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Game theoretical approach of user behavior based on personal opinion in Online Video Social Networks

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ABSTRACT: In the last decade, the web has known a major evolution with the appearance of web 2.0 and its applications. One of those popular tools is the Online Video Social Networks (OVSN). Video content is becoming a predominant part of the daily life of users on the Web. Henceforth the study and modeling this kind of platforms, emerge as necessity.

In this paper, we study the interaction of user community with videos shared and viewed in online video social networks. The concept of freedom giving to users in these platforms allows them to express their opinion toward those videos. Based on the analysis of the mechanisms of interaction in OVSN, we developed a personal opinion model for online users in this case. To deal with this problem we constructed a Petri Net model and we use it to derive a payoff function, these bring us to the Game theory field.

Although our model is inspired from earlier studies, at the heart of our whole approach is abstracting the complex mechanism of interactions by the solution concept of Nash equilibrium, which allowed us to deal with richer problem instances. We conclude this paper by outlining several interesting lines of future work.

KEYWORDS: OVSN, Petri Net, Payoff, Nash Equilibrium.

1 INTRODUCTION

Web 2.0 was introduced, as term and concept, in October 2004 by Tim O'Reilly [1]. Since then, web 2.0 (known also as participative and social web) has been considered as the evolution of the web. Its fundamental concept is based on the involvement of users in the process of creating, producing and sharing the content. From this perspective rises the primordial role of users in the participative web. Many applications and tools constitute the core of this web: Blog, Social networks, Wiki, Content syndication and aggregation, video social networks... [2].

Online Video Social Networks (OVSN) nowadays becomes an essential part of users' daily life on the web. These platforms provide to users many features such as creating and sharing their own videos. Furthermore, they can view and share videos of other users. OVSN enhance the interaction between users by allowing them to behave toward these videos by liking, disliking, commenting, sharing or reporting [3], [4], [5].

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The video created or produced by users can be sorted into two forms: homemade content remixes of pre-existing works; and hybrid forms that combine some form of self-produced video with already existing content. Video content may be hosted on a user's personal website or blog, peer-to-peer networks or hosted by OVSN platforms such as *YouTube*, *Google Video*, *Dailymotion*, etc. Increasingly these sites are also enabled for access (upload and download) from mobile phones and devices. To illustrate the popularity of OVSN, we will use Youtube as reference [6] .For example; *Youtube*[1] has over 800 million unique users visit monthly. In term of video viewing, it had over 4 billion hours of watched video each monthly. The amount of video uploaded to Youtube every minute is 72 hours of video. The heterogeneous mixture of cultures in this OVSN can be noticed by analyzing the statistics collected about visitors: 70% of YouTube traffic comes from outside the US, whereas *YouTube* servers are localized in 53 countries and across 61 languages.

In this paper, we study the interaction of user community with videos shared and viewed in online video social networks. Many previous works tried to deal with similar problem in different situations and form different angles [6]-[7].

In the first section, we will introduce our vision to this problem as the Petri Net model which allowed us to clearly understand the relationship between the various components involved in the process and its mechanisms. In the next section we will use this Petri Net model to construct the payoff function for each user, thus the game theory framework. Finally we will terminate our paper by given a conclusion that summaries the work.

Throughout this paper we suppose that opinion expressed by users in the OVSN is a complex process where multiple contrasting influences are engaged in the action.

2 PETRI NET MODEL FOR ONLINE INTERACTION MECHANISMS IN OVSN

In many social networks research areas, the actions of users dependent on each other due to the interactions among users directly and indirectly.

In order to model a system interaction problem, scientists use "Petri Net" to illustrate the process of constructing a formal model from informal description [8]-[9]. Due to the complexity of the present problem we have been also obligated to use a Petri Net that satisfies the requirement of our case.

Let $G=(V,E)$ be a user graph for social network and suppose we have several classes of information $I=\{1,\cdots m\}$.

Let $x_i^{(j)}\in[0,1]$ be the probability that videos i to be liked by user j, let $y_i^{(j)}\in[0,1]$ be the probability that video i to be withheld by user j. And $z_i^{(j)}\in[0,1]$ is the probability that video i to be liked by user j. Then we have:

$$x^{(j)}+y^{(j)}+z^{(j)}=1$$

Let:

$$\overline{x}_i^{(j)}=\frac{1}{|N(j)|}\sum_{k\in N(j)}x_i^{(k)}$$

Where $N(j)$ is the neighborhood of user j in G. We make similar definition for $\overline{y}_i^{(j)}$ and $\overline{z}_i^{(j)}$.

The user actions' are organized as following:

- First category action: Like, Withhold and Dislike.
- Second category action: Report, Comment+, Sharing and Comment- .

[1] http://www.youtube.com/yt/press/statistics.html

We assume that four elements constitute each user's objective function:

- Social admission gained by making a second category action.
- Personnel privacy benefit gained from just making a first category action.
- Social reject cost caused by a subjective comment.
- Moral cost caused by subjective comment or report.

Based on the elements cited above, we constructed the following Petri Net:

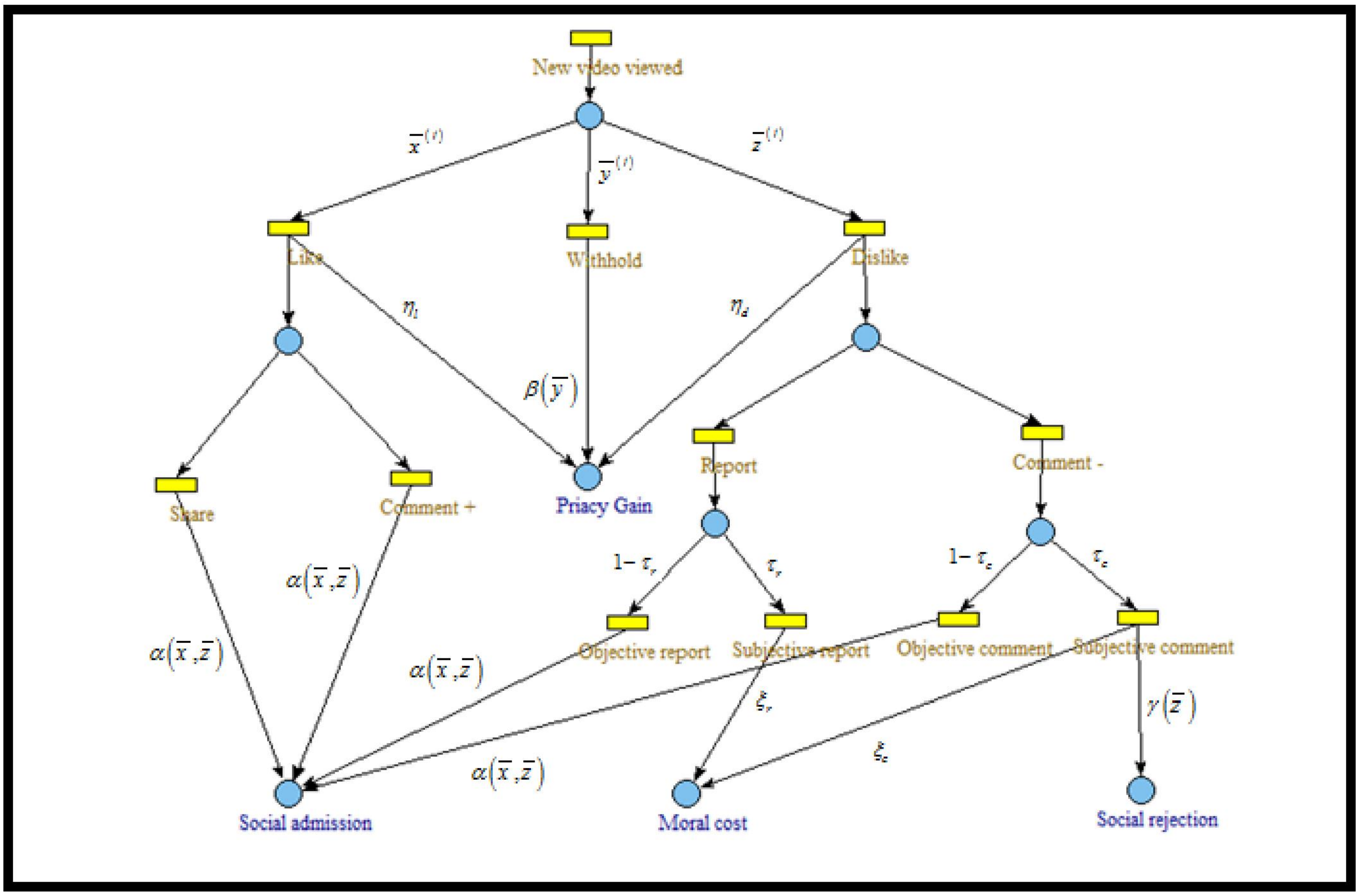

Fig. 1. The Petri Net illustration of the mechanisms generated by viewing a new video.

This model allows us to clearly understand the relationship between the various components involved in the process and its mechanisms. Such illustration will serve us to build a formal model.

3 USERS' PERSONAL OPINION IN OVSN BY GAME THEORETIC MODEL

In order to build our game theoretic model, we will reuse the terminology and the notations used in the Petri Net illustration bellow. The structure of the model is as follows: there is a user j among a set of *N* users where there are *N-1* neighbors in each single video in an OVSN. Each player (user) j makes a choice from a finite set {Like, Withhold, Dislike} .

We let $X^{(j)}$, $Y^{(j)}$ and $Z^{(j)}$ be correlated random variables whose dynamics are chosen by user j .

At time t, user $j's$ stochastic payoff function is:

$$\pi^{(j)}(t) = \omega_1 \alpha\left(X^{(j)}(t), Z^{(j)}(t), \overline{x}^{(j)}(t), \overline{z}^{(j)}(t), t, \tau_c(t), \tau_r(t)\right)$$
$$+\omega_2\left[\beta\left(Y^{(j)}, \overline{y}^{(j)}, t\right)Y^{(j)}(t) + \eta_d\left(Z^{(j)}(t)\right) + \eta_l\left(X^{(j)}(t)\right)\right]$$
$$-\omega_3 \gamma\left(Z^{(j)}, \overline{z}^{(j)}, t, \tau_c(t)\right) - \omega_4\left[\xi_r\left(Z^{(j)}(t), \tau_r(t)\right) + \xi_c\left(Z^{(j)}(t), \tau_c(t)\right)\right]$$

In this equation:

- $\alpha\left(X^{(j)}(t), Z^{(j)}(t), \overline{x}^{(j)}(t), \overline{z}^{(j)}(t), t\right)$ is a *social admission* that provide reward obtained by reacting with videos in OVSN.
- $\beta\left(Y^{(j)}, \overline{y}^{(j)}, t\right)$ is privacy capital function that provide the reward obtained by not making an action toward a video.
- $\gamma\left(Z^{(j)}, \overline{z}^{(j)}, t\right)$ is cost function represent social rejection resulted from writing a subjective commentary.
- ξ_r and ξ_c are moral cost functions associated respectively to subjective reporting and commenting.
- η_d and η_l are privacy capital functions that provides the reward obtained respectively by just by liking and disliking.
- $\tau_r(t)$ and $\tau_c(t)$ are the probabilities of making respectively subjective reporting and commenting.

The variables $\omega_k \quad (k = 1, \cdots, 4)$ are relative weights user j places on each component of his objective function.

Over a period of time, the complete stochastic payoff function for user j is:

$$\Pi^{(j)} = \sum_{t=0}^{T} \pi^{(j)}(t)$$

The solution to the game is then defined by the simultaneous optimization problem:

$$\forall j \quad \begin{cases} \max E\left(\pi^{(j)}\left(x(t), y(t), z(t)\right)\right) \\ \text{s.t} \quad x(t) + y(t) + z(t) = 1 \\ \quad x(t), y(t), z(t) \geq 0 \ \forall \text{t} \end{cases}$$

Where $x(t), y(t), z(t)$ are the vectors of decision variables for the users. Let

$$\Omega = \prod_{j,t}\left\{\left(x^{(j)}(t), y^{(j)}(t), z^{(j)}(t)\right) \in [0,1]^3 : x^{(j)}(t) + y^{(j)}(t) + z^{(j)}(t) = 1, x^{(j)}(t), y^{(j)}(t), z^{(j)}(t) \geq 0\right\}$$

This is the *complete strategy* space for all users over the course of time $t \in [0, T]$. Any Nash equilibrium will be chosen from this strategy space. The theorem 1 of [10] provides the following results:

Lemma: If $E\left(\pi^{(j)}\left(x(t),y(t),z(t)\right)\right)$ is concave for all j , then there is a Nash equilibrium in Ω for this game. Furthermore, the uniqueness of this equilibrium is completely a function of the structure of specific objective functions.

The structure of $E\left(\pi^{(j)}\left(x(t),y(t),z(t)\right)\right)$ is complicated. For simplification, we replace the functions in equation with piecewise constant multipliers. Then we have a specific form of the stochastic payoff function:

$$\begin{aligned}\pi^{(j)}(t) &= \omega_1\alpha\left(x^{(j)}(t),z^{(j)}(t),\overline{x}^{(j)}(t),\overline{z}^{(j)}(t),t\right)\left(X^{(j)}(t)+\left(2-\tau_c(t)-\tau_r(t)\right)Z^{(j)}(t)\right)\\ &+\omega_2\left[\beta\left(y^{(j)},\overline{y}^{(j)},t\right)Y^{(j)}(t)+\eta_d Z^{(j)}(t)+\eta_l X^{(j)}(t)\right]\\ &-\omega_3\gamma\left(z^{(j)},\overline{z}^{(j)},t\right)\tau_c(t)Z^{(j)}(t)-\omega_4\left(\xi_r\tau_r(t)+\xi_c\tau_c(t)\right)Z^{(j)}(t)\end{aligned}$$

Henceforth,

$$\begin{aligned}E\left(\Pi^{(j)}(t)\right) &= \sum_{t=0}^{T}\ \omega_1\alpha\left(x^{(j)}(t),z^{(j)}(t),\overline{x}^{(j)}(t),\overline{z}^{(j)}(t),t\right)\left(x^{(j)}(t)+\left(2-\tau_c(t)-\tau_r(t)\right)z^{(j)}(t)\right)\\ &+\omega_2\left[\beta\left(y^{(j)},\overline{y}^{(j)},t\right)y^{(j)}(t)+\eta_d z^{(j)}(t)+\eta_l x^{(j)}(t)\right]\\ &-\omega_3\gamma\left(z^{(j)},\overline{z}^{(j)},t\right)\tau_c(t)z^{(j)}(t)-\omega_4\left(\xi_r\tau_r(t)+\xi_c\tau_c(t)\right)z^{(j)}(t)\end{aligned}$$

That is, a user's expected payoff engaging in this game is a function of time duration in which he expressed his opinion toward the video. Since we assumed that the social gain/cost functions are implicitly controlled by neighbors' strategies, then the user's stochastic payoff function is so.

We have showed that while this game has at least one Nash equilibrium (see the Lemma above), hence we can apply the well known algorithm such as the Eliminating Dominated Strategies.

A possible future development is to study the application of our mathematical framework on different technological fields, That involves the complexity of human interactions with others or artificial intelligence. We hope that some researcher with an expertise in those fields may be interested in extending our findings.

4 CONCLUSION

In this paper, we gave an introductory model on users' opinion expression and their interactions' toward a video in an OVSN platform. The model is inspired from a Petri Net illustration of the mechanisms generated by viewing an OVSN's content. We used this Petri Net to construct objective function for each user in which the stochastic payoff function to a given user depends not only on his actions but also on his neighbors' ones'.

We showed that there is a unique Nash equilibrium for this game; henceforth the ground it has been setup to the classical game theory algorithm's.

This work will open new directions in the field of social networks and its applications. Our future work will be focused in the study of social interactions phenomenon in similar web 2.0 applications.

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