important role on hydrocarbon exploration and exploitation in the continental fault-block reservoirs.

KEYWORDS: Diagenesis, continental fault-block reservoirs, reservoir quality, paragenetic sequence, reservoir characterization.

1 INTRODUCTION

Faults are well developed in many continental fault basins in eastern China, forming a number of fault-block reservoirs. Since most of the fault blocks are generally small, structure and distribution of hydrocarbon and water seem to become relatively complex. Therefore, sandstones in continental fault-block reservoirs vary significantly and reservoir heterogeneity becomes severe, which bring difficulties in hydrocarbon exploration and exploitation.

Diagenesis exerts an important control on the quality and heterogeneity of most clastic reservoirs, and usually accentuates the variations in physical properties [1], [2]. Sandstone diagenesis is on the basis of the formation of depositional sandstones [3]. Carrying out analysis on factors affecting the diagenetic history and summarizing diagenetic model plays an importantl role in predicting distribution of favorable reservoirs and formation of diagenetic traps. The general trend of

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diagenesis is to make the combination of rocks towards a more stable and balance direction in aspects of composition and texture. For this reason, sedimentary rocks will experience changes in mineral composition and adjustments on the rock fabric during the whole series of diagenetic stage.

The studied rocks occur in the Western Dongying Sag of Bohai Bay Basin in eastern China with an aerial extent of about 15.3 km^2. The Second Member of Shahejie Formation (S2) of the study area has long been a site of hydrocarbon exploration and exploitation in China; however, diagenesis and related reservoir quality have not been studied in detail due to the complex geological conditions in these fault-block reservoirs. It is here demonstrated that the diagenesis and reservoir quality contribute to a better understanding of the spatial and temporal distribution of porosity and permeability in such fault-block reservoirs. Also, the research results are expected to resolve the problems of low degree of recovery and low production rate to enrich the knowledge of fine reservoir characterization.

2 METHODS

Sandstone samples were prepared by counting 300 points per thin section, which were vacuum impregnated with red epoxy prior to thin-section preparation. A Quanta 200 scanning electron microscope (SEM) was performed to study cement morphology, paragenetic relationships, and the pore-system geometry in the representative samples, which was coated with a thin layer of gold.

3 RESULTS AND DISCUSSIONS

3.1 DIAGENETIC ALTERATIONS

The S2 Sandstone samples show evidence of variable degrees of mechanical compaction, which refers to the formation of deposits due to the overlying sediments in the heavy load. With sandy sediments deposition after the burial depth increases, mechanical compaction of the detrital grains also from the point contact to point - line contact dominated (Fig. 1A), and plastic particles being deformed are visible in the study area. Chemical compaction, which is manifested by intergranular pressure and lattice formation of quartz cements, is less common.

Carbonate cementation refers to minerals or cements precipitation out of solution from the pores and then the consolidation of loose sediments. It plays an important role in transferring sediments into sedimentary rocks, but also is one of the main reasons of reducing the porosity and permeability of continental reservoirs [4], [5], [6]. Calcite mainly fills the intergranular pores as dominant pore occluding carbonate cement in this area (Fig. 1B), where as dolomite and ankerite occur partially in trace amounts (Fig. 1C).

Quartz overgrowths constituent the main siliceous cementation and always occur on quartz grains with clean surfaces. Generally, quartz overgrowths seem to follow pore-filling growth direction, which occupy the pore space (Fig. 1D), change the pore structure and significantly reduce the reservoir properties. Quartz overgrowths transform sandstone pore structure and cut the original good connectivity pore throats into a series of systems ranging in size pore systems, which greatly reduce their pore throat sorting level. Some angular authigenic quartz outgrows are visible in local area observed in SEM.

In the sandstone reservoirs, the clay mineral cements are difficult to identify in the polarizing microscope due to the limited magnification. However, SEM for mineral identification, basically kind of morphology identification, is easy to compensate these deficiencies according to the typical mineral crystal morphology and crystal polymer morphology to determine minerals [7], [8]. By scanning electron microscopy, clay minerals in this study area mainly involve mixed-layer illite-smectite, kaolinite, illite and minor chlorite. Under controls by parameters such as subsurface pore fluid properties, paleosalinity, debris composition, and diagenesis, these authigenic clay minerals in different depositional and diagenetic environments can form different combination and types, showing the evolution of clay minerals in varying degrees. As an important bridge between inorganic and organic world, clay minerals and their evolution are of extremely importance in the porosity evolution of oil and gas bearing basins. Mixed-layer illite-sectite (I/S), which is the most common clay mineral in the S2 Sandstones, exhibits fiber flake-like textural form with the observation of SEM (Fig. 1E). Chlorite occurs dominantly as leaf-shaped with less content in this study area. Kaolinite occurs as booklets and vermicular aggregates that fill in adjacent pore space (Fig. 1F). SEM observation reveals that the crystal of kaolinite can be often found among a large number of pore spaces. So it is rare to see that kaolinite has completely blocked pores although the pore-filling kaolinite often occupies parts or most of the pore spaces. Illite occurs as scattered patches, which is derived from diagenetic evolution of mixed-layer I/S, as coatings around framework grains or pore-occluding cement (Fig. 1G). Chlorite occurs as pore-filling and thin fringes around detrital grains with a minor content (Fig. 1H). Sandstone cementation is strongly controlled by continental components and its provenance, sediments and sedimentary environments, grain coating of clay minerals, presence and

alternation of pore water, impact of hydrocarbon, and so on. The formation conditions of clay minerals are varied, depending on mineral composition of sandstones, the pore fluid properties, temperature and hydrogen ion concentration [9], [10], [11].

Dissolution of minerals in sandstones corresponds to authigenic mineral precipitation, which is common in S2 Sandstones. According to the scanning electron microscope and thin section observation, partial dissolution of feldspars, lithic fragments and carbonate cements can be seen. In contrast with the cementation, dissolution plays an important constructive role on the reservoir space (Fig. 1I). The occurrence of dissolution is the combined effect of chemical, physico-chemical and biochemical factors, leading to a better porosity and permeability in the reservoirs.

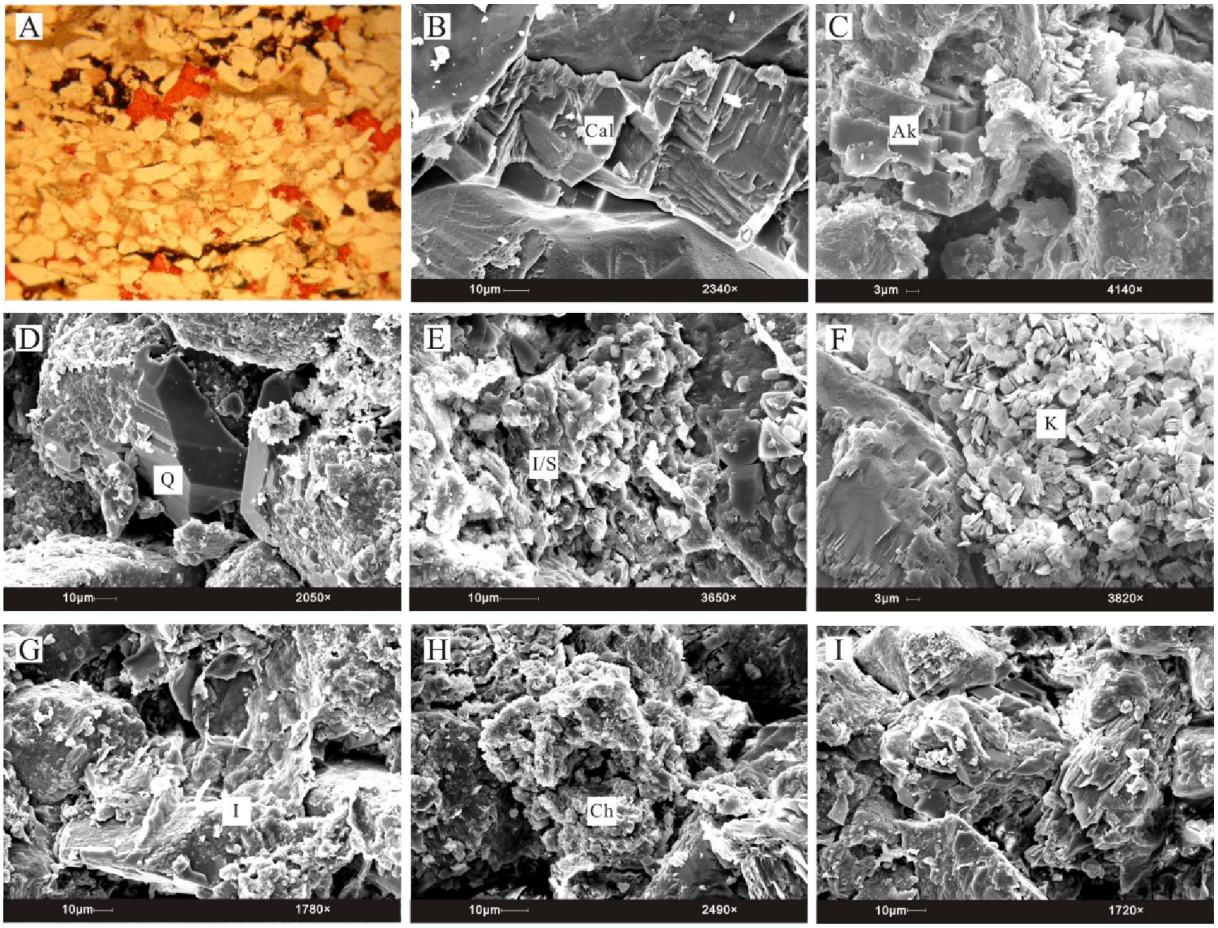

Fig. 1. Thin section and scanning election photomicrographs of the S2 Sandstone subsurface samples

3.2 POROSITY AND PERMEABILITY

The observation of thin section and SEM in the S2 Sandstones reveals that porosity in this area includes primary intergranular, secondary intragranular, intergranular, and mouldic porosity. Micro pores can also be found between clay crystals and within dissolved feldspars. Statistical analysis of reservoir physical properties on core samples shows that there is a large range distribution of porosity and permeability within the study area. Porosity measured by core samples mainly range between 20 to 30% showing a single peak (Fig. 2A), and statistics on permeability occur mainly between 10 to 1000mD (Fig. 2B), reflecting a strong heterogeneity. Also, porosity exhibits a good correlation (r^2=0.8224) with permeability (Fig. 2C), but there is relatively weak correlation between porosity and carbonate contents.

Physical properties of sandstone reservoirs are often controlled by many factors, such as depositional structures and a series of diagenetic process in rock sediments during burial. Sedimentation controls to some extent on the type, shape, size, original condition and spatial distribution of reservoir sands, whereas diagenesis influences reservoir evolution and reservoir physical properties.

According to the statistical data of physical properties in different sedimentary sandstone reservoirs, it shows deposition has relatively good control effect on reservoir properties. The best quality reservoirs appear in distributary channel, whereas mouth bar show a moderate quality and interdistributary display a poor quality (Fig. 2D).

For diagenesis, mechanical compaction and cementation are the main reasons for the destruction of primary porosity. Pore blocking can be seen by carbonate cements in local intervals, which reduce pore space significantly. Dissolution is very common is this area, which is a major constructive factor to improve the reservoir quality.

3.3 PARAGENETIC SEQUENCES OF DIAGENETIC PROCESSES

Diagenetic stages of clastic reservoirs are the results of interaction among structure change, fluid properties, burial depth and other factors, which determine the degree of maturity of organic matter, and internal composition, structure, properties of sedimentary rocks [12]. Therefore, the determination of diagenetic stages sets an important basis for predicting the formation of oil and gas, and assessing reservoir conditions. Besides, it is of great importance for determining a regional exploration target.

The overall paragenetic sequence of the sandstones is shown in Fig. 3, and the main diagenetic modifications occur in Eodiagenesis. And the diagenetic processes are strongly governed by parameters such as chemical composition of surface waters, detrital composition of the sands, deposition rates, and organic-matter content, which is in turn controlled by pore-water chemistry. Buried depth in the study area is generally between 1950 and 2250m, with mainly semi-consolidated to consolidated, and point - line contact. Precipitation of early calcite, dolomite, and late ankerite cements is visible in S2 Sandstones, resulting in deterioration in reservoir quality. Quartz overgrowth and authigenic quartz crystal occur as core-occluding cements [13]. Clay minerals including mixed-layer illite-smectite, illite, kaolinite, and minor chlorite appear to prevent quartz overgrowth, indicating a preservation of reservoir quality. Feldspar, lithic and calcite can be seen dissolved to form a certain degree of secondary porosity, and thus enhance the reservoir quality to some content.

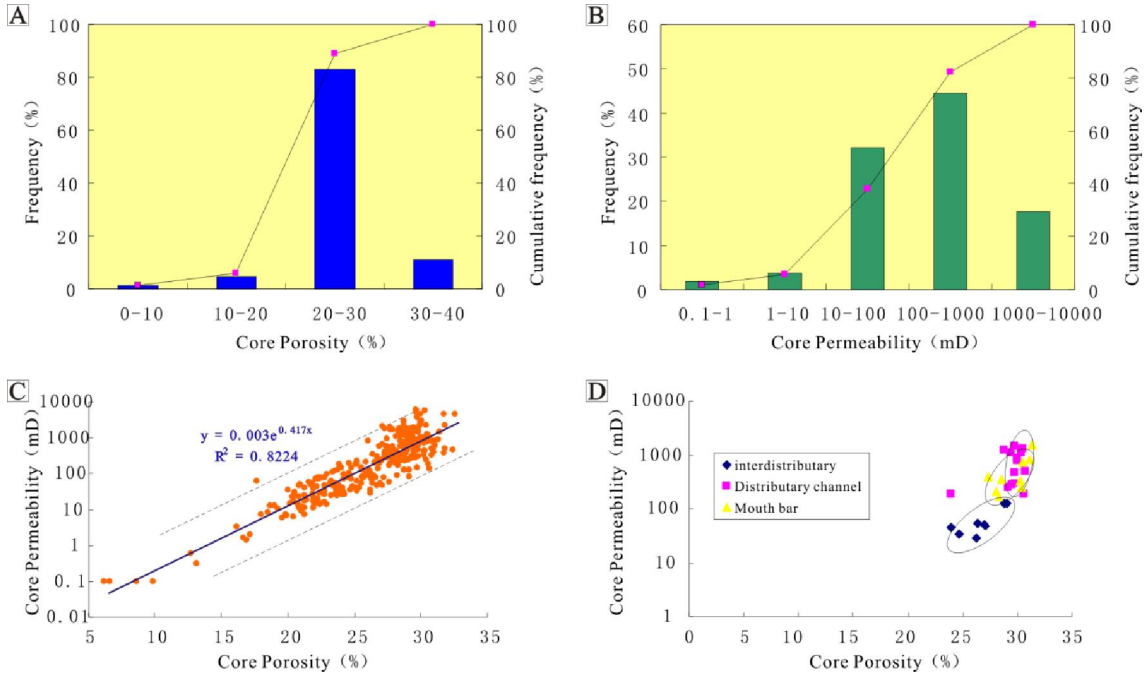

Fig. 2. Maps for the statistical data of physical properties in the study area

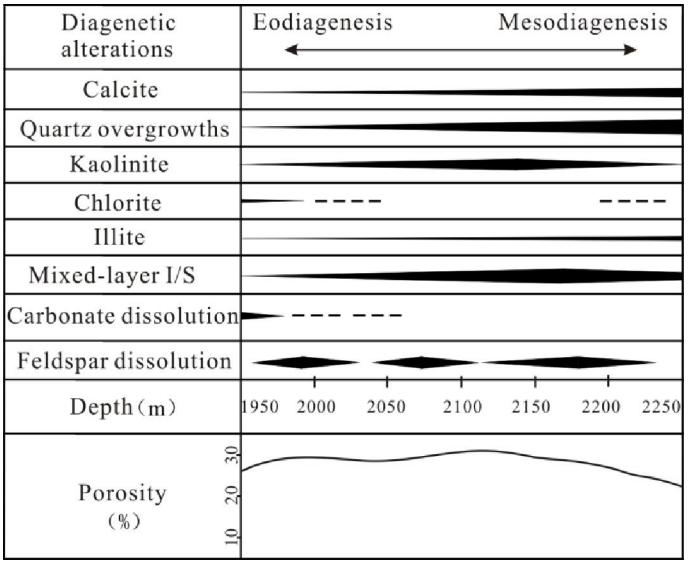

Fig. 3. Paragenetic sequences of diagenetic processes that occurred in the study area

4 CONCLUSION

Fault-block sandstone reservoirs are well developed especially in continental basins of eastern China. Diagenetic alterations that have been linked to the geological conditions include mechanical compaction, precipitation of quartz cements, calcite, dolomite, ankerite, illite, mixed-layer I/S, and kaolinite, and dissolution of carbonates, feldspars, and lithic grains. Diagenesis and depositional facies have controlled the reservoir quality of the study area. Distributary channel and mouth bar sandstones have good-moderate quality, whereas interdistributary sandstones have poor quality. When it comes to diagenetic modifications, sandstones with framework dissolution and precipitation of clay coats are considered to be favorite area with a better potential. Carrying out studies on diagenesis and related reservoir quality are particularly important in the late period in the oil fields development.

ACKNOWLEDGMENT

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REFERENCES

[1] S. Morad, K. Al-Ramadan, J. M. Ketzer, and L. F. De Ros, "The impact of diagenesis on the heterogeneity of sandstone reservoirs: A review of the role of depositional facies and sequence stratigraphy," *AAPG Bulletin*, vol. 94, no. 8, pp. 1267-1309, 2010.
[2] S. D. Burley, R. H. Worden, Sandstone Diagenesis: Recent and Ancient. *Blackwell Pub. Ltd*, 2003.
[3] R. L. Folk, Petrology of Sedimentary Rocks. *Hemphill Publishing*, 1980.
[4] R. C. Selley, Elements of Petroleum Geology. *Academic Press*, 1997.
[5] S. Gier, R. H. Worden, W. D. Johns, and H. Kurzweil, "Diagenesis and reservoir quality of Miocene sandstones in the Vienna Basin, Austria", *Marine and Petroleum Geology*, vol. 25, pp. 681-695, 2008.
[6] A. Karim, G. Pe-Piper, D. J. W. Piper, "Controls on diagenesis of Lower Cretaceous reservoir sandstones in the western Sable Subbasin, offshore Nova Scotia", *Sedimentary Geology*, vol. 224, pp. 65-83, 2010.
[7] J. A. Kupecz, J. Gluyas, S. Bloch, Reservoir Quality Prediction in Sandstones and Carbonates, *AAPG Memoir 69*, 1997.
[8] N. J. Hancock, A. M. Taylor, "Clay mineral diagenesis and oil migration in the Middle Jurassic Brent Sand Formation, Sandstone diagenesis", *Journal of the Geological Society of London*, pp. 69-72, 1978.
[9] M. D. Wilson, E. D. Pittman, "Authigenic clays in sandstones: recognition and influence on reservoir properties and paleoenvironmental analysis", *Journal of Sedimentary Petrology*, vol. 47, pp. 3-31, 1977.
[10] M. E. Tucker, Sedimentary Petrology. *Blackwell Scientific Publications*, 1991.

[11] D. W. Houseknecht, E. D. Pittman, W. D. F. Keller, Origin, Diagenesis, and Petrophysics of Clay Minerals in Sandstones. *SEPM Special Publication 47*, 1992.
[12] F. X. Ying, P. Luo, D. B. He, clastic reservoir diagenesis and diagenetic numerical simulation in petroliferous basin of China. *Petroleum Industry Press*, 2004.
[13] F. Leader, W. Park, "Porosity reduction in sandstone by quartz overgrowth", *AAPG Bulletin*, vol. 70, no. 11, pp. 711-713.

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The Potential of Charcoal Making Stove to Enhance Energy Efficiency

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ABSTRACT: Wood and charcoal are the frontier energy sources in developing countries mainly for heating and cooking. However, the achievable efficiency of woodstove is limited due to the poor combustion characteristics of wood in its natural form; and production of charcoal on the other hand dissipates major portion of the primary energy on the kiln site as smoke. Hence, this paper assesses the likelihood of integrating charcoal making with cooking in a charcoal making stove to enhance energy efficiency by attaining better control over combustion and increasing energy availability for end use. The scenario was demonstrated by using a Top-Lit UpDraft natural draft (TLUD-ND) gasifier stove which employs flaming pyrolysis that generates and combusts wood-gas for cooking and then recovers charcoal as a byproduct. Through standard procedures of Water Boiling Test (WBT) and proximate analysis, the average values of cooking efficiency and energy recovery in charcoal were found to be 18.05±1.53% and 31.75±2.40% respectively. The results achieved were slightly higher than the algebraic sum of an independently operating woodstove and charcoal kiln, thus showing a potential of over 50 percent saving in fuel wood consumption. Furthermore, a loose (r^2 = 0.3098) relationship was observed between cooking efficiency and charcoal yield verifying the prospect of improving either parameter without negatively affecting the other to enhance the overall efficiency. Likewise, the technology of integrated cooking and charcoal making can also considerably contribute to global climate stability by reducing release of greenhouse gases and other pollutants from burning and carbonization of biomass.

KEYWORDS: Stove, pyrolysis, cooking efficiency, charcoal yield, combined efficiency.

1 INTRODUCTION

Utilization of fuelwood as energy source is an aged process that yet remains dominant at the households of developing countries in spite of its proven negative effects on the environment and livelihood [1]. Conversion of fuel wood to required energy form mainly trails either direct combustion in wood stoves or carbonization in earth mould kilns (efficiency = 10-20%) also causing indoor pollution via health threatening smoke [2]. The conventional charcoal making process in kilns that leaves about 70% of energy in the kiln site [3], when followed by 10-30% efficient charcoal stove [4] verify that an overall efficiency of charcoal utilization for cooking in traditional way is lower than 10%. Hence, this study hypothesizes enhancement of better efficiency of overall fuel wood conversion to end use in an apparatus that obeys the principle of flaming pyrolysis, namely, top-lit updraft natural draft (TLUD-ND) gasifier stove that embraces two basic attributes. Primarily, it disintegrates wood into combustible gas and charcoal which can be burned more efficiently in separate convenient medium. Secondly, it avails the energy in the smoke that would have been lost in the kiln site for cooking in the form of combustible gas. The operating principle of charcoal making stove thus incorporates separation of the volatiles and solid carbon (charcoal) by pyrolysis and then combust the volatiles to supply heat for cooking thereby recovering charcoal for further use in charcoal

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stove as illustrated in Fig. 1. This is possible by supplying limited primary air to the fuel to maintain pyrolysis and provide secondary air to combust the volatiles coming out of pyrolysis.

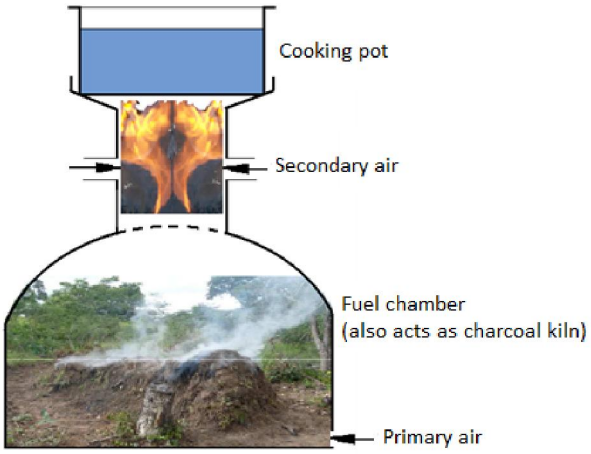

Fig. 1. A schematic of a charcoal making stove

Moreover, gasifier stoves are also reported to be appealing in ensuring fuel wood saving as it runs over wide variety of dry biomass and reduction of emissions improving the air quality of cooking environment [5]. However, this paper gives special attention to analysis of energy recovery in terms of both cooking efficiency and charcoal production.

2 EXPERIMENT DESIGN AND METHODOLOGY

Total of twelve experiments have been conducted on the stove to analyze its performance under possible combination of three selected parameters (fuel size, presence and absence of chimney, and full load and part load conditions), based on which the experiments were named (see Table 1).

Eucalyptus wood prepared in cubes with sizes: A=25x25x25mm^3, B=20x20x20mm^3 and C=15x15x15mm^3 in harmony with the recommended limit of 5 x 10 x 20 mm, plus or minus half of each dimension established for similar stoves [4],[6] were used as feedstock. Additional experiments conducted on eucalyptus feedstock have revealed moisture content of 8.9% on dry basis and proximate analysis of dry fuel: fixed carbon (FC) =23.2%, volatile matter (VM) =75.1% and Ash=1.7%, with corresponding lower heating value (LHV) of 16.9MJ/kg.

Table 1. Nomenclature of stove tests

Fuel size	Without chimney		With chimney	
	Part load	Full load	Part load	Full load
A	STA1	STA2	STA3	STA4
B	STB1	STB2	STB3	STB4
C	STC1	STC2	STC3	STC4

Performance of the stove was then determined using the standard Water Boiling Test (WBT) procedure for all the twelve experiments [7]. The quantity of fuel used, remaining charcoal at the end, water used for WBT, and water remained in pot at the end of each experiment as shown in Table 2 were measured using digital weighing balance having 0.1gram precision level. The changing temperature of water was also measured using a thermocouple placed in cooking pot 5cm above its bottom surface. Higher heating value (HHV) of the yielding charcoal was then determined based on proximate analysis made according to ASTM D 1762-84 procedure [8].

3 RESULT AND ANALYSIS/DISCUSSION

3.1 DATA MEASURED FROM WBT

Measurements were taken during the WBT to determine values of several parameters that are required to compute performance of the charcoal making stove. Table 2 presents gravimetric and temperature measurements recorded both in the input and result side of each experiment. The parameters to be gauged were decided so as to enable tracing the energy flow.

Table 2. Data recorded from WBT on charcoal making stove

Test No	M_{iw} [gm]	M_f [gm]	M_{ch} [gm]	M_{ew} [gm]	T_i [^{0}C]	ΔT [^{0}C]	T_{avg} [^{0}C]
STA1	2503.78	302.87	43.62	58.7	29	39	48.5
STA2	2500.06	443.84	59.96	125.4	30	43	51.5
STA3	2500.02	374.08	63.57	59.07	28	50	53
STA4	2500.00	443.48	73.43	135.42	30	58	59
STB1	2499.97	376.31	69.06	107.88	29	56	57
STB2	2500.03	411.89	71.18	147.53	28	61	58.5
STB3	2500.46	354.20	64.38	54.71	27	48	51
STB4	2500.94	399.44	65.44	171.73	29	58	58
STC1	2503.76	344.00	58.68	131.64	28	48	52
STC2	2500.03	400.48	68.83	132.34	30	58	59
STC3	2500.00	360.26	61.11	84.17	28	56	56
STC4	2500.05	432.52	69.32	149.92	28	64	60

Where: M_f = Weight of fuelwood used, M_{iw} = Initial weight of water used, M_{ew} = Weight of water evaporated, M_{ch} = weight of charcoal remained, T_i = Initial temperature of water, ΔT = Change in temperature of water, and Average temperature of the boiling water, $T_{avg} = T_i + \Delta T/2$,

Establishment of the stove's overall performance requires determination of the deciding factors like charcoal yield along its energy content and thermal efficiency. As such, energy flow during cooking in a charcoal making stove and the subsequent charcoal stove is discussed in the following sections.

3.2 ENERGY RECOVERY IN CHARCOAL

The charcoal yield and its proximate analysis were evaluated for ease of comparison with earth mould kiln both on quantity and quality basis. The energy recovered in charcoal was then determined by multiplying the yield in kilograms and heating value (computed based on proximate analysis (see Table 3) in Mega joules per kilogram. The obtained charcoal was richer in fixed carbon content than charcoal from kilns, which is reported to have 20-40% volatile matter [2]. Nonetheless, the produced charcoal can be used in a nearby stove to reduce the possible losses during handling due to its friable behavior that arise from volatile matter content less than 30% [9].

Table 3. Proximate analysis and higher heating value (HHV) of the yielding charcoal

Test No	Proximate analysis of produced charcoal			*HHV[MJ/kg]
	%FC	%VM	%ASH	
STA1	89.36	9.61	1.01	33.10
STA2	89.01	9.36	1.63	32.92
STA3	88.34	10.02	1.64	32.79
STA4	86.38	11.32	2.30	32.29
STB1	81.39	17.48	1.13	31.50
STB2	83.72	14.72	1.56	31.89
STB3	85.24	12.86	1.89	32.13
STB4	84.21	13.43	2.35	31.85
STC1	86.96	11.54	1.50	32.54
STC2	87.56	9.72	2.72	32.46
STC3	84.85	12.99	2.16	32.01
STC4	87.26	10.33	2.41	32.45

*HHV = 0.3536(%FC) + 0.1559 (%VM) – 0.0078(%ASH), [10]

Fig. 2 below shows the charcoal yield and energy recovered in charcoal for which average value were found to be 18.05±1.53% and 31.75±2.40% respectively. The observed variation illustrates the effect of feedstock size on the yield although the heating value was more or less the same, thus pointing out the importance of using appropriate feedstock size for a give stove.

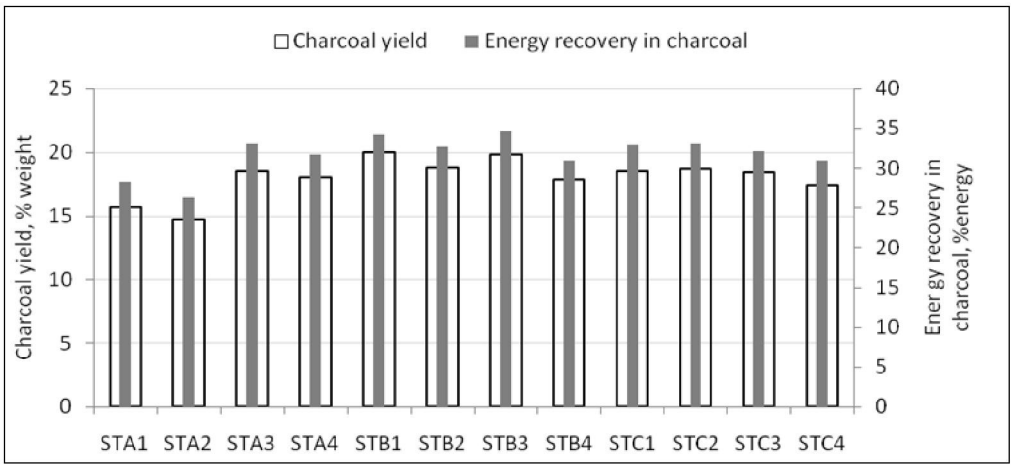

Fig. 2. Charcoal yield and corresponding energy recovery by charcoal making stove

Since the charcoal was produced in a cooking stove, its production efficiency in this context was calculated by considering the summation of heat transferred to water during WBT and the energy recovered in charcoal as useful energy. Hence is calculated using Eq. 1 to enable comparison between considered cooking stove and the conventional earth mould kiln as charcoal makers.

$$\eta_{ch.p} = \frac{[L \times M_{wev} + M_{wi} \times C_{pw}\ (\Delta T)\ ] + [M_{ch} \times HHV_{ch}\ ]}{M_f \times LHV_f} \qquad (1)$$

Accordingly, charcoal production efficiency of 36.41 - 47.54% has been achieved with mean value of 44.37±3.36%. Corresponding values of charcoal production efficiency for each stove test are also graphically presented in Fig. 3.

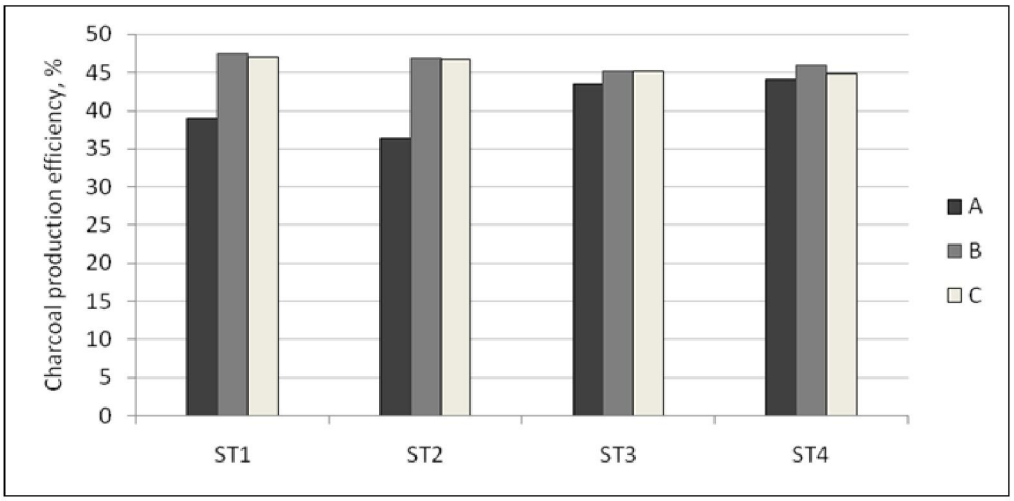

Fig. 3. Charcoal production efficiency of the TLUD-ND gasifier stove

When similar calculation is made for charcoal production in traditional kilns, the figure becomes smaller since there is no heat recovered from the released gases for cooking in the site. Hence, a typical traditional kiln fed with feedstock having LHV of 16.86MJ/kg and resulting in charcoal yield of 20% or less [2] with HHV of 28MJ/kg realizes charcoal production efficiency of 33.21% or less. This is considerably lower compared to the result from charcoal making gasifier stove analyzed in this study. Hence, production of charcoal in a stove avails more energy for end use than the independent conventional firewood burning and charcoal production practice do.

3.3 COOKING EFFICIENCY OF THE CHARCOAL MAKING STOVE

Cooking efficiency shows how well the stove performed in terms of transferring fuel energy into water in the cooking pot. Since the stove produces charcoal as end product, cooking efficiency is computed by exclusive of the energy recovered in charcoal from the energy input as shown in Eq. 2. Thus, cooking efficiency is the ratio of useful energy that has been transferred to water in the pot to the energy extracted from the fuel during WBT.

$$\text{Cooking efficiency }, \eta_c = \frac{(L \times M_{wev}) + (M_{wi} \times C_{pw} \times \Delta T)}{(M_f \times LHV_f) - (M_{ch} \times HHV_{ch})} \quad (2)$$

Where:

LHV_f = Lower heating value of fuel

HHV_{ch} = Higher heating value of charcoal

L = latent heat of vaporization at average temperature rise (read from steam table)

C_{pw} = specific heat capacity of water at constant pressure (=0.004186MJ/kg.K)

η_c = Cooking efficiency

As it is shown in Fig. 4, the average cooking efficiencies over the four runs with each fuel size were *15.63%, 19.82%* and *20.17%* for size A, B, and C respectively. The level of efficiency variation with respect to fuel size was tested using Analysis of Variance (ANOVA).

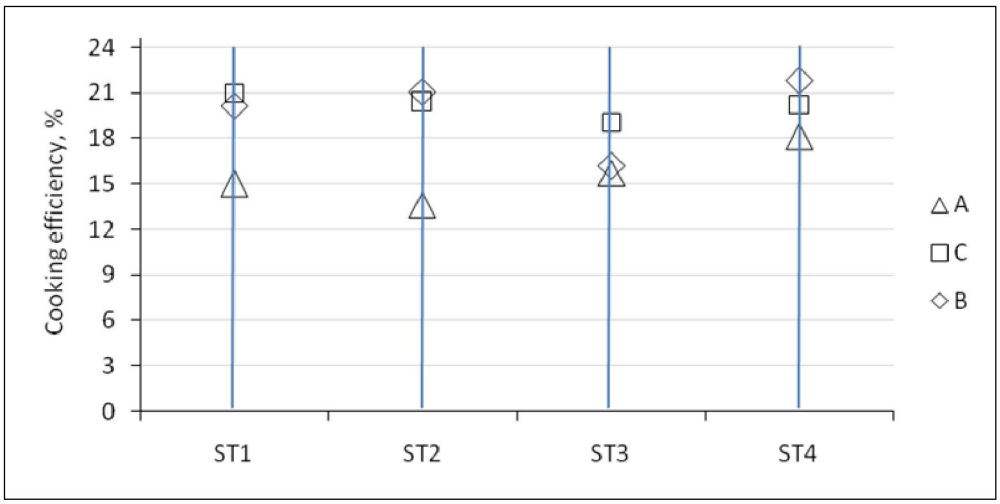

Fig. 4. Cooking efficiency of the charcoal making stove under all test conditions

The test by ANOVA revealed existence of significant difference among the efficiencies recorded with the three different sized fuels. Furthermore, the Tukey-Kramer procedure used to identify where the difference lies has also indicated that the stove tests conducted with fuel size "A" have resulted in lower cooking efficiency than the runs with "B" and "C" sized fuel at significance level of 5% ($\alpha = 0.05$). The observed low cooking efficiency for "A" sized fuel was attributed to combined effect of uneven fuel distribution and low bulk density which let combustion in place of pyrolysis by allowing free air flow and localized starting.

3.4 COMBINED EFFICIENCY

The need of determining combined efficiency is to enable comparison of fuel saving capacity of the charcoal making stove with the conventional charcoal production and utilization route that is diagrammatically shown in Fig. 5.

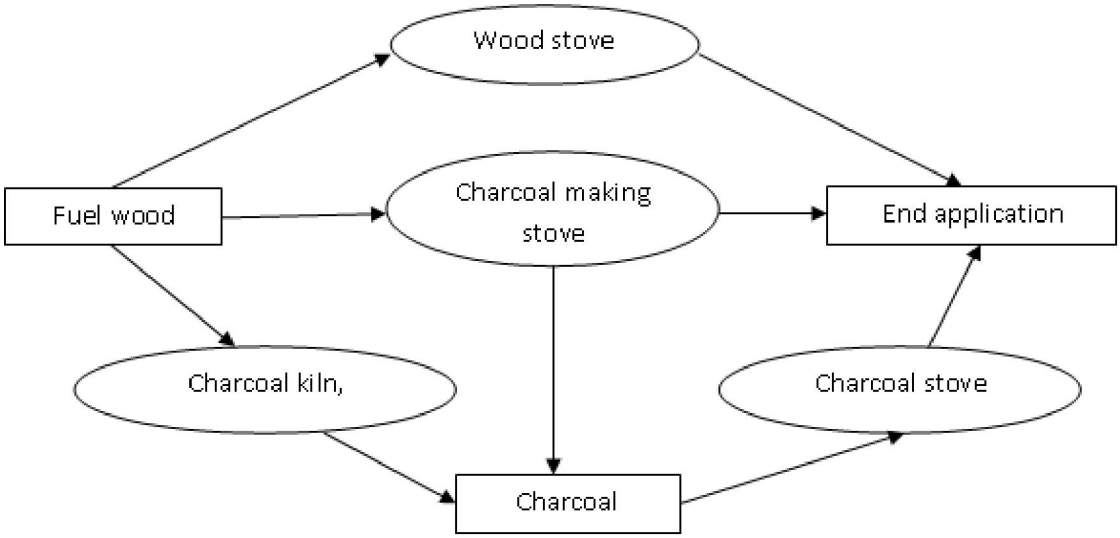

Fig. 5. Energy flow diagram of cooking with fuel wood

Combined efficiency thus describes the cumulative outcome of cooking efficiencies in charcoal making stove and the subsequent charcoal stove that run on charcoal produced in the gasifier stove. This study assumed a charcoal stove with efficiency of 30% for combustion of charcoal produced in the charcoal making stove. As such, it is the fraction in percent of fuel energy that can be put into the final application under a given combination of charcoal making stove and charcoal stoves (see Eq. 3).

$$\eta_{comb} = \frac{[L \times M_{wev} + M_{wi} \times C_{pw} (\Delta T)] + M_{ch} \times LHV_{ch} \times \eta_{chs}}{M_f \times LHV_f} \quad (3)$$

Equation (3) can be rewritten in simplified form as Eq. 4 below

$$\eta_{comb} = \frac{\eta_c \times (LHV_f - y_{ch} \times HHV_{ch}) + y_{ch} \times LHV_{ch} \times \eta_{chs}}{LHV_f} \quad (4)$$

Where:

y_{ch} = charcoal yield,

η_{chs} = Assumed efficiency of charcoal stove, and

LHV_{ch} = Higher heating value of charcoal (Note:-Charcoal contains almost no hydrogen at temperatures above 700^0C [11], hence the net heating value is equal to HHV)

The combined efficiency of the stove falls in the range between 18.33 and 24.55% with mean value of 22.05±2.01% (see Fig. 6 for the values from each experiment). Thus, when the scenario of similar charcoal yield from charcoal making stove and earth mould kiln is considered, the energy used for cooking in the stove can be regarded as bonus.

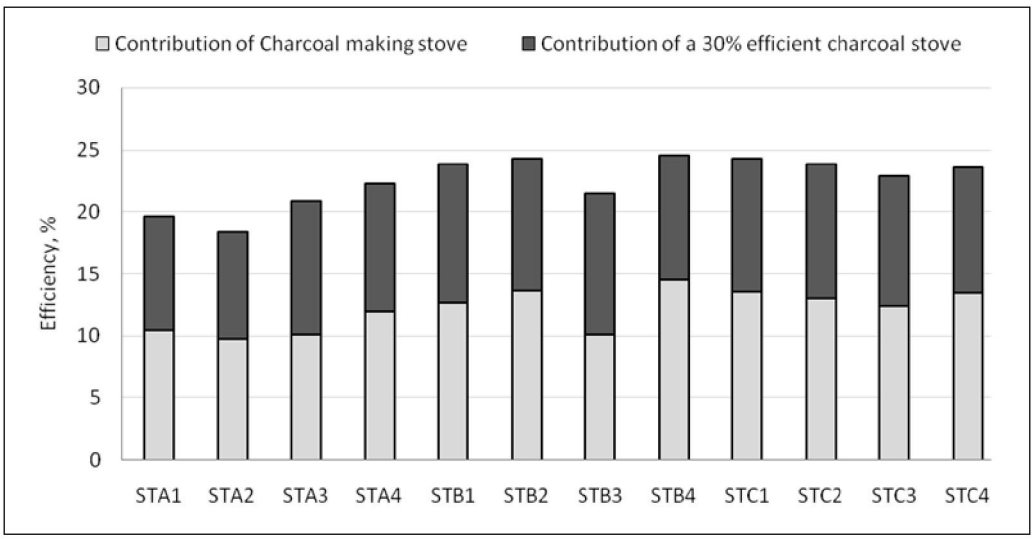

Fig. 6. Combined efficiency of charcoal making stove and 30% efficient charcoal stove

For ease of comparison, the combined efficiency of conventional charcoal production in kilns followed by burning in charcoal stove was calculated using Eq. 5 shown below. The formula was deduced from Eq. 4 by eliminating the component of energy that has been transferred to water in the pot while making charcoal.

$$\eta_{comb} = \frac{y_{ch} \times LHV_{ch} \times \eta_{chs}}{LHV_f} \quad (5)$$

Where: η_{chschs}= Efficiency of charcoal stove

Accordingly, when a typical charcoal from earth mould kiln having yield of 15-25% and LHV of about 28 MJ/kg [4] is burned in a 30% efficient charcoal stove, it results in an overall efficiency of only 7.5-12.52%. Thus, the studied charcoal making stove when used in place of charcoal kiln doubles efficiency of conventional charcoal utilization practice thereby reducing fuel consumption to half. In other words, an individual that produces charcoal making TLUD-ND gasifier stove gains bonus of that energy used for cooking in the stove compared to the one that uses charcoal from kiln. These values also give clue about possibility of making carbon credits through charcoal sequestration (depositing charcoal in to soil) whenever found of higher importance.

Moreover, the contribution of charcoal making stove and the assumed 30% efficient charcoal stove to the total useful energy, the former contributing 53.68±3.33% in average, is also shown in Fig. 6. Based on the fact that only about 32% of

energy is recovered in charcoal (see Fig. 2), the above figure justifies occurrence of larger loss in the charcoal making stove. This result therefore dictates that effective strategy to enhance combined efficiency is focusing on improvement of cooking efficiency of the charcoal making stove. The effect of improving cooking efficiency on charcoal yield is analyzed in the following section.

3.5 Relationship between Cooking Efficiency and Charcoal Yield

Since combined efficiency is function of both cooking efficiency and charcoal yield, its further improvement depends on augmenting either one or both if possible. Hence, relationship between the two parameters is investigated to see the likelihood of negative effect on charcoal yield that may occur from improvement on cooking efficiency or vice versa. Thus, study of their correlation intends to decide the focus point for further improvement of overall performance by optimizing the two.

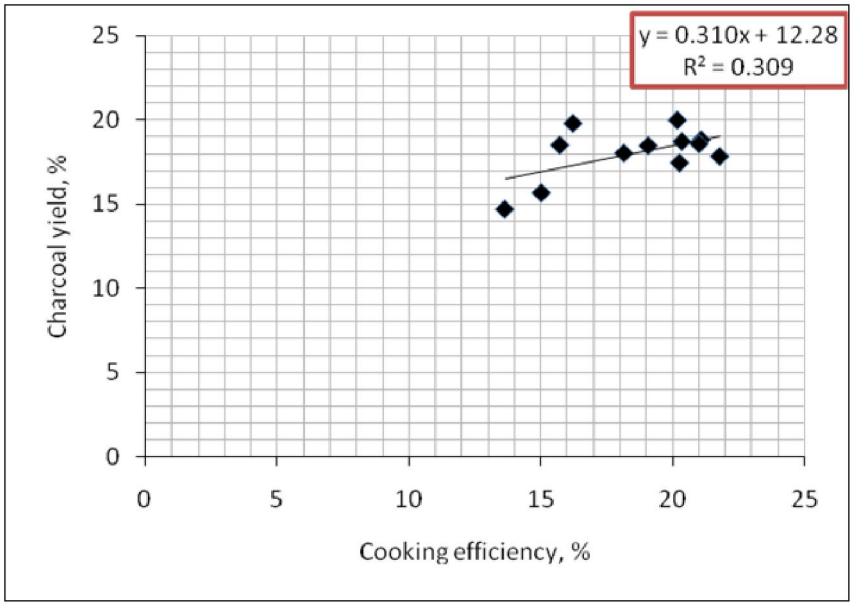

Fig. 7. Charcoal yield against cooking efficiency graph for the charcoal making stove

The strength of correlation was expressed in terms of Karl Pearson's Coefficient of Correlation (r) calculated as follows:

$$r = \frac{\sum xy}{\sqrt{(\sum x^2)(\sum y^2)}} \qquad (6)$$

Where: $x=(\eta_c)_i - \eta_{c,Avg.}$ and $y=(y_{ch})_i - y_{ch,Avg.}$, for i=1,2,3,….12

Substituting values from Fig. 7,

$$r = \frac{25.55}{\sqrt{82.27 x 25.62}} = 0.5566$$

$$r^2 = 0.3098 = 30.98\%$$

The obtained value of r is interpreted as loose as it falls out of the fair correlation range, 0.7 to 1 or -0.7 to -1 [12], and the relation is not significant at α=5%. However, the existence of positive correlation implies that 30.98% percent of total variation in one variable is accounted for the variation on the other variable in a similar direction. Hence, the calculated value of correlation coefficient illustrates that improvement on thermal efficiency is accompanied by improvement on charcoal yield although it is slight; and it has no declining effect at all. For instance, improving combustion efficiency of the volatiles in the stove is unlikely to have any effect on the charcoal yield since this is post pyrolysis activity. On the other hand, eventual

restoration of charcoal helps to increase efficiency as combustion of charcoal in the stove leads to large amount of heat loss due to the distance gap between the pot and charcoal.

4 CONCLUSION

In contrast to conventional cooking with charcoal, it has been shown that charcoal making stove is capable of reducing fuel wood consumption by about fifty percent when loaded with appropriately sized fuel. Besides, since a charcoal making stove primarily breaks the biomass feedstock into volatiles and carbon rich charcoal, both burn nearly free of visible smoke in respective stoves resulting in cleaner cooking environment. Moreover, enhancement of efficiency reduces load on fuel collectors, minimizes deforestation rate, and trims down related pollutants and greenhouse gases.

In addition, the relationship between thermal efficiency and charcoal yield was found to be loose and positive (r=0.56) indicating that recovering charcoal from the stove (or avoiding burning of charcoal in the stove) contributes to improvement of the overall stove performance. Hence, efficiency of charcoal making stove can be further improved without affecting charcoal yield.

Accordingly, it is strongly recommended to avoid production of charcoal in remote forest area by encouraging further researches that customize charcoal making stoves to existing cooking habits and improve its efficiency.

REFERENCES

[1] Hazell, P. & R.K. Pachauri, *Overview: Bioenergy and Agriculture, Promises and Challenges* #14. IFPRI, Washington, D.C, 2006.

[2] Antal, M.J., Croiset, E., Dai, X., DeAlmeida,C. Mok,W.S., and Norberg, N., "High-yield biomass charcoal," *Energy and Biofuels*, vol. 10, pp. 652-658, 1996.

[3] Quaak, P., Knoef, H., and Stassen, H., *Energy from biomass: A review of combustion and gasification technologies*, Energy Series: World Bank Technical Paper No. 422, 1999.

[4] Charles Y. Wereko-Brobby Essel B. Hgen, *Biomass Conversion Technology*, John Wiley & Sons, Centre for Energy and Environmental Development, Ghana, 2000.

[5] Anderson, S. and Reed, B., *Biomass gasification: Clean residential stoves, commercial power generation, and global impacts*, Biomass Energy Foundation, USA, 2004.

[6] Reed, T.B. and Larson, R.A., "Wood-gas stove for developing countries," *Energy for Sustainable Development*, vol. 3, pp. 34–37, 1996.

[7] Bailis, R., Ogle, D., MacCarty, N. and Still, D., *The water boiling test: WBT version 3.0*, Shell Foundation, 2007.

[8] Antal, M. J., "The Art, Science, and Technology of Charcoal Production", *Ind. Eng. Chem. Res,* vol. 42, pp.1619-1640, 2003.

[9] FAO, *Simple technology for charcoal making*, 1987. [Online] Available: *http://*www.*fao.org* (Aug 28, 2009).

[10] Parikh, J, Channiwala, S.A. and Ghosal, G.K., "A correlation for calculating HHV from proximate analysis of solid fuels," *Fuel,* vol. 84, pp. 487–494, 2005.

[11] Baker, A. J., Ragland, K. W. and Aerts, D. J., "Properties of wood for combustion analysis," *Bioresource Technology,* vol. 37, pp. 161-168, 1991.

[12] Motulsky H.J. and Christopoulos A., *Fitting Models to Biological Data Using Linear and Nonlinear Regression: A Practical Guide to Curve Fitting*, GraphPad Software Inc., San Diego CA, 2003.

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A New Image Interpolation Using Gradient-Orientation and Cubic Spline Interpolation

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ABSTRACT: Several factors can interfere in the quality of image such as aliasing, noise, artifact, and blurring, these factors can cause the degradation of image especially in edge regions. In order to reduce the effect of these factors, it is necessary to choose a robust interpolation method which can play important role of the reconstruction of the high-resolution image from its low-resolution counterpart, so as to preserving the edges and textures, increasing the resolution, and improving the image quality.

In this paper, a new image interpolation method is proposed using gradient orientation; in the first step, we estimate the edges directions for a missing pixel location using the gradient-orientation in horizontal and vertical directions. Then, in the second step we interpolate the missing pixels along the detected edge directions using a cubic spline interpolation.

We begin from a gray high-resolution image which is down-sampled by a factor of two, to obtain the low-resolution image, then; this image is reconstructed using the proposed algorithm. Our method is implemented and tested to several gray test images, and compared to other image interpolation methods. The simulation results show the effectiveness of the proposed technique using the PSNR and compared with the traditional interpolation techniques. The results showed that the proposed technique has higher accuracy, and can preserve the sharp edges and textures, and avoid the problems of blurring and the visual artifacts caused by the classical interpolation methods.

KEYWORDS: Image interpolation, gradient orientation, edges direction, cubic spline interpolation, super-resolution.

1 INTRODUCTION

Image interpolation aims to generate a high-resolution image from its low-resolution counterpart. The image interpolation is a technique which estimates a set of unknown pixels from a number of known and discrete pixels, especially the adjacent pixels. The interpolation can be used in image resizing, upscaling, enlargement, and image enhancement. The interpolation can be applied in many fields such as remote sensing, surveillance, medical imaging, computer vision, high definition television, and consumer electronics.

Interpolation methods can be divided into two main classes, the first one is the non-adaptive interpolation, this type of interpolation algorithms treats all images using classical linear interpolation techniques such as nearest neighbor, bilinear, or bi-cubic interpolation [12]. These latter are simple and hence popular, but they all produce images with various artifacts, especially around edges on the image. Nearest neighbor interpolation produces block artifacts and jagged edges, while bilinear and bicubic interpolations usually produce blur edges.

The second class of interpolation methods is the adaptive interpolation, some edge-adaptive interpolation techniques try to explicitly detect the edges on the original image, firstly to generate an edge map and then use it to assist interpolation later. Examples of these techniques are presented in [18], [20]. This class of methods involves multiple steps and is usually complicated and computational costly. Another class of edge-adaptive techniques attempts to have edge information built into the algorithms. These techniques do not require explicit detection of edges. Example of these methods can be found in [4], [5], [19], [21].

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Several interpolation algorithms have been presented in the literature either in adaptive class or non- adaptive class or by combining the two classes. G.ramponi [1] proposes to use the warped distance to the interpolated pixel instead of a regular one, thus modifying the one-dimensional kernel of a separable interpolation filter. An amelioration of this method was made by Huang and Lee [2] which consists in modifying the two-dimension interpolation Kernel by the characteristics of local gradient.

A method of edge detection was introduced by Jensen and Anastassion [3]; they apply a projection onto orthonormal basis to detect the edge direction, and modify the interpolation process to avoid interpolating across the edges to improve the visual perception of the interpolated image.

An iterative edge-directed scheme was developed in [20]. The authors use an estimate of the edge mapping of the high-resolution image to guide a bilinear interpolation such that interpolation across edges is avoided.

An NEDI interpolation was presented by Li and Orchard in [4].The authors used the local covariance of low-resolution images to estimate the covariance of high-resolution image. Asuni and Giachetti [17] propose INEDI (Improved New Edge-Directed Interpolation) to improve the algorithm of Li and all by adopting circular windows and adaptively selecting the size of windows. However, in the region of fast luminance change, the windows are too small to get a stable solution.

Li and Zhang [6] propose an Edge-guided algorithm via directional filtering and data fusion, they have estimated the missing pixels which can be interpolated, by two sets of observations which are defined in two orthogonal directions, these latter are fused through linear minimum mean-square-error (LMMSE). The authors in [9] propose a regularity-preserving interpolation method which consists in extrapolating a new wavelet sub-bands based on the decay of the finer scale.

Muresan and Park [5] extended this strategy which based on the influence of a full cone sharp edge in the wavelet scale spaces, for estimation the coefficient of scale by an optimal recovery theory. An interpolation scheme was proposed by Giachetti and Asuni [8] , its principle is to interpolate locally the missing pixels in the two diagonal directions, while the second order image derivative is lower, these interpolated pixels value are modified using an iterative refinement to minimizing the differences in second order image derivative. Cha and Kim [7] describe an interpolation method by utilizing a bilinear interpolation and correcting the errors by adopting the interpolation error theorem in an edge-adaptive way. The authors in [11] develop an interpolation approach based on edge-oriented algorithm, they classify the image into two partition, the homogenous zones which its missing pixels are interpolated by a bilinear interpolation, and the edges area, which its missing pixels are interpolated using all neighboring pixels, this neighboring pixels contains the originals pixels and the interpolated pixels in the homogenous area.

Zhou and Shen [10] propose an image zooming using cubic convolution interpolation with detecting the edge-direction, this method is based on the detection of edge-direction of the missing pixels by computing the gradient of horizontal, vertical, 45° diagonal and 135° diagonal directions, then they interpolated the missing pixels utilizing a cubic convolution interpolation.

In our paper, we propose a new approach of image interpolation using gradient-orientation; which the missing pixels are interpolated along the detected edge direction, these latter are estimated by the gradient in the horizontal and vertical directions, a cubic spline interpolation is used to interpolate the missing pixels along the strong edge.

The paper is organized as follows: in section II we recall the principle of the cubic spline interpolation. Section III describes the proposed interpolation method. Simulation and results are shown in section IV. Finally, the conclusion is drawn in section V.

2 CUBIC SPLINE INTERPOLATION

The spline interpolation is based on piecewise polynomial functions. Among the large family of polynomial functions (Lagrange, Hermite…). A polynomial spline is a piecewise polynomial function of degree n with pieces that are patched together such as to guarantee the continuity of the function and its derivatives up to order n-1. The spline interpolation is based on the following principle is that the interpolation interval is divided into small subintervals. Each of these subintervals is interpolated by using the third-degree polynomial. The polynomial coefficients are chosen to satisfy certain conditions. The function must be continuous of higher derivatives and passing through all the given points. Spline interpolation was introduced by Schoenberg [16], and has been described exhaustively by Thévenaz et al. and Unser [13], [14], [15], the main advantages of the spline interpolation are the stability and the calculation simplicity.

Let p be a polynomial piece, the spline interpolation can be defined as ([16]):

$$p(x) = \sum_{k \in Z} c(k) \beta^{n}(x-k)$$

Where the c(k) are the B-spline coefficients, and β(x) is the B-spline basis functions of degree n, all the B-spline bases of degree n can be obtained by the recursive continuous convolution of the box function with the B-spline basis of degree (n−1) ([13], [14], [15]):

$$\beta^{n}(x) = (\beta^{n} * \beta^{0})(x)$$

With

$$\beta^{0}(x) = \begin{cases} 1 & |x| < \frac{1}{2} \\ \frac{1}{2} & |x| = \frac{1}{2} \\ 0 & |x| > \frac{1}{2} \end{cases}$$

Therefore, the cubic B-spline can be written as:

$$\beta^{3}(x) = \begin{cases} \frac{2}{3} - \frac{1}{2}|x|^{2}(2-|x|) & 0 \le |x| < 1 \\ \frac{1}{6}(2-|x|)^{3} & 1 \le |x| < 2 \\ 0 & 2 \le |x| \end{cases}$$

3 THE PROPOSED METHOD

The known interpolation methods such as spline interpolation, cubic convolution, nearest neighbor interpolation, and linear interpolation method, interpolate the missing pixels in the same direction, and so non-horizontal or non-vertical edges are smoothed. In contrast, edge-directed interpolation methods detect the edge orientations, and then interpolate along the detected edge directions. The frequent problem is that the detected edges are usually imprecise, especially in the regions with composite edges such as textures.

In order to avoid detecting weak edges, we propose a novel interpolation method. By interpolating the missing pixels on the strong edge and then applying the cubic spline interpolation along the estimated edge direction.

An LR image Im can be considered to be a directly downsampled version of the HR image corresponding to Im, where the downsampling factor is 2. The High resolution image Im is restored by copying the LR image Im pixels into an enlarged grid and then filling with the missing pixels. Here we propose an estimation method of the strong edge for a missing pixel location. The proposed method can be described as follows:

Step1: Compute the image gradient of the low-resolution image I_m:

$$[G_x, G_y] = \text{Gradient}\ (I_m)$$

Let G_r be the complex gradient of the image I_m described by the following equation:

$$G_r = G_x + \mathrm{i}\, G_y$$

Where i is the basic imaginary unit sqrt (-1).

Step 2: For every pixel to be estimated (i, j), in the 7x7 neighbour of this pixel, they are four immediate diagonal pixels to be known, the orientation of the gradient at the central location (i,j) can be determined using the given equations:

$$d_1(i,j) = \sum_{k=3,\pm 1} \sum_{l=3,\pm 1} \left\| G_r(i+k; j-l) - G_r(i+k-2; j-l+2) \right\|$$

$$d_2(i,j) = \sum_{k=3,\pm1} \sum_{l=3,\pm1} \left\| G_r(i+k; j+l) - G_r(i+k-2; j+l-2) \right\|$$

Where $\|x\|$ denotes the complex modulus (magnitude) of the complex number x.

Using $d_1(i,j)$ and $d_2(i,j)$, the edge direction for a pixel location (i, j), can be estimated as follows:

$$\begin{cases} if\ d_1(i,j) > d_2(i,j) \\ the\ gradient\ is\ greater\ in\ the\ horizontal\ direction \\ else \\ the\ gradient\ is\ greater\ in\ the\ vertical\ direction \\ end \end{cases}$$

Step 3: Compute the intensity value at the missing pixel position using the estimated edge direction. Indeed, the intensity pixel value can be computed using the cubic spline interpolation by interpolating the four neighbour pixels along the strong edge.

4 SIMULATION AND RESULTS

In order to demonstrate the accuracy of the proposed method, a number of simulations are provided to examine the performance of the proposed method, this latter has been implemented in Matlab and tested on several images, and compared with the state of art of interpolation algorithms, cubic spline interpolation [14], directional filtering and data fusion [6], new edge-directed interpolation [4], Accuracy improvements and artifacts removal in edge based image interpolation [17], and fast artifacts-free Image interpolation [8].

CS was implemented by Matlab 'interp2' function; the Matlab codes of ICBI, DFDF, INEDI, and NEDI were available from the original authors.

Eight gray test images are used for simulation; Fig.1 represents the eight gray images used for test.

We started from an original high-resolution gray image; this latter was down-sampled by a factor of two to obtain the low resolution image. The LR image was reconstructed by a set of interpolation methods.

Various experimental factors are used to investigate the quality of the interpolated images, the first one is the subjective quality of the output images, Figs. 2–4 compare the results of the six different image interpolation methods on test images Lena, Face, and Monarch, respectively.

The second criterion is the PSNR ratio.

Table 1 indicates the resulting PSNR values on the set of 8 gray images of the compared methods with the proposed one.

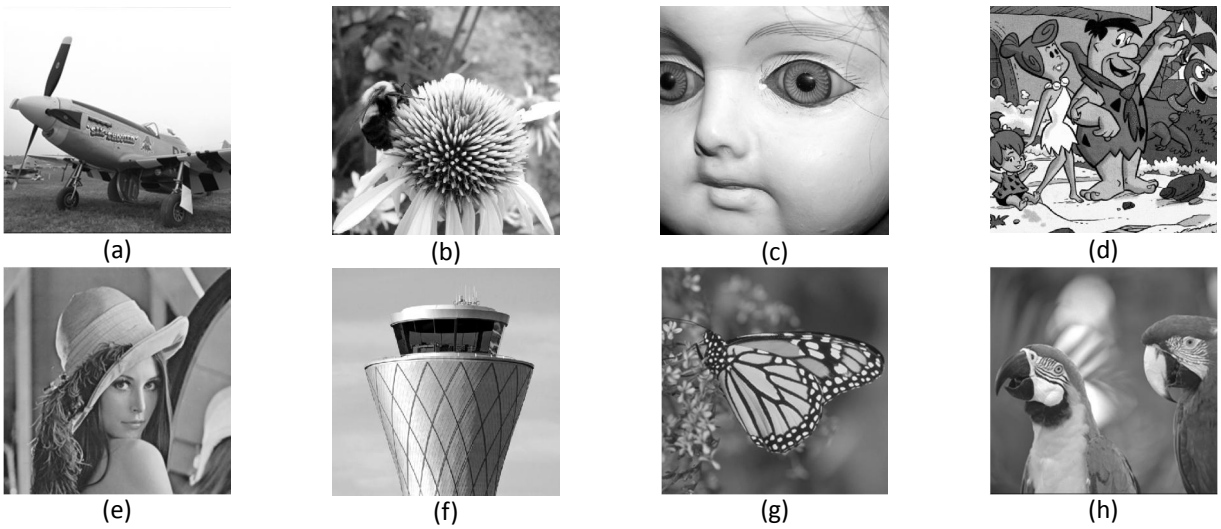

Fig. 1. Set of images test (a) Airplane; (b) Bee; (c) Face; (d) Flinstones; (e) Lena; (f) Lighthouse; (g)Monarch; (h) Parrot

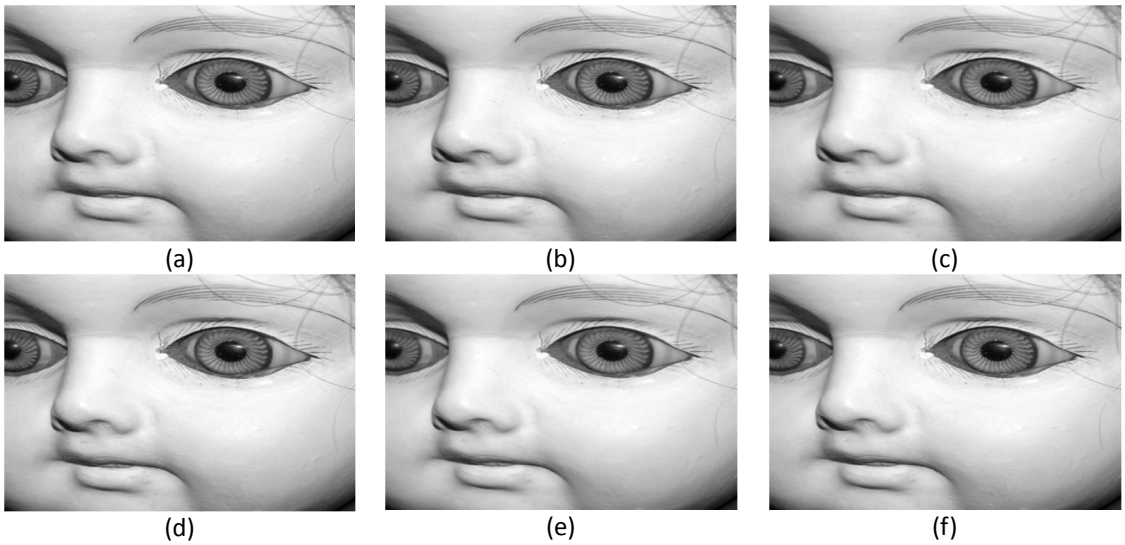

Fig. 2. The interpolated images results of 'Face' (a) Cubic spline; (b) DFDF; (c) ICBI; (d) INEDI; (e) NEDI; (f) Proposed

Fig. 3. The interpolated images results of 'Lena' (a) Cubic spline; (b) DFDF; (c) ICBI; (d) INEDI; (e) NEDI; (f) Proposed

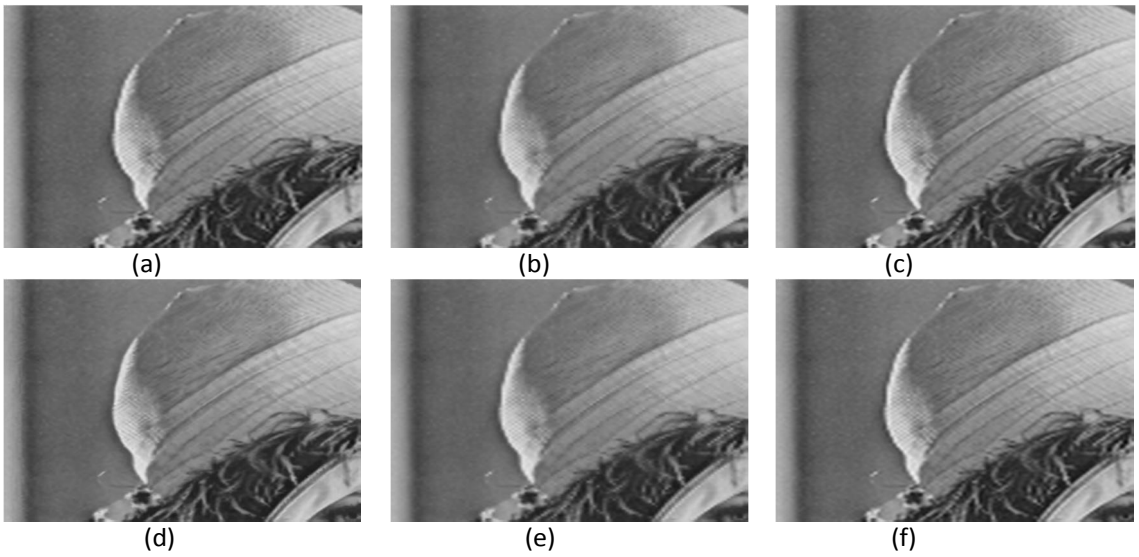

Fig. 4. The interpolated zoomed image results of 'Lena' a) Cubic spline; (b) DFDF; (c) ICBI; (d) INEDI; (e) NEDI; (f) Proposed

The above proposed method was compared to the other interpolation methods; in the part of the subjective appearance of the resulted image, as can be seen in Fig. 2-4, the cubic spline interpolation [14] contains many aliasing artifacts and generates prominent jaggies along sharp edges. This method is in general inferior to the others in visual quality. The NEDI [4] and INEDI [17] are very competitive in terms of visual quality. This is primarily because they preserve long edges well,but these methods are still affected by the ringing effect. DFDF [6] and ICBI [8] interpolation methods take a middle ground between the cubic spline interpolation [14] and edge-directed interpolation NEDI [4] and INEDI [17]. They reproduce sharper large scale edges than the bicubic method, but the reconstruction of these methods is not as good as the method of [4] and [17].

Table 1. Comparison of PSNR results of the reconstructed images(db)

Image	**CS** [14] **(db)**	**DFDF** [6] **(db)**	**ICBI** [8] **(db)**	**NEDI** [4] **(db)**	**INEDI**[17] **(db)**	**Proposed (db)**
Airplane	29,77	30,20	29,65	**30,33**	30,01	30,28
Bee	34,39	35,05	34,31	33,59	33,32	**35,18**
Face	40,53	40,84	40,11	40,21	39,19	**41,27**
Flinstones	26,93	27,03	26,97	26,49	27,03	**27,65**
Lena	33,81	33,77	33,87	33,75	33,20	**34,13**
Lighthouse	32,52	32,61	32,62	33,64	32,82	**33,59**
Monarch	30,16	30,71	30,85	30,21	**31,26**	31,13
Parrot	33,31	33,15	33,10	33,51	33,49	**33,87**
Average	32,68	32,92	32,69	32,71	32,54	**33,39**

The interpolated image of our proposed algorithm can still reconstruct the sharp edges without introducing many artifacts, and the edges and textures reconstructed by our method are much sharper and cleaner than others. Also, more image details are recovered by our method. This proves the strong edge preservation capability of the proposed method.

On the other hand, the highest PSNR value of each row is shown in bold. The PSNR results of the proposed method yields the better performance over the above-mentioned methods for all testing images, and exceeds the average PSNR value of the second best method by 0.47 dB. For the image 'Parrot' with rich textures, the proposed method also has a PSNR improvement of 0.36 dB over the second best method.

5 CONCLUSION

A novel method of image interpolation has been developed; this method consists in interpolating the missing pixel along the detected edge direction by using a cubic spline interpolation. Furthermore, this method has been implemented and tested. From the experimental results, it's clear that the proposed method provided the best improvement than the other interpolation methods, and generated a best high-resolution image, which their PSNR indicates the performance of the proposed method over the afore-mentioned interpolation methods.

Therefore, the proposed method can preserve a number of directional edges in the interpolation process along the estimated edge directions, and can suppress undesirable artifacts such as noise and blurring, caused by the classical interpolation methods.

REFERENCES

[1] G. Ramponi, "Warped distance for space-variant linear image interpolation," *IEEE Trans. Image Process.*, vol. 62, no. 5, pp. 629 – 639, 1999.

[2] J. W. Hwang and H. S. Lee, "Adaptive image interpolation based on local gradient features," *IEEE Signal Process. Lett.*, vol. 11, no. 3, pp. 359 – 362, 2004.

[3] K. Jensen and D. Anastassiou, "Subpixel edge localization and the interpolation of still images," *Image Process. IEEE Trans.*, vol. 4, no. 3, pp. 285 – 295, 1995.

[4] X. Li and M. T. Orchard, "New edge-directed interpolation," *IEEE Trans. Image Process.*, vol. 10, no. 10, pp. 1521 – 1527, 2001.

[5] D. D. Muresan and T. W. Parks, "Prediction of image detail," *Process. Int. Conf. Image 2000*, vol. 2, 2000.

[6] L. Zhang and X. Wu, "An edge-guided image interpolation algorithm via directional filtering and data fusion," *Image Process. IEEE Trans.*, vol. 15, no. 8, pp. 2226 – 2238, 2006.

[7] Y. Cha and S. Kim, "The error-amended sharp edge (EASE) scheme for image zooming," *Image Process. IEEE Trans.*, vol. 16, no. 6, pp. 1496 – 1505, 2007.

[8] A. Giachetti and N. Asuni, "Fast Artifacts-Free Image Interpolation," *Br. Mach. Vis. Conf. Leeds UK*, pp. 123–132, 2008.

[9] W. K. Carey and S. S. Hemami, "Regularity-preserving image interpolation," *IEEE Trans. Image Process.*, vol. 8, no. 9, pp. 1293 – 1297, 1999.

[10] D. Zhou, X. Shen, and W. Dong, "Image zooming using directional cubic convolution interpolation," *IET Image Process.*, vol. 6, no. 6, pp. 627 – 634, 2012.

[11] M.-J. Chen and W.-L. Lee, "A fast edge-oriented algorithm for image interpolation," *Image Vis. Comput.*, vol. 23, no. 9, pp. 791 – 798, May 2005.

[12] R. Keys, "Cubic convolution interpolation for digital image processing," *IEEE Trans. Acoust. Speech Signal Process.*, vol. 29, no. 6, pp. 1153 – 1160, May 1981.

[13] M. Unser, "Splines: A perfect fit for signal and image processing," *IEEE Signal Process. Mag.*, vol. 16, no. 6, pp. 22 – 38, Nov. 1999.

[14] P. Thevenaz, T. Blu, and M. Unser, "Image Interpolation and Resampling," *Handb. Med. Imaging Process. Anal. Bankman Ed Acad. Press San Diego Ca USA*, pp. 393 – 420, 2000.

[15] P. Thévenaz and M. Unser, "Interpolation revisited [medical images application," *IEEE Trans. Med. Imaging*, vol. 19, no. 7, pp. 739 – 758, 2000.

[16] I. J. Schoenberg, "Contribution to the problem of approximation of equidistant data by analytic functions," *Quart Appl Math*, vol. 4, no. 2, pp. 45 – 99, 1946.

[17] N. Asuni and A. Giachetti, "Accuracy improvements and artifacts removal in edge based image interpolation," *Proc 3rd Int Conf Comput Vis Theory Appl. VISAPP08*, 2008.

[18] S. Dube and L. Hong, "An adaptive algorithm for image resolution enhancement," *Signals Syst. Comput. 2000 Conf. Rec. Thirty-Fourth Asilomar Conf.*, vol. 2, 2000.

[19] R. Kimmel, "Demosaicing: Image reconstruction from color CCD samples," *IEEE Trans. Image Process.*, vol. 8, pp. 1221 – 1228, 1999.

[20] J. Allebach and P. W. Wong, "Edge-directed interpolation," *Proc. Int. Conf. Image Process. 1996*, vol. 3, pp. 707–710, 1996.

[21] D. R. Cok, "Signal processing method and apparatus for producing interpolated chrominance values in a sampled color image signal," *US Pat. No 4642678*, 1987.

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Numerical study of natural ventilation in a channel integrated below the roof tiles of Buildings

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ABSTRACT: In this work, a comparative numerical study of natural convection in a channel with two types of walls was presented. This channel has two flat walls in the first case and flat wall and sinusoidal one in the second case. This type of channels is used as a thermosyphon system under the tiles of the roof of the buildings. It maximizes natural ventilation and minimizes the solar energy absorbed by the construction.

To evaluate the effectiveness of the air channel, a numerical model is developed for the studied thermosyphon using the software FLUENT.

The governing equations are solved by using the software Fluent where the SIMPLER algorithm is used for the coupling of velocity and pressure. The flow is turbulent and the turbulence is modeled by using the k-ε model.

The distributions of speeds, temperatures and mass flow induced are determined. The obtained results are in good agreement with the experimental ones.

A comparative study of the air flow in the second type of channel with sinusoidal wall was performed, it fined that it gives a flow with a high rate and the use of the corrugated surface allows us to increase the heat transfer to the fluid and the rate of mass flow without affecting the length of the channel.

KEYWORDS: Natural ventilation, temperature, speed, air channel, comparative study.

1 INTRODUCTION

The numerical and experimental studies of natural convection in inclined channels have become very interesting. This is due to the importance of the geometry in the heating and cooling of collective or individual buildings (solar chimney, Trombe wall, etc ...), in the cooling of electronic components and other applications.

The roofs are usually constructed with an air gap of 3cm located below the tiles. This thickness was recommended by the rules of buildings construction [1].

In this system, air movement which occurs naturally as a result of temperature difference caused by solar radiation can be used in heating (in winter) and cooling (in summer) of constructions.

This thermosyphon system depends on various parameters such as geometry, inclination, channel opening, solar radiation...

The increase in the exchange surface of the channel may increase the heat transfer to the fluid [2]. For this reason and in order to increase the air flow in the thermosyphon system, we propose a sinusoidal shape of the upper plate (hot plate) of the channel.

In this work, we studied the natural convection in two types of channels, the first is composed of two parallel flat plates and the second consists of a flat bottom plate and a sinusoidal top plate. The geometries are given below.

The objective of this work is to study numerically the airflow produced in both thermosyphon systems. To see the effectiveness of the two channels, a numerical model was developed. The results obtained in the form of airflow,

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temperature profiles, average coefficient of convection, and Nusselt n-umber in the case of the first channel are validated with experimental results of J. Khedari [3]. The numerical model used in the first type of channel was extended to the study of natural convection in the second one having a sinusoidal plate, this allows us to say in which channel the airflow is better.

Nomenclature

L	Channel length	m
W	Channel width	m
A	Surface of the hot plate	m^2
H	Thickness of the air gap	m
T_H	Hot temperature	K
T_b	Average temperature of the air	K
V_i	Inlet speed	$m.s^{-1}$
K	Turbulent Kinetic Energy	$m^2.s^{-2}$
U	Velocity	$m.s^{-1}$
P	Pressure	Pa
ε	Dissipation rate	$m^2.s^{-3}$
Pr	Prandtl number	
Ra	Rayleigh number	
Nu	Nusselt number	
Pr_t	Turbulent Prandtl number	
Gr	Grashauf number	
ρ	Fluid density	$kg.m^{-3}$
ν	Kinematic viscosity	$m^2.s^{-1}$
C_P	The specific heat of the fluid	$j.Kg^{-1}.K^{-1}$
β	Coefficient of thermal expansion of the fluid	K^{-1}
λ	Thermal conductivity of the fluid	$W.m^{-1}.K^{-1}$
g	Gravity	$m.s^{-2}$
ν_t	Turbulent kinematic viscosity	$m^2.s^{-1}$
b	Block	
T	Turbulent	
o	Outlet	
i	Inlet	
θ	Inclination angle of the channel	°
Mean	Mean	
Min	Minimum	
Max	Maximum	

In the literature, several numerical and experimental studies of natural and forced convection in passive systems are available. Some studies that we found, we note those of:

- The passive solar wall, which was used for heating and natural ventilation of buildings.

- The Systems of classical compounds walls. In this case, we find the numerical study validated experimentally of Jibao Shen et al. [4] and the comparative study of four types of solar walls [5].

Yanik Boutin et al [6] studied the effect of the channel width, the Rayleigh number and heat transfer coefficient on the air flow and proposed a correlation between these parameters. Another numerical study concerns the effect of heat sources distribution in the fluid flow in a channel was developed by using the Fluent software [7] and [8].

The concept of fireplace used for heating buildings is also an example of these studies and we can found the numerical study of turbulent natural convection in a vertical channel with asymmetric heating walls [9]. The objective of this study is to see the effectiveness of solar collectors installed on the walls of school buildings.

Another numerical study of solar chimney systems is that of a channel composed of two parallel walls [10].

The effect of the inclination of the solar chimney on the air flow has been studied theoretically and experimentally [11] and CFD modeling techniques [12] have been used to determine the ventilation rate in the presence of double glazing.

Another numerical study on laminar and turbulent flows induced by natural convection in channels for several Rayleigh

numbers obtained for different values of the ratio of the high to the length of the channel and for different heating conditions was developed and correlation between these parameters and the Nusselt number was obtained [13]. Jongjit et Hirunlabh [14] studied the performance of a thermosyphon system similar to a solar collector integrated in the building roof. This system improves the thermal comfort of constructions.

The design of double skin walls is known as an effective method to reduce the solar gain of the building, for that an inclined open channel with a top plate heated by a lighting system is used to simulate roofs with double walls exposed to sunlight. [15].

Models of roofs inspired from the concept of walls with double skin and technical barriers to radiation have been specifically designed to reduce solar gain received by construction [16].

Experimental results have been obtained in the case of a tilted cavity heated from the top to try to reproduce the effect of solar radiation on a roof [17]. For this, the variation of the different heat flow and air flow in the cavity have been measured and interpreted.

One method of increasing the heat transfer by convection through the channels is to use corrugated surfaces. For this purpose, W. Gao [18] studied numerically the natural convection in a solar collector consisting of a flat cover and a wavy absorber.

2 STUDIED GEOMETRIES

The two geometries studied are shown in Figure.1; for each geometry the length (L) and width (w) are respectively equal to 1.36 m and 0.68 m. The height of the channel consisting of flat plates is H = 0.14 m. Channel with sinusoidal plate has a maximum height Hmax = 0.16 m and a minimum height Hmin = 0.12 m. The inclination angle is selected equal to 30°.

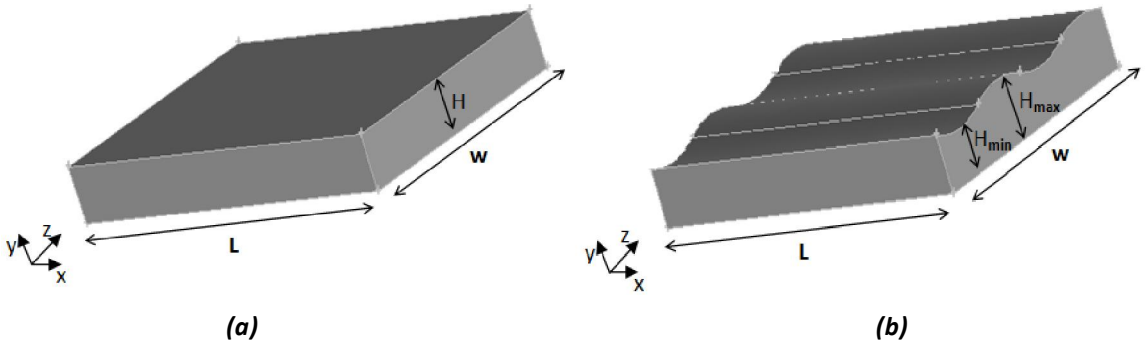


Fig. 1. Studied geometries: (a) flat plate channel, (b) channel with sinusoidal upper plate

3 THEORY

The flow within the channel is turbulent. For a steady, turbulent and compressible flow in two directions (x,y), the equations of continuity, momentum and energy can be written as [19, 20]:

$$\frac{\partial \bar{U}_\iota}{\partial \bar{x}_j} = 0 \tag{1}$$

$$\bar{U}_J \frac{\partial \bar{U}_\iota}{\partial x_j} = -\frac{1}{\rho}\frac{\partial \bar{P}}{\partial x_i} + \frac{\partial}{\partial x_j}\left[(\nu + \nu_t)\frac{\partial \bar{U}_\iota}{\partial x_j}\right] + g_i\beta(\bar{T} - T_0) \tag{2}$$

$$\bar{U}_J \frac{\partial \bar{T}}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\frac{\nu}{Pr} + \frac{\nu_t}{Pr_t}\right)\frac{\partial \bar{T}}{\partial x_j}\right] \tag{3}$$

This system of equations is obtained under the assumption that the viscous dissipation is neglected, the physical properties for the fluid are assumed constant and the gravity has a vertical effect. The Boussinesq approximation [21] is applied to the entire domain. As the flow in the channel is turbulent, the turbulence is modelled using the k-ε model.

$$\bar{U}_J \frac{\partial k}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\nu + \frac{\nu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + \nu_t \frac{\partial \bar{U}_\iota}{\partial x_j}\left[\frac{\partial \bar{U}_\iota}{\partial x_j} + \frac{\partial \bar{U}_J}{\partial x_i}\right] + \frac{\beta}{\rho} g_i \frac{\nu_t}{Pr_t}\frac{\partial \bar{T}}{\partial x_j} - \varepsilon \quad (4)$$

$$\bar{U}_J \frac{\partial \varepsilon}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\nu + \frac{\nu_t}{\sigma_k}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + \frac{C_{1\varepsilon}}{\rho}\frac{\varepsilon}{k}\nu_t \frac{\partial \bar{U}_\iota}{\partial x_j}\left[\frac{\partial \bar{U}_\iota}{\partial x_j} + \frac{\partial \bar{U}_J}{\partial x_i}\right] + \frac{C_{1\varepsilon}C_{3\varepsilon}}{\rho}\frac{\varepsilon}{k}\left[\frac{\beta}{\rho} g_i \frac{\nu_t}{Pr_t}\frac{\partial \bar{T}}{\partial x_j}\right] - C_{2\varepsilon}\frac{\varepsilon^2}{K} \quad (5)$$

For shear layers which the direction of the main flow is parallel to the gravity direction, $C_{3\varepsilon}$ = 1 and for the shear layers perpendicular to gravity, $C_{3\varepsilon}$ is zero. The other constants have the following values [22]:

$C_\mu = 0.09$, $\sigma_k = 1.0$, $\sigma_\varepsilon = 1.3$, $C_{1\varepsilon} = 1.44$, $C_{2\varepsilon} = 1.92$.

In this case, the dimensionless Nusselt number Nu is a function of the Rayleigh number Ra, the Prandtl number Pr, the ratio (H/L) and the angle of inclination θ.

The fluid used is air (Pr = 0.71). The Rayleigh number Ra is defined as:

$$Ra = Gr.\Pr \quad (6)$$

Gr is a dimensionless number defined by :

$$Gr = \frac{g\beta(T_H - T_b)H^3}{\nu^2} \quad (7)$$

g is the gravity acceleration, β is the coefficient of thermal expansion, ν is the kinematic viscosity, T_H is the temperature of the hot wall and T_b is the average temperature of the air. The flow regime in the Thermosyphon is related to the values of the Rayleigh number Ra.

For large values of this number, the flow becomes turbulent. The Nusselt number Nu is a function of the height H of the thermosyphon, the Rayleigh number Ra and the angle of inclination ɵ.

$$Nu = f(Ra, H, \theta) \quad (8)$$

The Nusselt number is defined by:

$$Nu = \frac{\bar{h}H}{\lambda} \quad (9)$$

The average coefficient of convection $\bar{h}$ is given by [16]:

$$\bar{h} = \frac{Q}{A(T_H - T_b)} \quad (10)$$

Q is the convective heat flux which is expressed by:

$$Q = \dot{m}C_P(T_O - T_i) \quad (11)$$

To calculate the convective heat flux, the average temperature of the air can be used to estimate the temperature of the air at the outlet of the channel [3].

$$T_O = 2T_b - T_i \quad (12)$$

Where:

$$T_O - T_i = 2(T_b - T_i) \quad (13)$$

4 BOUNDARY CONDITIONS

The boundary conditions must be defined to solve different equations obtained. The pressure is equal to the ambient pressure at the outlet of the channel, and at the inlet temperature is equal to the ambiant temperature. For the upper and lower walls, the speed satisfies the non-slip condition and temperatures are taken equal to those chosen by J. Khedari et al [3]. This allows us to validate our model in the first type of channel. The other walls were considered adiabatic (figure.2).

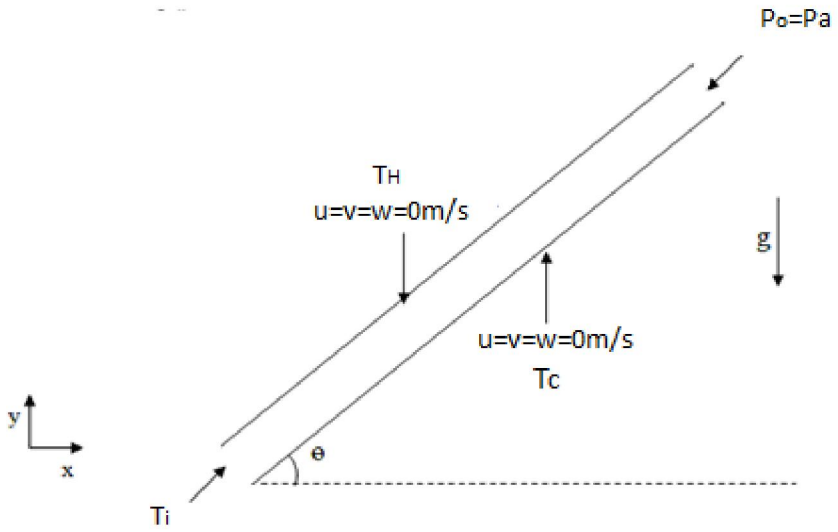
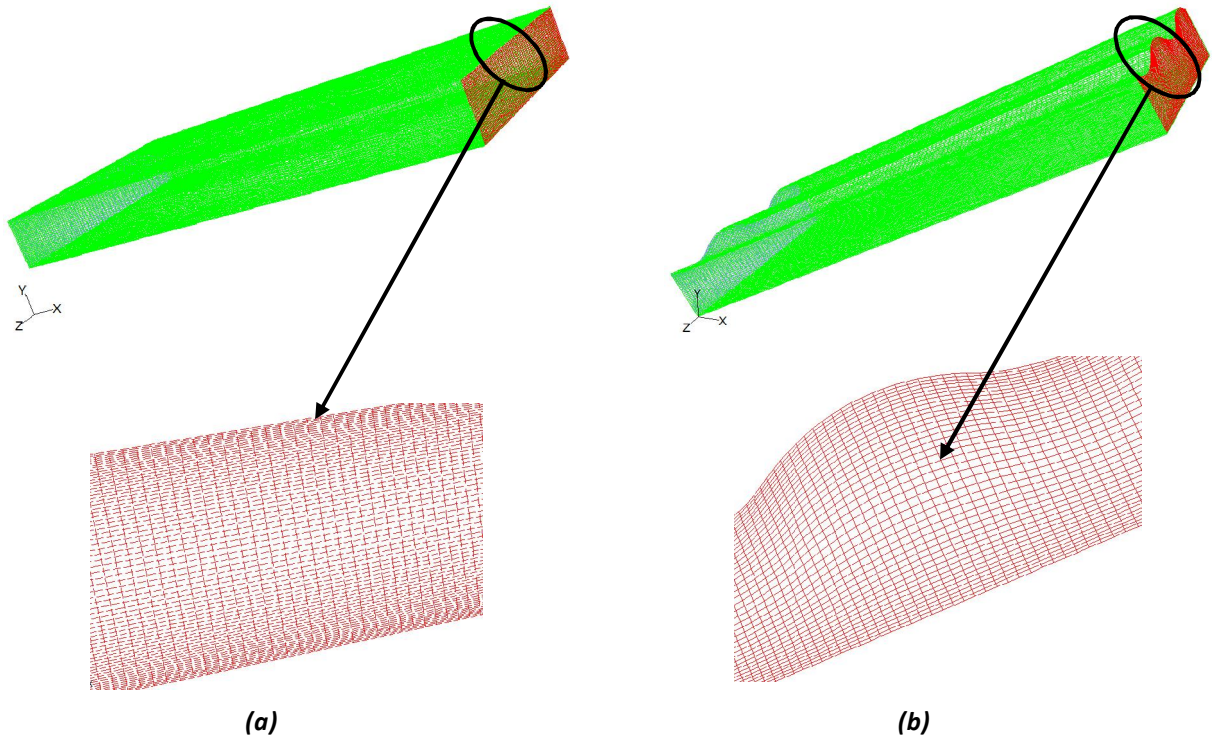


Fig. 2. boundary conditions

5 CONVERGENCE OF THE NUMERICAL RESULTS

Heat transfer and air flow which is the thermosyphon system is due to buoyancy forces (natural convection). The numerical study in these channels was performed by using the commercial computational fluid dynamics software FLUENT.

The results convergence is strongly linked to the choice of the grid, a good choice of mesh is necessary. Finer mesh can give good results, however the computation time depends on the chosen mesh, thus it needs to define the optimal between mesh and the computation time. The solution is to take a tight mesh close to the walls and slightly changing to the center of the channel (figure. 3).

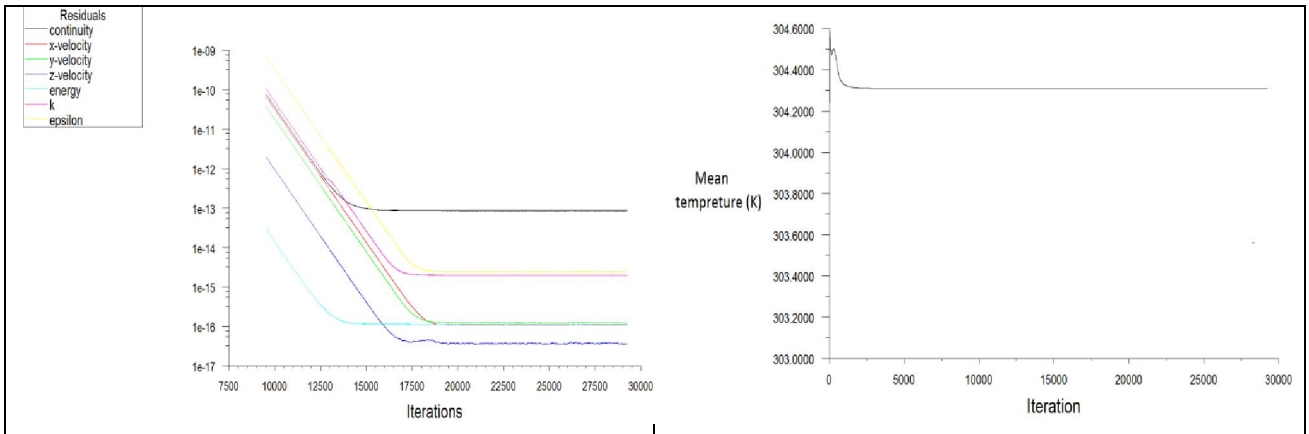


(a) *(b)*

Fig. 3. Mesh geometries studied, (a) channel flat plate, (b) channel with sinusoidal upper plate

The convergence of the numerical results is considered satisfactory if the residuals of the various parameters and the mean temperature become constant in each section.

Table 1. Tests for convergence



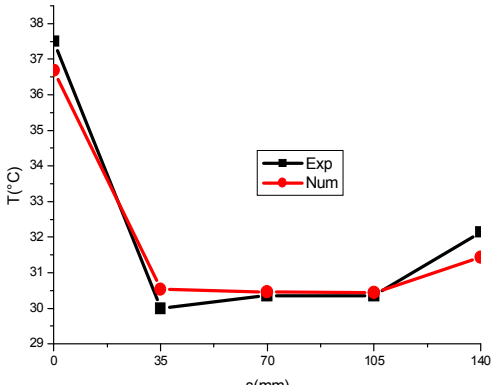
Residuals	***Convergence test of the mean temperature of the air***

6 RESULTS AND DISCUSSION

6.1 VALIDATION

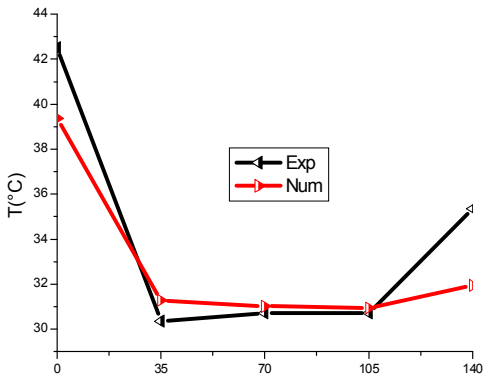
Several cases are treated to validate our numerical model. The tests are performed by using experimental data found in the literature [3]. The inlet temperature and the hot temperature are taken as variables.

Figure 4 shows a comparison between the temperature profiles across the channel at different positions along the length, with T_H = 40.83 °C. The comparison between numerical and experimental results shows that the maximum difference is 7% for the air temperature.



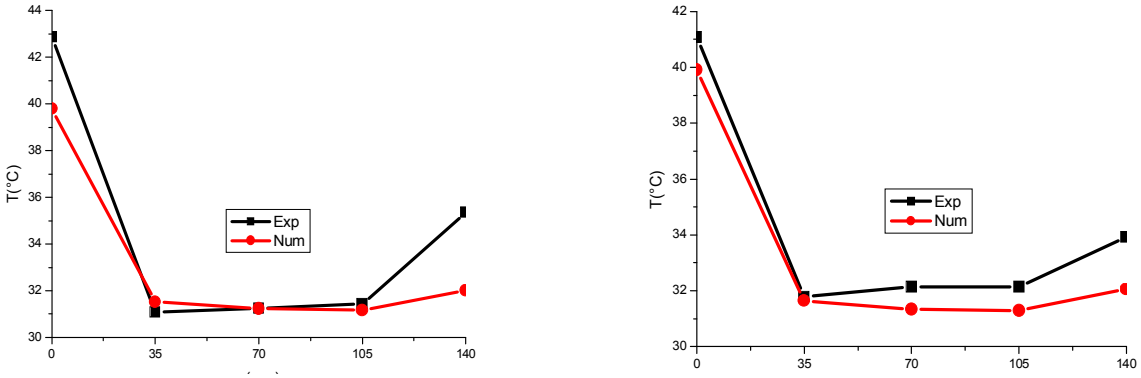
H (mm)

(a): 0.0367L



H (mm)

(b): 0.3456L



(c): 0.6544L ***(d): 0.9632L***

Fig. 4. Temperature profiles through the channel at different positions where Tc = 40.83 °C

The comparison between the experimental and numerical results of the values of Nusselt number (figure.5), and average convection coefficient (figure.6), shows a good agreement between the two results. The results obtained show a maximum difference of 2.6% for the Nusselt number (Nu), and an average value of 3.36% for the coefficient of heat transfer (h_{moy}). The increase of the parameter ((H/L) $Ra_H sin30°$) or the Rayleigh number increases the heat transfer coefficient and consequently, the Nusselt number.

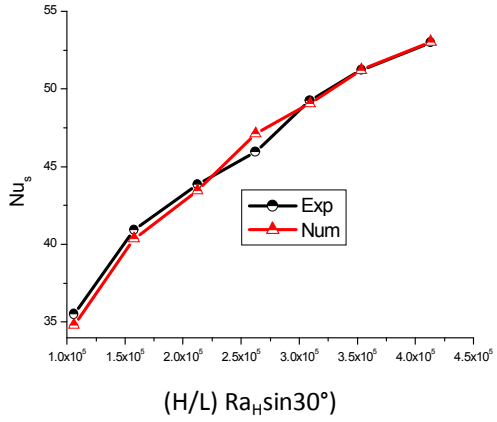


Fig. 5. Comparison of experimental and numerical Nusselt number

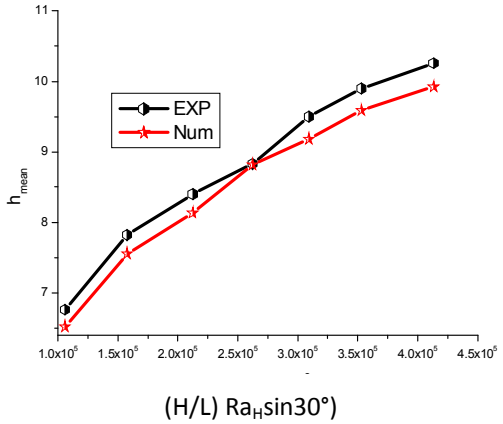


Fig. 6. Comparison of experimental and numerical average coefficient of convection

A good agreement is obtained between the numerical values and the experimental values of the mass flow (Figure.7). Both results show that the mass flow increases with the increase of the parameter ((H/L) $Ra_H sin30°$)).

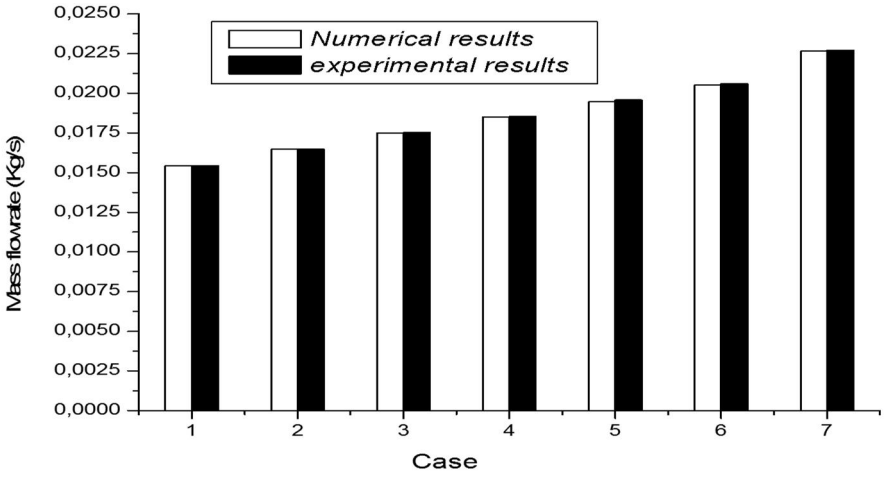


Fig. 7. Experimental and numerical results of the mass flow

6.2 COMPARISON BETWEEN THE TWO TYPES OF CHANNEL

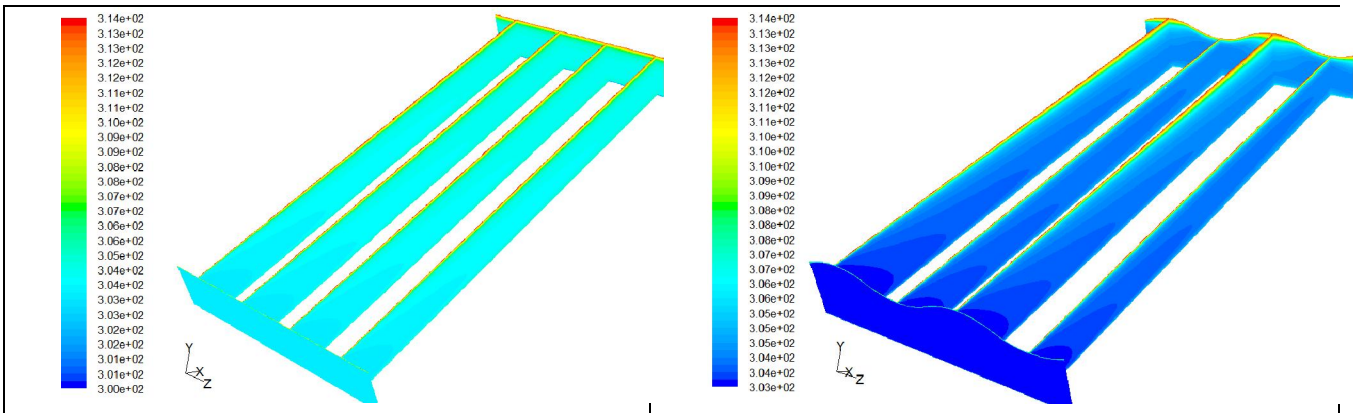
6.2.1 VELOCITY AND TEMPERATURE

The table.2 shows the velocity and temperature determined in several sections along the width of the two channels types.

The fields of temperature were highly asymmetric; this is due to the boundary conditions imposed. The high values of the velocity are near the hot plates where buoyancy forces are more dominant and on all walls the velocity satisfies the condition of non-slip.

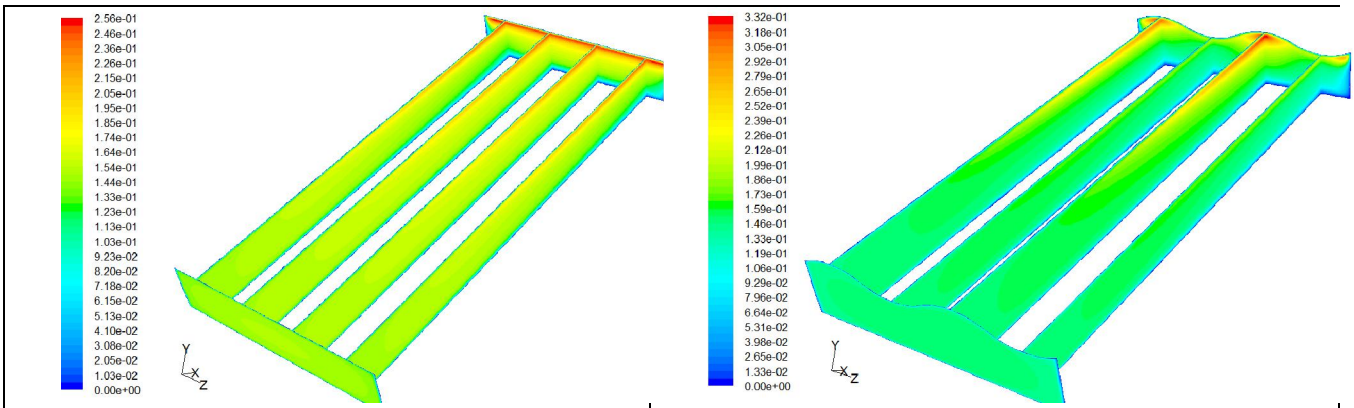
We note that the velocity is high in the case of a sinusoidal channel then that with flat plates. For the velocity field presented in different sections of the channel, we can note that there is no recirculation of the airflow.

Table 2. Velocity and temperature field



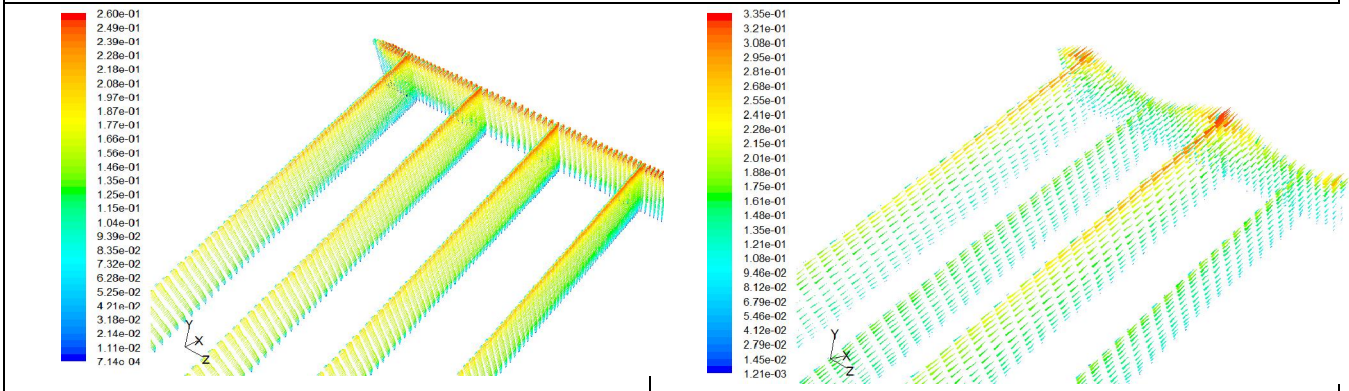
(a)	*(b)*

Field of the temperature in several sections: (a) channel flat plate, (b) channel with sinusoidal upper plate.



(a)	(b)

Velocity field in several sections: (a) channel flat plate, (b) channel with sinusoidal upper plate.



(a)	(b)

Velocity vectors in multiple sections: (a) channel flat plate, (b) channel with sinusoidal upper plate.

6.2.2 MASS FLOW RATE

A comparison of the mass flow in both types of channels is shown in Figure.8. There was a significant difference in the value of the flow in both geometries. The channel with corrugated plate provides a fluid flow with a high rate. This rate is proportional to the Rayleigh number Ra.

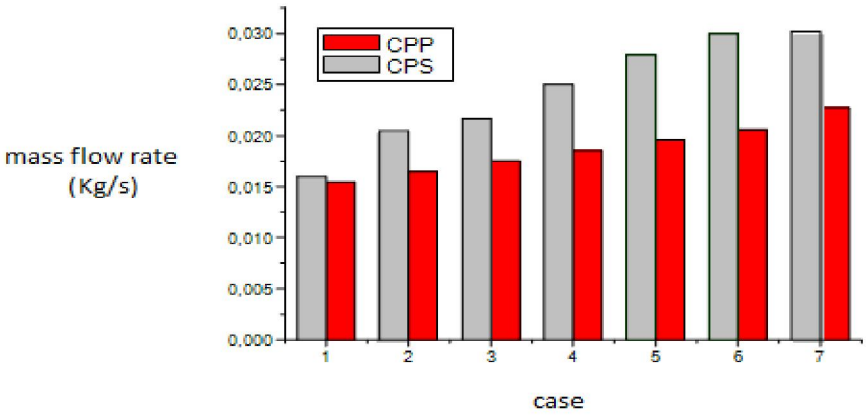


Fig. 8. Comparison of mass flow rates for both channels CPP (channel with flat plates) and CPS (channel sinusoidal plate)

6.2.3 AVERAGE CONVECTION COEFFICIENT AND AVERAGE NUSSELT NUMBER

Figures.9 and 10 show respectively the comparison of the average convection coefficient and the average Nusselt number in both types of channels. We can see that the Nusselt number and the heat transfer coefficient have higher values in the case of channel with sinusoidal plate.

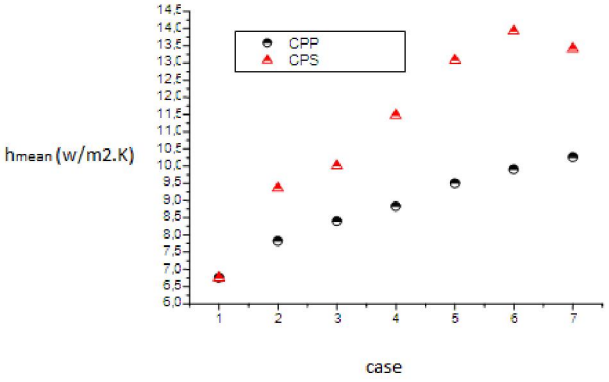


Fig. 9. Comparison of the average convection coefficient for the two types of channels

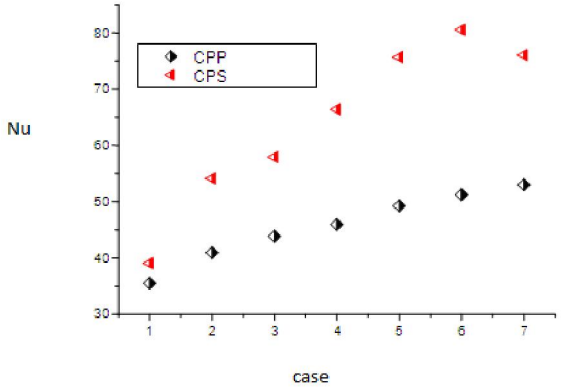


Fig. 10. Comparison of the average Nusselt number for the two types of channels

7 CONCLUSION

In this work the heat transfer in an inclined channel was investigated numerically by a comparison between two types of channels which can be integrated in the roof of constructions. The numerical model for the studied thermosyphon systems was developed using the software FLUENT.

The first type of channel (CPP), the temperature profiles and mass flow were validated by existing experimental results [3]. In the second channel (CPS), the velocity and temperature were presented and a comparison of the mass flow, the heat transfer coefficient and the Nusselt number for both types of channels was performed.

During this study we noticed that the temperature difference of the plates and the air temperature affects clearly the mass flow, the average coefficient of convective heat transfer, and the average Nusselt number. We can also note that the use of the corrugated surface allows us to increase the heat transfer to the fluid and the rate of mass flow without affecting the length of the channel.

REFERENCES

[1] N. Chami. A. Zoughaib, “modeling natural convection in a pitched thermosyphon system present in building roofs and experimental validation using particle image velocimetry,” Energy and building, Vol. 42, pp. 1267-1274, 2010.

[2] Ho-Ming Yeh and Tong-Tshien Lin, “The effect of collector’s aspect ratio on the collector’s efficiency of flat-plate solar air,” Energy, Vol.20, pp. 1041-1047, 1995.

[3] Joseph Khedari, Patsada Yimsamerjit, Jongjit Hirunlabh, “Experimental investigation of free convection in roof solar collector,” Building and Environment, Vol.37, pp. 455-459, 2002.

[4] Jibao Shen, Stéphane Lassue, Laurent Zalewski, Dezhong Huang, “Numerical study on thermal behavior of classical or composite Trombe solar walls,” Energy and Buildings, Vol. 39, pp. 962–974, 2007.

[5] L. Zalewski, S. Lassue, B. Duthoit, M. Butez, “Study of solar walls-validating a simulation model,” Building and Environment, Vol. 37, pp. 109–121, 2002.

[6] Yanik Boutin, Louis Gosselin, “Optimal mixed convection for maximal energy recovery with vertical porous channel (solar wall),” Renewable Energy, Vol. 34, pp. 2714–2721, 2009.

[7] Jérémie Vareilles, Cristian Muresan, Stéphanie Giroux-julien, christophe menezo, ‘’étude numérique des transferts de chaleur et de masse en convection naturelle dans un canal vertical soumis a des perturbations thermiques

periodiquement reparties sur ses parois,'' 12èmes Journées Internationales de Thermique, Tanger, Maroc du 15 au 17 Novembre 2005.

[8] M. Fossa, C. Ménézo , E. Leonardi, "Experimental natural convection on vertical surfaces for building integrated photovoltaic (BIPV) applications," Experimental Thermal and Fluid Science, Vol. 32, pp.980–990, 2008.

[9] A.M. Rodrigues, A. Canha da Piedade, A. Lahellec, J.Y. Grandpeix, "Modelling natural convection in a heated vertical channel for room ventilation," Building and Environment, Vol. 35, pp. 455–469, 2000.

[10] H.F. Nouanégué, E. Bilgen, "Heat transfer by convection, conduction and radiation in solar chimney systems for ventilation of dwellings," International Journal of Heat and Fluid Flow, Vol. 30, pp. 150–157, 2009.

[11] Jyotirmay Mathur, Sanjay Mathur, Anupma, "Summer-performance of inclined roof solar chimney for natural ventilation," Energy and Buildings, Vol. 38, pp. 1156–1163, 2006.

[12] D.J. Harris, N. Helwig, "Solar chimney and building ventilation", Applied Energy, Vol. 84, pp. 135–146, 2007.

[13] B. Zamora, A.S. Kaiser, "Optimum wall-to-wall spacing in solar chimney shaped channels in natural convection by numerical investigation," Applied Thermal Engineering, Vol. 29, pp. 762–769, 2009.

[14] Jongjit Hirunlabh, Sopin Wachirapuwadon, Naris Pratinthong, Joseph Khedari, "New configurations of a roof solar collector maximizing natural ventilation," Building and Environment, Vol. 36, pp. 383–391, 2001.

[15] Chi-ming Lai, J.Y. Huang, J.S. Chiou, "Optimal spacing for double-skin roofs," Building and Environment, Vol. 43, pp. 1749–1754, 2008.

[16] Pei-Chi Chang, Che-Ming, Chi-Ming Lai, "development and preliminary evaluation of double roof prototypes incorporating RBS (radiant barrier system)," Energy and building, Vol. 40, pp. 140-147, 2008.

[17] L. Susanti, H. Homma, H. Matsumoto, Y. Suzuki, M. Shimizu, "A laboratory experiment on natural ventilation through a roof cavity for reduction of solar heat gain," Energy and building, Vol. 40, pp. 2196-2206, 2008.

[18] Wenfeng Gao, Wenxian Lin, Enrong Lu, "Numerical study on natural convection inside the channel between the flat-plate cover and sine-wave absorber of a cross-corrugated solar air heater", Energy Conversion & Management, Vol. 41, pp. 145-151, 2000.

[19] J. F. Sacadura, Initiation aux transferts thermiques, 6eme tirage, édition Technique et Documentation, 2000.

[20] Sébastien Candel, Mécanique des fluides, 2eme édition, édition Dunod, 2001.

[21] Gray DD, Giorgini A, "The validity of the Boussinesq approximation for liquids and gases," International Journal of Heat and Mass Transfer, Vol. 19, pp. 545-551, 1976.

[22] Fluent 6.3 User's Guide, Fluent Inc (2005).

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Genetic Algorithms in Intrusion Detection Systems: A Survey

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ABSTRACT: Securing the digital assets is a major concern in the present digital information era. Various tools and techniques have been researched and implemented to secure the digital assets at both individual and organizational levels. Intrusion detection systems are considered as the cornerstone of modern information security. These systems enable us to be safe from the malicious users, who intend to misuse our digital data and resources. There are different approaches, methods, and techniques employed within the field of intrusion detection. Intrusion detection based on evolutionary methods is currently a hot topic of research. Various evolutionary techniques have been successfully implemented for intrusion detection. In this paper, a survey on applications of genetic algorithms in intrusion detection systems is carried out. The paper provides an introduction to the basic concepts of intrusion detection and genetic algorithms. The generic implementation of genetic algorithms using pseudo code is presented. Pseudo code for genetic algorithm based intrusion detection method is also included for clear understanding. The paper also provides an overview of the advantages and disadvantages of genetic algorithms in general, and as applied to intrusion detection in particular. This survey will provide helpful insight into the related literature and implementation of genetic algorithms in intrusion detection systems. It will also be a good source of information for people interested in the genetic algorithms based intrusion detection systems.

KEYWORDS: Misuse Detection, Anomaly Detection, IDS Architecture, Optimization, Classification, Model Generation.

1 INTRODUCTION

In the past few decades, the computer technology has evolved at a very fast pace. This fast growth of computer technology has resulted in the transfer of more and more services to computer based systems. The dependency of more and more services on computer technology has resulted in the increase of computer related threats. With each passing day, the avoidance and detection of threats to computer technology is becoming more and more difficult. The increase in the number and severity of threats has given birth to a new field of study. Information security is the field of study dealing with security of computer systems in general. Most of the security mechanisms designed so far, try to prevent unauthorized access to system resources and data. However, it appears that such systems are not able to completely prevent intrusions into computer systems. The need is to detect intrusions efficiently, so that their impact can be realized and damages can be repaired. Also, efficient detection of the intrusions will enable security professionals to devise measures that can be used to prevent them from happening in the future. Intrusion detection systems are the tools used for prevention and detection of threats or breaches to computer systems. A lot of research has been carried out in developing and implementing new techniques ranging from basic statistical methods to highly complex evolutionary methods for intrusion detection.

The aim of this paper is to present a survey of the contributions from researchers and industry that investigate and support the use of genetic algorithms in designing intrusion detection systems.

The remainder of this paper is divided into several sections. It will start with a formal introduction to intrusion detection systems and genetic algorithms in section 2 to make readers familiar with the basic concepts needed. In the section 3, a

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survey of the literature supporting the use of genetic algorithms for intrusion detection is presented. Section 4 details the genetic algorithms in intrusion detection. Finally, section 5 presents the conclusion derived from the survey.

2 BACKGROUND

2.1 INTRUSION DETECTION SYSTEMS

Intrusion detection systems are considered as the first line of defense in securing computer systems. They are designed to monitor and defend computer systems against intrusions. Intrusion detection systems dynamically monitor and analyze the events occurring in a system, and decide the degree of their legitimateness [1]. Intrusion detection systems are classified as network intrusion detection systems (NIDS), host intrusion detection systems (HIDS), or distributed intrusion detection systems (DIDS), based on whether an intrusion detection system monitors a network, or a host, or both [2].

Intrusion detection systems are also classified into two types on the basis of detection approach used, namely (i) misuse detection based and (ii) anomaly detection based. In misuse based intrusion detection systems, the intrusions are identified by matching collected data with a pre-specified set of signatures or by applying a set of defined rules [3]. Therefore, known intrusions are identified easily, but the problem arises with such systems when no signature exists for an intrusion. This approach has advantage of producing very low false positives. To overcome the problem of unknown intrusions, another approach to implement is anomaly detection. This approach was proposed by Denning [4] in 1987.

Anomaly based intrusion detection systems detect intrusions by analyzing deviation from expected behavior in the captured data. If the deviation crosses a certain threshold, the data is said to be anomalous. The anomaly detection approach has the capability of detecting unknown intrusions, but the major difficulty with anomaly based approach is defining what constitutes normal behavior and abnormal behavior. Another problem with the anomaly detection approach is high false positive rate [5].

Figure 1, adopted with modifications from [6], gives a generic architecture of an intrusion detection system.

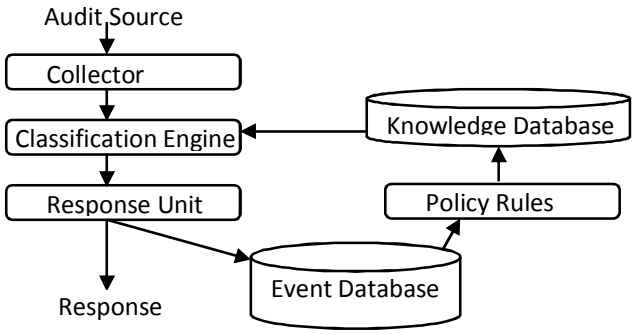

Fig. 1. Generic Architecture of Intrusion Detection System

In figure 1, the audit source represents the input to the intrusion detection system. The format of input data can be of different types depending upon the type and location of the intrusion detection system. The collector samples and pre-processes the audit source data. The data is transformed into a standard format known to the internal components of the intrusion detection system. The knowledge database contains information about attacks. The classification engine determines the legitimateness of the received data by comparing it with the attack information stored in the knowledge database. The policy rules are used to configure the response and detection of intrusion system. The response unit produces different types of responses depending upon the incoming events and their severity. The event database stores the detailed information about the events, which is used for various purposes like attack report generation, and framing new rules.

2.2 GENETIC ALGORITHMS

Li [7] describes genetic algorithm as a family of computational models based on evolution and natural selection. Bobor [8] has defined a genetic algorithm as a programming technique, which mimics biological evolution as a problem solving approach. An early work by Holland highlights the benefits of applying nature inspired adaptability function into artificial systems [9]. The genetic algorithms use techniques inspired by biological concepts like inheritance, mutation, selection, and

crossovers. The genetic algorithms are said to follow the famous "Darwinian Principle of Evolution" in functioning, which advocates the survival of the fittest among a population. Therefore, a solution obtained by applying genetic algorithms to any problem, consists of only those optimal candidate solutions which are said to satisfy a predefined fitness value [10], [11].

2.2.1 STRUCTURE OF GENETIC ALGORITHMS

Genetic algorithms are implemented as chromosome-like data structures. Figure 2 adopted from [12] depict the structure and processing in a genetic algorithm.

A genetic algorithm has many parameters, operators and processes which decide its arrival to an optimal solution. A short description of the parameters, operators and processes as depicted in figure 2, is as:

Fitness Function: The fitness function is the measure of the quality of a particular solution. The fitness function is used to determine the most optimal solution from a number of solutions in a population.

Selection: The selection process in genetic algorithms is used to select the most optimal solution determined by using the fitness function. The solutions which are not optimal are discarded.

Crossover: The crossover process in genetic algorithms is used to exchange characteristics between two different solutions. The pairs of solutions to exchange characteristics are selected randomly and keep exchanging characteristics, until a completely new generation of solutions is obtained.

Mutation: The mutation process in genetic algorithms changes some random bits in a solution. The change in the bits results in the genetic diversity of the mutated algorithms.

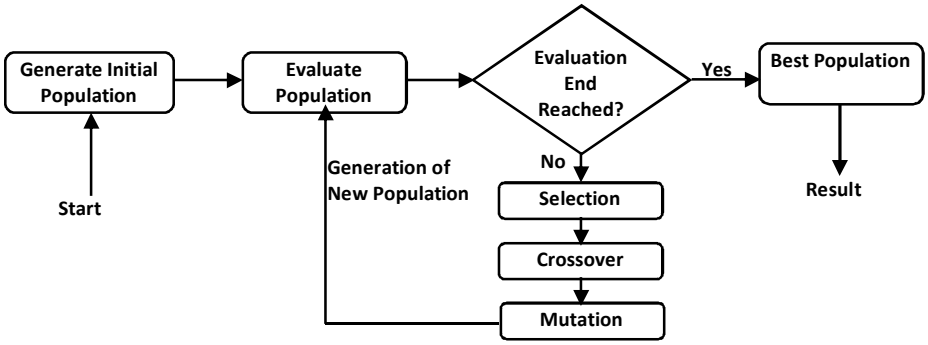

Fig. 2. Structure & Processing in a Genetic Algorithm.

2.2.2 FUNCTIONING OF GENETIC ALGORITHMS

The genetic algorithms start processing by initially selecting a random population of chromosomes. Each chromosome is composed of a finite number of genes, which is predefined in every implementation [13]. These chromosomes are the data representing the problem. This initial population is refined to a high quality population of chromosomes, where each chromosome satisfies a predefined fitness function. According to the requirements of the solution needed, different gene positions in a chromosome are encoded as numbers, bits, or characters. Each population is refined by applying mutation, crossover, inversion, and selection processes. The generic pseudo code for a genetic algorithm taken from [14] is given below for better understanding of the process:

```
InitPopulation (P)
Fitness(P)
While MaxGenerationNotReached do
        for i = 0 to xfactor do
                p1 = Selection(P)
                p2 = Selection(P)
                (o1, o2) = crossover(p1, p2)
```

```
                Crowding(p1, p2, o1, o2)
        end for
        for i = 0 to dfactor do
                p = Selection(P)
                Dropping(P)
        end for
        for i = 0 to mfactor do
                p = Selection(P)
                Mutation(p)
        end for
Fitness(P)
end while
SelectionBestIndual(P)
```

2.2.3 ADVANTAGES OF GENETIC ALGORITHMS

The various advantages of genetic algorithms are:

- Genetic algorithms possess tremendous capabilities for parallel processing.
- Genetic algorithms provide a wider solution space.
- Genetic algorithms possess easily discoverable global minima.
- Genetic algorithms are easy to modify.
- Genetic algorithms handle functions with noise efficiently.
- Genetic algorithms show high performance even in the case of multi – modal problems.
- Genetic algorithms do not need prior knowledge of the problem space.
- Genetic algorithms are least affected by the discontinuities in the problem space.
- Genetic algorithms are reliable enough not to become trapped in local minima.

2.2.4 LIMITATIONS OF GENETIC ALGORITHMS

Genetic algorithms are efficient, but in practice they have certain limitations:

- It is not always easy to find a fitness function.
- Representing a problem space in genetic algorithms is very complex.
- In many cases genetic algorithms converge prematurely to a solution.
- It is a tough task to choose the optimal parameters for a genetic algorithm.
- Genetic algorithms need to be coupled with a local searching technique for effective functioning.
- Genetic algorithms need a large number of fitness function evaluations.
- It is not easy to configure a genetic algorithm based system.

2.2.5 DIFFERENCE BETWEEN GENETIC ALGORITHMS AND CONVENTIONAL METHODS

Genetic Algorithms differ from conventional methods used for optimization. The main differences are:

- Conventional optimization methods operate on the problem parameters directly, while as genetic algorithms operate on the coded version of the problem parameters.
- Most of conventional methods operate on a single solution for producing an optimal solution, while as genetic algorithms operate on a population of solutions, selecting more optimized solutions in each iteration.
- Conventional methods usually use derivatives for evaluating the solution produced, while as genetic algorithms use a fitness function for evaluating the optimal solution produced.

- Conventional methods use deterministic transition operators, while as genetic algorithms use probabilistic transition operators.

3 LITERATURE REVIEW

Li [7] has applied genetic algorithms on both temporal and spatial network connection data to identify anomalous network behaviors. The early work regarding the application of genetic algorithms for intrusion detection is by Forrest, et. al. [15]. They have used an algorithm based on rough sets and improved genetic algorithms to improve feature selection. Crosbie and Spafford [16] have applied genetic algorithms and multi-agent technique for network anomaly detection. A combination of genetic algorithms and fuzzy data mining techniques for network intrusion detection has been proposed by Bridges and Vaughn [17]. Chittur [18] presented a genetic algorithm based model for intrusion detection, which achieved a significantly low false alarm rate. Castro and Zubin in [19] proposed a hybrid algorithm with correlation based feature selection (CFS), and employed the SVM and genetic algorithm to achieve the optimization of intrusion detection. Gome [20] used log file trace events in an off-line mode to improve the classification rules of genetic algorithm. The implementation of genetic algorithms on top of information theory to enhance intrusion detection has been proposed by Xiao, et. al. [21]. Genetic algorithms have been used for classification of Smurf attack labels in training data set, achieving a false positive rate as low as 0.2% by Goyal and Kumar [22]. Abdullah, et. al. [23] have used genetic algorithms for obtaining classification rules for intrusion detection. Ojugo, et. al. [24], have used genetic algorithms to develop rule-based intrusion detection. The fitness function has been used to evaluate the rules.

4 GENETIC ALGORITHMS IN INTRUSION DETECTION SYSTEMS

This section begins with an introduction to the working of genetic algorithms when applied to intrusion detection and an overview of an intrusion detection algorithm implemented using genetic algorithm technique. Then, the role played by genetic algorithms in intrusion detection is discussed. At the end, the advantages of implementing intrusion detection systems using genetic algorithms are presented.

The working of a genetic algorithm when applied to intrusion detection can be viewed as a sequence of following steps:

i) The packet capturing module or sniffer present in the intrusion detection system collects the information about the network traffic or logs.
ii) The intrusion detection system applies genetic algorithms to the captured data. The genetic algorithm at this stage has classification rules learned from the information collected.
iii) The intrusion detection system then applies the set of rules produced in the previous phase to the incoming traffic. Application of rules to captured data results in the population initialization, which in turn results in the creation of a new population with good qualities. This population is then evaluated and a new generation with better qualities is created. Then genetic operators are applied to the newly created generation until the most suitable individual is found.

Figure 3, provides an example of genetic algorithm implementation in intrusion detection systems:

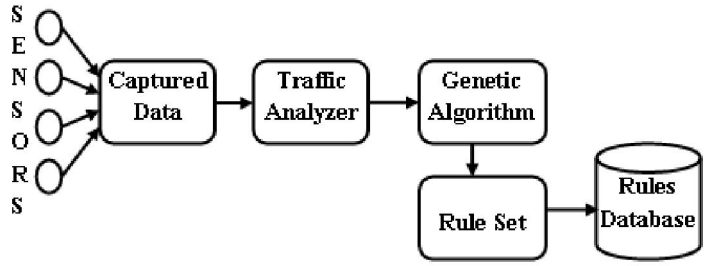

Fig. 3. Genetic Algorithm Implementation in Intrusion Detection Systems.

The working of genetic algorithms as applied to intrusion detection systems can be represented in pseudo code as:

```
initializePopulation(P)
setWeight(W)
```

```
setFitness(F)
numRules(R)
for each chromosome in P
   numAttack = 0
   numAttackNormal = 0
   for each record in T
      if the record matches the chromosome
         numAttackNormal = numAttackNormal + 1
      end if
      if the rule matches only the "condition" part
         numAttack = numAttack + 1
      end if
   end for
   calculate(F)
   if F > T
      apply the selection algorithm
      select the chromosomes into pNew
   end if
end for
for each chromosome in pNew
   apply crossover operator
   apply mutation operator
end for
if numGen not reached
   gotoline5
end if
```

Where,

P = Initial population, W = Weight value, F = Fitness function threshold, T = Training set, pNew = New population created, and numGen = Total number of generations created.

4.1 Role of Genetic Algorithms in Intrusion Detection

The subfields within the intrusion detection where genetic algorithms have been used extensively are – optimization, automatic model designing, and classification. Chittur [18] and Xiao, et. al. [21] used genetic algorithms for searching for transformation functions. Gassata [25] and Dass [26] have used a genetic algorithm for optimization purposes within the intrusion detection system. Gomez, et. al. in [20] and [27], have improved upon the application of genetic algorithm provided in [25]. Hofmann, et. al. [28] have used a genetic algorithm for optimal feature set selection and learning the structure of a radial basis function (RBF) net. Lu and Traore [29] used genetic algorithms to decide the number of clusters. Mischiattiand Neri [30], Jianet, et. al. [31], and Bankovic [32] have used genetic algorithm based classification rules as classifiers in intrusion detection systems.

A brief list of research works presenting the use of genetic algorithms in intrusion detection systems for different purposes is given in table 1:

Table 1. Fields of Application and Related Research Papers

Field of Application	List of Research Papers
Optimization	[20], [25], [26], [27], [33].
Automatic model Generation	[28], [34], [35].
Classification	[29], [30], [31], [32].

4.2 GENETIC ALGORITHM ADVANTAGES TO INTRUSION DETECTION SYSTEMS

The implementation of genetic algorithms offers many advantages to intrusion detection systems. The benefits of using genetic algorithms for intrusion detection can be summarized as:

- Genetic algorithms offer intrusion detection systems an intrinsic parallelism.
- Genetic algorithms are capable of working in multiple directions simultaneously. This makes them beneficial for analyzing the huge volumes of multi-dimensional data to be processed by an intrusion detection system.
- Genetic algorithms work with populations of solutions rather than a single solution. This makes them suitable for behavior based intrusion detection, where the behavior attributes may exhibit varying values.
- Genetic algorithms are highly re-trainable. Therefore, using genetic algorithms for intrusion detection will add to the adaptability of the system.
- Genetic algorithms evolve over time by using crossover and mutation. Property of evolving over time makes them a good choice for dynamic rule generation.

5 CONCLUSION

Intrusion detection methods based upon genetic algorithms have attracted considerable attention from the research community and the industry during the past decade. The correspondence between the requirements for building efficient intrusion detection systems and the features of genetic algorithms is the main reason behind genetic algorithms getting such an attention from the intrusion detection research community.

This survey provides an introduction to intrusion detection and genetic algorithms. The generics of genetic algorithm based intrusion detection systems are discussed. Also, the work done by different researchers in the direction of applying genetic algorithms for intrusion detection is surveyed. The paper will prove as a good starting point for newcomers to the field of genetic algorithms based intrusion detection and will also be useful for people looking for a quick review of the recent developments in the field .

REFERENCES

[1] H. Debar, M. Dacier, and A. Wespi, “Towards a Taxonomy of Intrusion Detection Systems,” *Computer Networks*, vol. . 31, no. 8, pp. 805–822, 1999.

[2] D. B. P. and M. Pels, “Host-Based Intrusion Detection Systems,” Faculty of Science, Informatics Institute, University of Amsterdam, Technical Report, 2005.

[3] Aleksandar, Kumar, and Jaideep, *Managing Cyber Threats: Issues, Approaches, and Challenges*. Springer Science + Business Media, 2005.

[4] D. E. Denning, “An Intrusion Detection Model,” *Special issue on Computer Security and Privacy*, vol. 13, no. 2, pp. 222–232, 1987.

[5] P. Garcı´a-Teodoro, J. Dı´az-Verdejo, G. Macia´-Ferna´ndez, and E. Va´zquez, “Anomaly-based Network Intrusion Detection: Techniques, Systems and Challenges,” *Computers & Security*, vol. 28, pp. 18 – 28, 2008.

[6] M. Arvidson and M. Carlbark, “Intrusion Detection Systems: Technologies, Weaknesses, and Trends,” 2003.

[7] W. Li, “Using Genetic Algorithm for Network Intrusion Detection,” in *Proceedings of the United States Department of Energy Cyber Security Group 2004 Training Conference*, 2004, pp. 1–8.

[8] V. Bobor, “Efficient Intrusion Detection System Architecture Based on Neural Networks and Genetic Algorithms.” Department of Computer and Systems Sciences, 2006.

[9] J. Holland, *Adaptation in Natural and Artificial System*. Ann Arbor, The University of Michigan Press, 1975.

[10] F. EidHebba, A. Darwish, A. E. Hassanien, and K. Tai-Hoon, “Intelligent Hybrid Anomaly Network Intrusion Detection System,” in *CCIS 265*, 2011, vol. Part I, pp. 209–218.

[11] K. G. Srinivasa, “Application of Genetic Algorithms for Detecting Anomaly in Network Intrusion Detection Systems,” *Lecture Notes of The Institute for Computer Sciences, Social Informatics & Telecommunication Engineering*, vol. 84, pp. 582–591, 2012.

[12] P. Hartmut, *Genetic and Evolutionary Algorithms: Principles, Methods and Algorithms, Genetic and Evolutionary Algorithm Toolbox*.

[13] S. Sivanandam and S. N. Deepa, *Introduction to Genetic Algorithms*. Springer-Verlag Berlin Heidelberg, 2008.

[14] V. Bapuji, R. N. Kumar, A. Goverdan, and S. Sharma, “Soft Computing and Artificial Intelligence Techniques for Intrusion Detection System,” *Networks and Complex Systems*, vol. 2, no. 4, 2012.

[15] S. Forrest, A. S. Perrelason, L. Allen, and R. Cherukur, "Self-Non-Self Discrimination in a Computer," in *Proceedings of the 1994 IEEE Symposium on Research in Security and Privacy*, 1994, pp. 202–212.
[16] M. Crosbie and E. Spafford, "Applying Genetic Algorithms to Intrusion Detection," in *Proceedings of the AAAI*, 1995.
[17] S. M. Bridges and R. B. Vaughn, "Fuzzy Data Mining and Genetic Algorithms Applied to Intrusion Detection," in *Proceedings of the National Information Systems Security Conference*, 2000, pp. 13–31.
[18] A. Chittur, "Model Generation for an Intrusion Detection System Using Genetic Algorithms," High School Honors Thesis, Ossining High School, Ossining, NY, 2001.
[19] L. De Castro and F. Von Zuben, "Learning and Optimization Using the Clonal Selection Principle," *IEEE Transactions on Evolutionary Computation*, vol. 6, no. 3, pp. 239–251, 2002.
[20] P. A. Diaz-Gome and D. F. Hougen, "Improved Off-Line Intrusion Detection Using a Genetic Algorithm," in *Proceedings of the Seventh International Conference on Enterprise Information Systems*, Miami, USA, 2005.
[21] T. Xiao, G. Qu, S. Hariri, and M. Yousif, "An Efficient Network Detection Method Based on Information Theory and Genetic Algorithm," in *Proceedings of the 24th IEEE International Performance Computing and Communications Conference*, USA, 2005.
[22] A. Goyal and C. Kumar, "GA-NIDS: A Genetic Algorithm based Network Intrusion Detection System," Electrical Engineering & Computer Science, North West University, Technical Report, 2008.
[23] B. Abdullah, Abd-algafar I., G. I. Salama, and Abd-alhafez A., "Performance Evaluation of a Genetic Algorithm Based Approach to Network Intrusion Detection System," in *Proceedings of 13th International Conference on Aerospace Sciences and Aviation Technology (ASAT-13)*, Military Technical College, Cairo, Egypt, 2009.
[24] A. A. Ojugo, A. O. Eboka, O. E. Okanta, R. E. Yora, and F. O. Aghware, "Genetic Algorithm Rule-Based Intrusion Detection System (GAIDS)," *Journal of Emerging Trends in Computing and Information Sciences*, vol. 3, no. 8, pp. 1182 – 1194, 2012.
[25] L. Mé. GASSATA, "A Genetic Algorithm as an Alternative Tool for Security Audit Trails Analysis," in *Proceedings of the 1st International Workshop on the Recent Advances in Intrusion Detection (RAID 98)*, Belgium, 1998.
[26] M. Dass, "LIDS: A Learning Intrusion Detection System," M. Sc. Dissertation, The University of Georgia, Athens, Georgia, 2003.
[27] P. A. Diaz-Gomez and D. F. Hougen, "Analysis of an Off-line Intrusion Detection System: A Case Study in Multi-objective Genetic Algorithms," in *Proceedings of the Eighteenth International Florida Artificial Intelligence Research Society Conference*, USA, 2005, pp. 822–823.
[28] A. Hofmann, C. Schmitz, and B. Sick, "Rule Extraction from Neural Networks for Intrusion detection in computer networks," in *Proceedings of IEEE International Conference on Systems, Man and Cybernetics*, 2003, vol. 2, pp. 1259–1265.
[29] W. Li, "A Genetic Algorithm Approach to Network Intrusion Detection," SANS Institute, Technical Report, 2004.
[30] M. Mischiatti and F. Neri, "Applying Local Search and Genetic Evolution in Concept Learning Systems to Detect Intrusion in Computer Networks," in *Proceedings of the 11th European Conference on Machine Learning (ECML '00)*, 2000, vol. 1810.
[31] G. Jian, L. Da-Xin, and C. Inge, "An Induction Learning Approach for Building Intrusion Detection Models using Genetic Algorithms," in *Proceedings of The 5th World Congress on Intelligent Control and Automation (WCICA 2004)*, Hangzhou, China, 2004, vol. 5, pp. 4339–4342.
[32] Z. Bankovic, D. Stepanovic, S. Bojanica, and O. Nieto-Taladriz, "Improving Network Security using Genetic Algorithm Approach," *Security of Computers & Networks*, vol. 33, pp. 438–451, 2007.
[33] P. A. Diaz-Gomez and D. F. Hougen, "A Genetic Algorithm Approach for Doing Misuse Detection in Audit Trail Files," in *Proceedings of The 15th International Conference on Computing (CIC '06)*, 2006, pp. 329–338.
[34] Q. Xu and W. Pei, "An Intrusion Detection Approach Based on Understandable Neural Network Trees," *International Journal of Computer Science and Network Security*, vol. 6, no. 11, pp. 229–234, 2006.
[35] S. Chavan, K. Shah, N. Dave, S. Mukherjee, A. Abraham, and S. Sanyal, "Adaptive Neuro-Fuzzy Intrusion Detection Systems," in *Proceedings of IEEE International Conference on Information Technology: Coding and Computing (ITCC'04)*, 2004, vol. 1, pp. 70–74.

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Digestion en anaérobiose des fientes de poulets : impacts sur la qualité microbiologique des feuilles de *Solanum macrocarpon* Linn (Solanaceae) cultivé au Bénin

[Anaerobic digestion of poultry manure: impact on the microbiological quality of leaves of *Solanum macrocarpon* Linn (Solanaceae) produced in Benin]

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ABSTRACT: *S. macrocarpon* is a vegetable produced by nearly of 95 % of growers in Benin. Although the consumption of this vegetable is such important in this country, there are no data on its hygienic properties. This study aims to propose a technique for producing vegetable with improved health quality, based on anaerobic biodigestion of poultry manure. A method of vegetable's production based on anaerobic digestion of poultry manure was proposed and evaluated. The study showed that levels of bacteria decreased in the compost, with values from $6.5.10^6$ CFU/g to $3.4.10^4$ CFU/g for fecal coliforms and from $3.5.10^5$ CFU/g to $5.4.10^3$ CFU/g for *Enterococcus*. Lead complexed by chemical reactions was reduced with an amount from 2.39 mg/kg to 0.204 mg/kg. The amendante value of these chickens manure was improved by increasing phosphorus with a value from 9.96 % to 16.40 % and the reduction of total nitrogen from 18900 mg/kg to 13096.33 mg/kg. The data from this study allow to consider a large-scale production of *S. macrocarpon* with improved hygienic quality.

KEYWORDS: Vegetables, Bacteria, Heavy metals, Biodigester, Solanaceae.

RESUME: *S. macrocarpon* est un légume produit par près de 95% des maraîchers béninois. Bien que la consommation de ce légume soit tout aussi importante dans ce pays, il n'existe aucune donnée relative à ses propriétés hygiéniques. La présente étude a eu pour objectif de proposer une technique de production du légume de qualité sanitaire améliorée, basée sur la

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biodigestion en anaérobiose des fientes de poulets. Une méthode de production du légume basée sur la digestion en anaérobiose des fientes de poulets a été ainsi proposée et évaluée.
L'étude a montré que la charge des bactéries a diminué dans le compost produit, avec des valeurs passant de $6{,}5.10^6$ UFC/g à $3{,}4.10^4$ UFC/g pour les coliformes thermotolérants et de $3{,}5.10^5$ UFC/g à $5{,}4.10^3$ UFC/g pour *Enterococcus*. Le plomb, complexé par les réactions chimiques, a été réduit avec une teneur passant de 2,39 mg/kg à 0,204 mg/kg. La valeur amendante de ces fientes de poulets a été améliorée à travers l'augmentation des phosphores assimilables, de 9,96 % à 16,40 % et la réduction de l'azote total, de 18900 mg/kg à 13096,33 mg/kg. Les données résultant de cette étude permettent d'envisager une production à grande échelle de *S. macrocarpon* de qualité hygiénique améliorée.

MOTS CLEFS: Légumes, Bactéries, Métaux lourds, Biodigesteur, Solanaceae.

1 INTRODUCTION

Les légumes constituent des apports excellents d'enrichissement et de diversification de l'alimentation de l'homme. Il s'agit de véritables sources primaires de nutriments minéraux, de vitamines et autres composés qui interviennent dans la santé humaine [1]. Au Bénin, nombreux sont les légumes cultivés par les maraîchers. Au nombre de ceux-ci, *S. macrocarpon* occupe une place de choix. En effet, il est produit par près de 95% des maraîchers [2]. L'intérêt accordé à ce légume s'explique par sa forte appréciation par les consommateurs de tous âges. Communément appelé «Gboma» dans une des langues locales du Bénin, *S. macrocarpon* est également consommé dans plusieurs pays de l'Afrique de l'Ouest tels que le Togo, la Côte d'Ivoire et le Nigéria [2-3].

S. macrocarpon est aussi utilisé pour ses vertus thérapeutiques. Ainsi, en Sierra Léone, les feuilles chauffées sont mâchées pour traiter les affections de gorge [4]. Au Nigéria, les fruits sont consommés comme laxatifs et les fleurs pour traiter les affections dentaires [4]. Au Kenya, le jus des racines bouillies sert à lutter contre les troubles de l'estomac [4]. L'extrait aqueux des fruits présenterait des activités hypolipidémiantes et hépatoprotectrices [3], [4]. Ceci pourrait constituer une alternative pour la prise en charge des maladies cardiovasculaires dont essentiellement l'hypercholestérolémie qui constituent un véritable problème de santé publique dans le monde [3].

La culture de *S. macrocarpon* nécessite une grande quantité de nutriments. Ces nutriments peuvent facilement être mis à disposition par l'utilisation d'engrais inorganiques. Cependant, il y a de nombreuses conséquences liées à leur utilisation. Au nombre de celles-ci, le lessivage, la dégradation des sols et la pollution de l'eau souterraine peuvent être cités [5]. C'est pourquoi la fumure organique dont l'application fournit des éléments nutritifs aux plantes et améliore la structure du sol est de plus en plus promue [5-6]. Il a été rapporté que l'application de la fumure organique, comparée à la fumure inorganique, augmente significativement le rendement dans la production d'aubergines par exemple [5-6]. Parmi ces fumures organiques, il y a les fientes de poulets, très prisées en agriculture urbaine à Cotonou [7]. Ces fientes reviennent moins chères aux maraîchers. Dans le sol, elles contribuent à alimenter la plante en éléments nutritifs majeurs tels que l'azote, les phosphores et le potassium. L'azote favorise la végétation, accélère la croissance de la plante et donne une bonne coloration verte aux feuilles. Les ions phosphores favorisent le développement des racines et des bulbes. Ils exercent une action accélérante sur la maturité des fruits, légumes et céréales. La potasse rend la plante vigoureuse ; ce qui lui permet de mieux résister à la sécheresse et aux maladies. Les fientes sont aussi une source de microéléments dont le magnésium, le zinc, le cuivre, le souffre et le bore. Outre les éléments nutritifs, la décomposition des fientes de poulets produit l'humus, très utile pour la consistance du sol qui devient meuble et perméable à l'air et aux racines [8].

Malgré les avantages que présente l'utilisation des fientes de poulets en agriculture urbaine, des risques potentiels de contamination des légumes produits, liés à la présence de bactéries pathogènes et de métaux lourds [9-10] dans les fientes, restent une préoccupation. L'hygiénisation des fientes de poulets devient donc impérative, compte-tenu du contexte actuel: produits potentiellement contaminés dans les élevages et sécurisation de produits destinés à être commercialisés [11]. Cela est primordial afin de garantir la qualité sanitaire de *S. macrocarpon* produit à Cotonou.

Ainsi, les risques sanitaires seraient minimisés en cas de compostage correct des fientes avant amendement des légumes. Le compostage en aérobiose dont la durée varie entre sept et huit semaines selon Znaïdi [12] n'est pas du tout respecté par les maraîchers, souvent pressés de produire et de vendre leurs cultures. Il urge alors de mettre en place une technique de compostage en temps réduit pour produire des légumes sains du point de vue microbiologique. Le présent travail aborde alors la mise en évidence de l'effet d'un type de compostage appelé digestion en anaérobiose des fientes de poulets sur la qualité microbiologique de *S. macrocarpon* cultivé à Cotonou.

2 MATÉRIEL ET MÉTHODES

2.1 MATÉRIEL

Le matériel utilisé dans le cadre de cette étude est composé entre autres des feuilles et des fruits de *S. macrocarpon*, des réactifs de laboratoire, des milieux de culture, d'un broyeur, un Spectrophotomètre d'Absorption Atomique de marque VARIAN SPECTRA 110, un Spectrophotomètre d'Absorption Moléculaire de marque HACH DR 2800 et d'un biodigesteur familial. Pour la fabrication du biodigesteur familial, un matériel simple et adapté selon ce qui est disponible localement a été employé suivant le procédé modifié de Lecesve [13]. Il s'agit essentiellement de petits tuyaux PVC, de chambre à air, de tige métallique, de papier de verre, de robinet, de boîtes de conserve, d'un grand fût et d'un petit fût pouvant s'encastrer dans le premier. Initialement conçu par Lecesve [13] pour produire du gaz domestique, ce biodigesteur a été dépourvu du dispositif devant conduire le gaz vers le robinet.

2.2 MÉTHODES

L'étude s'est déroulée dans un champ expérimental à Abomey-Calavi et s'est appesantie sur le rôle des fientes de poulets dans la contamination, vu que d'après les résultats des travaux préliminaires, les eaux d'arrosage posent moins de problèmes. En effet, du moment où les eaux de forages sont utilisées sur les sites maraîchers, la pollution microbiologique est moindre [10].

2.2.1 COLLECTE DES ECHANTILLONS ET TESTS PRELIMINAIRES

Neuf fermes ont été repérées dans la commune d'Abomey-Calavi (Figure 1). Dans chacune d'elles, 25 kilogrammes de fientes ont été collectés selon la méthode décrite par [10] puis convoyés vers le site de culture.

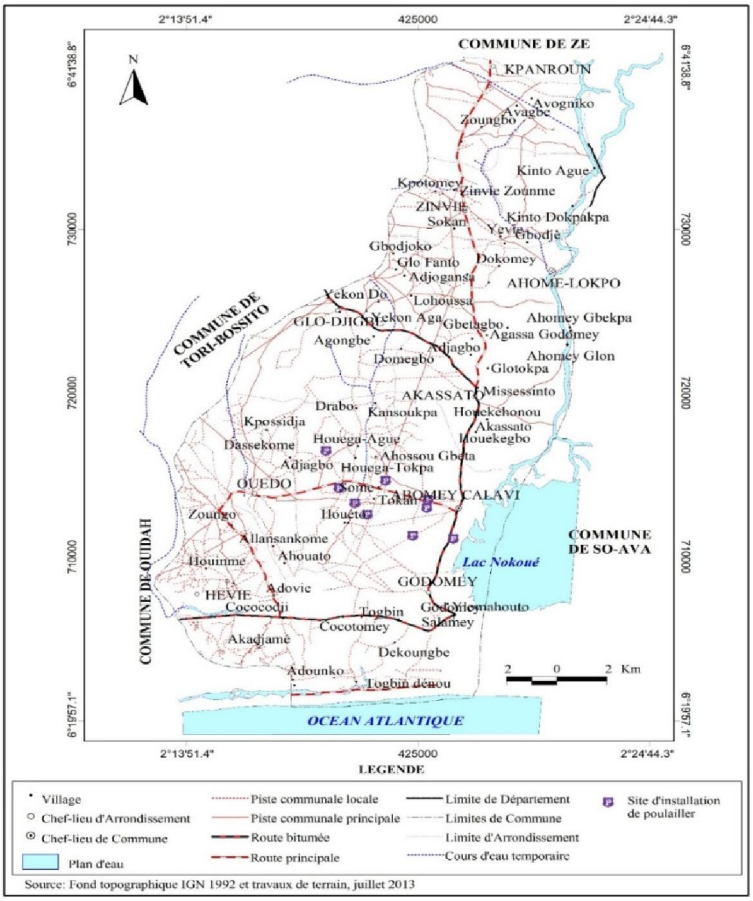

Fig. 1. Localisation des fermes avicoles parcourues

Après mélange du contenu de tous les sacs à raison de 3 kilogrammes par sac, cinq prélèvements aléatoires ont été réalisés dans le tas formé. Cinq prélèvements de sol ont été également effectués au centre et aux quatre extrémités du site de culture. Tous ces prélèvements ont été ramenés au laboratoire pour la recherche de germes aérobies mésophiles, de *Staphylococcus* à coagulase positive, d'*Enterococcus*, de coliformes thermotolérants et de *Salmonella*.

Les méthodes utilisées sont les méthodes de routine NF V08-051 février 1999 de la norme française relative à ces germes et adoptée dans l'espace UEMOA [14]. Les phosphores totaux, les phosphores assimilables et l'azote total ont été déterminés dans les échantillons de fientes pour apprécier la valeur amendante du compost fabriqué [15]. Les échantillons de sol ont connu les mêmes dosages afin d'établir la situation de départ du terrain de culture.

2.2.2 DIGESTION EN ANAEROBIOSE DES FIENTES DE POULETS

La fermentation de matières biologiques dans une enceinte en anaérobiose entraîne une suite de réactions chimiques qui produisent un gaz appelé biogaz. Après ce processus, l'effluent obtenu est un fertilisant naturel, reconnu comme source riche en azote et très assimilable [13]. Ainsi, un digesteur familial formé de deux fûts a été conçu suivant la technique de Lecesve modifiée. Le plus grand est appelé socle (Figure 2). Le dessus du fût a été au préalable découpé pour permettre au petit fût renversé d'y rentrer. A l'aide d'une chambre à air, la partie du tuyau à coller pour permettre la sortie des effluents a été enduite de colle. Le tuyau a été introduit dans le trou et maintenu pour qu'il soit bien fixé. L'espace entre le grand et le petit fût a été le plus restreint possible. Le petit fût est appelé cloche (Figure 3). Le fond a été découpé. Les deux extrémités du fût ont été perforées. En haut, un trou a été créé et recouvert d'une boîte vide. Un second trou a permis d'installer un robinet grâce auquel le débit du gaz produit a été régulé. En bas, le couvercle a été entièrement découpé, donnant directement accès au socle. L'étanchéité du dispositif a été totale. Des fûts en plastique ont été choisis afin de les travailler facilement à l'aide d'outils métalliques chauffés.

Fig. 2. Socle du digesteur familial fabriqué

Fig. 3. Cloche du digesteur familial fabriqué

Trente kilogrammes de fientes, en tenant compte de la réduction du volume du produit obtenu après digestion, ont été introduits dans le digesteur ainsi fabriqué avec 60 litres d'eau de robinet et deux boîtes de yaourt de 0,5 litres obtenues en pharmacie. Le rôle du yaourt est d'accélérer le processus de fermentation. Un volume de fientes de poulets pour deux volumes d'eau permet de maintenir l'anaérobiose [13].

Le mélange a été laissé dans le biodigesteur en anaérobiose pendant 3 semaines. Les sédiments de fientes ainsi obtenus ont été séchés au soleil pendant 7 jours. Tout le processus a duré quatre semaines, soit la moitié de la durée réglementaire du compostage des fientes [12]. Selon Lecesve [13], il faut au minimum trois semaines pour que la fermentation soit optimale or au-delà d'un mois, les maraîchers n'auront pas la patience d'attendre. C'est cette double contrainte qui a motivé le choix d'un compostage en anaérobiose de trois semaines en plus d'un séchage en aérobiose d'une semaine. La qualité microbiologique et la valeur amendante de ces sédiments ont été évaluées dans les mêmes conditions que celles du compost prélevé avant la mise en place de l'expérimentation culturale.

2.2.3 MISE EN PLACE DES ZONES DE CULTURE SUR LE SITE EXPERIMENTAL

Sur le site de culture, 2 zones ont été délimitées et repérées de la manière suivante :

- une zone A où les sédiments issus de la digestion en anaérobiose et des eaux de robinet recueillies la veille ont été utilisés,
- une zone B où des fientes de poulets non compostées et des eaux de robinet recueillies la veille ont été utilisées.

Chaque zone a été subdivisée en sous-zones (Figure 4).

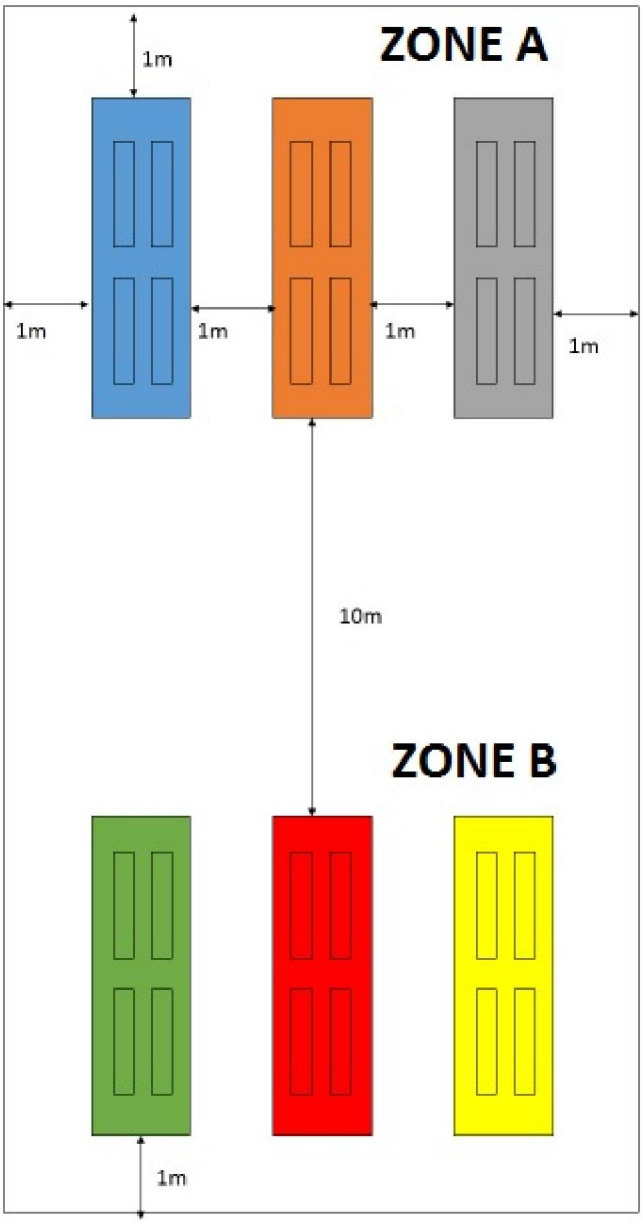

Fig. 4. Disposition des sites de culture pour le volet microbiologique

La culture de *S. macrocarpon* a été faite pendant 6 semaines selon la méthode de CERPADEC-ONG [16].

2.2.4 EVALUATION DE LA QUALITE MICROBIOLOGIQUE DES FEUILLES DE *S. MACROCARPON*

La récolte a été faite en coupant les feuilles à quatre centimètres environ de la racine à l'aide d'une lame stérile. Cinq cents grammes de feuilles fraîches ont été récoltés sur 5 plants de légume par sous-zones et introduits dans des sachets en plastique stériles hermétiquement fermés. Les échantillons ont été ramenés au laboratoire pour recherche de germes aérobies mésophiles, de *Staphylococcus* à coagulase positive, d'*Enterococcus*, de coliformes thermotolérants, d'*Escherichia coli* et de *Salmonella* selon la méthode précédemment citée [14].

2.2.5 ANALYSES STATISTIQUES

Soit un ensemble de n mesures X1, X2, …, Xn. Il est possible d'avoir une idée globale sur la répartition des mesures par le calcul de deux paramètres spécifiques qui sont la moyenne et l'écart-type [17]. La moyenne est un paramètre statistique de tendance centrale. En effet, elle permet de connaître l'ordre de grandeur des mesures d'un type donné. Les moyennes obtenues dans le cadre de cette étude ont été calculées sur la base de la formule :

$$M = (X_1 + X_2 + X_3 + X_n) / n \text{ avec } n = \text{effectif considéré}$$

L'écart-type est un paramètre statistique de dispersion permettant de savoir si la moyenne peut représenter valablement chacune des mesures de la série statistique. Si l'écart type est faible, les valeurs de l'échantillon sont regroupées autour de la moyenne. S'il est important, elles sont en revanche très dispersées. Il est calculé à l'aide de la formule :

$$\sigma = 1/ n \sqrt{\sum} (X_i-X)^2 \text{ allant de } i = 1 \text{ [17]}$$

Des comparaisons ont été faites à l'aide du test de Student p (T>t) = 0,05. Après le volet exploratoire, des comparaisons multiples ont été faites entre les résultats issus des deux zones de culture. Les logiciels Microsoft Excel 2010 et XL Stat 2011 ont été utilisés. Par ailleurs, le pourcentage de réduction des différents paramètres a été calculé par la formule :

$$\% \text{ de réduction} = (\text{Valeur d'arrivée} – \text{Valeur de départ} / \text{Valeur de départ}) \times 100 \text{ [18]}$$

3 RESULTATS

3.1 TENEUR EN BACTERIES DES SOLS DE CULTURE ET DES FIENTES AVANT COMPOSTAGE

Les fientes de poulets renferment plus de germes aérobies mésophiles (3.10^{11}±2020 UFC/g) que les sols de culture [(2.10^9 UFC/g) (p<0,05)] comme le présente la figure 5.

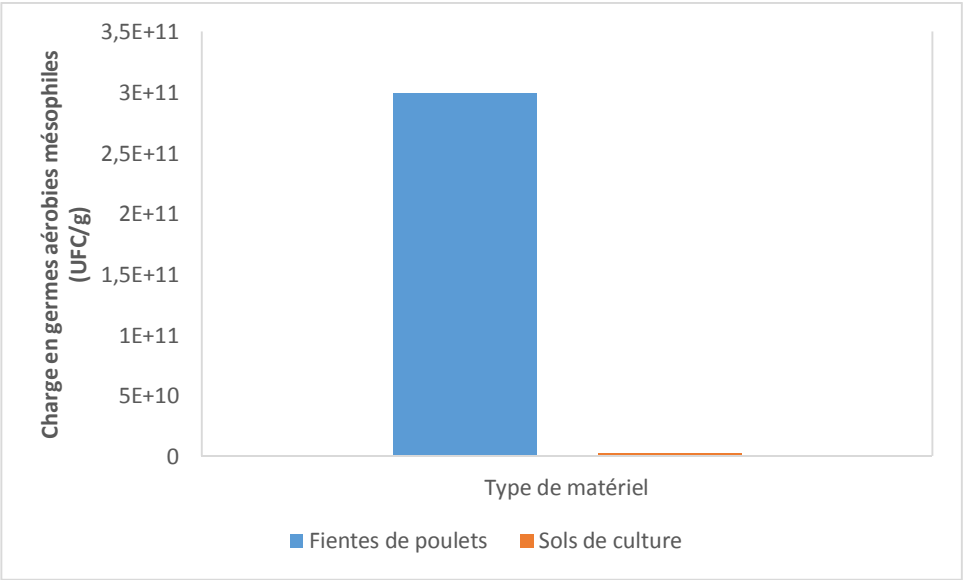

Fig. 5. Charge des fientes de poulets et des sols en germes aérobies mésophiles

5E+10 = 5.10^{10} et ainsi de suite

Les fientes de poulets ont une charge plus élevée en *Enterococcus*, *Staphylococcus* coagulase positive et en coliformes thermotolérants et en *E. coli* que celle des sols de culture [(p<0,05) (Tableau I)]. *Salmonella* a été retrouvé dans les échantillons de sols tandis que les fientes en sont exemptes.

Tableau I : Teneur des fientes de poulets et des sols en bactéries

	Bactéries recherchées (UFC/g)			
	Enterococcus	Coliformes thermotolérants	*Staphylococcus* coagulase +	*Salmonella*
Fientes de poulets	$3,54.10^6$ ± 2020a	$6,518.10^6$ ± 1421,38a	10200 ± 1,42a	Absence dans 25 g
Sols de culture	10.000 ± 430b	980 ± 20,12b	100 ± 6,20b	Présence dans 25 g

Les moyennes portant les mêmes lettres verticalement ne sont pas significativement différentes au seuil de significativité α = 0,05.

3.2 IMPACT DE LA DIGESTION EN ANAEROBIOSE SUR LA CHARGE BACTERIENNE DES FIENTES DE POULETS

Le compostage réalisé a significativement abaissé les charges des fientes de poulets en germes aérobies mésophiles (99 % de réduction), en coliformes thermotolérants (99,5 % de réduction) et en *Enterococcus* (99,8 % de réduction). Par contre, la diminution des *Staphylococcus* à coagulase positive n'est pas significative même si le pourcentage de réduction est de 0,3 % (Tableau II).

Tableau II : Evolution de la population bactérienne après compostage

	Bactéries recherchées (UFC/g)			
	Germes aérobies mésophiles	Coliformes thermotolérants	*Enterococcus*	*Staphylococcus* coagulase +
Charge en bactéries des fientes brutes	3.10^{11} ± 30150a	$6,5.10^6$ ± 1421,38a	$3,54.10^6$ ± 3044,73a	10.200 ± 142a
Charge des fientes compostées en bactéries	3.10^9 ± 23520b	34.000 ± 2020b	5.433,33 ± 1500b	10.166,66 ± 230a

Les moyennes portant les mêmes lettres ne sont pas significativement différentes au seuil de significativité α = 0,05.

3.3 CULTURE DE *S. MACROCARPON* AVEC LES FIENTES COMPOSTEES ET QUALITE MICROBIOLOGIQUE DES FEUILLES

Les feuilles de la zone amendée avec les fientes compostées ont une charge bactérienne inférieure à celles de la zone amendée avec les fientes non compostées (Tableau III).

Tableau III : Charge des légumes en bactéries selon les fientes utilisées pour l'amendement

Bactéries (UFC/g)	**Feuilles**	
	Fientes non compostées	Fientes compostées
Germes aérobies mésophiles	$4,2.10^7$±5348,25a	$5,13.10^5$±4853,2b
Coliformes thermotolérants	$5,9.10^5$±10320a	855±26,05b
E. coli	18250±2543,25a	9±0,34b
Salmonella	Absence dans 25 g	Absence dans 25 g
Enterococcus	1000±45a	400±32,4b
Staphylococcus à coagulase +	Présence dans 25 g	Absence dans 25 g

Les moyennes portant les mêmes lettres ne sont pas significativement différentes au seuil de significativité α = 0,05 et UFC/g = Unité Formant une Colonie par gramme

Les pourcentages de réduction des charges bactériennes des feuilles de *S. macrocarpon* cultivé avec les fientes compostées sont respectivement de 98,8 %, 99,9%, 100 % et 60 % pour les germes aérobies mésophiles, les coliformes thermotolérants*, E. coli* et *Enterococcus*. *Salmonella* et *Staphylococcus* à coagulase positive n'ont pas été mis en évidence dans les feuilles de *S. macrocarpon* cultivé avec les fientes compostées (Tableau IV).

Tableau IV : Charge des légumes en bactéries selon les fientes utilisées pour l'amendement

Bactéries (UFC/g)	Feuilles	
	Fientes non compostées	Fientes compostées
Germes aérobies mésophiles	$4{,}2.10^{7}$±5348,25a	$5{,}13.10^{5}$±4853,2b
Coliformes thermotolérants	$5{,}9.10^{5}$±10320a	855±26,05b
E. coli	18250±2543,25a	9±0,34b
Salmonella	Absence dans 25 g	Absence dans 25 g
Enterococcus	1000±45a	400±32,4b
Staphylococcus à coagulase +	Présence	Absence

Les moyennes portant les mêmes lettres ne sont pas significativement différentes au seuil de significativité α = 0,05 et UFC/g = Unité Formant une Colonie par gramme

3.4 IMPACT DE L'UTILISATION DES FIENTES COMPOSTEES SUR LA QUALITE CHIMIQUE DES FEUILLES DE *S. MACROCARPON* CULTIVE

3.4.1 VALEUR AMENDANTE DES SOLS DE CULTURE ET DES FIENTES AVANT COMPOSTAGE

La figure 6 montre que les fientes de poulets ont une teneur plus élevée en phosphores totaux (20200±1365,65 mg/kg), en phosphores assimilables (2013,20±249,02 mg/kg) et en azote total (18900±1307,67 mg/kg) que les sols (1016,20±143,50 mg/kg pour les phosphores totaux, 121,86±17,43 mg/kg pour les phosphores assimilables et 1095±139,50 mg/kg pour l'azote total).

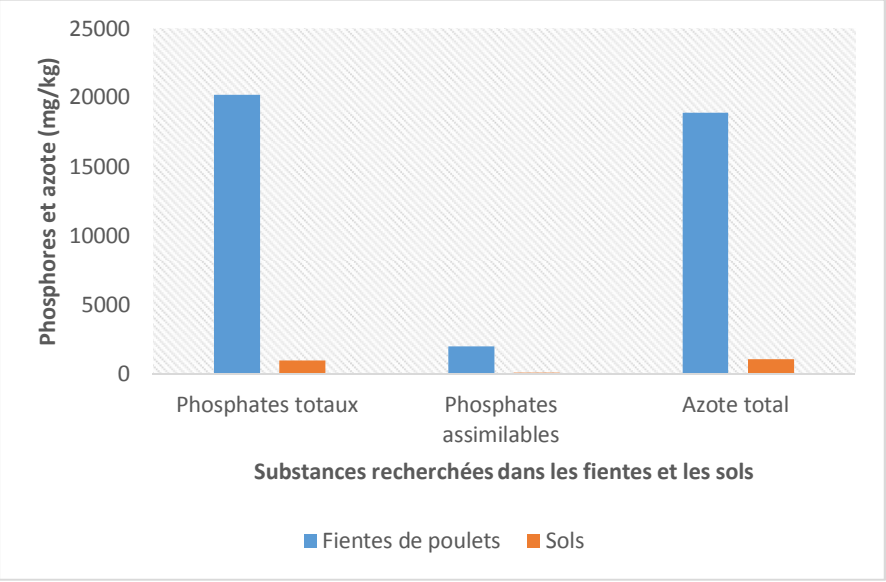

Fig. 6. Valeur amendante des fientes de poulets et des sols de culture

3.4.2 EFFET DE LA DIGESTION EN ANAEROBIOSE SUR LA VALEUR AMENDANTE DES FIENTES DE POULETS

La digestion en anaérobiose des fientes de poulets n'a nullement entamé la valeur amendante du compost obtenu. En effet, ce dernier a conservé une teneur élevée en phosphores totaux (17652,33±1171 mg/kg) et en phosphores assimilables

[(2896,46±143,56 mg/kg) (Figures 7 et 8)]. Mieux, le pourcentage des phosphores assimilables est passé de 9,96 % à 16,40 % et la teneur en azote total a connu une réduction significative [(p<0,05) (Figures 7 et 8)].

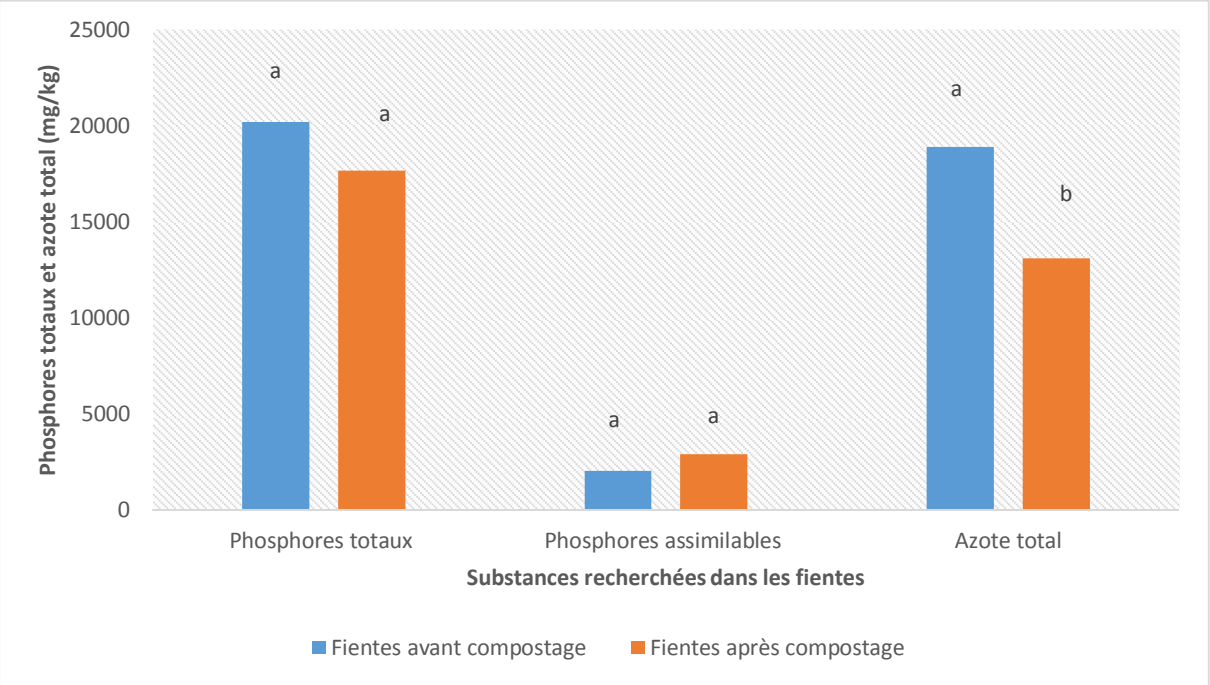

Fig. 7. Teneur des fientes en éléments fertilisants avant et après compostage

Les moyennes portant les mêmes lettres ne sont pas statistiquement différentes au seuil de significativité de 5% (p>0,05).

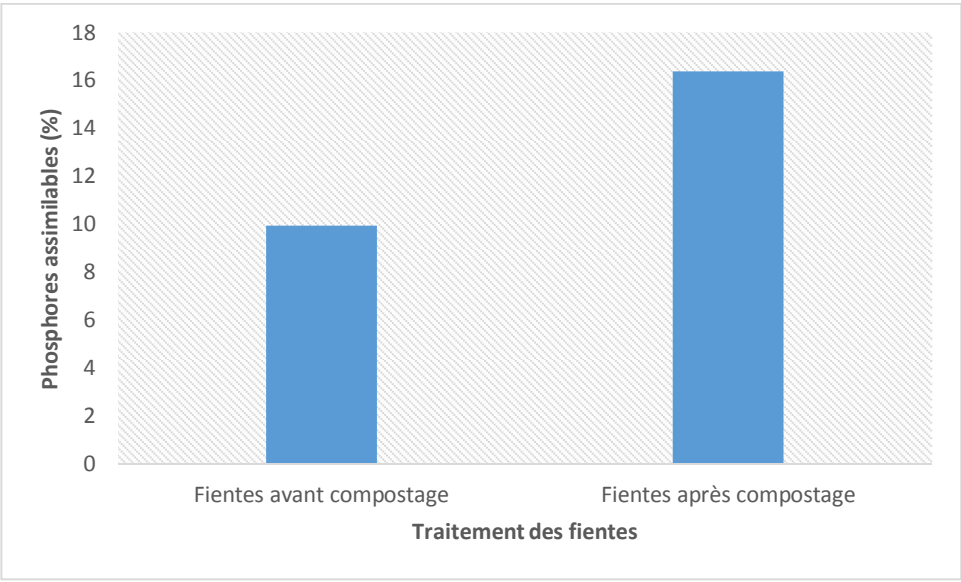

Fig. 8. Teneur des fientes en phosphores assimilables avant et après compostage

4 DISCUSSION

4.1 ROLE DE LA DIGESTION EN ANAEROBIOSE DES FIENTES DE POULETS DANS LA QUALITE MICROBIOLOGIQUE DES FEUILLES DE *S. MACROCARPON* CULTIVE

La charge bactérienne importante des fientes de poulets comparativement aux sols est due au fait qu'il s'agit ici des rejets d'animaux. Les microorganismes hébergés par les poulets sont donc présents dans leurs déjections [19]. La présence d'*E. coli* dans les fientes est une évidence [19]. Par contre, sa présence dans les légumes est un problème. Les salmonelles isolées des sols de culture tiennent leur origine de l'utilisation faite du terrain dans le passé. En effet, il s'agit d'un terrain vague qui, bien que clôturé, était un dépotoir de déchets de tous ordres. Il a fallu un travail de sensibilisation des populations environnantes pour amoindrir cette pollution. Le transfert de *Salmonella* dans les légumes est à surveiller, bien que la zone contaminée ait été évitée lors de la culture. L'absence de *Salmonella* dans les fientes est due au type de traitement dont font l'objet les poulets des fermes parcourues. Suivis par des vétérinaires, ces poulets sont régulièrement vaccinés et traités périodiquement [20]. Il ne faut pas perdre de vue l'hypothèse que *Salmonella* pourrait ne pas résister hors de l'organisme. C'est à la même conclusion qu'ont abouti El Jalil *et al*. au terme d'une étude sur la biotransformation des déchets de volailles en vue de leur valorisation dans l'industrie de l'alimentation animale [21].

La digestion en anaérobiose des fientes réalisée dans le cadre de la présente étude a eu un impact destructif sur la charge bactérienne. Ces résultats corroborent ceux de Couturier [22] qui souligne que la digestion en anaérobiose vise à réduire l'exposition par élimination ou par inactivation des organismes pathogènes. Les principaux paramètres d'élimination des agents pathogènes sont le temps et la température. Globalement, la digestion mésophile classique permet d'éliminer 99 % des germes pathogènes comme ce fut le cas dans la présente étude. Pour Couturier [22], une digestion en anaérobiose pendant 24 heures suffit à réduire la charge bactérienne contrairement aux trois semaines réalisées. Le taux de réduction dépend de nombreux autres paramètres intervenant dans la pratique. Il s'agit de la concentration initiale en agents pathogènes, du mode d'alimentation du digesteur et de la compétition avec les autres microorganismes [22]. La digestion en anaérobiose présente donc plusieurs atouts fondamentaux liés à la puissance des mécanismes biologiques mis en jeu pour assurer un taux de dégradation élevé de la matière organique, aux conditions chimiques particulières de l'anaérobiose [23].

Staphylococcus à coagulase positive n'a pas totalement disparu des fientes traitées pour la raison que ces bactéries supportent mal la concurrence avec les streptocoques et les entérobactéries [24]. La quasi-disparition de ces deux derniers groupes de bactéries dans le milieu expliquerait alors la présence de *Staphylococcus*. C'est ce constat qui a soutenu la recherche de cette bactérie dans les légumes produits avec les fientes compostées.

L'absence de *Salmonella* dans les feuilles de *S. macrocarpon* en provenance des deux zones d'amendement signifie qu'il n'y a pas eu un transfert de cette bactérie du sol aux légumes. Il est vrai que les régions où la contamination par les *Salmonella* avait été détectée, ont été évitées lors des semis mais le risque de pollution liée au transport par le vent était à craindre. Ces résultats sont en accord avec ceux de Florin *et al*. [25] qui ont prouvé que *Salmonella* a tendance à vite disparaître du milieu extérieur. La forte diminution de la charge bactérienne remarquée au niveau des feuilles de la zone amendée par les fientes de poulets compostées montre à quel point le processus d'hygiénisation de ces matières premières en agriculture urbaine [2] est à prendre au sérieux. La canalisation des eaux d'arrosage en remplacement des eaux de marécage alliée à cette hygiénisation permet de produire des légumes peu contaminés par les bactéries.

4.2 ROLE DE LA DIGESTION EN ANAEROBIOSE DES FIENTES DE POULETS SUR LEUR VALEUR AMENDANTE

Les matières organiques ont une présence plus élevée dans les fientes que dans les sols, ce qui explique pourquoi l'amendement par les fientes est une nécessité depuis quelques décennies sur les sites maraîchers. La teneur en azote total, très élevée avant compostage a significativement diminué et a atteint une valeur comprise entre 10 et 16 mg/kg, proche de celle recommandée par les normes [23]. En effet, une teneur trop élevée en azote provoque une surchauffe du compost, ce qui aboutit à la mort des jeunes pousses. Cette diminution de l'azote est due au processus de méthanisation lié à la digestion en anaérobiose [22]. Cette action réductrice permet donc d'obtenir des fientes compostées qui sont prêtes pour l'amendement direct des légumes. Bien qu'il n'y ait eu aucune différence significative relative à la teneur en phosphores totaux des fientes avant et après compostage, le pourcentage de phosphores assimilables a néanmoins connu une forte augmentation. Ce détail est assez important car c'est la forme disponible du phosphore pour la plante qui détermine la valeur d'un compost [23]. Le volet agronomique n'ayant pas fait l'objet de ce travail, il serait intéressant que des travaux en agronomie se fassent sur ce modèle de compostage afin que ses bienfaits culturaux soient établis en dehors de l'intérêt sanitaire prouvé par la présente étude.

5 CONCLUSION

Les légumes sont très utiles pour le bien-être des populations. Avec l'essor de l'agriculture urbaine, de nombreuses cultures maraîchères sont disponibles à Cotonou. Parmi celles-ci, *S. macrocarpon* occupe une place importante. La présente étude a permis de se rendre compte que les fientes de poulets de plus en plus utilisées en substitution des engrais chimiques contribuent à la contamination des légumes cultivés. Pour trouver une alternative au défaut de compostage des fientes, l'évaluation d'une technique a été proposée. Les résultats ont montré que le compostage des fientes pendant quatre semaines conduit à une chute de la charge bactérienne dans le compost. C'est un processus de digestion en anaérobiose qui conserve les propriétés amendantes du compost en rendant disponibles les phosphores au profit des légumes. L' hygiénisation du compost a conduit à la production de légumes peu contaminés au regard des normes internationales régissant les contaminations microbiologiques des denrées alimentaires. A l'issue de ces travaux, nous recommandons de :

- Restituer les résultats aux maraîchers et de les accompagner financièrement afin que chaque site maraîcher soit doté du modèle de digesteur évalué.
- Mettre sur pied un 'Programme Cultures Maraîchères' en vue de gérer cette thématique. Le rôle de l'Approche Ecosystémique de la Santé dans le processus revêt une importance capitale. Les consommateurs ne doivent pas être exclus de cette démarche. Loin de les effrayer, cette étude a été menée en vue de permettre la production de légumes exempts de polluants divers. Les règles minimales d'hygiène (lavage des mains, désinfection des produits maraîchers à consommer crus, cuisson correcte des aliments) ne doivent pas pour autant être occultées.

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REFERENCES

[1] N.K. Sinha, "Handbook of vegetables and vegetables processing", Blackwell Publishing Ltd, England, 788p, 2011.

[2] F. Assogba-Komlan, P. Anihouvi, E.Achigan, R. Sikirou, A. Boko, C. Adje, V. Ahle, R. Vodouhè and A. Assa, "Pratiques culturales et teneur en éléments antinutritionnels (nitrates et pesticides) du *Solanum macrocarpum* au Sud du Bénin", African Journal of Food Agriculture Nutrition and Development, vol. 7, no. 4, pp. 1-21, 2007.

[3] O.A. Sodipo, F.I. Abdulrahman, T.E. Alemika and I.A. Gulani, "Chemical composition and biological properties of the petroleum ether extract of *Solanum macrocarpum* L. (Local Name: Gorongo)", British Journal of Pharmaceutical Research, vol. 2, no.2, pp 108-128, 2012.

[4] G.J.H. Grubben and O.A. Denton, "Plant Resources of Tropical Africa Vegetables, Ponennad Looijenhv, Wageningen, Netherlands", 667p, 2004.

[5] M.S. Ullah, M.S. Islam, M.A. Islam and T. Hague, "Effects of organic manures and chemical fertilizers on the yield of brinjal and soil properties", Journal of the Bangladesh Agricultural University, vol.6, no.2, pp. 271-276, 2008.

[6] C.U. Agbo, P.U. Chukwudi and A.N. Ogbu, "Effects of rates and frequency of application of organic manure on growth, yield and biochemical composition of *Solanum melongena* L. (cv. 'Ngwa local') fruits", Journal of Animal & Plant Sciences, vol. 14, no.2, pp. 1952-1960, 2012.

[7] S.C.C. Atidégla, "Effets des différentes doses d'engrais minéraux et de la fiente de volaille sur l'accumulation de biocontaminants et polluants (germes fécaux, composés azotés et phosphorés, métaux lourds) dans les eaux, les sols et les légumes de Grand-Popo au Bénin" Thèse de doctorat unique, Ecole Doctorale Pluridisciplinaire, Université d'Abomey-Calavi, Bénin, 316p, 2011.

[8] L.G. Onana Onana, "Pratiques de fertilisation et caractéristiques des sols en zone maraîchère périurbaine de Yaoundé : cas des bas-fonds de Nkolondom", Mémoire de fin d'étude, Université de Dschang, Cameroun, 73p, 2006.

[9] R. Métras, "Utilisations et dangers sanitaires microbiologiques liés aux effluents d'élevage", Thèse de doctorat unique de médecine vétérinaire, Université Claude Bernard, France, 150p, 2003.

[10] T.V. Dougnon, "Apports de *Solanum macrocarpon* Linn (Solanaceae) en santé humaine et intérêt de l'hygiénisation des fientes de poulets utilisées pour sa culture au Bénin", Thèse de Doctorat Unique, Université d'Abomey-Calavi, Bénin, 284p, 2013.

[11] R. Derel and C. Aubert, "Evolution de la qualité microbiologique de fientes de poules pondeuses après séchage et au cours du stockage", TeMA, vol. 7, pp. 4-11, 2008.
[12] A. Znaïdi, "Etude et évaluation du compostage de différents types de matières organiques et des effets des jus de composts biologiques sur les maladies des plantes", Master of Sciences, Bari Mediterranean Organic Agriculture, CIHEAM Mediterranean Agronomic Institute, Italie, 94p, 2002.
[13] L. Lecesve, "Fabrication d'un biodigesteur familial", Rapport d'atelier, Hybrid Energies, 5p, 2008, disponible sur www.hybridenergies.org, consulté le 15 février 2012 à 20 heures 15 minutes.
[14] A. Tété-Bénissan, K.A. Lawson-Evi, K. Kokou and M. Gbéassor, "Effet de la poudre de feuilles de *Moringa oleifera* Lam. sur l'évolution du profil de l'hémogramme des enfants malnutris au Togo: évaluation chez les sujets HIV positifs", African Journal of Food, Agriculture, Nutrition and Development, vol. 12, no. 2, pp. 6007-6026, 2012.
[15] Hach, "Digesdahl digestion apparatus: Instruction manual for models 23130-20-21" Hach, United States of America, 95p, 1999.
[16] CERPADEC-ONG, "Manuel de l'apprenant en techniques de conduite et de production de cultures maraîchères", Ed. Tundé, République du Bénin, 20p, 2008.
[17] L. Gabada, "Pollution des eaux de boisson en milieux urbains par les métaux toxiques (Cu, Ni, Fe, Pb, Cd) : Cas de Kpalimè au Togo", Mémoire de Master, Centre Interfacultaire de Formation et de Recherche en Environnement pour le Développement Durable, Université d'Abomey-Calavi, République du Bénin, 74p, 2010.
[18] JR. Klotoé, "Etude ethnobotanique et propriétés hémostatiques de quelques plantes médicinales du Sud-Bénin", Thèse de doctorat Unique, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, République du Bénin, 217p, 2013.
[19] A. Bouedo, M. Bertru, F. Guiziou and M. Bertrand, "Etude du risque de contamination fécale des eaux après épandage de lisier", hors-série octobre 1993, informations techniques, Editions CEMAGREF, France, 55p, 1993.
[20] J.T. Dougnon, A.P. Edorh, H.S. Bankole, M. Sezonlin, P. Guedenon, M. Kpodekon and M. Gbeassor, "Bacteriological study of the fishmeal used in feed for imported chicken in Atlantic department", International Journal of Animal and Veterinary Advances, vol. 4, no. 1, pp. 53-57, 2012.
[21] M.-H. El Jalil, M. Faid and M. Elyachioui, "Biotransformation des déchets de volailles et essai de valorisation dans l'industrie de l'alimentation animale", Cahiers Agricultures, vol. 12, no. 3, pp. 175-180, 2003.
[22] C. Couturier, "Effets de la digestion anaérobie sur les micropolluants et germes pathogènes", Solagro, pp. 1-5, 2002.
[23] ADEME. Dossier documentaire « Les boues d'épuration municipales et leur utilisation en agriculture », réf. 3832, ISBN 2-86817-561-9, 2001, disponible sur www.ademe.fr, consulté le 15 mars 2012 à 14 heures 30 minutes.
[24] P.B.G. Arnal, "Sources et caractère entérotoxinogène des staphylocoques en élevage ovin laitier", Thèse de doctorat en médecine vétérinaire, Université Paul-Sabatier de Toulouse, France, 57p, 2003.
[25] N.H. Florin, A.R. Maddocks, S. Wood and A.T. Harris, "High-temperature thermal destruction of poultry derived wastes for energy recovery in Australia", Waste Management, vol. 29, no. 4, pp. 1399-1408, 2009.

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Determination of equilibrium distances of Si-F and Si-Cl, certain thermodynamic values and electron affinities of silanes and silyl radicals using the Hartree-Fock (HF) and density functional theory (DFT) *ab initio* methods

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ABSTRACT: The two quantum methods Hartree-Fock HF/6-31G* (d, p) and density functional theory DFT/3-21G* (d, p) were used to calculate the equilibrium of the Si-F and Si-Cl bonds in SiH_3X compounds where X may be F^- or Cl^-; the atomic electron affinity of chloride (Cl^-), fluoride (F^-), chlorine (Cl) and fluorine (F); entropy (S), heat capacity (C_v), total energy and reaction enthalpy of fluorosilanes, chlorosilanes and silyl radicals; and bond angles and bond lengths of SiH_3F and SiH_3Cl. Inter-atomic distances of the Si-F and Si-Cl bonds in SiH_3F and SiH_3Cl calculated using HR and DFT are in good agreement with the experimental values. The optimal distance of the Si-F bond is shorter than that of the Si-Cl bond in SiH_3X. Electron affinities calculated using HF and DFT are not in agreement with those obtained experimentally. The values of entropy (S) increase in parallel with the increase in the number of fluorine atoms in the silanes. The geometric structures of SiH_3F and SiH_3Cl both belong to the C_{3v} point group. Their bond angles are slightly different. SiH_3F has slightly higher energy than SiH_3Cl. This might be due to the value of the bond angle in SiH_3F, which is 109.18°. This is the same value obtained using the MP_2 quantum method.

KEYWORDS: Bond angle, electron affinity, enthalpy, entropy, energy of reaction, calorific capacity, state correlation diagramme, SN_2 reaction.

1 INTRODUCTION

In the field of chemical reactivity, quantum chemistry is an indispensable complement to experimentation, and has become an important tool for studying the stereoselectivity of concerted reactions. Quantum methods are used to solve problems relating to structure and chemical reactivity.

The application of quantum methods to molecular spectroscopy has become increasingly important in recent years [1], [2], [3], [4], [5], [6]. The majority of studies use *ab initio* rather than semi-empirical methods, although most molecular properties (e.g. enthalpy of formation, molecular geometry, dipole moments, ionization energy, and zero-point vibrational energy) have been obtained by semi-empirical methods [7], [8], [9], [10].

All calculations presented in this work were carried out using Hartree-Fock (HF) and density functional theory (DFT) methods in Gaussian 09 [11].

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2 RESULTS AND DISCUSSION

2.1 STUDY OF REACTION BETWEEN THE NUCLEOPHILE F^- AND THE SUBSTRATE SiH_4

The attack by the nucleophile F^- on theSiH_4 substrate is represented as a nucleophilic substitution of type SN_2 (Figure 1).

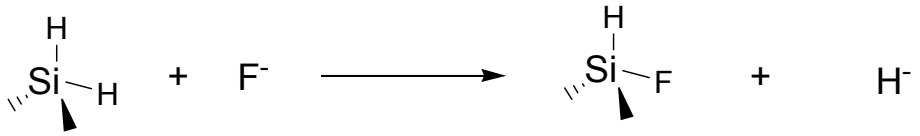

Fig. 1. Attack by the nucleophile F^- on SiH_4

The state correlation diagram (Fig. 2) shows two dips, marked B and D. The energy difference between states A and B is ΔE_1, equal to -98.75 atomic units (a.u.) The energy difference between states C and D is ΔE_2, equal to -99.352 a.u. The energy differences ΔE_1 and ΔE_2 correspond to intrinsic barriers. The final energy E is significantly lower than the initial energy A. The probability of the inverse reaction is very low and the system evolves fully to the final state E.

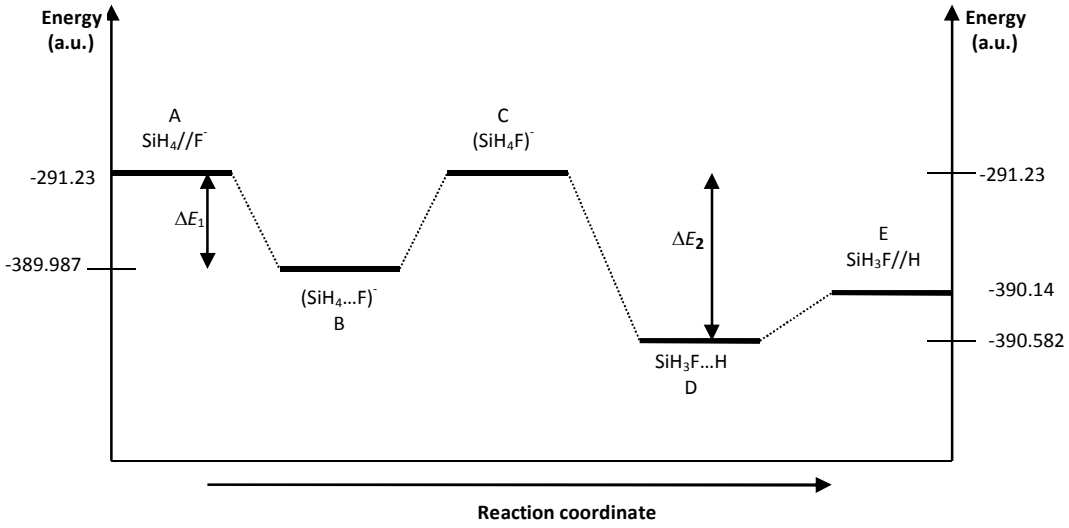

Fig. 2. State correlation diagram showing reaction between nucleophile F^- and substrate SiH_4

Energy as a function of equilibrium distance of the Si-F bond calculated using the HF and DFT methods is shown in Figure 3. Reaction energies and inter-nuclear equilibrium distances of the SiH_3X substrate with $X=F^-$ are shown in Table 1.

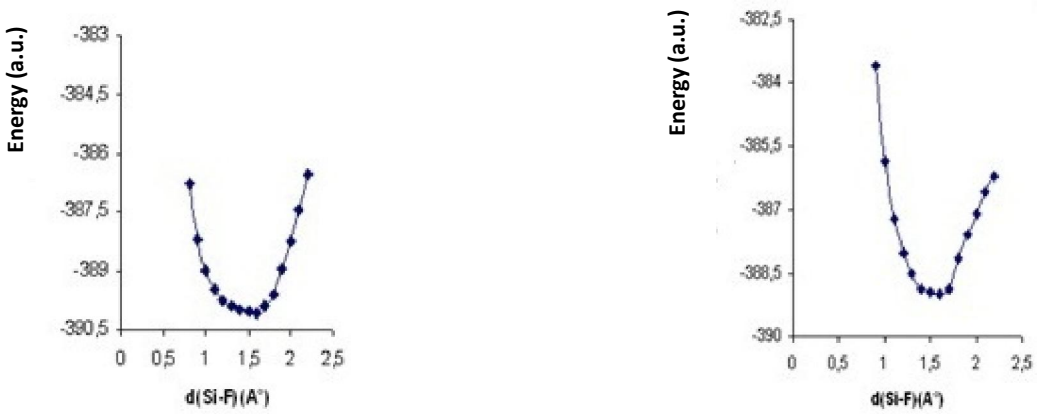

Fig. 3. Energy as a function of equilibrium distance of the Si-F bond (HF and DFT respectively)

Energy graphs of SiH_3F in Figure 3 show that the optimal distance for the silicon-fluorine bond is 1.6 Å according to HF/6-31G*, compared to 1.7Å according to DFT. The value calculated by the HF method is in good agreement with the result obtained by H.B. Schlegel, S. Wolf and F. Bernardi [12]. Total energy calculated by HF is -390.056 a.u., compared to -389.135 a.u. calculated by DFT. Energy calculated by the HF method is more stable than that calculated by DFT.

Table 1. Energy of the reaction between nucleophile F^- and SiH_4 substrate

d (Å)	Energy (a.u.) HF/6-31G* (d, p)	Energy (a.u.) DFT/3-21G* (d, p)
0.9	-388.177	-383.582
1.0	-388.985	-385.835
1.1	-389.455	-387.220
1.2	-389.732	-388.032
1.3	-389.894	-388.511
1.4	-389.986	-388.976
1.5	-390.035	-388.112
1.6	-390.056	-388.135
1.7	-389.705	-389.142
1.8	-390.140	-389.138
1.9	-388.941	-389.129
2.0	-387.242	-389.116
2.1	-387.421	-389.102
2.2	-386.554	-389.083

2.2 STUDY OF REACTION BETWEEN THE NUCLEOPHILE Cl^- AND THE SiH_4 SUBSTRATE

The attack by the nucleophile Cl^- on the SiH_4 substrate is represented as a nucleophilic substitution of type SN_2 (Figure 4).

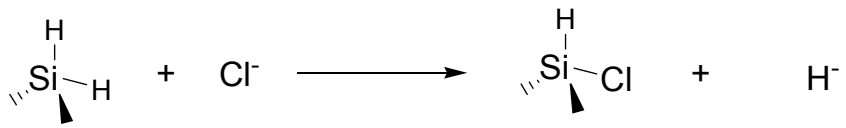

Fig. 4. Attack by the nucleophile Cl^- on SiH_4

The state correlation diagram (Figure 5) shows two dips, marked B' and D'. The energy difference between states A' and B' is ΔE'1, equal to -0.11 a.u. The energy difference between states C' and D' is ΔE'2, equal to -0.1 a.u. The reaction between Cl^- and SiH_4 shows the same behaviour as that between $F^-$and SiH_4, which means that this too evolves to the final state E'.

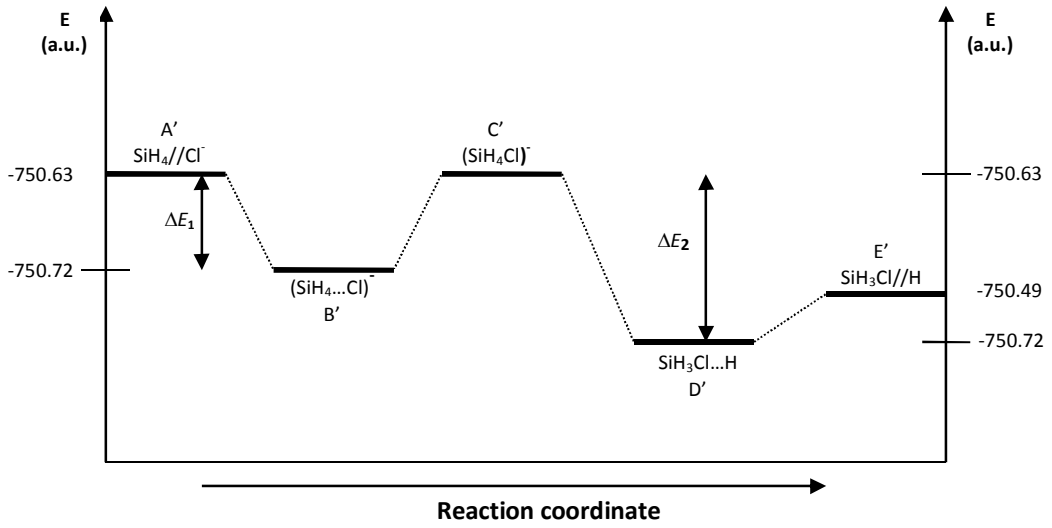

Fig. 5. State correlation diagram showing reaction between nucleophile Cl^- and substrate SiH_4

Reaction energies and inter-nuclear equilibrium distances of the SiH_3X substrate with X= Cl^- are given in Table 2. Energy as a function of the equilibrium distance of the Si-F bond calculated using the HF and DFT methods are shown in Figure 6.

Table 2. Energy of the reaction between nucleophile Cl^- and substrate SiH_4

d (Å)	Energy (a.u.) HF/6-31G* (d, p)	Energy (a.u.) DFT/3-21G* (d, p)
0.9	-745.923	-741.354
1.0	-747.275	-742.722
1.1	-748.241	-743.702
1.2	-748.920	-744.391
1.3	-749.383	-744.867
1.4	-749.691	-745.190
1.5	-749.893	-745.406
1.6	-750.022	-745.549
1.7	-750.102	-745.640
1.8	-750.150	-745.698
1.9	-750.176	-745.732
2.0	-750.187	-745.750
2.1	-750.188	-745.757
2.2	-750.183	-745.758
2.3	-750.174	-745.754
2.4	-750.163	-745.747
2.5	-750.150	-745.739
2.6	-750.138	-745.729

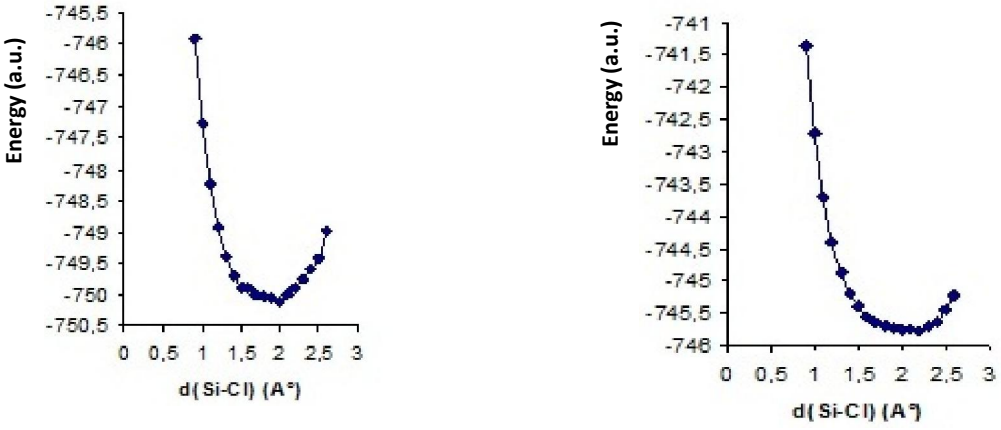

Fig. 6. Energy as function of equilibrium distance of the Si-Cl bond (HF and DFT respectively)

Energy graphs of SiH_3Cl in Figure 6 show that the optimal distance for the silicon-chlorine bond is 2.1 Å according to HF/6-31G*, compared to 2.2 Å according to DFT. The value calculated by the HF method is in good agreement with the theoretical result obtained using the MP_4 method [13].

SiH_3F and SiH_3Cl belong to the some point group C_{3v}, although bond angles and bond lengths of SiH_3F and SiH_3Cl are slightly different. SiH_3F has slightly greater energy than SiH_3Cl, possibly because of the bond angle in SiH_3F, which is 109.18°. This value is in good agreement with theoretical results obtained by the MP_2 method using the base 6-31++G [14].

2.3 CERTAIN THERMODYNAMIC PROPERTIES OF SILANES AND SILYL RADICALS

Table 3 shows the thermodynamic and reaction energy results and equilibrium distances for the reaction between the halogen X (F^-, Cl^-) and the substrate SiH_4, calculated by the more reliable method, namely low HF 6-31G*:

Table 3. Thermodynamic properties of silanes and silyl radicals

Species	Distance Si-X (Å)	Entropy (S) (Cal/mol.K)	Heat capacity (C_v) (Cal/mol.K)	Theoretical energy (Kcal/mol)	Enthalpy ΔH_r (H)
H^-	------	26.014	2.981	889	-0.420
SiH_4	1.47	48.658	7.685	22.784	-291.195
F^-	------	36.145	2.981	0.889	-99.365
SiH_3F	1.6	56.726	8.763	20.354	-390.130
SiH_2F_2	1.601	62.384	10.486	17.648	-489.066
$SiHF_3$	1.60	65.985	12.782	14.595	-588.009
Cl^-	-------	36.586	2.981	0.889	-459.537
SiH_3Cl	2.10	59.608	9.665	19.737	-750.156
SiH_2Cl_2	2.05	68.069	12.333	16.371	-1209.117
$SiHCl_3$	2.037	74.347	15.613	12.710	-1668.077

The reaction between a nucleophile X^- (F^-, Cl^-) and the substrate SiH_4 leads to loss of a proton. Silyl radicals are more polarized than silanes, possibly due to the effect of the substituents. For polarization of fluorosilane in the gaseous phase at 298 K°, the values of entropy S (cal/mol.K) of the compounds SiH_4, SiH_3F, SiH_2F_2 and $SiHF_3$ are respectively 48.658, 56.726, 62.384 and 65.985. This increase indicates that interactions between fluorine atoms lead to increased polarity [15]. For chlorosilanes, the effects of the substituents are greater. The values of entropy S (cal/mol.K) for the compounds SiH_4, SiH_3Cl, SiH_2Cl_2 and $SiHCl_3$ are respectively 59.608, 68.069 and 74.347. When a chlorine atom replaces a fluorine atom in the fluorosilanes, the polarity of the silane increases by 3 Cal/mol, leading to stabilization of the silane.

2.4 CALCULATION OF ELECTRON AFFINITY

Electron affinity and the energy of the nucleophil X^- ($X=F^-$ and Cl^-) and the atoms F and Cl are shown in Table 4.

Table 4. Electron affinity of atomic species

Species	Energy (a.u.) HF/6-31G* (d, p)	Energy (a.u.) DFT/3-21G* (d, p)
Cl^-	-459.539	-458.057
Cl	-459.448	-457.945
Electron affinity (eV)	2.74	2.29
F^-	-99.418	-99.150
F	-99.371	-99.182
Electron affinity (eV)	3.28	1.33

We see that the configuration interaction stabilizes Cl and Cl-by 0.1 a.u. Electron affinities calculated using HF/6-31G*(d,p) and DFT/3-21G(d,p) are 2.74 eV and 2.29 eV respectively. This latter value is not in good agreement with that obtained experimentally, namely 3.61 eV. Electron affinities previously obtained by O'Neil et al [16] and Meyer [17] are 3.32 eV and 3.48 eV respectively. This difference is certainly due to the small size of the base used for the study of the chlorine atom.

For the species F and F^-, electron affinity is 1.33eV calculated using DFT/3-21G (d,p) and 2.93 eV using HF/6-31G*(d,p). These two values are not in good agreement with the value obtained experimentally, namely 3.43eV. Using a Gaussian base of type 4s4ps4d, we calculated an electron affinity of 3.28 eV, which is closer to the experimental value.

3 CONCLUSION

In this study, we looked at the ability of the HF and DFT *ab initio* methods to calculate equilibrium distances of Si-F and Si-Cl bonds in silanes and silyl radicals, thermodynamic values (entropy S, heat capacity Cv, total energy and enthalpy ΔHr) and electron affinities of the fluoride and chlorine nucleophiles. Results obtained were in good agreement with experimental and theoretical data obtained using other *ab initio* methods. The HF/6-31G* method appears to give the best results.

REFERENCES

[1] Y. G. Smeters and M. Villa, "Influence of the vibrational zero-point energy correction on the amine inversion barrier and the far-infrared spectrum of methylamine" *Chem. Phys. Lett*, vol. 324, no. 4, pp. 273-278, 2000.

[2] I. Bandyopadhyay and S. Manogran, "Force field and assignment of the vibrational spectra of phenanthrene—an *ab initio* study" *J. Mol. Struct. (Theochem)*, vol. 496, Issues 1–3, pp. 107-119, 2000.

[3] M. Sana, G. Leroy, D. Deeters and G. Wilanle, "The theoretical study of the heats of formation of organic compounds containing the substituents CH_3, CF_3, NH_2, NF_2, NO_2, OH and F " *J. Mol. Struct. (Theochem)*, vol. 164, issues 3-4, pp. 249-274, 1988.

[4] Y. I. Binev, R. R. Petrova, J. A. Tsenov and I. G. Binev, "IR spectra and structure of (4-nitrophenyl)acetonitrile and of its carbanion: experimental and *ab initio* studies" *J. Mol. Struct. (Theochem)*, vol. 516, Issue 1, pp. 23–29, 2000.

[5] M. Sana, G. Leroy, M. Hilali, M. T. Nguyen and L.G. Vanquickenborne, "Heats of formation of isomeric $[C,H4,O]^{+\cdot}$, $[C,H3,N]^{+\cdot}$ and $[C,H5,N]^{+\cdot}$ radical cations," *Chemical Physics Letters*, vol. 190, pp. 551-556, 1992.

[6] T. D. Klots, D. Devlin and W. B. Collier, "Heteroatom derivatives of indene V. vibrational Spectra of benzimidazole," *Spectrochimica Acta Part A*, vol. 53, pp. 2445-2456, 1997.

[7] M. J. S. Dewar, E. G. Zoebisch, E. F. Healy and J. J. P. Stewart, "The development and use of quantum mechanical molecular models. 76. AMI: a new general purpose quantum mechanical molecular model," *J. Am. Chem. Soc*, Vol. 107, pp. 3902-3909, 1985.

[8] H. Zhou, E. Tajkhorshid, T. Frauenheim, S. Suhai and M. Elstner, "Performance of the AM1, PM3, and SCC-DFTB methods in the study of conjugated Schiff base molecules," *Chemical Physics,* vol. 277, pp. 91-110, 2002.

[9] M. Rahal, I. Bouabdallah and A. El Hajbi, "Rapid estimation of vibrational zero-point energies of silicon compounds," *Computational and Theoretical Chemistry*, vol. 1017, pp. 182–187, 2013.

[10] R. L. Lord, M. M. Allard, R. A. Thomas, O.S. Odongo, H.,B. Schlegel, Y.,J. Chen and J.,F. Endicott, "Computational modeling of the triplet metal-to-ligand charge-transfer excited-state structures of mono-bipyridine-ruthenium (II) complexes and comparisons to their 77 K emission band shapes," *Inorg. Chem.,* vol. 52 pp. 1185-1198, 2013.

[11] M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, B. Mennucci, G. A. Petersson, H. Nakatsuji, M. Caricato, X. Li, H. P. Hratchian, A. F. Izmaylov, J. Bloino, G. Zheng, J. L. Sonnenberg, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. Bearpark, J. J. Heyd, E. Brothers, K. N. Kudin, V. N. Staroverov, R. Kobayashi, J. Normand, K. Raghavachari, A. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, N. Rega, J. M. Millam, M. Klene, J. E. Knox, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, R. L. Martin, K. Morokuma, V. G. Zakrzewski, G. A. Voth, P. Salvador, J. J. Dannenberg, S. Dapprich, A. D. Daniels, O. Farkas, J. B. Foresman, J. V. Ortiz, J. Cioslowski, and D. J. *Fox, Gaussian, Inc., Wallingford CT*, 2009.

[12] H. B. Schlegel, S. Wolfe and F. Bernardi, "*Ab initio* computation of force constants, the second and third period hydrides," *J. Chem. Phys.,* vol. 63 pp. 3632-3638, 1975.

[13] F. Bernardi, H. B. Schlegel and S. Wolfe, "*Ab initio* computation of force constants. IV. A simple procedure for the evaluation of X-H bond dissociation energies," *Journal of Molecular Structure*, vol. 35, pp 149-153, 1976.

[14] H. B. Schlegel, "Optimization of equilibrium geometries and transition structures," *J. Comput. Chem.*, vol. 3, pp. 214-218, 1982.

[15] J. A. Pople, H. B. Schlegel, R. Krishnan, D. J. DeFrees, J. S. Binkley, M. J. Frisch, R. A. Whiteside, R. F. Hout and W. J. Hehre, "Molecular orbital studies of vibrational frequencies," *Int. J. Quantum Chem., Quantum Chem. Sym.,* vol. 15, pp. 269-278, 1981.

[16] S. V. O'Neil, P. Rosmus, D. W. Norcross and H.-J. Werner, "Bound electronic states of H−Cl," *J. Chem. Phys.*, vol. 85, pp. 7232-7232, 1986.

[17] W. Meyer, "PNO-CI studies of electron correlation effects. I. Configuration expansion by means of nonorthogonal orbitals and application to the ground state and ionized states of methane" *J. Chem. Phys.*, vol. 58 pp. 1017-1035, 1973.

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Simulation Based Study to Present the Performance of Ad-hoc Routing Protocols

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ABSTRACT: Ad-hoc mobile/802.11 networks are fully considered as networks with no fixed physical line connections. Ad-hoc networks have no fixed topology due to the movement of the end nodes. All the nodes in ad-hoc networks are mobile. Each node taking part in this network can act as host and router which can send and receive data. In this type of situations some kind of routing protocols are needed for these mobile nodes to fully operate and function properly. Ad-hoc network has some common features, which need some routing protocol. The most significant one is the dynamic routing protocols, which quickly change the topology. Reactive routing protocols search a route to destination/remote device on needed basis. Proactive protocols maintain the whole routing table at each node. In order to show the performance, NS2 network simulator has been used. The purpose of this study is to show the performance of two widely known ad-hoc routing protocols, AODV and DSR, in terms of packet delivery ratio, average end-to-end delay and routing overhead by changing the mobility. The simulation has been carried out using NS2 2.29 as the simulation platform.

KEYWORDS: AODV, DSR, OLSR, Mobility, MPR, Traffic Pattern.

1 INTRODUCTION

Ad-hoc/802.11 networks are implemented with type of remote data transmission system that uses some form of waves as a media. Electromagnetic and radio waves are used as a carrier and this implementation normally takes place at the physical layer. In the last few years, the word networks have increasingly become a mobile. This is because the recent advancement in devices such as laptops and PDA (personal data assistant), which has brought these devices to the lower prices and increase the high data rates.

Ad-hoc networks can be characterized into two forms (i) Infrastructure network and (ii) ad-hoc network. In infrastructure mobile network, mobile devices have wired base stations in a specific range. The base station contains the central controller for an infrastructure network. In contrast, mobile ad-hoc networks are self-organized networks without infrastructure support. Devices move in a random manner, therefore the network may experience a quick and unknown topology changes. Furthermore, because devices in a mobile ad-hoc network normally have limited communication range, some devices will not send or receive data packets directly. Hence, routing paths in ad-hoc networks contain multiple hops. Every device in ad-hoc networks has the responsibility to act as a router to send and receive the data packets [1].

1.1 AD-HOC APPLICATIONS

Mobile ad-hoc network has different applications, which can be used in commercial and industrial site [2].

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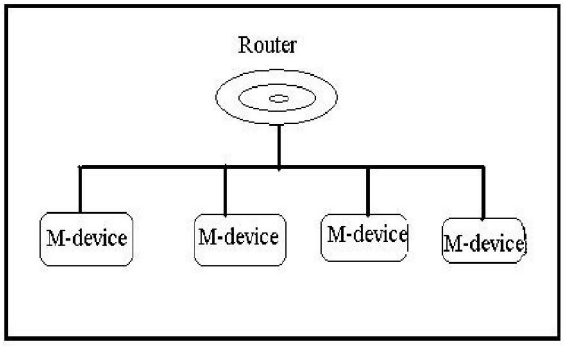

Fig. 1. Diagram of a mobile device

Important applications of ad-hoc applications are emergency services, commercial services, Education services, enterprise application, and Entertainment services.

1.2 ROUTING PROCESS

Routing is a process of taking data over the network from source to a defined destination. Routing operate at layer 3 of the OSI model. Routing is almost defined with switching. The main difference between routing and switching is that routing operates at layer 3 and switching operates at layer 2 of the OSI model. Using both switching and routing mechanism the whole process moves the data from source to destination. Routing process is however different than switching process.

When the source router sends the information to the neighbour router, the neighbour router checks the route of the destination router in the routing table. If the route is available in the routing table, it will send the information, if not then the router will discard the packet. If the router has more than one route available in the routing table the router will select the best available path to the destination and sends the information's [3].

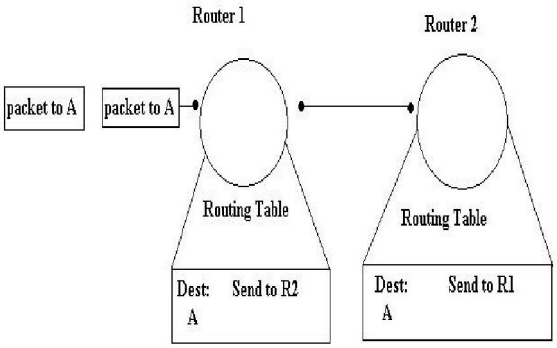

Fig. 2. The routing process from source to destination

The rest of the paper is organized as follows: the related work is presented in Section II. Section III contains the proposed work. Results are discussed in Section IV. We conclude the paper in Section V.

2 RELATED WORKS

In this section the followings routing protocols are discussed.

2.1 AD-HOC ON-DEMAND DISTANCE-VECTOR PROTOCOL (AODV)

AODV is a hop by hop routing protocol or in other words, AODV is an on demand distance vector routing protocol. AODV is combination of DSR and DSDV [4]. It has some features of DSDV protocol, for example using hop by hop routing, periodic notification messages and sequence numbers. By means of an updated DSDV, it reduces the amount of broadcasting

messages and only creates routes on need basis [5], when a mobile device need to send some information/data, then AODV find out a route to a destination, and it keeps the routes in the routing table up to the time, when they are needed by the source. In AODV the sequence numbers guarantee the loop free and freshness of routes in the routing table. AODV is relatively the same as the bellman-ford distance vector algorithm, but it does work in mobile environment [5]. It can also be seen as an updated DSR protocol. Like DSR AODV use route discovery and route maintenance properties and it uses sequence number and periodic hello message properties of DSDV.

2.1.1 ROUTES TABLE IN AODV

Routing table [6] only adds all active routes, when source need to send data to the destination. Each entry has some information to the destination. Some of them are defined here, for example Number of total hops to the destination, sequence number, next hop, online neighbours for this route. Expiry time for this route is called life time. The life time reset itself every time, when the route has been used by any device to send the data. It has also another active time out which is the sum of expiry time and the current time. AODV only keeps information about the active links and hence offload the management of table. AODV deletes all the information about a link if it does not receive any information for RREQ message. AODV utilizes maximum of the bandwidth. This is because AODV does not broadcast periodic hello messages across the network. AODV always route packets on demand. Destination sequence number plays very important role in keeping the routing table fresh.

2.2 THE DYNAMIC SOURCE ROUTING PROTOCOL (DSR)

The Dynamic Source Routing Protocol (DSR) [7] is a reactive unicast routing protocol. DSR is popular for some of its important features, which are, it is simple, dedicated to ad-hoc networks and very efficient. DSR has two methods for communication, which are,

- Route discovery
- Route maintenance

2.2.1 ROUTE DISCOVERY MECHANISM

DSR is a reactive routing protocol and the route discovery mechanism is very simple. For a communication, DSR send a route discovery broadcast message to the whole network to find the feasible route to the destination. For example if a source device A wants to communicate with destination device Z, if device A has an active route in its routing table, then there is no need to send a discovery broadcast message, but if there is no active route in the routing table for device Z, then device A will send a broadcast the route discovery message. In the above example say, device A does not have an active route, so it will broadcast route discovery message to the network, each device between A and Z will receive this route discovery request message. All the intermediate devices will put their own information/address and will reply with route reply message to device A. when the device Z receive the route discovery request message, it reply back with route reply message to device A only. With this process all the intermediate devices save all active routes in the cache. This way the source can send and receive the packets.

2.3 DESTINATION SEQUENCED DISTANCE VECTOR PROTOCOL (DSDV)

DSDV [1], [8] is a proactive routing protocol in ad-hoc network, which uses bellman-ford algorithm. By using bellman-ford algorithm in ad-hoc network, it increment the sequence number of the new entry in the routing table for each device in the network. In order to operate correctly, DSDV end device has to send its full routing table to all neighbours periodically and vice versa to update its own routing table by getting the latest information from neighbour. All the end devices in the network have to update the routing table as soon as they get any update from neighbour. DSDV uses sequence number as its routing table attribute. The sequence number shows the updated information. A route with higher sequence number is favourable than lower sequence number. Higher sequence number shows most updated information. If the two routes have same sequence number then the route with lower hop count will be preferred [2]. The sequence number is incremented with each broadcast. If there is any broken link the sequence number is tagged as infinity.

2.3.1 DSDV ACTIVITIES

The DSDV protocol requires that every device in the network should send its own routing table periodically, as soon as they receive an updates from its neighbour. The entry in the routing table can change at any time, so the updated table should be sent to help locate the other devices in the network. This will ensure that if a device moves its actual location, then still it will be able to communicate with other destination devices, even if there is no direct link exists. When the devices move in the network, then they send the routing information by broadcasting the packets periodically. The information broadcasted by any device will have its own sequence number and further information.

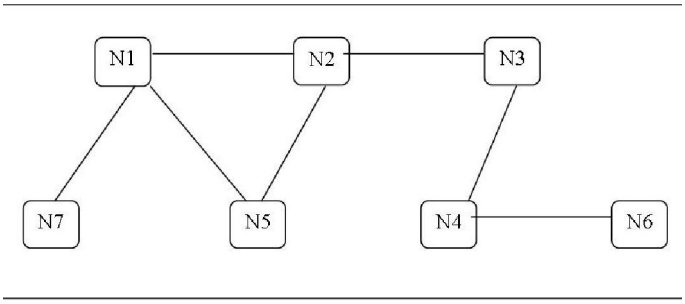

Fig. 3. Routing process mobile devices

2.4 OPTIMIZED LINK STATE ROUTING PROTOCOL

Optimized link state Protocol (OLSR) is a proactive routing protocol. OLSR is the updated version of link state routing protocol. This means that the active routing paths will always be available in the routing table, if any mobile device needs them for communication. As soon as the topology gets changed, then every device sends a full routing table to all other mobile devices in the network. This will create an over head and bottleneck on the actual link. In order to reduce the overhead created by a big pile of broadcast messages, there is a technique used to reduce these broadcast messages. A network protocol uses Multipoint Relays (MPR). The basic job of MPR is to reduce the broadcast messages in some areas in the network and also to provide the shortest path [7].

OLSR [15] is an independent routing protocol, which does not have a fixed central administration and perform flat routing. OLSR is proactive routing protocol which requires all nodes have full updated routing information in the network. On the other hand the limitation of OLSR can be that it sends the updated information across the network which use a lot of the link bandwidth. But it has still minimized the flooding by the selection of MPR, which are only allowed to advertise Hello message. By changing the time interval between the broadcast timing the protocol can be more suitable for ad-hoc network. OLSR is very easy to be integrated in the existing operating system without changing header of IP.

3 PROPOSED SOLUTION

In a general perspective about the reactive routing protocols, it is clear from the results below that both the protocols perform very well under high pause time i.e. low mobility but their performance tends to degrade at higher mobility. This is due to the fact that high mobility often results in route failures which mean often route discoveries will be made by these protocols due to their reactive nature. Performance wise the results showed that

- AODV performed better than DSR in terms of packet delivery ratio

The performance gap was high at low pause time (high mobility) but with high pause time (low mobility).

- DSR started performing better and the gap was significantly reduced.

In terms of average end-to-end delay,

- DSR performed well with lower delay than AODV with at high mobility.
- DSR outperforms the AODV at high mobility with a high performance gap.

This is because AODV uses more route requests than DSR. The reason is that these route requests propagate to all the mobile nodes in the network. The low overhead of DSR is due to the route cache feature and non-propagating route requests.

Both protocols have their advantages and disadvantages in terms of different metrics and scenarios. The prime reason for low performance of AODV relies on a single route and at high mobility this results is often route requests. This can be overcome with a route caching technique to maintain multiple routes to a destination. However, on the other hand the route caching technique has negative impact on the performance of DSR at high mobility. At high mobility, the probability of stale routes in cache is high which degrades the performance. If some sort of cache route expiry mechanism is implemented than it would eliminate the probability of stale routes and thus would improve the performance of DSR and AODV can also benefit from a similar caching technique.

4 SIMULATIONS AND RESULTS

NS-2 network simulation is the best method to present the performance of mobile routing protocols. Several simulation tools are available, like NS2, GLOMOsim, Mat-lab and OPNET. But I have selected to use NS2. There are two files which are input to the NS and these files give you output.

- File which shows the traffic.
- File which shows the movement pattern of the mobile nodes.

4.1 MOBILITY SEQUENCE

The mobility file is generated using NS2 set-dest script. This model used by set-dest is changing position in mobility model. The model imposes a randomly motion, which a node move towards a different destination with a speed varying between zero and high speed parameter, while at the same time generating the mobility file. After stopping at different destination for a specified 'pause time', the node continues this changing motion and stopping at a different destination until the simulation come to an end. The pause time parameter controls the motion of the node and is therefore a measure of mobility. For this reason, the pause time is varied to see its total effect. The selected pause times for this simulation are 10s, 15s, 20s, 30s, 50s, 100s and 110 sec. All parameters used to generate mobility file along with pause time is shown in the following table below,

Table 1. Simulation parameters of Mobility Sequence

No of nodes	30
Pause time	10, 15, 20, 30, 50, 100, 110
Maximum speed (m/s)	20
Simulation Time (s)	110
Area – X,Y	1500,300 (rectangular)

4.2 TRAFFIC PATTERN

Traffic files have been generated using cbrgen.tcl script which is part of NS2. Constant bit rate (CBR) traffic sources have been used. The parameters used for the traffic files are shown below in the table,

Table 2. Simulation parameters of Traffic Pattern

No of nodes	30
Seed	1
Maximum connections	10
Rate (Packet per second)	2.0

The three performance metrics have been counted and plotted against the pause time. The results of the simulation are shown in the following graphs along with a detailed discussion.

4.3 PERFORMANCE METRICS

The followings performance metrics are used in the comparison of the protocols.

4.3.1 PACKET DELIVERY RATIO

Packet delivery ratio is low for both AODV and DSR at lower pause time i.e. when the motion is too high. Higher mobility causes often route breaks which means more route discoveries are made in case of reactive protocols. With lower mobility the route breaks are not very often which results in few route discoveries and hence better performance for reactive protocols. Between AODV and DSR, it is clear that AODV outperforms DSR in packet delivery ratio in case of high motion/mobility. The fact is that AODV uses fresh routes each time in case of route failure while DSR has route caching feature which means multiple routes to a destination are maintained. After one route fails, the other routes are tried instead of trying to discover another one. In case of high mobility, link breaking often occurs, so chances for stale routes in DSR routing cache is high which is obvious from the results. DSR route caching has a positive effect at lower mobility as shown in the graph since they are not very often route failures. Figure shows the packet delivery ratio below,

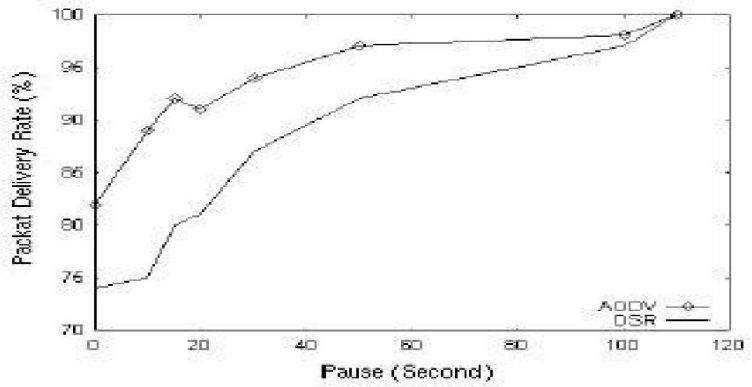

Fig. 4. Packet Delivery Rate vs. Pause Time

4.3.2 AVERAGE DELAY

Average delay of AODV was higher than DSR at low pause time i.e. high mobility. This is because AODV generates more routing packet for discovering new routes in case of route failure which consumes bandwidth and therefore contributes to the delay in the network. On the other hand, DSR is utilizing route caching ability making less route discoveries in case of route failures thus using little bandwidth and therefore delay is low for DSR. But the difference between the two is not much even though DSR is using route caching. The reason for this is that when stale routes in DSR cache are chosen it adds to the delay as well as to the bandwidth utilization and delivery time is wasted. As the pause time is increased i.e. mobility is decreased, the average delay for both AODV and DSR starts decreasing. Both start performing better with low mobility with AODV matching DSR at pause time of 110. Figure shows the plotted graph below,

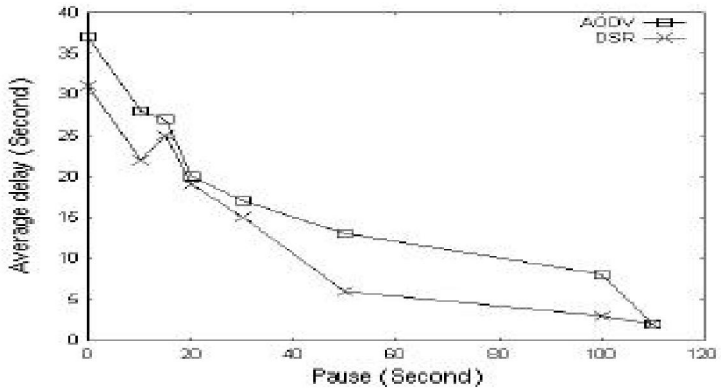

Fig. 5. Average Delay vs. Pause Time

4.3.3 AVERAGE ROUTING LOAD

Average routing load for AODV is higher than DSR. The difference is high at lower pause time i.e. high mobility/motion. The reason for high overhead of AODV is often route request packets for route discoveries which send this to every mobile node in the network. With high mobility this overhead is very high for AODV which relies upon fresh routes. DSR produces less overhead than AODV by utilizing route caching feature and using non-propagating route request packets for route discovery. With high pause time i.e with lower mobility. The difference reduces with the decreased mobility. Figure below shows the average routing load.

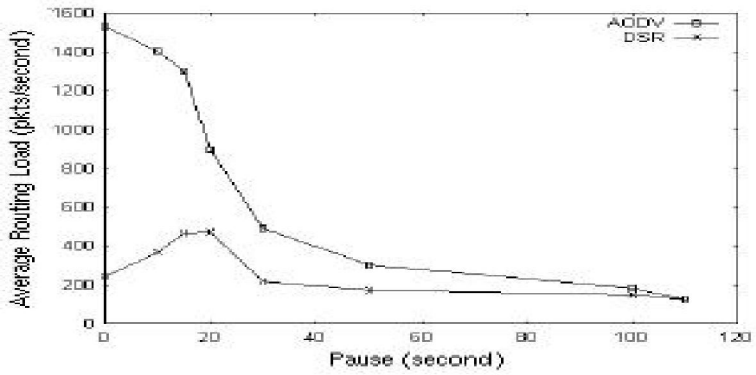

Fig. 6. Average Routing Load vs. Pause Time

5 CONCLUSIONS

Many routing protocols designed for mobile ad hoc networks are proactive, reactive or the combination of both (hybrid). The proactive derives their mechanism from traditional fixed line network to the ad hoc networks. These protocols maintain a table of all the routes in the network. These protocols have high routing overhead in maintaining and updating these tables and are therefore recommended in situation where bandwidth is not a problem. While typical mobile ad hoc networks have bandwidth constraint, reactive routing protocols were designed for mobile ad hoc networks to address the issues in proactive protocols and conserve the bandwidth and power. Being reactive in nature, these protocols adapt to topological changes better than proactive protocols and are therefore best suited for mobile ad hoc networks.

ACKNOWLEDEMENT

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REFERENCES

[1] Working Group IEEE 802.11, April 2008. [Online] Available: http://www.ieee802.org/11.
[2] I.Chlamtac, M.Conti, J.N.A.Liu, “Mobile Ad hoc networking: imperatives and challenges”, Ad Hoc Networks, Vol.1, no.1, pp.13–64, 2003.
[3] R. Perlman, “Network Layer Protocols with Byzantine Robustness,” Ph.D. Dissertation, MIT/LCS/TR-429, MIT, pp.77-82, 1988.
[4] PERKINS, C. E. BHAGWAT, “Highly dynamic destination-sequenced distance-vector routing for mobile computers”. ACM SIGCOMM, Proc. of the conference on Communications architectures, protocols and applications, Vol.5, no.3, pp.27-37, 2000.
[5] B.Kaur, Sonia, ”Performance Evaluation of MANET Routing Protocols with Scalability and Node Density issue for FTP Traffic”, International Journal of Advanced Research in Computer Science and Software Engineering, Vol.3, no.5, pp.543-548, 2013.
[6] S.J. Lee, E. M. Belding Royer, C. E. Perkins, “Scalability study of the ad hoc on-demand distance vector routing protocol” Int. J. Network Mgmt, Vol.13, no.1, pp. 97–114, 2003.
[7] D.B.J. Rao, K. Sreenu, P. Kalpana, “A Study on Dynamic Source Routing Protocol for Wireless Ad Hoc Networks”, International Journal of Advanced Research in Computer and Communication Engineering, Vol. 1, Issue 8, 2012.

[8] S. Murphy, "Routing Protocol Threat Analysis"2002. [Online] Available: www.ietf.org/mail
[9] T. Clausen and P. Jacquet "Optimized Link State Routing Protocol (OLSR)." RFC 3626, IETF Network Working Group, 2008.
[10] Scalable Routing Protocols for Mobile Ad-hoc Networks Xiaoyan Hong, Kaixin Xu, Mario Gerla Computer Science Department, University of California, Los Angeles, 2008.
[11] Aleksandra Huhtonen "Comparing AODV and OLSR Routing Protocols", Helsinki University of Technology Telecommunication Software and Multimedia Laboratory, 2007.
[12] Tony Larsson and Nicklas, Hidman Routing protocols in wireless ad-hoc networks, 2007.
[13] Perkins, C., Royer, E. M. and Das S., 2000. Performance comparison of Two On-Demands routing Protocols for Ad-Hoc Networks, IEEE INFOCOM 2000.
[14] Kalyan Kalepu, Shiv Mehra and Chansu Yu, "Experiment and Evaluation of a Mobile Ad Hoc Network with AODV Routing Protocol" Department of Electrical and Computer Engineering Cleveland State University, 2004.
[15] H.Paul, P.Sarkar, "A study and comparison of OLSR, AODV and ZRP routing protocols in ad hoc networks", International Journal of Research in Engineering and Technology, Volume: 2, no.8, 2013.

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A Study of Series FACTS Devices for the Control of Power Flow in Electrical Power Networks

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ABSTRACT: This paper concentrates on controlling of power flow in power lines with the help of series Flexible Alternating Current Transmission Systems (FACTS) device. The power flow control deals with the task of taking remedial measures against overloads and nonlinear loads in the system due to the occurrence of contingencies. The series FACTS devices considered in this paper are Thyristor Controlled Series Capacitor (TCSC), Thyristor Controlled Phase Shifter (TCPS) and Static Synchronous Series Compensator (SSSC). This paper presents the modelling of these series FACTS devices suitable for incorporation in load flow program for the study of steady state operation of power system. A systematic foundation on the theory and practice of positive sequence power flow is presented here. An efficient Newton-Rapshon (NR) method is used for solving the nonlinear algebraic load flow equations in the load flow problem. A step by step procedure for incorporation of series FACTS devices within the NR load flow algorithm is described. The effectiveness of the proposed models and convergence of the proposed load flow algorithm is tested on standard IEEE 30 bus test network without and with these series FACTS devices. Programming for the solution of series controllable branches with these proposed models is done by using MATLAB software. Results are reported and studies are presented to demonstrate and compare the efficiency of TCPS, TCSC and SSSC.

KEYWORDS: Flexible AC Transmission Systems (FACTS), Newton-Raphson method, Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC), Thyristor Controlled Phase Shifter (TCPS).

1 INTRODUCTION

Mainly two bases encourage the control of power flow, first one is improvement in high power electronic devices and the second one is deregulation of power market and continually increasing demand of electric power. In order to meet the growing demand of electricity while maintaining economic and secure operation, either utilize the existing network high proficiently or construct the new power lines and power generators. Due to right of way issues and environmental problems the latter one is very difficult. Implementation of former one is easy and provides a smart solution to control the power flow. The idea of utilize the existing power system efficiently has pointed in the forward direction of power electronics based equipment i.e., Flexible AC Transmission Systems (FACTS) controllers [1]. Recent development in high power electronic devices makes it possible to control the power flows in the network.

The concept of FACTS devices is implemented in power lines, to increase the power transfer capability, either in series or in shunt with the power lines. FACTS device introduced in series with the line is the most efficient one to control the power flow and to enhance the power transfer capability of the line. Series compensation [1] enhances the line power transfer capability, damping sub-synchronous oscillations and power oscillations, improves the voltage profile and system stability and also reduces losses. The efficient tool is needed to be developed to determine the effectiveness of the series FACTS devices. Hence, existing program of load flow studies is required to be modified for include the series devices in the power

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system. Newton-Raphson (NR) method has very strong convergence characteristics for the solution of load flow. This paper presents the solution of series controllable branches through the NR method to rule the power flow in the transmission lines.

Two methods of load flow solution [2] exist for include the series FACTS device in NR algorithm, those are 1) Simultaneous or Unified method [3], 2) Sequential or Alternating method [4]. In former method, the equations related to the FACTS device specification and the conventional load flow equations are pooled into set of nonlinear equations and solved simultaneously. In this method, major modifications are made in existing program. In latter method, the equations related to the FACTS device specification and the conventional load flow equations are solved sequentially and separately. In this method insignificant modifications are made in existing program. Among these, unified method has very strong convergence characteristics i.e., convergence is attained within the half number of iterations requisite for the alternating method. This paper presents the unified method for solving the load flow equations with series FACTS devices. Standard IEEE 30 bus system is used for testing the effectiveness of the proposed method by using MATLAB.

In this paper, section 2 presents a steady state modeling of TCSC[3], [5], [6], [7], [8], [9], SSSC[9], [10], [11] and TCPS[12], [13] that can pooled in NR power flow algorithm. Section 3 summarizes the step by step procedure for incorporating the series FACTS device in the NR method. Section 4 presents a test case and simulation results and section 5 presents a conclusion.

2 SERIES FACTS DEVICE MODELLING

The power flow through the transmission line connected between the nodes x and y depends on sending and receiving buses voltage magnitudes V_x and V_y, voltage phase angle difference between the sending and receiving buses $\delta_x - \delta_y$ and the branch reactance X_{xy} is expressed in (1). A simple power line connecting the buses x and y is shown in Fig. 1.

$$P_{xy} = \frac{V_x V_y}{X_{xy}} \sin(\delta_x - \delta_y) \tag{1}$$

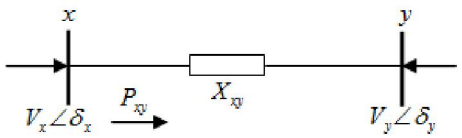

Fig. 1. The representation of transmission line between nodes x and y

TCSC device controls branch reactance and TCPS device controls voltage phase angle difference so as to control power flow across controlled line at specified value. SSSC is the most versatile member of FACTS family and control phase angles, bus voltage and line impedance. Power flow can be controlled and optimized by changing power system parameters using FACTS devices.

2.1 TCSC DEVICE MODELLING

The main objective of TCSC is to enhance the power transfer capability and to control the power flow by increasing or decreasing the series transmission reactance. The modeling of this device is based on the idea of varying reactance. The reactance value of the TCSC is changed automatically to restrict the branch power at pre-defined value. With the help of NR method, the reactance of the TCSC is gritty efficiently. The TCSC equivalent circuit is shown in Fig. 2. The equivalent reactance of TCSC device is X_{TCSC} given by

$$X_{TCSC} = -X_C + C_1(2(\pi - \alpha) + \sin(2(\pi - \alpha))) - C_2 \cos^2(\pi - \alpha)(\varpi \tan(\varpi(\pi - \alpha)) - \tan(\pi - \alpha)) \tag{2}$$

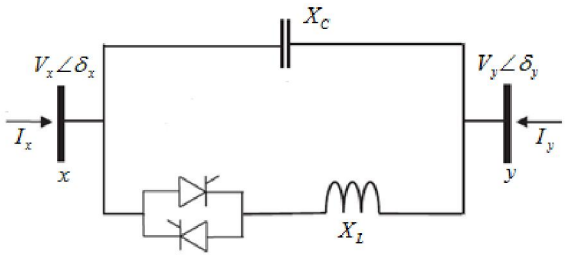

Fig. 2. Equivalent Circuit of TCSC

Where X_C is the capacitive reactance and X_L is the reactance of the thyristor controlled reactance and:

$$X_{LC} = \frac{X_C X_L}{X_C - X_L}$$

$$C_1 = \frac{X_C + X_{LC}}{\pi}$$

$$C_2 = \frac{4X_{LC}^2}{X_L \pi}$$

From the equivalent circuit of TCSC, the current equations at node x and y represented in the form of matrix is

$$\begin{bmatrix} I_x \\ I_y \end{bmatrix} = \begin{bmatrix} jB_{xx} & jB_{xy} \\ jB_{yx} & jB_{yy} \end{bmatrix} \begin{bmatrix} V_x \\ V_y \end{bmatrix} \quad (3)$$

Where

$$B_{xx} = B_{yy} = B_{TCSC} = -\frac{1}{X_{TCSC}}$$

$$B_{xy} = B_{yx} = -B_{TCSC} = \frac{1}{X_{TCSC}}$$

The active and reactive power equations at node x are

$$P_x = -V_x V_y B_{TCSC} \sin(\delta_x - \delta_y) \quad (4)$$

$$Q_x = -V_x^2 B_{TCSC} + V_x V_y B_{TCSC} \cos(\delta_x - \delta_y) \quad (5)$$

Exchange the subscripts x and y for power equations at node y. The set of linearized power flow equations when the TCSC controls the real power flow from node x to y is

$$\begin{bmatrix} \Delta P_x \\ \Delta P_y \\ \Delta Q_x \\ \Delta Q_y \\ \Delta P_{xy}^{X_{TCSC}} \end{bmatrix}^k = \begin{bmatrix} \frac{\partial P_x}{\partial \delta_x} & \frac{\partial P_x}{\partial \delta_y} & \frac{\partial P_x}{\partial V_x}V_x & \frac{\partial P_x}{\partial V_y}V_y & \frac{\partial P_x}{\partial X_{TCSC}}X_{TCSC} \\ \frac{\partial P_y}{\partial \delta_x} & \frac{\partial P_y}{\partial \delta_y} & \frac{\partial P_y}{\partial V_x}V_x & \frac{\partial P_y}{\partial V_y}V_y & \frac{\partial P_y}{\partial X_{TCSC}}X_{TCSC} \\ \frac{\partial Q_x}{\partial \delta_x} & \frac{\partial Q_x}{\partial \delta_y} & \frac{\partial Q_x}{\partial V_x}V_x & \frac{\partial Q_x}{\partial V_y}V_y & \frac{\partial Q_x}{\partial X_{TCSC}}X_{TCSC} \\ \frac{\partial Q_y}{\partial \delta_x} & \frac{\partial Q_y}{\partial \delta_y} & \frac{\partial Q_y}{\partial V_x}V_x & \frac{\partial Q_y}{\partial V_y}V_y & \frac{\partial Q_y}{\partial X_{TCSC}}X_{TCSC} \\ \frac{\partial P_{xy}^{X_{TCSC}}}{\partial \delta_x} & \frac{\partial P_{xy}^{X_{TCSC}}}{\partial \delta_y} & \frac{\partial P_{xy}^{X_{TCSC}}}{\partial V_x}V_x & \frac{\partial P_{xy}^{X_{TCSC}}}{\partial V_y}V_y & \frac{\partial P_{xy}^{X_{TCSC}}}{\partial X_{TCSC}}X_{TCSC} \end{bmatrix}^k \begin{bmatrix} \Delta\delta_x \\ \Delta\delta_y \\ \frac{\Delta V_x}{V_x} \\ \frac{\Delta V_y}{V_y} \\ \frac{\Delta X_{TCSC}}{X_{TCSC}} \end{bmatrix}^k \quad (6)$$

Where $\Delta P_{xy}^{X_{TCSC}} = p_{xy}^{reg} - P_{xy}^{X_{TCSC},cal}$, is the mismatch equation for active power flow across TCSC and $\Delta X_{TCSC} = X_{TCSC}^{(k+1)} - X_{TCSC}^{(k)}$, is the incremental change in the TCSC firing angle α . Superscript k indicates the iteration value.

2.2 SSSC DEVICE MODELLING

The SSSC is a static, synchronous generator which can generates a sinusoidal ac voltage at fundamental frequency of changing and controllable phase angle and magnitude. The output voltage of this converter is in quadrature with the line current. It can absorb or generate the reactive power from the line thus it can be used as power flow controller for the transmission line. The line injected voltage emulates an inductive or a capacitive reactance in series with a transmission line; hence it provides variable transmission line reactance. This changing reactance affects the power flow in the line. The SSSC equivalent circuit is shown in Fig. 3. The SSSC output terminal voltage is changed automatically to control the branch power flow at a pre-defined value.

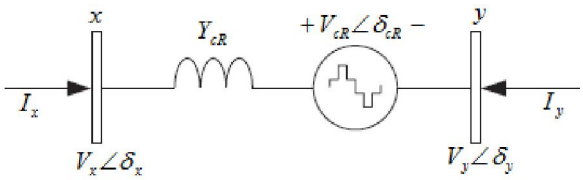

Fig. 3. Equivalent Circuit of SSSC

The series voltage source of SSSC

$$E_{cR} = V_{cR}(\cos\delta_{cR} + j\sin\delta_{cR}) \quad (7)$$

where V_{cR} and δ_{cR} are the magnitude and phase angle of the voltage source representing series compensator. The voltage source introduces two new state variables V_{cR} and δ_{cR} to the load flow problem. so, we need two new equations for the load flow solution.

The active and reactive power equations at node x is

$$P_x = V_x^2 G_{xx} + V_x V_y[G_{xy}\cos(\delta_x - \delta_y) + B_{xy}\sin(\delta_x - \delta_y)] + V_x V_{cR}[G_{xy}\cos(\delta_x - \delta_{cR}) + B_{xy}\sin(\delta_x - \delta_{cR})] \quad (8)$$

$$Q_x = -V_x^2 B_{xx} + V_x V_y[G_{xy}\sin(\delta_x - \delta_y) - B_{xy}\cos(\delta_x - \delta_y)] + V_x V_{cR}[G_{xy}\sin(\delta_x - \delta_{cR}) - B_{xy}\cos(\delta_x - \delta_{cR})] \quad (9)$$

And active and reactive power equations for voltage source is

$$P_{cR} = V_{cR}^2 G_{yy} + V_x V_{cR}[G_{xy}\cos(\delta_{cR} - \delta_x) + B_{xy}\sin(\delta_{cR} - \delta_x)] + V_y V_{cR}[G_{yy}\cos(\delta_{cR} - \delta_y) + B_{yy}\sin(\delta_{cR} - \delta_y)] \quad (10)$$

$$Q_{cR} = -V_{cR}^2 B_{yy} + V_x V_{cR}[G_{xy}\sin(\delta_{cR} - \delta_x) - B_{xy}\cos(\delta_{cR} - \delta_x)] + V_y V_{cR}[G_{yy}\sin(\delta_{cR} - \delta_y) - B_{yy}\cos(\delta_{cR} - \delta_y)] \quad (11)$$

The set of linearized power flow equations when the SSSC controls the power flow from node x to y is

$$\begin{bmatrix} \Delta P_x \\ \Delta P_y \\ \Delta Q_x \\ \Delta Q_y \\ \Delta P_{xy} \\ \Delta Q_{xy} \end{bmatrix}^k = \begin{bmatrix} \frac{\partial P_x}{\partial \delta_x} & \frac{\partial P_x}{\partial \delta_y} & \frac{\partial P_x}{\partial V_x}V_x & \frac{\partial P_x}{\partial V_y}V_y & \frac{\partial P_x}{\partial \delta_{cR}} & \frac{\partial P_x}{\partial V_{cR}}V_{cR} \\ \frac{\partial P_y}{\partial \delta_x} & \frac{\partial P_y}{\partial \delta_y} & \frac{\partial P_y}{\partial V_x}V_x & \frac{\partial P_y}{\partial V_y}V_y & \frac{\partial P_y}{\partial \delta_{cR}} & \frac{\partial P_y}{\partial V_{cR}}V_{cR} \\ \frac{\partial Q_x}{\partial \delta_x} & \frac{\partial Q_x}{\partial \delta_y} & \frac{\partial Q_x}{\partial V_x}V_x & \frac{\partial Q_x}{\partial V_y}V_y & \frac{\partial Q_x}{\partial \delta_{cR}} & \frac{\partial Q_x}{\partial V_{cR}}V_{cR} \\ \frac{\partial Q_y}{\partial \delta_x} & \frac{\partial Q_y}{\partial \delta_y} & \frac{\partial Q_y}{\partial V_x}V_x & \frac{\partial Q_y}{\partial V_y}V_y & \frac{\partial Q_y}{\partial \delta_{cR}} & \frac{\partial Q_y}{\partial V_{cR}}V_{cR} \\ \frac{\partial P_{xy}}{\partial \delta_x} & \frac{\partial P_{xy}}{\partial \delta_y} & \frac{\partial P_{xy}}{\partial V_x}V_x & \frac{\partial P_{xy}}{\partial V_y}V_y & \frac{\partial P_{xy}}{\partial \delta_{cR}} & \frac{\partial P_{xy}}{\partial V_{cR}}V_{cR} \\ \frac{\partial Q_{xy}}{\partial \delta_x} & \frac{\partial Q_{xy}}{\partial \delta_y} & \frac{\partial Q_{xy}}{\partial V_x}V_x & \frac{\partial Q_{xy}}{\partial V_y}V_y & \frac{\partial Q_{xy}}{\partial \delta_{cR}} & \frac{\partial Q_{xy}}{\partial V_{cR}}V_{cR} \end{bmatrix}^k \begin{bmatrix} \Delta\delta_x \\ \Delta\delta_y \\ \frac{\Delta V_x}{V_x} \\ \frac{\Delta V_y}{V_y} \\ \Delta\delta_x \\ \frac{\Delta V_{cR}}{V_{cR}} \end{bmatrix}^k \quad (12)$$

2.3 TCPS DEVICE MODELLING

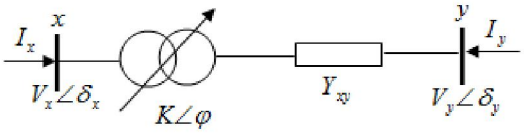

Fig. 4. Equivalent Circuit of TCPS

Thyristor Controlled Phase shifter with quadrature voltage injection controls the active power via phase adjustment, φ. The modeling of this device is based on the idea of varying phase angle. The phase angle value of the TCPS is changed automatically to restrict the branch power at pre-defined value. With the help of NR method, the phase angle of the TCPS is gritty efficiently. The TCPS equivalent circuit is shown in Fig. 4. From the equivalent circuit of TCPS, the current equations at node k and m represented in the form of matrix is

$$\begin{bmatrix} I_x \\ I_y \end{bmatrix} = \begin{bmatrix} Y & -Y(\cos\varphi + j\sin\varphi) \\ -Y(\cos\varphi - j\sin\varphi) & Y \end{bmatrix} \begin{bmatrix} V_x \\ V_y \end{bmatrix} \quad (13)$$

The active and reactive power equations at node x is

$$P_x = V_x^2 G_{xx} + V_x V_y[G_{xy}\cos(\delta_x - \delta_y) + B_{xy}\sin(\delta_x - \delta_y)] \quad (14)$$

$$Q_x = -V_x^2 G_{xx} + V_x V_y[G_{xy}\sin(\delta_x - \delta_y) - B_{xy}\cos(\delta_x - \delta_y)] \quad (15)$$

Exchange the subscripts x and y for power equations at node y.

From the (13),

$$\left.\begin{aligned} Y_{xx} &= Y_{yy} = Y \\ Y_{xy} &= -Y(\cos\varphi + j\sin\varphi) \\ Y_{yx} &= -Y(\cos\varphi - j\sin\varphi) \end{aligned}\right\} \quad (16)$$

Substitute (16) in to (14) and (15) gives the following more explicit expressions

$$P_x = V_x^2 G - V_x V_y [G\cos(\delta_x - \delta_y - \varphi) + B\sin(\delta_x - \delta_y - \varphi)] \quad (17)$$

$$Q_x = -V_x^2 B - V_x V_y [G\sin(\delta_x - \delta_y - \varphi) - B\cos(\delta_x - \delta_y - \varphi)] \quad (18)$$

The set of linearized power flow equations when the TCPS controls the power flow from node x to y is

$$\begin{bmatrix} \Delta P_x \\ \Delta P_y \\ \Delta Q_x \\ \Delta Q_y \\ \Delta P_{xy}^{\varphi^{ps}} \end{bmatrix}^k = \begin{bmatrix} \frac{\partial P_x}{\partial \delta_x} & \frac{\partial P_x}{\partial \delta_y} & \frac{\partial P_x}{\partial V_x}V_x & \frac{\partial P_x}{\partial V_y}V_y & \frac{\partial P_x}{\partial \varphi} \\ \frac{\partial P_y}{\partial \delta_x} & \frac{\partial P_y}{\partial \delta_y} & \frac{\partial P_y}{\partial V_x}V_x & \frac{\partial P_y}{\partial V_y}V_y & \frac{\partial P_y}{\partial \varphi} \\ \frac{\partial Q_x}{\partial \delta_x} & \frac{\partial Q_x}{\partial \delta_y} & \frac{\partial Q_x}{\partial V_x}V_x & \frac{\partial Q_x}{\partial V_y}V_y & \frac{\partial Q_x}{\partial \varphi} \\ \frac{\partial Q_y}{\partial \delta_x} & \frac{\partial Q_y}{\partial \delta_y} & \frac{\partial Q_y}{\partial V_x}V_x & \frac{\partial Q_y}{\partial V_y}V_y & \frac{\partial Q_y}{\partial \varphi} \\ \frac{\partial P_{xy}^{\varphi}}{\partial \delta_x} & \frac{\partial P_{xy}^{\varphi}}{\partial \delta_y} & \frac{\partial P_{xy}^{\varphi}}{\partial V_x}V_x & \frac{\partial P_{xy}^{\varphi}}{\partial V_y}V_y & \frac{\partial P_{xy}^{\varphi}}{\partial \varphi} \end{bmatrix}^k \begin{bmatrix} \Delta\delta_x \\ \Delta\delta_y \\ \frac{\Delta V_x}{V_x} \\ \frac{\Delta V_y}{V_y} \\ \Delta\varphi^{ps} \end{bmatrix}^k \quad (19)$$

Where $\Delta P_{xy}^{\varphi^{ps}} = P_{xy}^{\varphi,reg} - P_{xy}^{\varphi^{ps}}$, is the mismatch equation for active power flow across TCPS and $\Delta\varphi^{ps} = \varphi^{(k+1)} - \varphi^{(k)}$, is the thyristor controlled phase shifter angle incremental change. Superscript k indicates the iteration value.

3 PROCEDURE FOR LOAD FLOW SOLUTION WITH SERIES FACTS DEVICES

The load flow solution procedure with series FACTS devices is summarized as follows.

i) Each series FACTS device is assumed as an individual branch in the present network.
ii) One bus is assigned as a slack bus, and the remaining buses as either (P, V) or (P, Q) buses.
iii) Series FACTS device branches are assigned as (P, Q or V), or (P, I) branches.
iv) Because of the voltage magnitude at (P, V) bus is specified, it is no more addressed as a state variable and in the solution of equations, the shunt reactive power equation for that bus is not counted.
v) Similarly, because of the current magnitude in (P, *I*) branch is specified, it is no more addressed as a state variable and in the solution of equations, the series reactive power (or V) equation for that branch is not counted.
vi) The total number of equations to be solved = 2 × (no. of buses – 1) – (no. of (P, V) buses) + 2 × (no. of series FACTS device branches) – (no. of (P, I) series FACTS device branches). This gives the number of unknown state variables.
vii) The unknown state variables are initialized to supposed values.
viii) Solve the appropriate Jacobian.
ix) In order to find out the correction values of state variables, calculate mismatches and evaluate the linear equation. Based on this correction values, modify the values of the state variables.

x) Check for limit violation if any limit is violated then change the specifications[2] otherwise go to next step.
xi) Check convergence by comparing maximum mismatch with the tolerance (ε). If convergence is achieved then stop the process; otherwise, go to step viii.

4 TEST CASE AND SIMULATION

IEEE 30-bus test network is tested with TCSC, SSSC and TCPS separately, to examine the behavior of these devices in the network. The network necessary data is taken from [14].

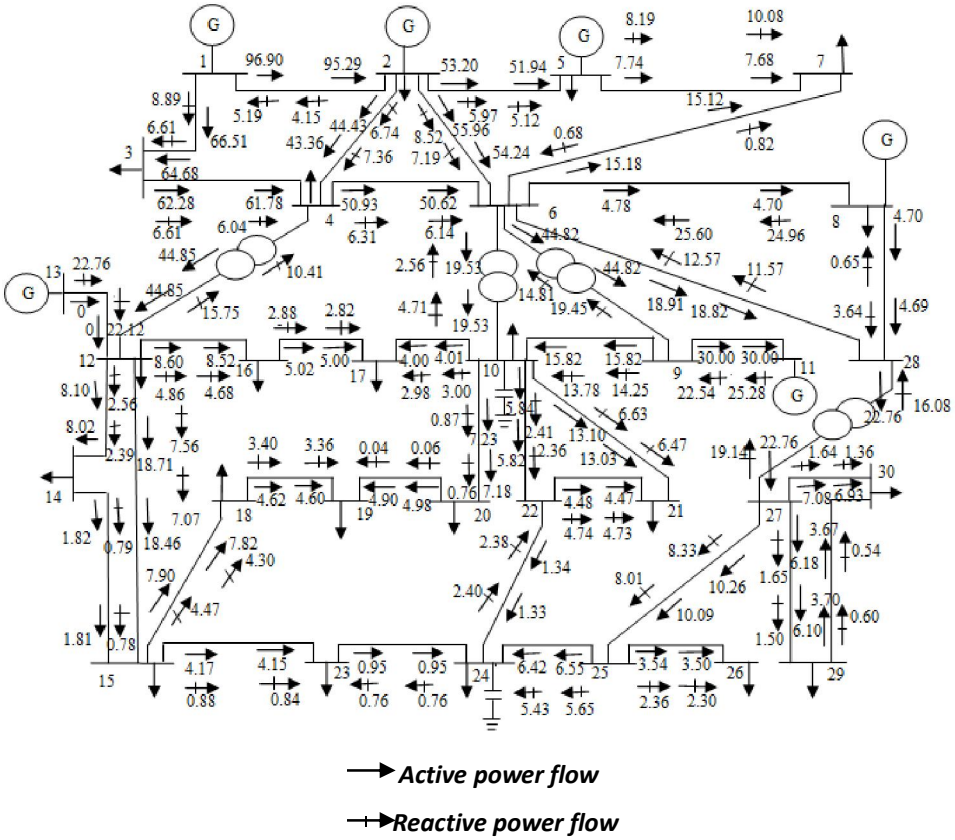

Fig. 5. Line Flow Results under Case 1

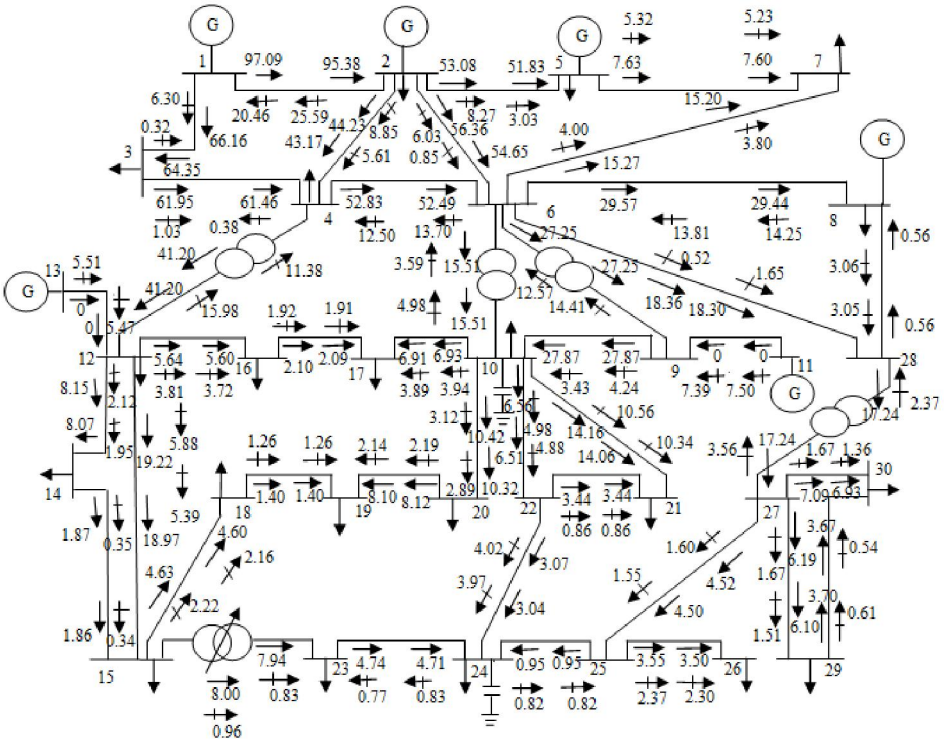

Fig. 6. Line Flow Results under Case 2

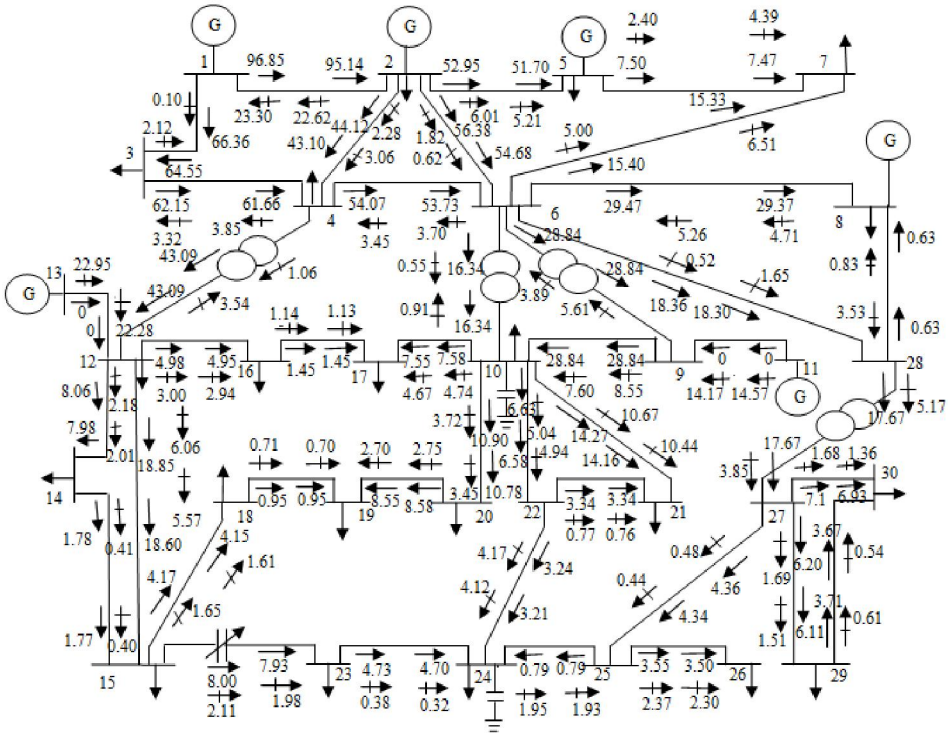

Fig. 7. Line Flow Results under Case 3

Load flow program is carried out on IEEE 30 bus test system for 4 cases. The first case is the conventional load flow case without introducing any FACTS-devices, while the others are modified load flow with FACTS device. In case 2, 3 and 4, transmission line connecting the buses 15 and 23 is installed with TCPS, TCSC and SSSC respectively to achieve the active

power flow at specified value in that line. The extra bus is added to enable the connection of these devices. These devices are used to preserve the real power flow at 8 MW in the line 15-23. Without installing these devices, the power flowing in that line is 4.17 MW, with these the power flow amplifies to 8 MW. The tolerance value is fixed at 0.0001.

In case 1, the convergence is attained within the 19 iterations and the active and reactive power losses are 0.1001 p.u and -0.1178 p.u respectively. The results of line flows are shown in Fig. 5.

In case 2, the voltage phase angle difference between the buses 15 and 23 is increased from -0.4178 to -1.2010 to enhance the active power from 4.17 MW to 8 MW. The result of the phase shifter angle required to achieve the specified active flow through the TCPS is -2.4809. The convergence is attained within the 7 iterations and the active and reactive power losses are 0.0986 p.u and -0.1749 p.u respectively. The results of line flows are shown in Fig. 6.

In case 3, the equivalent reactance of TCSC which is necessary to attain the specified active flow through the TCSC is -0.4430. The convergence is attained within the 8 iterations and the active and reactive power losses are 0.0981 p.u and -0.1639 p.u respectively. The results of line flows are shown in Fig. 7.

In case 4, voltage magnitude and angle of series converter required to achieve the active and reactive power flow at 8 MW and 5 MVAR respectively through the SSSC are 0.0134 p.u and -136.1871 deg respectively. The convergence is attained within the 4 iterations and the active and reactive power losses are 0.0976 p.u and -0.1625 p.u respectively. The results of line flows are shown in Fig. 8.

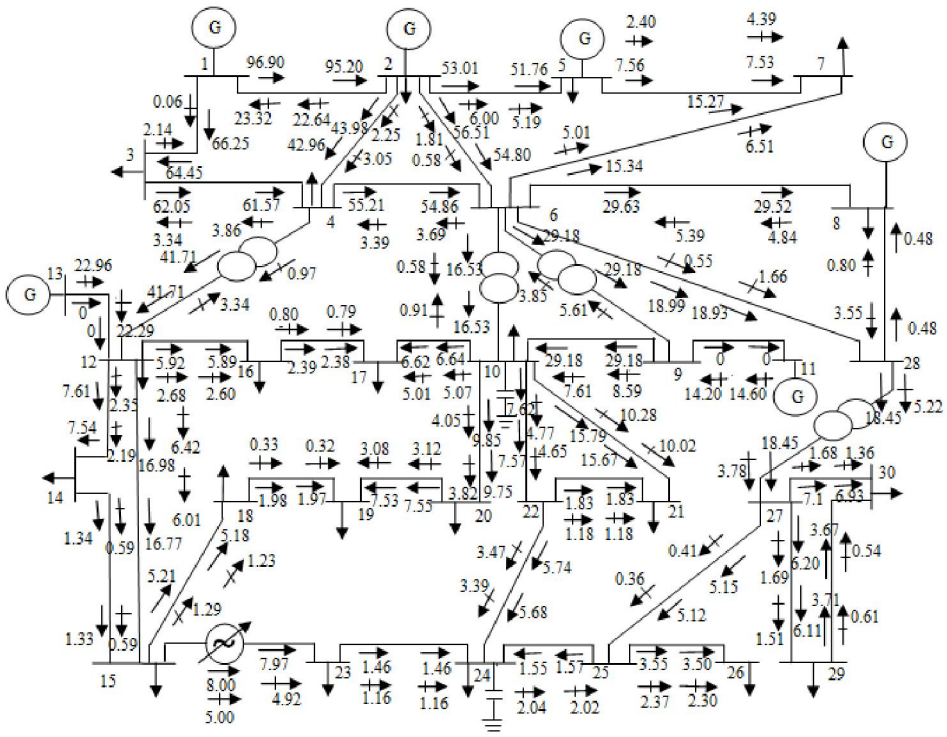

Fig. 8. Line Flow Results under Case 4

The variation of active power losses during each iteration under cases 2, 3 and 4 is shown in Fig. 9. From this figure, it can observe that active power losses in the presence of SSSC is less compared to TCSC and TCPS and also observe that SSSC convergent time is less compared to TCSC, TCPS and base case.

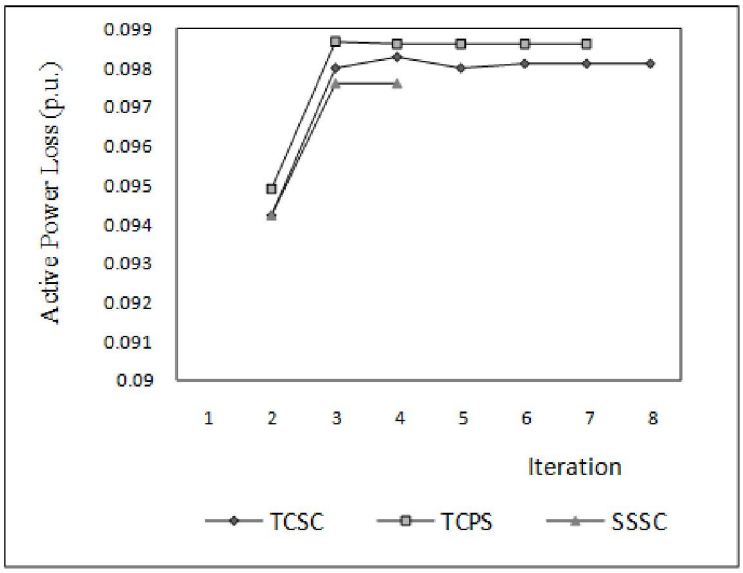

Fig. 9. Active power loss during each iteration under case 2, 3 and 4

5 CONCLUSION

This paper presents the modeling of series FACTS device: TCSC, SSSC, and TCPS suitable for the study of steady state operation of power system. To include FACTS devices: TCSC, SSSC, and TCPS, the base load flow solution is methodically changed. It is revealed that the effect of FACTS controllers on power flow can be provided by adjusting some existing entries and adding new entries in the conventional load flow linearized equation.

The conventional load flow program can simply be altered by using the proposed model in this paper. This proposed model is applied on the standard IEEE 30 bus test system and carried out by using the MATLAB software. The obtained results illustrate the strong convergence of the proposed models. The modeling of TCSC, SSSC, and TCPS are incorporated in NR algorithm and the result demonstrates that SSSC gives better performance compared to both TCSC and TCPS.

REFERENCES

[1] N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, New York: IEEE Press, 2000.

[2] U. P. Mhaskar, A. B. Mote, and A. M. Kulkarni, "A New Formulation for Load Flow Solution of Power Systems With Series FACTS Devices," IEEE Trans. PowerSyst., vol. 18, no. 4, pp. 1307-1315, Nov. 2003.

[3] C. R. Feurte Esquivel and E. Acha, "A Newton-Type Algorithm for the Control of Power Flow in Electrical Power Networks," IEEE Trans. PowerSyst., vol. 12, pp. 1474–1481, Nov. 1997.

[4] M. Noroozian and G. Anderson, "Power Flow Control by Use of Controllable Series Components," IEEE Trans. Power Delivery, vol. 8, pp.1420–1429, July 1993.

[5] D. J. Gotham and G. T. Heydt, "Power Flow Control and Power Flow Studies for System with FACTS Devices," IEEE Trans. Power Syst., vol.13, pp. 60–66, Feb. 1998.

[6] Povh.D, "Modeling of FACTS in Power System Studies," Proc. IEEE Power Eng. Soc. Winter Meeting, pp. 1435–1439, 2000.

[7] C. R. Fuerte-Esquivel, E. Acha, and H. Ambriz-PBrez, "A Thyristor Controlled Series Compensator Model for the Power Flow Solution of Practical Power Networks," IEEE Trans. PowerSyst., vol. 15, no. 1, pp. 58-64, Feb. 2000.

[8] Ramakrishna N, Choppa A.K, Sreekanth. B, "A Real Time Lab Scaled Thyristor Controlled Series Compensation (TCSC) Model for Voltage Regulation Studies," International conference on Energy Efficient Technologies for Sustainability (ICEETS), pp. 1315-1319, 2013.

[9] Metin Dogan, Salih Tosun, Ali Ozturk, and M. Kenan Dosoglu, "Investigation of TCSC and SSSC Controller Effects on the Power System," Electrical and Electronics Engineering (ELECO), 7th International Conference, pp. I-127 - I-131, 2011.

[10] Alireza Seifi, Sasan Gholami, and Amin Shabanpour, "Power Flow Study and Comparison of FACTS: Series (SSSC), Shunt (STATCOM), and Shunt-Series (UPFC)" The Pacific Journal of Science and Technology, vol. 11, no. 1, pp. 129-137, May 2010.

[11] Zhang, X.P, "Advanced Modeling of Multicontrol Functional Static Synchronous Series Compensator (SSSC) in Newton–Raphson Power Flow," IEEE Trans. Power Syst., vol. 18, no. 4, pp.1410–1416, Nov 2003.
[12] Enrique Ache, Claudio R. Fuerte-Esquivel and Hugo Ambriz-Perez, FACTS:Modeling and Simulation in Power Networks, John Wiley & Sons LTD, 2004.
[13] M. R. Iravani and D. Maratukulam, "Review of Semiconductor Controlled (Static) Phase Shifters for Power Systems Applications," IEEE Trans. Power Syst., vol. 9, no. 4, pp.1833-1839, 1994.
[14] Alsac and B. Stott, "Optimal Load Flow with Steady State Security:" IEEE Trans. on Power Apparatus and Systems, vol. PAS-93, pp.745-751, May/June 1974.

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Influence de la composition du milieu et des conditions de culture sur la prolifération *in vitro* de l'hybride de bananier FHIA- 01 (AAAB)

[Influence of the substratum composition and culture conditions on the *in vitro* proliferation of banana hybrid FHIA-01 (AAAB)]

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ABSTRACT: Two essays were carried out to evaluate the effect of different types of auxins on root formation and the influence of dark and culture substratum on tetraploid hybrid FHIA-01 proliferation (Musa spp. AAAB). The plant material consisted of tissue culture plantlets of FHIA -01 hybrid tetraploid banana (Musa AAAB). The trial, with a total of 10 replicates per treatment was carried out in each pot containing five explants. For both tests, a combination of two cytokinins was enriched in culture substratum. The results obtained show that regeneration was high in culture substratum with light than substratum without meta-methoxytopolin riboside (M2). The medium M2 to the light induced a higher number of the buds compared to medium dose reduced meta-methoxytopolin riboside (M1). Meanwhile, only explants inoculated on the medium M1 in the dark induced callus. The bud proliferation, induction of root, leaf and the broadcast callus induction are significantly influenced by the different substratum and photoperiod, increasing the explant size, the number of emerged leaves, roots and the number of the weight of explant with buds proliferated. Formulating specific culture media cultivars

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according to group (ABB or AAA) and the choice of culture conditions (light intensity) would avoid consecutive failures and low proliferation in *in vitro* culture.

KEYWORDS: Banana, *in vitro* culture, plant hormones, photoperiod, banana explants, micropropagation.

RESUME: Deux essais ont été mis en place en vue d'évaluer d'une part les effets de différents types d'auxines sur la rhizogénèse et de l'autre l'influence de l'obscurité et du milieu de culture sur la prolifération de l'hybride tétraploïde FHIA-01 (Musa spp. AAAB). Le matériel végétal était constitué des vitroplants de FHIA-01, hybride tétraploïde du bananier (Musa AAAB). L'essai, avec un total de 10 répétitions par traitement, a été réalisé en pot contenant chacun 5 explants. Pour les deux essais, une combinaison de deux cytokinines a été enrichie au milieu de culture. Les résultats obtenus montrent que pour le milieu de culture, la régénération des bourgeons a été supérieure à la lumière comparativement au milieu sans meta-methoxytopoline riboside (M2). Le milieu M2 à la lumière a induit un nombre de bourgeons supérieur comparativement au milieu à dose réduite de meta-methoxytopoline riboside (M1). Parallèlement, seuls les explants inoculés sur le milieu M1 à l'obscurité, ont induit les cals. La prolifération de bourgeons, l'induction de racines, l'émission foliaire et l'induction de cals sont nettement influencées par les différents milieux et photopériode, en augmentant la taille d'explant, le nombre de feuilles émises, le nombre de racines et le poids d'explant avec les bourgeons proliférés. La formulation des milieux de culture spécifiques aux cultivars selon le groupe (ABB ou AAA, etc.) et le choix des conditions de culture (intensité lumineuse) éviteraient des échecs consécutifs et les faibles proliférations lors de la culture *in vitro*.

MOTS-CLEFS: Bananier, culture *in vitro*, phytohormones, photopériodes, bananier, explants, micropropagation.

1 INTRODUCTION

Les phytohormones, peuvent parfois inhiber l'induction racinaire ou induire un système racinaire de mauvaise qualité, chez une espèce ou cultivar et faire le contraire chez un autre. Par ailleurs, la plupart des plantes montrent une régénération génotypique spécifique liée à l'espèce. A l'intérieur d'une même espèce, un génotype donne des bourgeons tandis qu'un autre ne peut fournir que des embryons [1]. De même, les concentrations de 10 µM à 20 µM BAP ont produit suffisamment de racines chez FHIA-01 [2]. Les résultats de l'étude sur l'effet de l'ajout des cytokinines BAP (10 µM) + MemTR (10 µM) sur la prolifération de l'hybride FHIA-01 ont montré une amélioration de la prolifération de bourgeons tout en inhibant l'enracinement [3]. La culture *in vitro* chez les Musacées est utilisée comme une méthode alternative à la propagation traditionnelle [4]. Depuis 30 décennies maintenant, la propagation du bananier à partir de culture de tissu a connu un essor, à cause de l'aptitude de cette technique à produire du matériel génétiquement uniforme et sain [5]; [6]; [7]; [8]. Mais également, la culture de tissus joue un rôle essentiel dans la distribution du matériel génétique, conservation, échange sécuritaires de matériel de plantation et la distribution rapide des variétés hybrides nouvellement sélectionnées [9]. Néanmoins, quelques cas d'instabilités génétiques ont été rencontrés chez les plantes régénérées à partir de cals, à la suite de subcultures répétées, de culture de protoplastes ou de suspensions cellulaires [10] ; [11]; [12]; [8]. Il s'avère que l'organogénèse directe à partir de méristèmes apicaux serait indiquée pour assurer une prolifération destinée à la production commerciale de vitroplants de bananier et de bananier plantain [8]. En effet, cette voie permet d'obtenir des plantes saines, indemnes de maladies et génétiquement plus stables [13]. Les vitroplants des bananiers obtenus à partir de culture de tissus ont un cycle précoce et un rendement élevé par rapport à ceux issus de la multiplication naturelle [14]; [8].

Beaucoup d'auteurs ont réalisé plusieurs travaux sur la multiplication du bananier à partir d'apex [15]. La stimulation de la multiplication des pousses par la variation du type et de la concentration des régulateurs de croissance et des sources de carbone, ont été rapportées par [16] ; [17] ; [18]; [19]; [20] ; [21]. [22] et [23] ont effectué des incisions sur l'apex de *Musa* afin de stimuler la production en masse de pousses. Par ailleurs, [8] ont évalué l'influence de la formulation vitaminique sur la micropropagation de bananier plantain. D'autres auteurs ont adapté divers types de bioréacteurs ou des systèmes d'immersion temporaire pour augmenter les taux de multiplication des vitroplants de bananiers [24]; [25]; [26].

D'autres encore ont évalué les effets des dérivés de l'Urée diphényle pour propager des cultivars [27]; [28]; [29]; [30]. Mais il n'y a pas eu beaucoup de publications sur l'impact de la photopériode et celle de [8] n'a évalué que l'influence de la photopériode sur les potentialités de la micropropagation du bananier plantain. Or, la culture en l'obscurité permettra d'économiser les coûts d'éclairage et de conditionnement de la salle de culture. La multiplication végétative des hybrides tolérants ou résistants offrirait également un moyen de lutte efficace contre certaines maladies qui constituent une menace

réelle pour la culture bananière en RD Congo et certaines régions du globe. Pour contourner ce problème, une étude a été réalisée avec deux essais dans la perspective d'évaluer l'influence de l'obscurité, de la lumière et du milieu de culture sur la prolifération de l'hybride tétraploïde FHIA-01 (*Musa spp*. AAAB).

2 MATERIELS ET METHODES

Dans cette étude, le matériel végétal utilisé dans les deux essais était constitué des vitroplants de FHIA-01, hybride tétraploïde du bananier (*Musa* AAAB) dont l'étape d'initiation a été réalisée au laboratoire de l'INIBAP à K.U. Leuven en Belgique, indexés pour les virus [17]. Les essais ont été réalisés au laboratoire de Biotechnologie de HogeSchool Gent et au laboratoire de Culture *in vitro* du CARAH à l'HEPH-Condorcet d'Ath en Belgique. Pour les deux essais, une combinaison de deux cytokinines, 10 µM de BAP et 10 µM de MemTR, a été enrichie au milieu de culture. Dans le premier essai réalisé sur l'effet des différentes auxines, les cultures ont été placées sous la température de 27 ± 2ºC, et une photopériode de 16 h pendant 45 jours. Le milieu de culture MS [31] a été utilisé. Les traitements contenaient 1 µM de différentes auxines soit 1µM de AIA, NAA ou IBA, sauf le contrôle qui n'a pas été enrichi en auxine.

Pour évaluer l'influence de la photopériode sur la prolifération des cals, trois milieux de culture (M1, M2, M3) ont été élaborés (Tableau 1). Chaque milieu M1, M2 ou M3, a été testé à l'obscurité totale et à la lumière sous une intensité lumineuse continue de 50 $\mu E.m^{-2}.S^{-1}$ tel que recommandé par [12]. L'ensemble de l'essai a été placé dans la chambre de culture Binder à 27°C, pour évaluer la prolifération de FHIA-01. Dans les deux essais, les racines ainsi que les feuilles des explants initiaux ont été enlevées et les explants ont été coupés à 0,5 cm au-dessus du méristème apical. La vérification des bactéries à croissance lente était réalisée selon la méthode décrite par [32]. Bien que n'intervenant généralement pas dans la multiplication *in vitro* des pousses, les bactéries peuvent être problématiques dans les stades ultérieurs [12]. Pour les deux essais, un total de 10 répétitions par traitement a été réalisé et 100 ml de milieu de culture par pot en raison de 5 explants inoculés. Au bout de 45 jours, les observations ont été réalisées sur les paramètres suivant : le nombre de cals induits, de bourgeons, de feuilles, de racines et la taille de l'explant initial.

Tableau 1. Composition de différents milieux de culture

Composition	Milieu 1	Milieu 2	Milieu 3
Eau UP (ml)	1000	1000	1000
MS MS macro, micro + vitamines (Duchefa) (g)	4,405	4,405	4,405
Acide ascorbique (mg)	10	10	10
BAP (µM)	10	10	20
MemTR (µM)	10	-	20
AIA (mg)	0,175	0,175	0,175
$CuSO_4.5H_20$ $CoCl_2.6H_2O$ (µl)	50	100	150
Sucrose	40	40	40
Gelrite pH 5.8	3	3	3

Les observations ont porté sur les paramètres de croissance et de développement (nombre de bourgeons, le nombre de feuilles, la taille de vitroplants, l'induction racinaire et le poids des explants et le nombre de cals) et les données obtenues ont été soumises à une analyse de la variance (ANOVA), à l'aide du logiciel SPSS. En cas de différences significatives, la comparaison des moyennes était réalisée par le test de Newman-Keuls au seuil 5 %. Des corrélations (Corrélation de Pearson) ont été également réalisées entre les paramètres étudiés.

3 RESULTATS

3.1 EFFETS DES AUXINES IAA, IBA ET NAA SUR LA PROLIFERATION DE L'HYBRIDE FHIA-01 (AAAB) DU BANANIER EN CULTURE *IN VITRO*

La Figure 1 présente l'évolution du nombre de bourgeons induits après 45 jours de prolifération de l'hybride FHIA-01 du bananier en culture *in vitro*. La comparaison de différentes auxines par rapport au nombre de bourgeons formés pendant la phase de prolifération a montré des différences significatives (p=0,03). Il a été constaté que l'ajout de l'acide indole acétique dans le milieu MS [31] a induit le nombre de bougeons supérieur comparativement aux deux autres auxines (IBA et NAA). Les

valeurs moyennes étaient respectivement de 4,7 ± 3,3 (a); 2,2 ± 1,6 (b); 2 ± 2,1 (b) et 3,1 ± 1,4 (ab) pour AIA, AIB, NAA et contrôle.

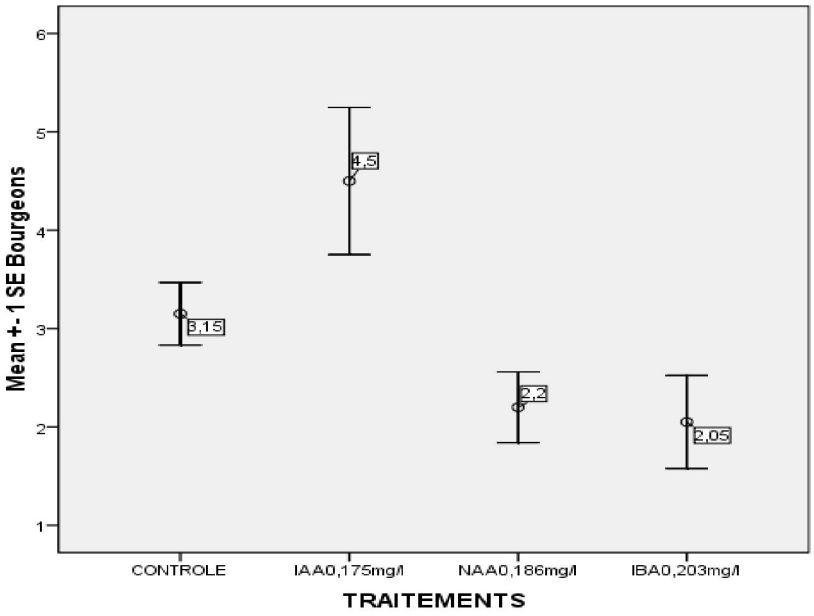

Fig. 1. Effets des auxines IAA, IBA ET NAA, sur le nombre de bourgeons proliférés

Une différence significative a été constatée entre les différentes auxines en ce qui concerne l'émission foliaire (p<0,05). Il ressort de cet essai que l'ajout de l'acide naphtalène acétique dans les milieux MS [31] était favorable à l'émission foliaire que les autres auxines (IBA et IAA). Les valeurs moyennes étaient respectivement de 4,9 ± 1,4 (a); 3,6 ± 1,8 (ab); 2,5 ± 2 (b) et 4,4 ± 0,9 (a) pour NAA, AIB, AIA et le contrôle (figure 2).

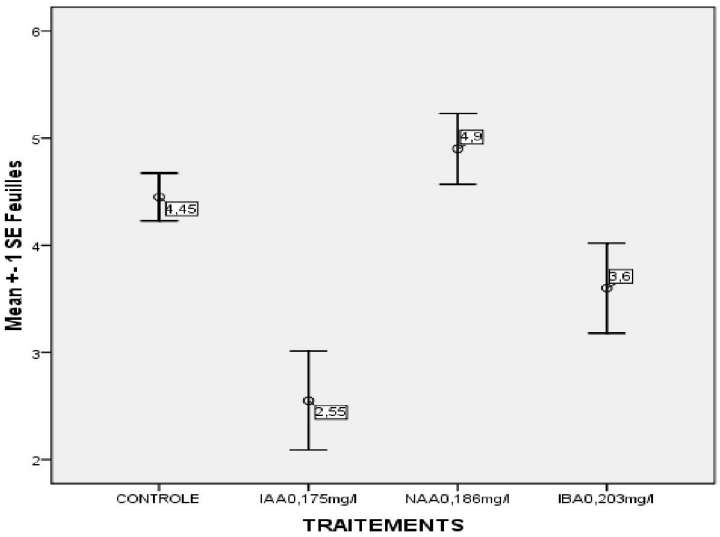

Fig. 2. Effets des auxines IAA, IBA ET NAA, sur le nombre de feuilles

La Figure 3 présente l'évolution de l'induction racinaire après 45 jours dans le milieu de prolifération. Une différence significative était constatée entre les différentes auxines en ce qui concerne l'induction racinaire (p=0,030). Il ressort de cet essai que l'ajout de l'acide naphtalène acétique dans les milieux MS [31] était favorable à l'induction racinaire que les autres

auxines (IAA). Les valeurs moyennes étaient respectivement de 4,8±1,3(a) ; 4,2±3 (ab) ; 2,8±2(b) et 4,9±2,5(a) pour NAA, AIB, AIA et contrôle. Les corrélations entre les différents paramètres sont reprises dans le tableau 2.

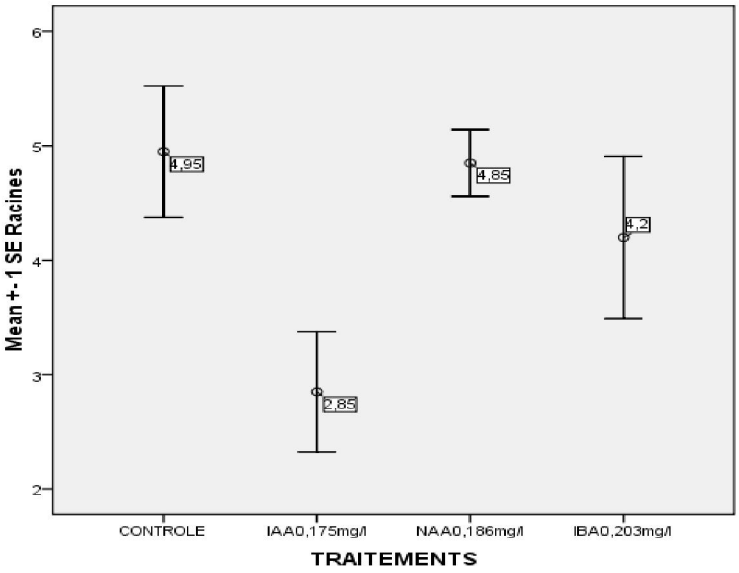

Fig. 3. Effets des auxines IAA, IBA ET NAA, sur l'induction racinaire

Il ressort du tableau 2 que la taille d'explant, nombre de feuilles émises, nombre de racines et le poids d'explants révèlent des corrélations négativement significatives avec les bourgeons qui prolifèrent. Par contre, les autres paramètres ont montré des corrélations positives significatives.

Tableau 2. Corrélations des différents paramètres de croissance et de développement

		Bourgeons	Feuilles	Taille	Racines	Poids
Bourgeons	Corrélation de Pearson	1	-,663**	-,273*	-,585**	-,557**
	Sig. (bilatérale)		,000	,014	,000	,000
	N	80	80	80	80	80
Feuilles	Corrélation de Pearson	-,663**	1	,445**	,714**	,474**
	Sig. (bilatérale)	,000		,000	,000	,000
	N	80	80	80	80	80
Taille	Corrélation de Pearson	-,273*	,445**	1	,367**	,328**
	Sig. (bilatérale)	,014	,000		,001	,003
	N	80	80	80	80	80
Racines	Corrélation de Pearson	-,585**	,714**	,367**	1	,444**
	Sig. (bilatérale)	,000	,000	,001		,000
	N	80	80	80	80	80
Poids	Corrélation de Pearson	-,557**	,474**	,328**	,444**	1
	Sig. (bilatérale)	,000	,000	,003	,000	
	N	80	80	80	80	80

**. La corrélation est significative au niveau 0.05 (bilatéral).*
***. La corrélation est significative au niveau 0.01 (bilatéral).*

3.2 EFFETS DE LA PHOTOPERIODE ET DES MILIEUX DE CULTURE SUR LA PROLIFERATION FHIA-01

L'analyse statistique n'a pas révélé des différences significatives de régénération des bourgeons en fonction des milieux et des conditions de culture considérées séparément ($p > 0,05$).

Cependant une différence significative était observée en terme d'interaction entre les deux facteurs étudiés ($p = 0,009$). Il a été constaté que la combinaison de M1 et lumière ainsi que M2 et obscurité avaient induit plus de bourgeons comparativement aux autres. Les valeurs moyennes d'interaction étaient de 4,9 ± 2,6 (a); 3,5 ± 2 (ab); 2,3 ± 0,8 (b); 2,5 ± 1,4 (b); 2,3 ± 2,2 (b); 2,2 ± 2 (b) (Figure 4).

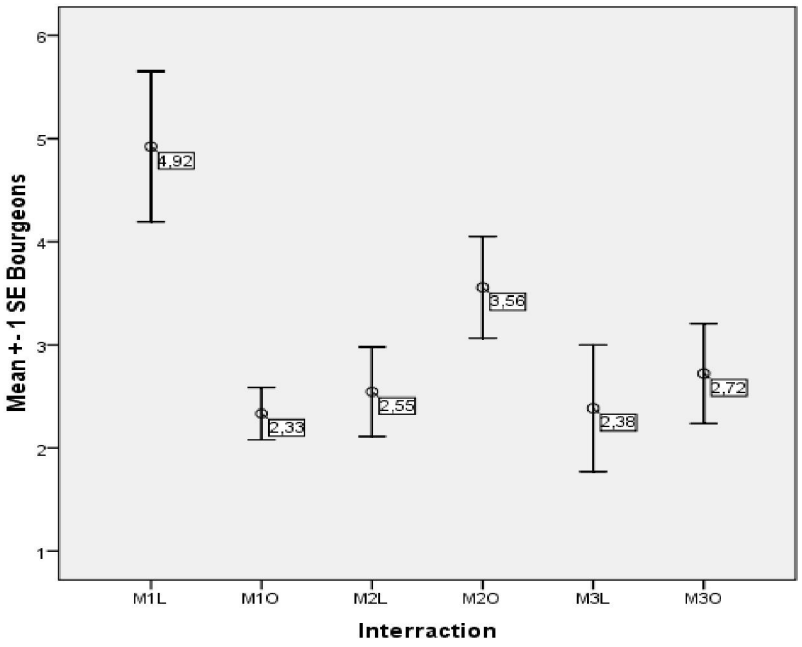

Fig. 4. Influence simultanée de F1 M1 sur le nombre de bourgeons. M1L = Milieu 1 à la lumière, M1O = milieu 2 à l'obscurité, M2L = milieu 2 à la lumière, M2O = milieu 2 à l'obscurité, M3L = milieu 3 à la lumière, M3O = milieu 3 à l'obscurité

Une différence significative a été observée entre les vitroplants dans les trois milieux de culture ; alors que la lumière accroit l'émission foliaire chez le vitroplants ($p < 0,05$). Les valeurs moyennes pour les milieux étaient respectivement de 0,15 ± 0,65 (c), 1,02 ± 1,1 (b), 2,1 ± 1,05 (a). La présence de la lumière avait présenté une moyenne de 1,33 ± 1,2 (a) et l'obscurité 0,85 ± 0,15 (b) (Figure 5).

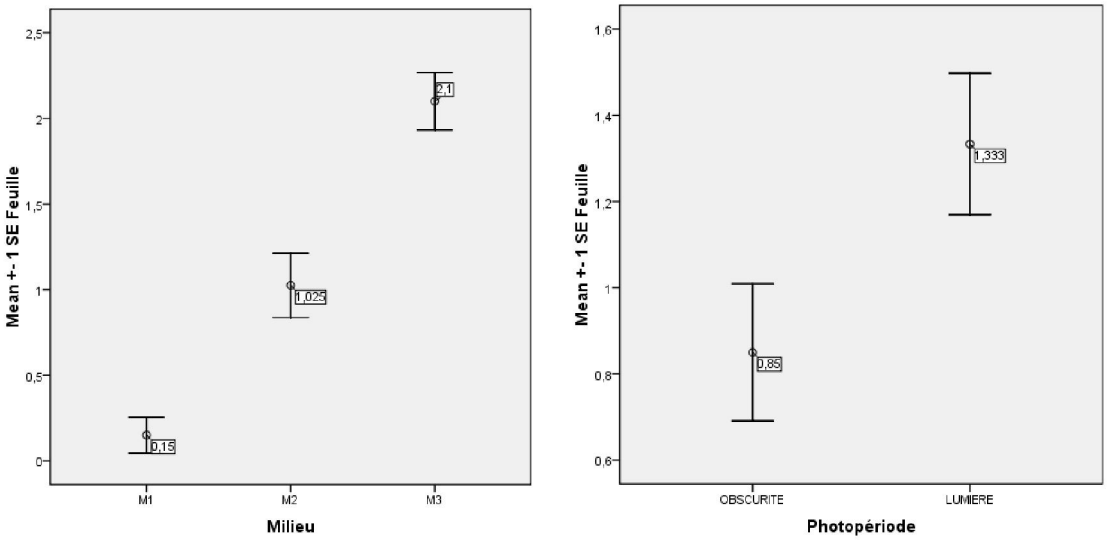

Fig. 5. Influence séparée de milieu et la photopériode sur l'émission foliaire

Une différence significative était observée en termes d'interaction entre les deux facteurs étudiés ($p < 0,05$). Il a été constaté que la combinaison de M3 dans les deux conditions et M2 à l'obscurité avait induit plus de feuilles comparativement aux autres. Les valeurs moyennes d'interaction étaient de 0 (b); 0,3 ± 0,9 (b); 0,2 ± 0,6 (b); 1,8 ± 1,1(a); 2,3 ± 0,9 (a); 1,9 ± 1,1 (a) respectivement pour M1L, M1O, M2L, M2O, M3L et M3O (Figure 6).

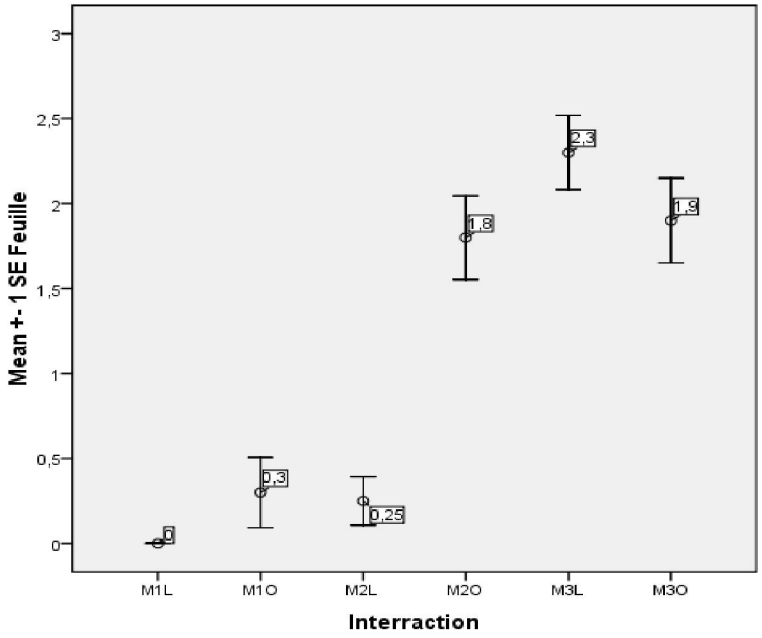

Fig. 6. Influence simultanée de milieu et de la photopériode sur les bourgeons

L'analyse statistique n'a pas révélé des différences d'induction racinaire en fonction des milieux et des conditions de culture considérés séparément ($p > 0,05$). En revanche, une différence significative a été observée en termes d'interaction entre les deux facteurs étudiés ($p < 0,05$). Il a été constaté que la combinaison de M1 et l'obscurité ainsi que M2 et lumière avait induit plus de racines comparativement aux autres. Les valeurs moyennes d'interaction étaient de 0,3 ± 0,9 (b); 1,5 ± 1,5 (a); 1,6 ± 1,8 (a); 0,3 ± 0,8 (b); 0,3 ± 0,5 (b); 0,7 ± 1,3 (ab) (Figure 7).

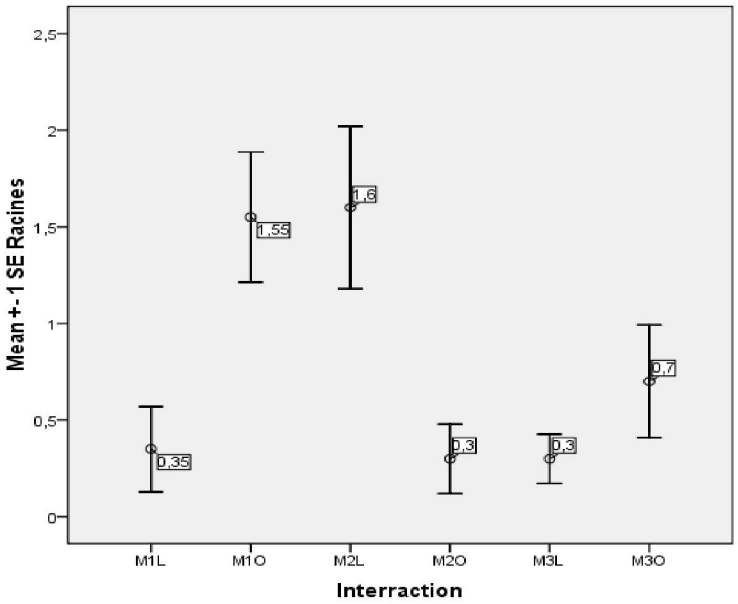

Fig. 7. Influence simultanée de milieu et de la photopériode sur l'induction racinaire

Les résultats sur l'induction de la calogénèse montrent que seul le milieu M1 a donné une réponse positive, avec une moyenne de 0,75 ± 0,42. Par ailleurs, en termes d'interactions, seul le milieu M1 avait induit les cals soit 1,5 ± 0,8. Par ailleurs, il ressort du tableau 3 qui démontre des corrélations négatives nettement significatives entre la taille d'explant, nombre de feuilles émises, nombre de racines, le poids d'explant avec les bourgeons proliférés. Par ailleurs, les corrélations positives significatives entre les autres paramètres ont été enregistrées à l'exception du nombre de bourgeons.

Tableau 3. Corrélations des paramètres de croissance et de développement en réponse aux milieux de culture et à la photopériode

		Bourgeon	Racines	taille	Feuille	Cals
Bourgeon	Corrélation de Pearson	1	-,214*	-,060	-,131	,170
	Sig. (bilatérale)		,049	,587	,232	,119
	N	85	85	85	85	85
Racines	Corrélation de Pearson	-,214*	1	,533**	-,082	-,095
	Sig. (bilatérale)	,049		,000	,372	,301
	N	85	120	120	120	120
Taille	Corrélation de Pearson	-,060	,533**	1	-,022	-,102
	Sig. (bilatérale)	,587	,000		,810	,268
	N	85	120	120	120	120
Feuille	Corrélation de Pearson	-,131	-,082	-,022	1	-,138
	Sig. (bilatérale)	,232	,372	,810		,132
	N	85	120	120	120	120
Cals	Corrélation de Pearson	,170	-,095	-,102	-,138	1
	Sig. (bilatérale)	,119	,301	,268	,132	
	N	85	120	120	120	120

**. La corrélation est significative au niveau 0.05 (bilatéral).*
***. La corrélation est significative au niveau*

En analyse multivariée (analyse discriminante), il a été constaté que la prolifération de bourgeons, l'induction de racines, l'émission foliaire et l'induction de cals étaient significativement influencées par les différents milieux et photopériode avant classement (Tableau 4).

Tableau 4. Résultats de l'analyse multivariée avant classement des effets des milieux et de la photopériode sur la rhizogénèse

	Traitements						
Paramètres	**M1L**	**M1O**	**M2L**	**M2O**	**M3L**	**M3O**	**Valeurs de p**
Bourgeons	4,9±2,6	2,3±0,8	2,5±1,4	3,5±2	2,3±2,2	2,7±2	<0,05
Racines	0±0	1,3±1,5	1,5±1,8	0,2±0,7	0,2±0,5	0,7±1,3	<0,05
Taille	1,9±1	2,3±1,3	1,7±1	1,8±0,7	0,9±0,7	2,7±0,5	<0,615
Feuilles	0±0	0,08±0,02	0,2±0,6	1,8±1,1	2±1	1,9±1,1	<0,05
Cals	2,3±4,3	0±0	0±0	0±0	0±0	0±0	<0,05
Classement (%)	40	55	40	35	55	20	

De l'analyse multivariée (analyse discriminante), il a été constaté que, après classement, tous les paramètres (prolifération de bourgeons, induction de racines, émission foliaire, induction de cals et taille d'explant) sont devenus significatifs avec des moyennes appropriées à chaque traitement (Tableau 5).

Tableau 5. Résultats de l'analyse multivariée après classement des effets des milieux et de la photopériode sur la rhizogénèse

	Traitements						
Paramètres	**M1L**	**M1O**	**M2L**	**M2O**	**M3L**	**M3O**	**Valeurs de p**
Bourgeons	6,6±2	0,3±1	2,5±1	5,1±2,1	1,8±0,7	2,5±2	<0,05
Racines	0, ±0	0,6±1,2	1,5±1,7	0±0	0,4±0,2	2,6±0,8	<0,05
Taille	1,8±0,9	2,4±1,3	1,4±0,6	1,8±0,5	2±0,5	2,6±0,7	<0,05
Feuilles	0±0	0,05±0,02	0,2±0,5	1,9±0,9	2,2±0,6	3±0,8	<0,05
Cals	3±4,2	0±0	0±0	0±0	0±0	0±0	<0,05
Classement (%)	80	94	63	50	100	72	

Le pourcentage de « bien classé » avant classement était de : 40%, 55%, 40%, 35%, et 20%. Après amélioration du classement le pourcentage est passé à 80%, 94, 63% 50% 100% et 72%. Illustrant une séparation nette entre les barycentres de chaque traitement (Figure 8).

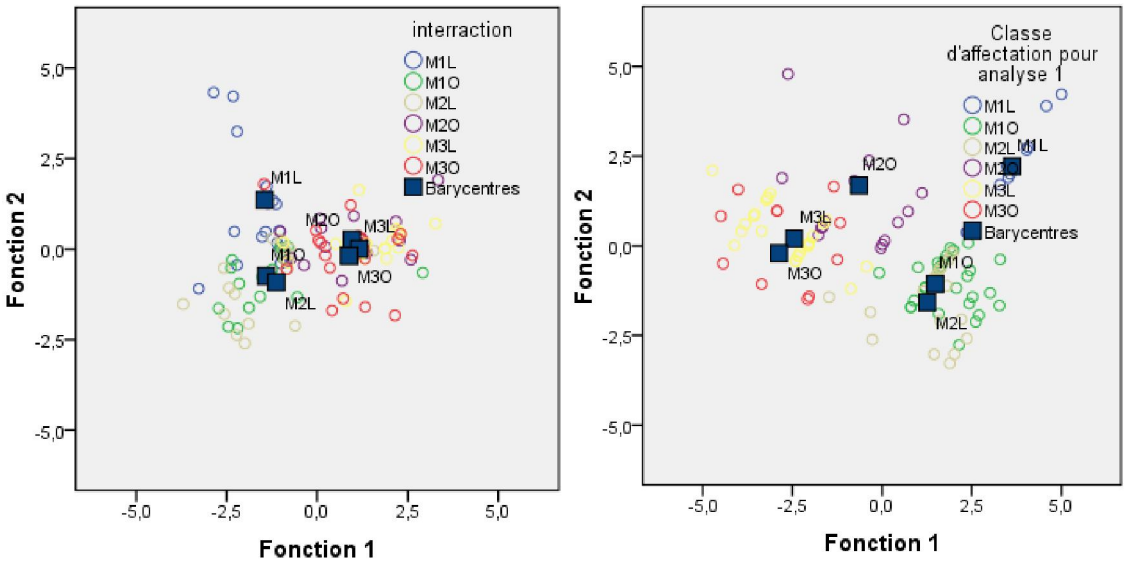

Fig. 8. Fonctions discriminantes canoniques de l'évolution moyenne de croissance et de développement des vitroplants de bananier sous différents milieux de culture et photopériode

4 DISCUSSIONS

L'analyse statistique a révélé une différence de régénération des bourgeons en fonction des conditions de culture (obscurité ou lumière) et du milieu de culture. Pour le milieu de culture (M1), la régénération des bourgeons obtenue de l'hybride FHIA-01 a été supérieure à la lumière comparativement au milieu M2. La production efficiente des pousses *in vitro* a fait l'objet de nombreuses études chez les monocotylédones et les dicotylédones [33] ; [34] ; [35]. Tous les systèmes de régénération semblent avoir en commun une première période de prolifération des méristèmes axillaires qui est caractérisé par un taux relativement faible de multiplication des pousses [8]. Cette situation peut également être attribuée à la faible capacité de prolifération du matériel végétal utilisé (FHIA-01, AAAB). Par ailleurs, cette situation peut changer pour les cultivars à fort potentiel de prolifération, la plupart appartenant au groupe ABB [36].

Le milieu M2 à la lumière a induit un nombre de bourgeons supérieur comparativement au milieu M1. Les mêmes résultats ont été obtenus par [8], qui ont enregistré une forte induction de bourgeons axillaires à la photopériode 12 heures. La régénération des bourgeons dépend non seulement des formulations vitaminiques auxquelles les explants sont soumis, mais aussi de la photopériode [8]. La différence du nombre de bourgeons obtenu avec le milieu M2 comparativement au milieu M1, peut s'expliquer par la différence de sa composition en phytohormone et de la concentration des phytohormones du milieu. La stimulation de la multiplication des pousses est souvent fonction de la variation du type de phytohormones, de la concentration des phytohormones et des sources de carbone [37].

Le milieu M2 à l'obscurité a induit un nombre des racines statistiquement supérieur comparativement à M1 et M3. [8] ont enregistré un taux d'enracinement élevé sur les milieux enrichis avec les vitamines MS et placés 2 semaines à l'obscurité avant de subir une photopériode de 12 heures ; mais ils n'ont pas atteint 80 % du taux d'enracinement. L'apparition des racines est plus rapide à l'obscurité qu'à la lumière. L'auxine endogène produit par la plante pourrait être plus active lorsque les plantules séjournent à l'obscurité [8]. En effet, l'obscurité permet une meilleure qualité de l'enracinement [38]. Les explants ont présenté à leur base des touffes de petites pousses et de plantules enracinées sans formation de méristèmes à la base de l'explant. Ceci est la caractéristique des cultivars à potentiel de prolifération faible [11].

Dans cet essai, l'induction des cals a été faible et seuls les explants inoculés sur le milieu M1 à l'obscurité, ont induit les cals. L'obscurité limite l'oxydation des composés phénoliques et optimise l'expression des phytohormones. Ceci impliquerait que l'obscurité réduirait la dominance apicale de la pousse primaire et favoriserait par conséquent la prolifération du tissu méristématique [8]. Les bourgeons axillaires ont été observés à la base de l'explant initial au détriment des bourgeons adventifs. Cependant, la formation des bourgeons, solliciterait deux champs morphogénétiques. Il existerait alors, suivant les variétés, un champ internodal (au niveau du "V" formé par les marges d'une gaine foliaire) et un champ nodal (à l'intérieur ou sur toute la largeur du nœud d'une feuille axillaire) [8]. Ces champs sont latents ou actifs pendant la vie de la plante et selon les variétés [39].

Il a été observé dans cette étude, des formations globulaires ayant un aspect blanchâtre à l'obscurité et jaune-verdâtre à la lumière. Les globules sphériques, des structures blanchâtres (à l'obscurité) et jaune verdâtre (à la lumière) ont déjà été décrits par [8] ; [18]. Les bourgeons axillaires ont été observés à la base de l'explant initial au détriment des bourgeons adventifs. D'après les observations de [39], les différences observées sur un même type d'explant seraient liées au site de formation du bourgeon d'une part, à l'exploitation variable de leurs potentialités morphogénétiques en culture *in vitro*, plus précisément à l'AGMA (Activité Globale du Méristème Apical). D'autre part, ces différences observées sur un même type d'explant seraient dues à l'absence d'une synchronisation de ce processus (l'AGMA). Les résultats similaires ont été signalés par [40]; [22]; [39]; [8]. Les sites morphogènes de formation des bourgeons seraient activés ou mis en dormance selon que l'explant soit ou non dans des conditions favorables qui pourraient déclencher la formation des bourgeons [8]. Par ailleurs, dans l'essai de l'évaluation des effets des auxines, il a été observé la présence de cals à la base de l'explant. Les observations similaires ont été faites par [41] ; [42]. L'AIA a souvent donné de faibles pourcentages d'enracinement, surtout quant elle est employée à de faibles concentrations, que ce soit avec le bananier, l'Artichaud [43], [42] ou avec d'autres espèces [44]. Plus on augmente la concentration exogène en obscurité, plus on stimule l'induction de racines, moins on favorise la formation de bourgeons [45]. Le nombre de racines par pousse enracinée est directement proportionnel à la concentration d'ANA dans le milieu de culture [46]. De même, une fréquence plus élevée de l'induction racinaire a été obtenue avec la combinaison AIB et NAA. La réponse de l'AIB à l'induction de racines obtenues dans cette étude serait due à la grande stabilité de l'AIB. L'AIB a une grande capacité pour activer l'enracinement chez plusieurs espèces [47] ; [48]. Cette auxine (AIB) a la capacité de se convertir en AIA [49] ; et aboutir dans les tissus à la formation de l'AIBsp (AIB-acide aspartique). Elle active l'enracinement mieux que l'AIA [50].

5 CONCLUSION

De ces trois auxines évaluées (AIA, AIB et ANA), l'AIA a un effet positif sur la formation de bourgeon. L'AIA réduit le nombre de racines et l'émission foliaire par explant en phase de prolifération de FHIA-01. L'ANA et l'AIB s'avèrent peu efficaces en ce qui concerne la formation de bourgeon. Dans cette étude, l'ANA et l'AIB induisent un nombre important de racines. Au cours de cette étude, il a été observé la formation des structures bulbeuses (cal non conforme) à la base de l'explant suite à l'ajout de l'ANA dans le milieu de culture.

Les milieux ensemencés devront être incubés en salle de culture à l'obscurité continue et la température fixée à 27 ± 1°C, jusqu'à la dernière phase de multiplication. Au cours de la phase de multiplication de FHIA-01, les explants doivent être ensemencés sur un milieu (M1), MS.

Il a été constaté que la prolifération de bourgeons, l'induction de racines, l'émission foliaire et l'induction de cals étaient significativement influencées par les différents milieux et photopériode qui a démontré des corrélations négatives nettement significatives entre la taille d'explant, nombre de feuilles émises, nombre de racines, le poids d'explant avec les bourgeons proliférés. Par ailleurs, les corrélations positives significatives entre les autres paramètres ont été enregistrées à l'exception du nombre de bourgeons.

La culture *in vitro* de bananier et plantain reste un challenge pour les pays tropicaux en développement où les problèmes des attaques des maladies de culture et de la sécurité alimentaire se posent avec acuité. La formulation des milieux de

culture spécifiques aux cultivars selon le groupe (ABB ou AAA, etc.) et le choix des conditions de culture (intensité lumineuse continue ou photopériode) éviteraient des échecs consécutifs et les faibles proliférations lors de la culture *in vitro*.

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REFERENCES

[1] R. Auge, G. Beauchesne, D. Boccon –Gibo, L. Decoutye, B. Digat, R. Jalouzot, R. Minier, C.L. Morand, J.P. Reynoird, G. Strullud, H. Vidalie, La culture *in-vitro* et ses application horticoles. *Ed Lavoisier*, Paris, p 225, 1989

[2] J. Dewitte, Growth and micropropagation of new banana varieties adapted to the agro-ecological conditions of Lubumbashi. *Hogeschool Gent, Master thesis*, p 145, 2008.

[3] K.M. Mazinga, G.J. Mario, L.L. Baboy, S.Y. Useni, M. Van Koninckxloo, Détermination des teneurs en phytohormones endogènes des organes caulinaires et racinaires des hybrides de bananier (Musa sp.). *Journal of Applied Biosciences* vol 58 pp 4243– 4250, 2012

[4] J.C. Robinson, Bananas and Plantain. *CAB International*, Cambridge, 1996.

[5] D.R. Vuylsteke, Shoot-tip culture for the propagation, conservation and exchange of Musa germplasm, Pratical manuals for handing crop germoplasm *in vitro*. *Int. Board Plant Genet. Resour*. (IBPGR), Rome, Italy, p55, 1989.

[6] J. Daniells, M. Smith, Post-flask management of tissue cultured bananas. *ACIAR technical report.* p 8, 1991.

[7] O. Arias, Commercial micropropagation of banana. In: Biotechnology Applications for Banana and Plantain Improvement. *Inibap, San Jose*, Costa Rica. pp. 139-142, 1992.

[8] T. Koné, M. Koné, D. Koné, T.H. Kouakou, S. Traoré, Y.J. Koudio, Effet de la photopériode et des vitamines sur la micropropagation du bananier plantain (*Musa* AAB) à partir de rejets écailles de rang1. *Journal of Applied Biosciences* vol 26: 1675 –1686, 2010.

[9] H. Gübbük, M. Pekmezci, *In vitro* Propagation of Some New Banana Types (Musa spp.), *Turk. J. Agric. For.* vol 28, pp355-361, 2004.

[10] A. Assani, R. Haicour, G. Wengel, B. Foroughi-Wehr, F. Bakry, F.X. Côte, G. Ducreux, A. Ambroise, A. Grapin, Influence of donor material and genotype on protoplast regeneration in banana and plantain cultivars (Musa spp.) *Plant Science* vol 162, pp 355-362, 2002.

[11] H. Strosse, H. Schoofs, B. Panis, E. Andre, K. Reyniers, R. Swennen, 2006. Development of embryogenic cell suspensions from shoot meristematic tissue in bananas and plantains (*Musa spp*.). *Plant Sci* vol 170 pp104–112, 2002.

[12] H. Strosse, E. Andre, L. Ságí, R. Swennen, B. Panis, Adventitious shoot formation is not inherent to micropropagation of banana as it is in maize. *Plant Cell Tiss Organ Cult* vol 95, pp321–332, 2008.

[13] R. Afza, M. Van Duren, R. Morpurgo, F.J. Novak, Banana tissue culture and its prospective use in developing countries. Pp. 58-70, 1996. In *Plant Tissue Culture* (A.S. Islam, ed.). Oxford et IBH Publishing Co. Pvt. Ltd. New Delhi/ Calcutta [Online] Available: www.springerlink.com/index/606160V880U823R2.pdf

[14] B.A. Adelaja, Rapid on-farm multiplication technique for plantain and banana. *MusAfrica* vol 8, pp 6-10, 1995.

[15] T.R. Ganapathi, J.S.S. Mohan, P. Suprasanna, V.A. Bapat, P.S. Rao, A low-cost strategy for *in vitro* propagation of banana. *Current Science* vol 68, pp 646-649, 1995.

[16] S.R. Dore, N.K.R. Srinivasa, E.K. Chacko, Tissue culture propagation of banana. *Scientia Horticulturae* vol 18, pp 247-252, 1983.

[17] M. Diekmann, C.A.J. Putter, FAO/IPGRI Technical guidelines for the safe movement of germplasm. No.15. Musa. 2 edition. Food and Agriculture Organization of the United Nations, Rome/International Plant Genetic Resources Institute, Rome. p29, 1996.

[18] D. Vuylsteke, E. De Langhe, Feasibility of *in vitro* propagation of bananas and plantains. *Trop. Agric*. Vol 62 n°4, pp323-328, 1985.

[19] W.C. Wong, *In vitro* propagation of banana (*Musa spp*.): initiation, proliferation and development of shoot tip cultures on defined media. *Plant Cell, Tissue and Organ Culture*. Vol 6, pp159-166, 1986.

[20] P. Madhulatha, S. Kirubaram, N. Zakihivel, Effects of carbon-sources and auxins on *in vitro* propagation of banana. *Biologia Plantarum* vol 50 n°4, pp782-784, 2006.

[21] W.B. Michael, W.F. Catherine, J. Van Staden, The effect of plant growth regulators on somaclonal variation in cavendish banana (*Musa* AAA cv. "zelig"), *Scientia Horticultuae* vol 108, pp 347-351, 2006.
[22] F.J. Novak, R. Afza, M. Van Duren, M.S. Omar, Mutation induction by gamma irradiation of *in vitro* cultured shoot tips of banana and plantain (*Musa* cvs). *Trop. Agric*. Vol 67, pp 21-28, 1990.
[23] E.N.A. Mbanaso, J. Crouch, F. Onofeghara, Effet de fragmentation et de l'incision sur la culture d'apex de différents génotypes de bananiers à cuire. *Info Musa* vol 15 n°2, pp 30-32, 2006.
[24] J.C. Lorenzo, B.L. Gonzales, M. Escalona, C. Teisson, P. Espinosa, C. Borroto, Sugarcane shoot formation in an improved temporary immersion system. *Plant Cell, Tissue Organ Culture* vol 54 n°3, pp197-200, 1998.
[25] H. Etienne, M. Berthouly, 2002. Temporary immersion systems in plant micropropagation. *Plant Cell, Tissue and Organ Culture* 69: 215-231.
[26] K. Matsumoto, A.C.B. Kaizer, Comparaison des systèmes d'immersion temporaire et permanente pour la culture *in vitro* du bananier. *Info Musa* vol 11 n°2, pp 36-37, 2002.
[27] M. Sarwar, R.M. Skirvin, M. Kushad, M.A. Norton, Selecting dwarf apple (*Malus* X *Domestica Borkh*.) three *in vitro*: multiple cytokinin tolerance expressed among three strains of ÔMcIntoshÕ that differ in their growth habit under field conditions. *Plant Cell, Tissue and Organ Culture*. Vol 54, pp71-76, 1998.
[28] P.J. Ainsley, F.A. Hammerschlag, T. Bertozz, G.G. Collins, M. Sedgley, Regeneration of almond from immature seed cotyledons. *Plant Cell, Tissue and Organ Culture.* Vol 67, pp 221-226, 2001.
[29] M.V. Joshi, N.A. Sahasrabudhe, S. Hazra, 2003. Responses of peanut somatic embryos to thidiazuron. *Biologia Plantarum*. Vol 46 n°2, pp 187-192, 2001.
[30] M. Kadota, Y. Niimi, Effects of cytokinin types and their concentrations on shoot proliferation and hyperhydricity *in vitro* pear cultivar shoots. *Plant Cell, Tissue and Organ Culture*. Vol 72, pp 261-265, 2003.
[31] T. Murashige, F. Skoog, A revised medium for rapid growth and bioassay with tobacco tissue culture. *Physiol. Plant*, vol 15, pp 473-492, 1962.
[32] I. Van den Houwe, J. Guns, R. Swennen, Bacterial contamination in *Musa* shoot tip cultures, *Acta Hort*. Vol 490, pp 485-492, 1998.
[33] N.K. Konan, C. Schöpke, R. Cárcamo, R.N. Beachy, C. Fauquet, An efficient mass propagation system for cassava (*Manihot esculenta* Crantz) based on nodal explants and axillary bud-derived meristems. *Plant Cell Rep* vol 16, pp 444–449, 1997.
[34] M. Srivatanakul, S.H. Park, J.R. Sanders, M.G. Salas, R.H. Smith, Multiple shoot regeneration of kenaf (*Hibiscus cannabinus* L.) from a shoot apex culture system. *Plant Cell Rep*. vol 19, pp 1165–1170, 2000.
[35] M.B. Sticklen, H.F. Oraby, Shoot apical meristem: a sustainable explant for genetic transformation of cereal crops. *In vitro Cell Dev Biol Plant* vol 41, pp 187–200, 2005.
[36] H. Schoofs, The origin of embryogenic cells in *Musa*. Thèse de PhD, KULeuven, Belgique, p 258, 1997.
[37] A. Garcia, B. Perez-Mederos, Z. Sarria-Hernandez, J.G. Clavero, Nouvelles méthodes de propagation *in vitro* du cultivar hybride FHIA-20. *INFOMUSA* vol 11 n°1, pp 18-26, 2002.
[38] T. Mateillle, B. Foncelle, Techniques de production de vitro-plants de bananier CV. « Poyo ». P.H.M. *Revue Horticole*, vol 294, n°44, pp 39-45, 1989.
[39] M. Kwa, Architecture, morphogenèse et anatomie de quelques cultivars de bananiers*. Université* Montpellier II, Thèse, Montpellier, France, p 286, 1993.
[40] N. Banerjee, E. De Langhe, A tissue culture technique for rapid clonal propagation and storage under minimal growth conditions of Musa (banana and plantain). *Plant Cell Report*. Vol 4, pp 351–354, 1985.
[41] G.J. De Klerk, J.T. Brugge, S. Marinova, S. Marinova, Effectiveness of indole acetic acid, indolebutyric acid and naphtaleneacetic acid during adventitious rootformation *in vitro* in *Malus* 'Jork 9'. *Plant Cell, Tissue and Organ Culture* vol 49, pp 39-44, 1997.
[42] D. Lauzer, J. Vieth, Micropropagation of seed-derived plants of *Cynara scolymus* L. cv. Green Globe. *Plant Cell Tissue and Organ Culture* vol 21, pp 237-244, 1990.
[43] G. Ancora, M.L. Belli-Donini, L. Cuozzo, Globe artichoke plants obtained from shoot apices through rapid *in vitro* micropropagation. *Scientia Hortic* vol 4, pp 207-213, 1981.
[44] G.M. Scarpa, M. Milia, M. Satta, The influence of growth regulators on proliferation and rooting of *in vitro* propagated myrtle. *Plant Cell, Tissue and Organ Culture* vol 62, pp 175-179, 2000.
[45] E.F. George, Plant tissue culture techniques. In: *Plant propagation by tissue culture*. Part 1: The technology, Exegetics Ltd., Edington, Wilts, England, p3-36, 1993.
[46] L.B. Andrade, S. Echeverrigaray, F. Fracaro, L. Rota, The effect of growth regulators on shoot propagation and rooting of common lavender (*Lavandula vera* DC). *Plant Cell, Tissue and Organ Culture* vol 56, pp 79-83, 1999.

[47] C.C. McCready, Movement of growth regulators in plants. I. Polar transport of 2, 4-dichlorophenoxyacetic acid in segments from the petiols of *Phaseolus vulgaris*. *New Phytol* vol 62, pp 3-18, 1963.
[48] H.T. Hartmann, V. Kester, F.T. Davies, Plant propagation: principles and practices. *Prentice Hall, Englwood Ciffs*, NJ. ISBN; 0-13 681007-1. pp. 246-247, 1990.
[49] S.S. Cronauer, A.D. Krikorian, Multiplication of *Musa* from excised stem tips. *Annals of Botany*. Vol 53, pp 321-328, 1984.
[50] Z. Wiesman, J. Riov, E. Epstein, Characterization and rooting ability of indole-3-butyric acid conjugates formed during rooting of mung bean cuttings. *Plant Physiol* vol 91, pp 1080-1084, 1989.

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Achieving MANETs Security by Exchanging Path Oriented Keys and Priority Based Secured Route Discovery

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ABSTRACT: In this work, two scenarios are considered, scenario-1 is key based communication and scenario-2 is priority based routing and communication. In scenario-1, MANET works on generated keys called KEY1 and KEY2 to establish communication between nodes. Here source node will have to generate and store a key called KEY2 and destination node will have to generate and store a key called KEY1. When source node initiates communication with destination-node, source node will send a request-packet to destination via shortest/less- cost path (PATH1) without any key mentioning in the packet. Now destination node will send the requested packet and KEY1 to source node via different path other than PATH1 (path of received packet). Source will send KEY2 to destination again through the same path (PATH2). In scenario-2, communication of each node is based on the neighbour node's priority, here, priority-1 being the highest, hence it is highly recommended for communication and priority three is being the lowest and it is rarely recommended for the communication. Nodes in the network classified into 3 types, unknown node, neighbor's known node, non-neighbors known node. Priority of nodes can be evaluated based on the security measures, energy level and other parameters of the node. It can also consider Trust Value (TV) of each node based on the duration spent in active efficient communication. With help of this strategy, we can achieve highly secured route discovery, which will help network to have smooth communication among its nodes.

KEYWORDS: Generated Key, Alternative Path, AODV, DSR, DSDV, Priority.

1 INTRODUCTION

Mobile Ad-Hoc Networks (MANET) is an infrastructureless network with limited provisioning of security, size, battery life, speed etc. Hence MANETs are more exposed to hackers including secret key breaking [1]. The routing process can be disrupted by internal or external attackers. Security threatening can affect even energy of the nodes; hence we need to achieve security goals as much as we can. These goals can include, confidentially, authentication, integrity, non-repudiation, availability, access Control etc. Since MANETs have a nature of ad hoc network formation in which nodes can join and leave easily with dynamics requests without a constant path of routing. These attacks are classified based on layers of MANETs which are mostly affected, application layer can have problems due to malicious code and repudiation; transport layer can have problems when session is hijacked or flooding the packets; attacks of network layer includes Sybil, worm/black/grey hole, link spoofing/withholding etc. ; data Link/MAC layer can be affected due to malicious behaviour of nodes, selfish behaviour, active/passive attacks, etc.; finally, physical layer can includes attacks such as interference, traffic jamming, eavesdropping etc. Due to the nature of MANETs, the design, development and implementation of secure routing is challenging work for researchers in an open and distributed communication environment. Hence, this work presents a novel approach to contribute the security goals where keys of source and destination nodes are shared through an alternative path such that nobody can misuse these keys.

The security requirements of MANETs include; availability, integrity, confidentiality, authentication and non-repudiation, because it is more susceptible to security attacks than fixed networks due to their inherent characteristics.

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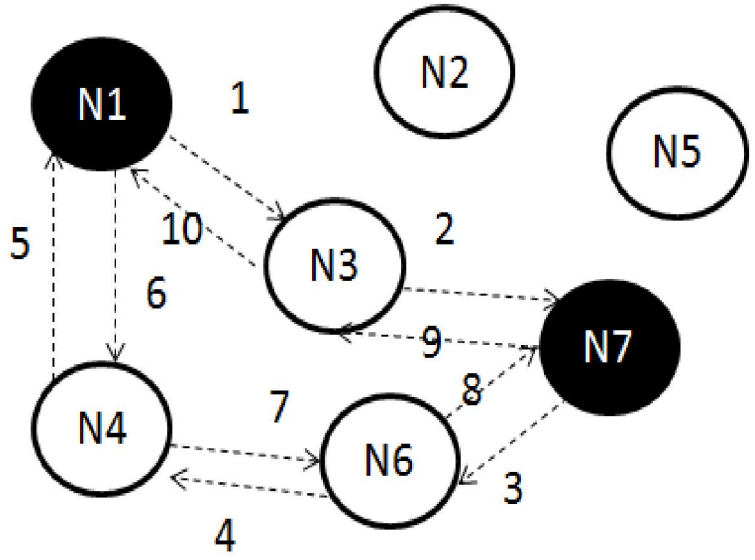
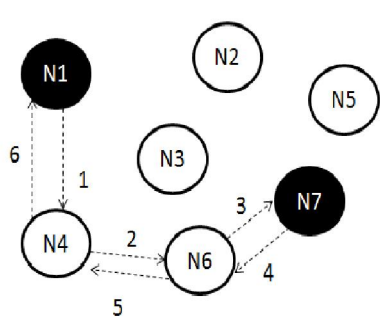


Fig. 1. Sample Nodes Communication for Scenario-1



For Steps:1,2,3

RReq
ID:1001 Src:N1 Dst:N7 LifeSpan:3

For Steps:4,5,6

RRep
ID:1001 Src:N1 Dst:N7

Table for N1 :

Node Id	Node Name	Old Priority(1-3)	Current Priority(1-3)
N1	1000001	-	-
N2	1000002	-	2
N3	1000003	3	3
N4	1000004	1	1
:	:	:	:

Fig. 2. Sample Nodes Communication for Scenario-2

The universal network goals of security like privacy, data accessibility, integrity, authenticity and non-repudiation are little hard to achieve in wireless network like MANET,WSN etc, this can be due to its open environment where all nodes co-operate in forwarding the packets in the network like hop-by-hop. Comparing to wired networks, wireless networks has more challenges in detecting fraud nodes or malicious nodes. Hence, allowing for overall research and its upcoming security challenges, it is fairly difficult to design a hundred percent secure protocol for WSN/MANET.

The organization of work goes like this, section 2 details about recent research in security of MANET's communication. Detailed design of two scenarios and its implementation with results has been explained in section 3. Finally, section 4 concludes the work and gives an outlook to further research.

2 LITERATURE SURVEY

This work has been improved and integrated two previous works [2] and [3]. Preeti and Sumitha [1] has analysed the MANETs in terms of security issues that are currently faced by the network including Bio-inspired Algorithms. BFOA (Bacterial foraging optimization algorithm) algorithm simulates behaviour of bacteria that can be effectively applied in various fields; hence this can be applied to secure the MANETs too. Reference [4] highlights about security architecture design and analysed features, insecurity factors and security threats of MANETs. The author used OSI hierarchy model as a reference model to design security architecture. The investigation on association between each layer of the architecture and that of OSI was also provided, which offers framework for planning and designing safe and consistent MANET. Reference [5] presents a concept of Dezert-Smarandache theory application for enhancing security in tactical MANET. The strategic MANET, due to its requirement, requires collection and processing of information from different sources of varied security and confidence metrics. The authors identified the needs for building a node's situational awareness and recognize data sources used for calculations of trust metrics. They provided some examples of connected works and presented their own conception of Dezert-Smarandache theory applicability for trust assessment in mobile hostile environment. Reference [6] presents a novel security mechanism to enhance security and performance of AODV (Adhoc On-demand Distance Vector) routing protocol under the attack for MANET. A robust key-management system with energy efficient is required to meet the security mechanisms of AVODV. Therefore, authors have proposed a novel security mechanism where digital signature and hash chain are integrated to protect the AODV routing protocol.

Reference [7] presents the major components of the security level of MANETs. Security issues of Data Query Processing and Location Monitoring. The security level assessment architecture, security level categorization and in applications is also presented.

Reference [8] highlighted ad-hoc network challenges and its affect on operations. Described about primary limitation of the MANETs like restricted resource capability that is, bandwidth, power back up and computational capacity etc. This stuff also affects the existing security schemes for wireless networks which makes them much more susceptible to security attacks.

Shakshuki et al. [9] has examined the study of self configuring nodes in the MANETs. Since MANET has the open communication medium and broad distribution of nodes make its more vulnerable to malevolent attackers. Hence, author recommended developing proficient intrusion-detection mechanisms to safeguard MANET from attacks with the developments of the technology and cut in hardware costs. To regulate such kind of movement, they muscularly believed that it is essential to address its potential security issues.

Tamilarasi, et al. [10] has analysed the energy desires of various cryptographic primitives with the purpose of using this data as a base for devising energy efficient security protocols also they have measured delay, packet delivery ratio and routing overhead to evaluate best security algorithm.

Reference [11] has proposed a conviction method for ad hoc network via three steps, they are honoring, calculating, and using the trust as a foundation to set up keys between the nodes in adhoc network, and make use of this belief as a measurement for setting up secure distributed control in ad hoc network. Mutual trust has been used to make decisions on establishing connection between group and/or pair wise keys.

Reference [12] highlighted MANET's challenges and its affect on operations. Described about primary limitation of the MANETs like limited resource capability that is, bandwidth, power back up and computational capacity etc. These things also affect the existing security schemes for wireless networks which makes them much more vulnerable to security [13] attacks.

Prajeet and co-authors [14] has proposed a mechanism which eliminates the need for a centralized trusted authority which is not practical in MANETs due to their self organizing nature. This mechanism defends the MANET through a self organized, fully distributed and localized procedure. The extra certificate publishing occurs only for a small amount of duration during which almost all nodes in the network get certified by their neighbors. After a period of time each node has a directory of certificates and hence the routing load sustained in this process is reasonable with a good network performance in terms of security as compare with attack case. The proposed mechanism can also be useful for securing the network from other routing attacks by altering the security parameters in harmony with the nature of the attacks.

Wireless devices in MANET communicates directly with each other when they are both within the same signal range else they rely on their neighbors to resend the messages. Shakshuki et al. [15] has examined the study of self-configuring nodes in the MANETs. Since MANET has the open communication medium and broad distribution of nodes make its more susceptible to malevolent attackers. Hence, author urged to develop proficient intrusion-detection mechanisms to guard MANET from attacks with the developments of the technology and cut in hardware costs. To adjust such kind of trend, they muscularly believed that it is essential to address its potential security issues. Finally, they anticipated and implemented a new intrusion-detection system named Enhanced Adaptive Acknowledgment (EAACK) particularly designed for MANETs. Compared to modern approaches, EAACK demonstrates higher malicious-behaviour-detection rates in definite condition while does not greatly influence the network performances.

3 DETAIL DESIGN

In this section, two abstracted scenarios are explained along with performance results. Below scenarios are extended from [16] and [17].

3.1 SCENARIO-1: KEY EXCHANGE METHOD

The overall communication sample is shown in Fig 1. In the figure, N1(src) wants to send RReq packet to N7(dst). N1 sends RReq packet to N3, and N3 sends same to N7. Here N7 does not reply back to N3 or does not reply back to the same node which has sent a RReq. N7 will choose a different/alternative path to validate the request of N3. Now N7 sends a RReq packet with secret KEY1 to N1 via N6 and N4, then N1 will reply back((RRep) to N7 with its own secret key called KEY2. Now N7 will validate and cross check the previous request and proceeds communication with N3 (previous path) with KEY2 being part of every packet and this is understood by N1 only. KEY1 and KEY2 needs to be stored in N1 to decrepit the packets of N7 for next communication. KEY1 will expire after communication session ends between nodes. KEY1 and KEY2 will be stored in N1 and N7 until session of communication ends, then this key will expiry. KEY1 and KEY2 should be used for particular session to decrepit each packet.

The basic algorithm of above proposal is specified in Algorithm 1 which describes major steps involved in the communication establishment and progress.

The simulation results are drawn in a graph for DSR, AODV and proposed algorithm is shown in Figure 3. The simulation experiment is implemented in JAVA with 100 nodes as network size. The packet End-to- End delay is the average time that a packet obtains to traverse the MANET. The delay includes the time from the generation of the packet in the source or sender up to its reception at the application layer of destination including all the delays in the network such as transmission time, buffer queues and delays induced by routing activities and MAC control exchanges. Hence, End-to- End delay is depends upon how well a routing protocol adapts to the variety of constraints in the network and represents the consistency of the routing protocol. As shown in figure, DSR shows better performance than AODV and proposed algorithm because AODV and proposed algorithm needs more time in route discovery where as DSR works on a static path routing , hence our algorithm it produces slightly more End-to-End delay than DSR but almost same as AODV. Hence, considering security perspective and above study on End- to-End delay, the proposed algorithm has higher consistency w.r.t secured communication than AODV and DSR.

3.2 SCENARIO-2: PRIORITY BASED ROUTING

The proposed algorithm has been simulated in Java and the overall working scenario is shown in Fig 2. In this figure, N1 (Source Node) wants to send an RReq packet to N7 (Destination Node), N2, N3 and N4 are neighbors of N1, from N1 to N7, there are 3 paths existed via N2, N3, and N4. Here, N1 will choose N4 for immediate communication as N2 and N3 has lower priority value compare to N4. After establishing a path, N7 sends RRep packet to N1. Hence, communication and packets are more secured through such enforcement.

In this approach we used 3 terms as follows,

Neighbors known node:

These nodes are immediate neighbors and are listed in the table along with their priority values. All neighbors need not have priority one. These nodes can be suffered from battery/energy, performance and other parameters; hence priority can vary from time to time.

Non-neighbors known node:

As its name says, these nodes are belonging to neighbors of neighbors. Here too, all neighbors need not have priority one.

Unknown node:

This node is no where listed in the table of neighbors; hence it has last priority (3). These nodes can have more battery/energy and can perform better in terms of speed.

There are few drawbacks of this approach, which includes, route could be longer than non-trusted or less priority node's path and network life time can be affected. If you need high security, we need to compromise few parameters like performance, energy etc.

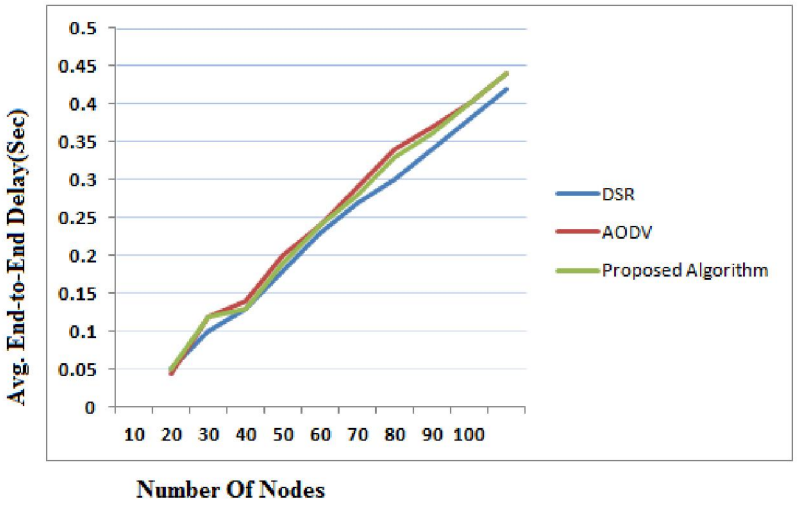


Fig. 3. End-to-end delay of DSR, AODV and Proposed Algorithm for Scenario-1

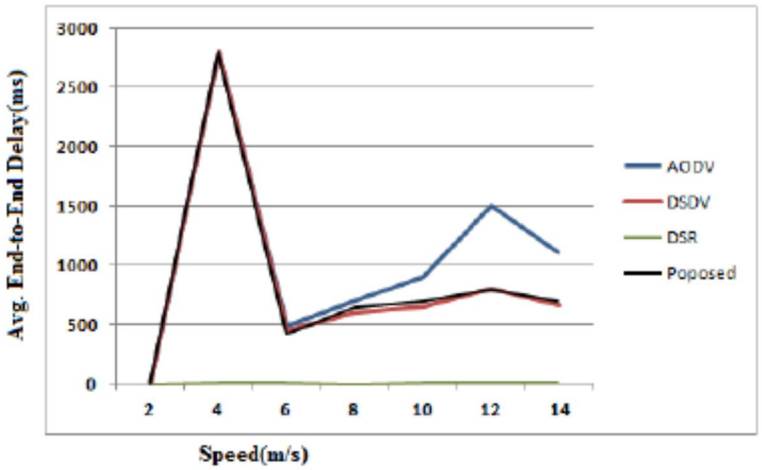


Fig. 4. End-to-End Delay V/S Mobility Response in MANET for Scenario-1

Important scenarios where algorithm needs to consider maximum security while nodes are above to initiate the communication or if communication is already progressing. Such scenarios are listed below:

1. How to do initial deployment of network?

When first time network is deployed, all nodes will have equal priority for each neighbour, here, if a node wants to communicate with other node, then it can choose any nodes for that matter or you can assign a priority considering resource constraints.

2. What happens when higher priority neighbour disappeared/dead/battery exhausted/left network?

This is one of the scenarios where communication link can be broken. If higher priority node is not available/disappeared, then next available priority node will be chosen for communication.

3. What happens when an unknown node enters into network?

Here we need to consider malicious and non- malicious nodes entry into network and needs to scrutinize the nodes based on validation.

4. What happens if legitimate Neighbour got infected with unusual behaviour like virus infected etc?

Here accessing node/genuine node needs to broadcast about malicious node participation to all other nodes and their tables can be updated for this particular node.

The figure 4 shows that DSR protocol has the lowest delay as compared to other protocols. AODV and DSDV have more or less same delay. The proposed algorithm and AODV has moderately more delay than DSR and DSDV, this is due to the source routing impression of DSR . Because DSR has all precalculated paths, that will help to have better performance than others. The proposed algorithm and AODV would have to send/calculate a specific request/path for that destination [18]. Before a path confirmation, the packets have to wait in a buffer until a valid route is found; hence this will take some time which increase the average delay as mobility rises.

Algorithm 1 $main()$

Require: Initialize $path1 \leftarrow null, path2 \leftarrow null, src \leftarrow null, dst \leftarrow null, n \leftarrow numberOfNodes, i \leftarrow 0, j \leftarrow 0, nodes[] \leftarrow listOfNodes, key1 \leftarrow 0, key2 \leftarrow 0$

```
1:  while i++ <= n do
2:    if nodes[i] ==' src' then
3:      key2 = generateRandomKey(nodes[i])
4:      while j++ <= n do
5:        if nodes[j] ==' dst' then
6:          key1 = generateRandomKey(nodes[j])
7:        end if
8:      end while
9:      src = nodes[i], dst = nodes[j]
10:     path1 = generateShortestPath(src,dst)
11:     path2 = generateRandomPath(src,dst)
12:     acknowledgement1=initializeCommunication(src,ds
        path1);
13:     acknowledgement2=initializeCommunication(dst,sr
        path2);
14:     acknowledgement3=initializeCommunication(src,ds
        path2);
15:     if acknowledgement2 contains key = key1 )
        then
16:       if acknowledgement3 contains key =
          key2 ) then
17:         proceedCommunication(src,dst,path1)
18:       end if
19:     end if
20:   else
21:     exit
22:   end if
23: end while
```

4 CONCLUSION

Based on the scenarios conclusion, Scenario-1 has proposed a novel approach where generated keys are used to authenticate each other by exchanging the keys via unusual paths (other than shortest path). Here both side communications should have keys of respective parties. I.e. source packet should have KEY1 and destination packet should have KEY2 and

these keys are compared for authentication purpose and evaluated accordingly. KEY1 and KEY2 keys are shared before the communication establishment and it will expire after each session exit. Hence, considering overall performance of simulation and strategy, the proposed idea is one the best method for secured communication. This work can be enhanced to support multi-key and multi-path routing so that security is much stronger.

Scenario-2 tries to propose a robust algorithm which protects nodes communication in a MANET. For communication with/via a neighbour is based on the neighbors node's priority, here, priority-1 being the highest hence it is highly recommended for communication and priority three is being the lowest and it is rarely recommended for communication. Priority of nodes can be evaluated based on the Trust Value, resource crunch, security measures and other parameters of the node. Trust Value (TV) of each node can be based on the duration spent in active efficient communication, history, etc. This strategy helps to choose a highly secured route which will help network to have a better communication among its nodes.

REFERENCES

[1] P. Gulia and S. Sihag, "Review and analysis of the security issues in MANET", International Journal of Computer Applications, 75(8), 23–26, August 2013.

[2] Chandrakant N, "Priority based secured route discovery in MANETs", In International Journal of Computer Science and Information Technology Research Excellence (IJCSITRE), Vol. 3, Issue 5, ISSN NO. 2250-2734, EISSN NO. 2250-2742, pages 17–20, 2013.

[3] Anil Choudhary, Dr O P Roy and Dr T Tuithung, "Performance analysis of routing protocols for mobile ad-hoc networks", IJIET, Vol-2, Issue-2, ISSN: 2319-1058, pages 327–336, Apr 2013.

[4] L. Shi-Chang, Y. Hao-Lan, and Z. Qing-Sheng, "Research on MANET security architecture design", International Conference on Signal Acquisition and Processing- ICSAP '10, pages 90–93, 2010.

[5] J. Glowacka and M. Amanowicz, "Application of dezertsmarandache theory for tactical MANET security enhancement", International Conference on Communications and Information Systems Conference (MCC), pages 1–6, 2012.

[6] S. Soni and S. Nayak, "Enhancing security features amp; performance of AODV protocol under attack for MANET", International Conference on Intelligent Systems and Signal Processing (ISSP), pages 325–328, 2013.

[7] M. Qayyum, P. Subhash, and M. Husamuddin, "Security issues of data query processing and location monitoring in MANETs", International Conference on Communication, Information Computing Technology (ICCICT), pages 1–5, 2012.

[8] S. J. Sudhir Agrawal and S. Sharma, "A survey of routing attacks and security measures in mobile ad-hoc net- works", JOURNAL OF COMPUTING, VOLUME 3, ISSUE 1, ISSN 2151-9617, pages 41–48, 2011.

[9] Shakshuki, E.M. and Nan Kang and Sheltami, T.R. Eaack, "A secure intrusion-detection system for MANETs", Volume 60, pages 1089–1098, 2013.

[10] Tamilarasi, M. and Sundararajan, T. V P, "Secure enhancement scheme for detecting selfish nodes in MANET", International Conference on Computing, Communication and Applications (IC- CCA), pages 1–5, 2012.

[11] R. Ferdous, V. Muthukkumarasamy, and A. Sattar, "Trust formalization in mobile ad-hoc networks", 24th International Conference on Advanced Information Networking and Applications Workshops (WAINA), pages 351–356, 2010.

[12] S. J. Sudhir Agrawal and S. Sharma, "A survey of routing attacks and security measures in mobile ad-hoc net- works", JOURNAL OF COMPUTING, VOLUME 3, ISSUE 1, ISSN 2151-9617, pages 41–48, 2011.

[13] Javad Pashaei Barbin, Mohammad Masdari, "Enhancing name resolution security in mobile ad hoc networks", International Journal of Advanced Science and Technology, pages 41–50, Jan 2013.

[14] N. S. Prajeet Sharma and R. Singh, "A secure intrusion detection system against DDOS attack in wireless mobile ad-hoc network", International Journal of Computer Applications (0975 8887), Volume 41 No.21, pages 16– 21, 2012.

[15] Shakshuki, E.M. and Nan Kang and Sheltami, T.R.Eaack, "A secure intrusion-detection system for MANETs", Volume 60, pages 1089–1098, 2013.

[16] Chandrakant N, "Exchanging path oriented n-generated keys via alternative path for secured communication in MANETs", International Journal of Inventive Engineering and Sciences (IJIES), Volume-1, Issue-11, ISSN: 23199598, pages 44–46, 2013.

[17] Chandrakant N, "Achieving MANETs security by exchanging path oriented single or n-generated keys via secondary path", International Journal of Science and Technology (IJST), Volume 3 Issue 2, ISSN (online): 2250-141X, pages 23–29, 2013.

[18] Sunil Taneja, Ashwani Kush, and Amandeep Makkar, "End to end delay analysis of prominent on-demand routing protocols", International Journal of Computer Science and Technology, Vol-2,Issue-1, ISSN:0976-8491, pages 42–46, March 2011.