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A Network Formation Model for Social Object Networks

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A Network Formation Model for Social Object Networks

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Abstract: Social networks can be differentiated according to the type of entities (i.e., humans or objects) that are represented within them. These networks can be called human networks and social object networks, respectively. Actors in human networks can act strategically to maximize their own payoffs during interactions with other humans. However, actors in social object network (e.g., SaaS service network) are not able to perceive the environment and act strategically upon that at any time. Only when they join the network, humans position them such that it maximizes their payoff. This paper contends that existing network formation models lack sufficient attention to social object networks (e.g., SaaS service networks). Therefore, we propose a new network formation model, through which we are able to explain how a SaaS service network emerges during the service composition procedure by service developers. The new network formulation model not only considers the usage frequency and reputation but also the similarity of the functionalities of the main SaaS services. It also explains how social objects (e.g., SaaS services) can benefit from establishment of links among each other in the network.

Keywords: Software-as-a-Service Network, Network Formation Model, Social Object Networks.

JEL Classification Numbers: C02, C6, C15, D85, L86, O33.

1. Introduction

The main software services (i.e., Software-as-a-Service (SaaS) services), which are typically presented by big enterprises, can be used by others through application programming interfaces (APIs). An API provides a way for applications to work with each other and deliver the information or functionalities users or other services need.

In spite of the variety of SaaS services in the market, service developers are moving so fast in combining the existing services (i.e., in order to build and deliver new ones) through APIs. This process is called service composition, which is one of the most important features of service-oriented architecture. The existing SaaS services belong to different service type categories (e.g., advertising, finance, Internet, social networking, music, games). Due to the different service types and the diversity of different types of APIs that go into the market, the process of service composition becomes more and more challenging. In order to deliver a new business solution to the market, we can augment new functionalities of existing services. For example, composing a new social networking service may require utilization of the services delivered through the APIs of Facebook, Twitter, or Flicker. Therefore, we can state that the main APIs of big enterprises are the foundations of newly generated services in the market.

Basically SaaS service network emerges from strategic integration of basic SaaS services by service developers. The process of web service composition creates a network, in which social activities (i.e., the use of APIs) among big enterprises are visualized. The emerging network can be seen as a graph that highlights similar or different types of SaaS services through their links. One thing to keep in mind is that the emerging network has a meaningful structure, through which interactions of objects lead to certain outcomes for them.

In literature, we can find strategic network formation models, in which payoffs of individuals in a network are the result of their strategic interactions with others [1]. However, existing models are mainly applicable to human networks and, this paper contends that they lack sufficient attention to social network of objects (e.g., SaaS service networks). The issues will be discussed in detail in section 3.1. Lack of responsiveness in objects limits entities to interact strategically with one another quickly. However, the human role is still the key for proper understanding of how a network of objects emerges (e.g., through the combination of functionalities of services through service developers). Other network formation models have also been proposed to explain the characteristics of the networks [2]. Barabási–Albert model is the best known example in this category. However, the method of growth in scale free network is only based on the relative frequencies of existing nodes' degrees but not on benefit and cost of link establishment with others.

Taking each of the discussed key elements about service composition procedure into account, this article aims to address the following research questions:

- What does the structural analysis of the SaaS service industry bring?
- Can current network formation models produce the topology of SaaS service networks?
- What kind of network formation model for social object networks is needed?

With respect to our research questions, in this paper, we propose a new network formation model for social object networks that explains how a SaaS service network emerges during the service composition procedure. The new formulation not only considers the use frequency and reputation but also the similarity of the functionalities of the main SaaS services. It also explains how social objects (e.g., SaaS services) can benefit from establishing links among each other in the network.

The remainder of this paper is organized as follows: In section 2, we discuss related works and theoretical background on strategic network formation models. In section 3, we define a social object network and differentiate it with social network of humans. We also present the proposed new social object network formation model. Finally, we conclude the paper with a discussion in section 4.

2. Theoretical Background

There are two branches of literature that are related to network formation models. The first branch focuses on strategic network formation models, while the second one presents the growth models of the network.

In the first category of literature reviews in this part, researchers look at a network as an emergent network structure from strategic interactions of the individuals that are located in it. Strategic network formation models assume that network entities are rational and opportunity seeking actors, who establish links with other actors if they find the link establishment beneficial. Therefore, each entity in the network obtains a payoff during its interaction with others. Such values are derived by a payoff function, which can be defined in different ways. For example, it can be defined in terms of the number of connections to other actors or the distance to other nodes (i.e., closeness centrality [3]). A comprehensive introduction to social and economic networks is presented by Matthew Jackson [4]. He presented different strategic network formation models, in which choices of players have certain impact on the topological features of the network. Two of those well-known examples of network formation models are the Symmetric connection model and the Co-author Model [1].

Symmetric connection model is a model, in which individuals directly communicate with their direct contacts and the value obtained through their interactions is proportional to their distance to the target players. As this distance increases, the obtained payoff value decreases. Co-author model focuses on the collaboration among the individuals and all the payoffs are due to the collaboration with direct contacts and there is no payoff for communicating with indirect contacts. The structural changes in the proposed models are the consequence of the composition of the strategies of rational actors or humans. Therefore, they are mainly applicable to social network of humans. We will describe both models in more details in section 3.4. Variations of symmetric connection models are presented in the literature which are degree-distance-based versions and have positive and negative externalities [5, 6]. Jackson and Rogers assumed geographic costs for forming links and players are grouped into so called islands [7].The connection costs are low within an island and high across islands. Further variations of connection models with geographic costs are investigated, in the models of Johnson and Gilles [8] and Carayol and Roux [9, 10]. Other studies that try to identify the effects of actors' interaction on their social networks can be grouped according to the topics on network games [11], public good provision, as well as bargaining and power in networks.

From the view point of network growth, which falls into second category of research in this area, proposing a model to produce predetermined structural properties is a challenging issue [12]. In this regard different network formation models have been proposed to produce a desired structure. The preferential attachment growth model, introduced by Barabási–Albert [2] is capable of generating power law degree distributions for example. In this model, new nodes are more willing to link to high-degree nodes during the growth of a network. The method of preferential attachment growth is based on the relative frequencies of existing nodes' degrees, not benefit and cost of link establishment with the others. Therefore, it is not suitable for object-based social networks. However, in some other types of the network the attachment point for the new nodes can be chosen randomly with the same probability of attachment for all nodes [13, 14, and 15]. A random network formation also is not suitable for object-based social networks because as we mentioned in the introduction section, the current overwhelming SaaS service composition is not the result of random selection of services from different APIs.

Although a lot of researches have been done on strategic network formation models but mostly they are applicable to network of humans. However, lack of flexibility and spontaneity in network of objects limits the strategic interaction. In short, social object networks are social network, where the interconnectivities among the objects have been taken from strategic manipulations of humans. When we think about a SaaS service network for example, the only way to depict how it emerges is to look for and identify specific patterns in the data related to new SaaS service composition by developers. Therefore, social networks form around social objects and human role is still the key for proper understanding of how the network of objects emerges. The thing to remember is that human beings do not connect the objects in a completely random way. They use and combine them as social objects to get value out of them. Therefore, we need a new network formation model for SaaS service network to explain how such a network emerges.

3. Proposed Social Object Network Formation Model

3.1. Definition of Social Object Networks

Social networks can be differentiated according to the actors (i.e., humans and objects), which are located in them. Two types can be distinguished: social networks of humans or social networks of objects. Actors in human networks can act strategically to maximize their own payoffs through interactions with others. Since in a human network time, attention and other resources of this type are limited, the number of connections to other actors determines the strength of interactions. The more connections exist, the lesser resources are available per connection in average. However, actors of social object networks (e.g., SaaS network) are not able to act strategically upon changes in the environment after they joined the network. Lack of responsiveness in objects limits them to interact strategically with one another quickly. Furthermore, in contrast to human networks, actors of a social object network can have a large number of connections to other actors.

The distinction between a social object network (e.g., Software-as-a-Service network) and human network is that collaboration between object A and object B does not depend strongly on the degree of connections to others. Therefore, a SaaS network can be considered as a network, which can have unlimited number of interactions with different members. Therefore, new services can combine the functionalities of existing services. However, the hidden influence of humans on the formation of social object networks should not be neglected if new objects join the network. That is to say, actors in social object networks can also receive payoffs, depending on how they have been arranged in the network by humans when they joined.

3.2. Definition of the Software-as-a-Service Network (SaaS Network)

The SaaS network is defined as a set of nodes, representing software services that opened up their APIs for other services to connect to them, and a set of links between these nodes. A link indicates the existence of a composite service that uses the nodes. Therefore, the creation of a composite service yields a graph of those SaaS services that are used for the development of the composite service [16, 17, and 18]. The generated network is a weighted graph, in which the weight of the link between SaaS service i and SaaS service j shows the degree of collaboration (i.e., collaboration is essential and can be considered as complementarity feature of the process of human needs satisfaction) between the two SaaS services.

We gathered the data from www.programmableweb.com, which lists information about SaaS services. The information collected includes the name of the service that offers open APIs, the services that reuse existing SaaS services, its launch date, and ratings from users on the newly developed services. We collected this information from February 2006 until August 2013. In total, we observed 1153 SaaS services with APIs that have been used by developers for service composition. According to the existing terminology in web services, a new SaaS service composition is also called mashup. The main characteristics of a mashup is its combination and aggregation of content from more than one source (i.e., from existing SaaS services and the developer) to create a single new service. An example of the SaaS network is shown in Figure 1.Since we generated a large network out of collected data we could not visualize the network in details in a single view and capture interesting patterns among the existing connections. Therefore, we filter the whole network and only show those top 20 SaaS services that have the highest node degree. We consider this network to be the core of the SaaS network. Figure 1 depicts the links of the SaaS network with different thickness, according to their weights (i.e., the number of composite services that used them). The core of the SaaS service network shows the service developers' use patterns of the most frequently used SaaS services. It shows that the most attractive SaaS service from the developer's perspective has been Google Maps. It also shows that in the process of SaaS service composition, service developers have been mainly interested in integrating micro blogging services (e.g., Twitter), social networking services (e.g., Facebook), photo sharing services (e.g., Flicker), video sharing services (e.g., YouTube) with Google Maps functionalities.

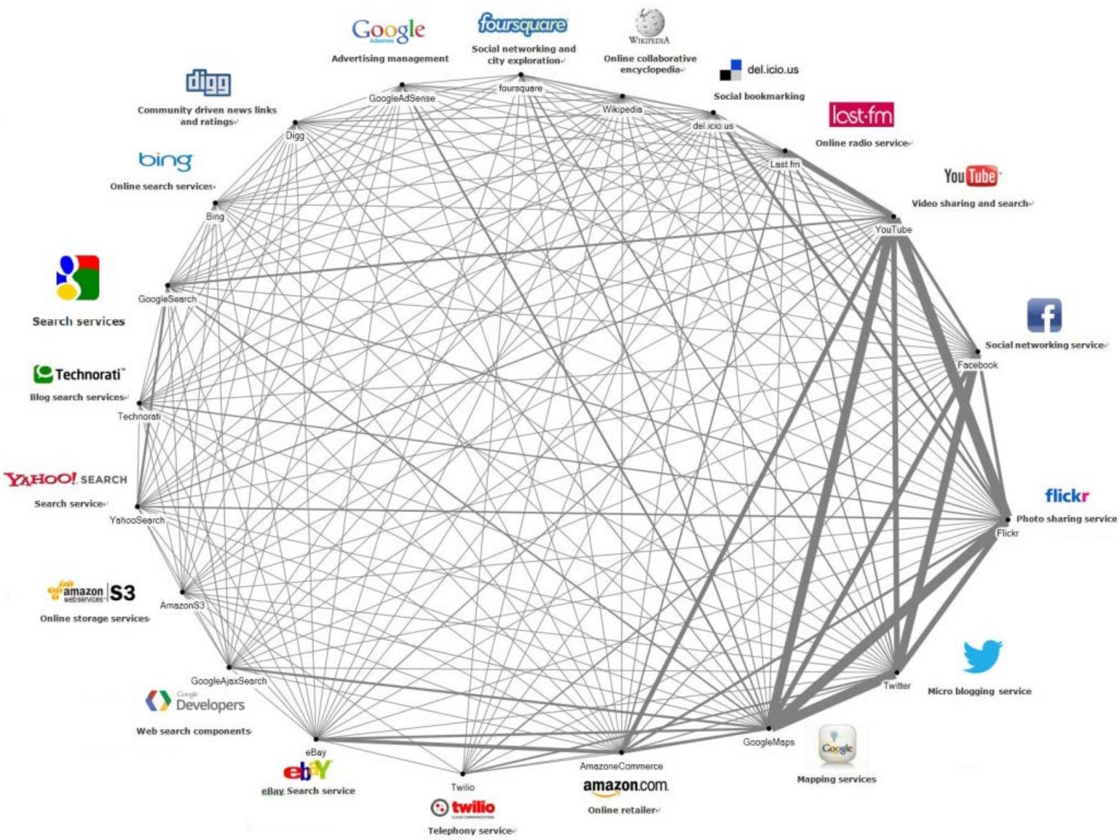

Figure 1. The core of a SaaS service network.

3.3. Network Formation Model

Existing network formation models mostly depict scenarios, in which network participants are humans and have desires and needs for efficient resource allocation among themselves. Since payoff functions of the previous models map individuals' degree of connections to utilitarian values during the course of individuals' link establishments, the more connections exist, the lesser resources are available per connection in average. However, many social objects do not have such a limitation. In addition to that, since there is no consideration about the frequency of interaction among the individuals in previous formulations, symmetric payoffs always will be generated for two individuals with similar connectivity patterns to the others. However, we believe that entities in a social object network with same connectivity patterns can make different contributions and, therefore, receive different payoffs. What really matters is the frequency of interactions and the relevance, quality, and novelty of new information produced as the result of link establishments. Although this issue is true for both human networks and social object networks, the latter is the main focus of the work presented in this paper.

In detail, social objects differ along many dimensions and such differences often arise on the basis of preexisting functionalities or services they provide. This suggests that networks of objects form because of the advantages to the end user through the combination of different functionalities they provide. In SaaS service networks for example, the benefits comes from developing new services by combining existing services. Entities' benefits are subject to the type of services combined and their contributions. In particular, if the combination of two SaaS services i and j of the same service category does not lead to an added functionality and cannot satisfy the functionality required by the user, there is no high benefit to such service integration.

Therefore, we need a network formation model for capturing and adjusting the cost and benefit of networking among social objects with respect to relevance, quality, and novelty of new information provided to and perceived by users. Specifically, social objects have chances to be linked together and new services are generated as a result. If there is no link between two objects, they will receive no utility from each other. If a link is established between object i and j they will receive benefit out of that, however, the amount of benefit depends on the frequency of interaction, reputation of the other parties and the type of services being integrated.

Due to the mentioned differences between social object networks and human networks above, we propose a network formation model for social object networks that distinguishes cost and payoff for establishing links when actors initially establish new relationships. We formulate the expected net utility L_i for SaaS service i from the link establishment with SaaS services j as follows:

$$L_i = \alpha_{i,j} P_{i,j} \tag{1}$$

In the same way, the expected net utility L_j for SaaS service j can be formulated (equation 2). The expected net utility of the new service n is given in equation 3.

$$L_j = \alpha_{j,i} P_{j,i} \tag{2}$$

$$L_n = V_n - C_{\{i,j,n\}} \tag{3}$$

Parameter $P_{i,j}$ is the undiscounted payoff that a SaaS service i receives, when its functionalities are integrated with SaaS service j through service composition and $C_{\{i,j,n\}}$ is the cost for integrating services i, service j, and value add of the new service n. The amount of expected payoff by combining the two SaaS services i and j depends on the probability of successful service integration between the two parties. We introduce parameter α that defines the evolution dynamics of the obtained payoff. This parameter evolves gradually over time and captures the amount of changes in the net utility of SaaS services. Therefore, with probability $\alpha_{i,j}$, service developers benefit from integrating the services i and j. Furthermore, service developers would not invest any effort in SaaS service composition, if the payoff V_n is smaller than the cost of integration $C_{\{i,j,n\}}$.

Consequently, the total net utility $L^n_{i,j}$ generated through the establishment of a new SaaS service n that builds on SaaS services i and j can be formulated as shown in equation 4:

$$L^n_{i,j} = \alpha_{i,j} P_{i,j} + \alpha_{j,i} P_{j,i} - C_{\{i,j,n\}} + V_n \tag{4}$$

Based on our observation in Figure 1, we propose to define α as a function of service developers' use patterns of different SaaS services. A tight degree of collaboration (i.e., high edge thickness) between SaaS service i and j shows the explicit interest of service developers on the integration of both services. In addition to this, as shown in the following formula, we normalize the degree of collaboration with the largest degree of collaboration of SaaS service j with its k direct contacts so that its value stays in the range [0, 1].

$$\alpha_{i,j} = \frac{\text{deg\_of\_col}_{i,j}}{\max\limits_{k} \text{deg\_of\_col}_{j,k}} \tag{5}$$

Similar to Co-author model, the focus of our model is on the collaboration among the entities and there is no payoff for non-collaborating ones. Therefore, at the beginning, the utilities of objects are assumed to be 0. As soon as a link is established between two objects i and j, α can be calculated to determine the actual amount of benefit during the service composition procedure. It should be noted that the proposed formulation produces asymmetric payoffs for two SaaS service i and j. Therefore, the only way that a newly entered SaaS service i can expect the increase in its own payoff during the interaction with SaaS service j, is to increase the level of collaboration with SaaS service j. Otherwise, the payoff will be largely discounted by a small value of $\alpha_{i,j}$.

Equation 4 can be further generalized by accounting for a combination of any number of SaaS services of all SaaS services S. Therefore, we formulate the expected net utility function for any new service n as follows:

$$\begin{aligned} \overleftrightarrow{L_{l\subset S}^{n}} &= \sum_{j,i\in l;j\neq i} \left(\alpha_{i,j}P_{i,j} + \alpha_{j,i}P_{j,i}\right) - C_l + V_n \\ &= \sum_{j,i\in l;j\neq i} \left(\alpha_{i,j}rep_j + \alpha_{j,i}rep_i\right) - \sum_{j,i\in l;j\neq i} sim_{i,j} + V_n \end{aligned} \tag{6}$$

In the expected net utility function, sim_{ij} can be considered a representative of the service integration cost. The more similarity exists, the more effort it takes to isolate the redundant components of the services. Similarity is a numerical value indicating the degree of similarity between the two SaaS service i and SaaS service j. If we consider $x = (x_{1,}, x_{2,}, x_{3 \ldots\ldots,} x_n)$ to be the profile of an object described by n characteristics, then, with the help of existing vector-similarity measures in the literature (such as cosine or Jaccard metric), we can compute the similarity between the two profile vectors. If the similarity measure is 1, the cost of SaaS service integration is the highest. The comparison of similarity measures is not the focus of our current work but will be considered as an extension of the current study. We use Jaccard Similarity Measure (JSM) to capture the degree of similarity between two SaaS services. The JSM for calculating the sim_{ij} is given as

$$sim_{ij} = \frac{SaaS\ service_{i_1 j_1}}{(SaaS\ service_{i_1 j_1} + SaaS\ service_{i_0 j_1} + SaaS\ service_{i_1 j_0})} \quad (7)$$

$SaaS\ service_{i_1 j_1}$ represents the total number of attributes, where *SaaS service i* and *SaaS service j* both have a value of 1. $SaaS\ service_{i_0 j_1}$ represents the total number of attributes, where *SaaS service j* has a value of 1 and *SaaS service i* has a value of 0, and $SaaS\ service_{i_1 j_0}$ represents the total number of attributes where *SaaS service i* has a value of 1 and *SaaS service j* has a value of 0. The JSM match profile of *SaaS service i* with the other SaaS service profiles by comparing the values of their attributes. The comparison result is a numerical value indicating the degree of similarity between SaaS service attributes.

We consider rep_j as the obtained payoff $P_{i,j}$ of SaaS service *i* during service integration with SaaS service *j* . Parameter rep_j is the predicted global reputation value of SaaS service *j* based on the issued ratings of users on newly developed services. The reputation of the integrated services reflects on the new service n. In order to calculate the obtained payoff of *SaaS service i* during new web service composition with *SaaS service j*, we predict the global reputation of *SaaS service j*. Therefore, first we extract a neighborhood N ⊆ M of the total set of Mashups M, in which *SaaS service j* has been used. Once N has been determined, we extract the issued ratings of users on n ∈ N and make their average to generate predictions for *SaaS service i's* preference for integration of services with *SaaS service j*. Parameter r_n shows the collected ratings from users on the newly developed services.

$$rep_j = \frac{\sum_N r_n}{|N|} \quad (8)$$

The proposed formulation is based on the idea that we can consider the new web service composition successful, if the issued rating of users on that is positive. Therefore, we gather *n* feedback values for each of the coupled SaaS service *i* and SaaS service *j* and we calculate the average of the observed ratings. Having said that, it seems like integration of SaaS services that fall into different categories are highly appreciated by service developers. For instance, the degree of collaboration between Yahoo search and Bing is quite low. Therefore, we assume that establishment of a link between two web services in the same category is inefficient and costly.

4. Conclusions

In this paper, we discussed about existing network formation models in literature and argued that they lack sufficient attention to social network of objects (e.g., SaaS service networks). We point to the fact that humans' desires and needs for efficient resource allocation is the reason for their strategic link establishment in their social networks. Since time, attention and other resources of this type are limited, humans prefer to act strategically in their network to maximize their own payoffs. However, this feature does not exist in social network of objects. SaaS service network for example can be considered as a network with unlimited P2P interactions with its members which results in new services with new functionalities to the final users. We believe that entities in a social object networks with same connectivity patterns can make different contributions and receive different payoffs. What really matters is the frequency of interactions and the relevance, quality, and novelty of new information produced as the result of link establishments. Therefore, we proposed a new social object network formation model that explains how a SaaS service network emerges during the service composition procedure. The proposed formulation is able to capture and adjust the cost and benefit of networking among objects with respect to relevance, quality, and novelty of new information provided to and perceived by the user. We captured the giant component of SaaS service network and based on our observations, we setup the new formulation. The new formulation not only considers the use frequency and reputation but also the similarity of the functionalities of the main SaaS services. It also explains how social objects (e.g., SaaS services) can benefit from establishing links among each other in the network. Due to the fact that the cost and benefit terms are introduced in the model someone may argue that the proposed model is one extension for the connection model. However, as it is discussed in [4], the only efficient network structure in symmetric connection model is a star network. Therefore, it is unable to explain the topology of a SaaS network, which is depicted in Figure 1 with symmetric connection model. Since there is no consideration about the frequency of interaction among the individuals in symmetric connection model, symmetric payoffs always will be generated for two individuals with similar connectivity patterns to the others. In short, what really matters in this model, is the number of connections or distance to other parties. However, our model considers the frequency of interaction, reputation of the second party and type of services being integrated to calculate the obtained benefits during link establishment. Co-author model with the focus on the collaboration among the individuals depicts a scenario, in which network participants have desires and needs for efficient resource allocation. Each actor will receive lower payoff, if the degree of their direct contacts becomes bigger than 1; a process which emerges in form of negative externality. However, as we mentioned in section 3.1, SaaS service network does not have this limitation. The payoffs of objects in our network formation model would not be affected by the connectivity degree of their direct contacts. As a future extension of the current work, we aim to work on the similarity measures on the profiles of SaaS services in detail. This paper focused on the P2P interaction of SaaS services, however, association rule mining of the observed usage patterns of different SaaS services by service developers may lead to interesting results and we consider it as a future work.

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