STRUCTURAL COUPLING IN WEB 2.0 APPLICATIONS

Maya Samaha Rupert [1]

[1]Department of Computer Science, Notre Dame University Louaize, Lebanon
msamaha@ndu.edu.lb

ABSTRACT

The evolution of the Web and its applications has undergone in the last few years a mutation towards technologies that include the social dimension as a first class entity in which the users, their interactions and the emerging social networks are the center of this evolution. The web is growing and evolving the intelligibility of its resources and data, the connectivity of its parts and its autonomy as a whole system. The social dimension of the current and future web is being at the roots of its dynamics and evolution. It is thus, fundamental to propose new underlying infrastructure to the web and applications on the web, to make more explicit this social dimension and facilitate its exploitation. The work presented is this paper contributes to this initiative by proposing a multi-agent modeling based on the system coupling to its environment through its social dimension. Applied to a collaborative tagging system, the exploitation of the social dimension of tagging allows an intelligent and better sharing of resources and enhancing social learning between users.

KEYWORDS

Multi-agent systems, collaborative tagging systems, social learning.

1. INTRODUCTION

Over the last ten years, we have witnessed a revolution in the content, usage and structure of the web and its various applications. The web evolution is not controlled by any authority, and despite the chaos generated by the intensive volume of content and usage, order has emerged and the system is self-organized.

Previously, it was believed that the evolution of the web is solely controlled by the evolution of the technology and its intelligent design. But the phenomenal progress of Web 2.0 contradicts this belief because the users and their local interactions are driving this evolution, and intelligent design has become a secondary issue in this trend.

The web is growing and evolving the intelligibility of its resources and data, the connectivity of its parts and its autonomy as a whole system. The social dimension of the current and future web is being at the roots of its dynamics and evolution. It is thus, fundamental to propose new underlying infrastructure to the web and applications on the web, to make more explicit this social dimension and facilitate its exploitation. The work presented is this paper contributes to this initiative. First, we propose a multi-agents modeling that is based on the system coupling to its environment, through its social dimension. We illustrate this modeling through an application of a collaborative tagging system, that shows how considering and exploiting the social dimension of tagging, permits an intelligent and better sharing of resources, enhancing social learning between users. From a general perspective, the research presented in this paper addresses the issue of developing computer systems able to evolve and adapt to their environment, while

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ensuring the emergence of new practices. This emergence is due to the usage that affects the environment of the system, which in turn affects the usage. These systems are characterized by the following characteristics:

- Complexity expressed by: 1) a large volume of resources and data 2) a complex networking 3) a wide distribution with a decentralized control and 4) high dynamics.
- Openness: to a wide environment including physical and conceptual characteristics (physical network, multiple users and usages, etc.).
- Self-Organization: no overall control guiding their organization. They self-organize into new emerging structures.

This problem lies within the field of situated multi-agent systems where the agents are real or virtual entities, operating in an environment that they are able to perceive and act upon. In these systems, the role of the environment is fundamental.

In our research, we try to integrate the social dimension within the complex systems of the web. This can be achieved by using an organizational agent-based model for the development of complex systems that are open to their dynamic environment. We use situated multi-agent systems to build computer systems embedded in their environment. The design of the multi-agent system must take into consideration the different couplings between the system and its environment:

- Spatial coupling represented by the spatial organization of the multi-agent system.
- Social coupling represented by the social organization of the multi-agent system.
- The co-evolution of the two organizations through the multi-agent system dynamics.

The model takes into consideration the co-evolution of social organization and spatial organization of the multi-agent system and the retroactive effect of one organization on the other. We applied this model to the design of a collaborative tagging system by applying the concepts of social and spatial organizations. The spatial organization of resources will create clusters of semantically similar resources that are very useful when searching for resources. This clustering will result in the generation of groups of users who share similar interests. By analyzing the similarities between the users in each group, the system recommends the most appropriate resources according to personal interest of each user, which will in turn refine the clusters of resources. And the cycle of co-evolution between the spatial organization (cluster of resources) and social organization (groups of users) continues. The results showed that the proposed tagging system based on this organization approach, offers new features that enhance the current collaborative tagging systems, especially at the search level that becomes more personalized and more efficient.

2. RESEARCH POSITIONING

Our research can be positioned in the context of three research areas: Web Science, Complex Systems and Multi-Agent Systems (Figure 1). In previous work, we presented the Web from a complex adaptive systems perspective [1], showing that the web exhibits the properties and characteristics of these systems. Emergent properties in the evolution of the web and its self-organizational nature are largely due to the usage, which in turn is largely affected by new emergent technologies.

On the other hand, most organizational approaches for multi-agent systems concentrate on the social organization and roles of agents, with less emphasis on the role of the environment in the evolution of these systems. By developing systems that have the properties of complex adaptive systems, the behaviors of users and the structure of the web graph are strongly related. It is important to consider the environment and its physical materialization by a spatial representation at the multi-agent system level, correlated with the social representation of the agents evolving in this environment. By adopting the multi-agent paradigm as a model of representation, the system will evolve through the coupling of the social and spatial organizations of the agents.

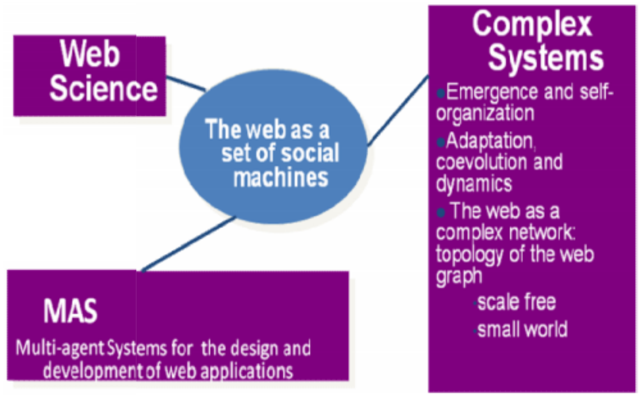

Figure 1. Web Science - Complex Systems - MAS

The concept of “social machines of the future” introduced in Web Science [2] finds its justification in our approach that integrates explicit linkage between the social and spatial organization in the evolution of complex systems. With the evolution of web 2.0 and the growing popularity of collaborative tagging systems, we explored these techniques of coupling between the social and spatial organizations in a system where the users’ actions leave persistent traces in the environment (the tags) that affect their future actions. With the integration of the social dimension in the system design, new features have emerged that have the potential to improve current collaborative tagging systems.

3. FOLKSONOMY AND COLLABORATIVE TAGGING SYSTEMS

A new generation of applications has emerged with the "web 2.0" such as wikis, blogs, podcasts and systems of resource sharing among different users. This revolutionary form allows web users to contribute extensively to the content of the web. We are interested in a particular system of sharing resources and that is collaborative tagging systems and folksonomy. Users add a tag or keyword to a resource on the Internet. The resource may be a web page, a blog, a photo or a podcast. Users are free to choose their own words to describe their favorite web resources. The result is an emerging social classification pattern created by the users themselves. This is categorically different from the traditional hierarchical classification. The terms and keywords exist in a flat space where the parent-child relationships no longer exist.

By studying and analyzing existing collaborative tagging systems, we noted the lack of adaptability and customization in these systems. At first glance, these systems provide information and tagged resources added by the users themselves. But by studying these systems in greater depth, taking into account the power of the social and the spatial aspect in these systems, the knowledge that can be extracted is well beyond just a list of resources corresponding to a particular tag. Current systems have many limitations at the search of information level and the integration of the social dimension ensures their evolution as complex systems. In this work, we took advantage of the co-evolution of the social and spatial organization in a complex system to develop a collaborative tagging system allowing the emergence of new features. This new

system is based on the retroactive effect of the social on the spatial and vice versa. The objective of this research is to complement the existing tagging systems by adding new features that can enhance these systems, taking into account the complex characteristics of these systems and the strong links that exist between the spatial and social organizations, which, to our knowledge has not been well explored so far in the design of these systems. Sharing of resources and tags with other users having the same interest offers two major advantages to users: the discovery of knowledge and better ways for searching for information. Tagging systems are being more and more used for users' profiling and in recommender systems [3, 4] and for personalization [5].
With the absence of hierarchical classification in collaborative tagging systems, problems of vocabulary and semantics become more persistent. There is no hierarchical structure, and the classification of information in these systems suffers from an inconsistency in the use of a word (what word or correct tag should be used to best describe a resource [6]. Users do not use tags consistently; for example, they can use a tag today for a particular resource and use a different tag in the future for the same resource, as their vocabularies and semantics change and evolve over time. When searching for resources by tags, the user must agree with the provider of the tag on the semantics of the resource.

To link users' non linked tags, an approach was proposed to build a collaborative and semi-automated semantic structuring of folksonomies by using a socio-technical system combining automatic handlings of tags, where the system allows every user to maintain his own view and benefits from others contributions [7].

3.1. Tagging systems as complex systems

Collaborative tagging systems can be represented by tripartite networks, where the users, the resources and the tags form the nodes. These three items form a triplet called a tag application, which is the fundamental unit of information in these systems [8]. Tagging systems have the characteristics of complex systems, such as a large number of users, lack of central coordination, non linear dynamics, and feedback cycles. Several studies [9-11] show that these systems exhibit the "small world" and "scale free" properties of self-organized complex networks. The clustering coefficient for datasets extracted from Del.icio.us and Bibsonomy is extremely high, and the relative path lengths are relatively low (3.6 in average). A high correlation between the outdegree and indegree clustering coefficients is present. The node degree distribution in social tagging systems follows the power-law distribution [9-11] $p=k-\lambda$, where the exponent $\lambda= 1.418$ (for a dataset extracted from Del.icio.us).

3.2. Tag Recommendation

For tag recommendation, the research main focus is on personalized tag recommendation, helping the user to add a new resource by providing tags' suggestions. This is mostly done by taking into account similarities between users, resources, and tags (collaborative filtering). This similarity is calculated based on the resources, tags, and users themselves using the folksonomy and personomy definitions [12]. Association rules and probabilistic models were also used to recommend tags[13, 14].

For social search, and social recommendation of tags, a model was introduced to search by relation where the user can choose to search either in his relations or in his "spiritual" relations, looking for who are his similar users in [15]. Users don't always search for the resources tagged by their similar users, as these ones might find their own resources; it is interesting sometimes to view the resources of users who are partially similar to them [16].

4. AN ORGANIZATIONAL MULTI-AGENT SYSTEM APPROACH FOR THE DESIGN OF A TAGGING SYSTEM

Multi-agent systems (MAS) coordinated by self-organisation and emergence mechanisms have been used for the development and design of complex systems, in which the role of the environment has increasingly been taken into consideration as a first class entity in building MAS. In order to engineer systems capable of "adequate" adaptation to their environment, we propose a coupling between the system and its environment (Figure 2):

- A structural coupling represented by the spatial organization of the MAS.
- A behavioral coupling represented by the social organization of the MAS.
- The co-evolution of both organizations through the MAS dynamics.

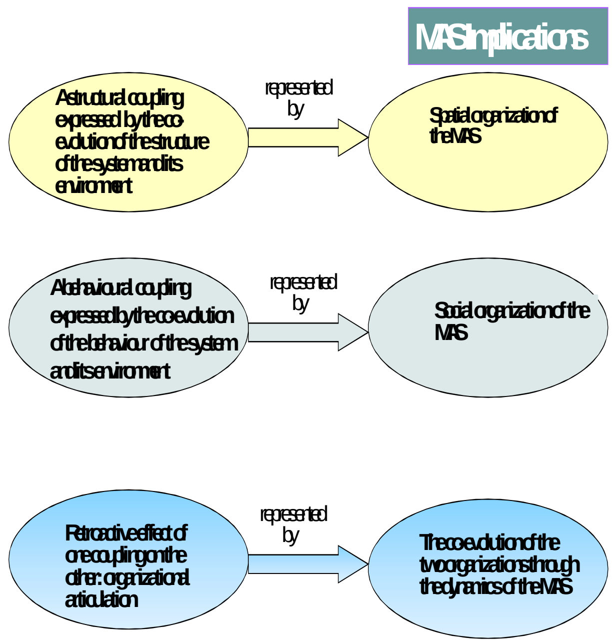

Figure 2. Coupling between the system and its environment

This model of representation allows us to develop systems for the web in which the coupling of structure and usage evolution (co-evolution) is made explicit, allowing for the emergence of new practices.

4.1. Social and spatial organizations of the agents

The social organization of the system is the social structure in which agents can act and interact with each other. Agents are organized in groups (organizational units) and play different roles (organizational positions) in each group. Roles in the system define the behaviours that agents exhibit as part of that role. The agents' perceptions depend on the position of the agents in the place, and the actions depend on the roles they can play. Agents' indirect communication and coordination are achieved through the use of the stigmergy mechanism and more particularly, through the diffusion, propagation, and evaporation of a specific digital pheromone. This digital pheromone is viewed as a spatial structure for coding the control and meta-control information.
The physical environment is represented by a network or a graph. Agents are situated in the different nodes of the graph called places. These places form the organizational positions that

agents can occupy at the physical level of the environment. The perceptions/actions of these agents are situated in the physical environment. A set of places forms a region. Regions form the organizational units of the spatial organization. As the network topology is highly dynamic, the regions are also dynamic and keep changing over time.

4.2. Organizational approach of our system

In our tagging application, users are represented by human agents who are involved in the accomplishment of a collective task. These agents are present in a physical environment, which is materialized by a complex network of physical resources that represents by itself the tagging system. These agents assume certain roles; they are able to perceive and influence their environment, as they accomplish some tasks in the considered network of resources, which consequently affects the system's evolution. Such physical materialization allows the implementation of the mechanism of stigmergy, leading to self-organization.

Agents communicate indirectly with each other and leave their traces on the environment in the form of tags. These tags could be considered as a pheromone, which allows self-structuring of the system through the users' actions on the environment. This emphasizes the influence exerted by the persistent effects in the environment of past behaviors of agents on their future behaviours. These effects were grouped into three categories:

- a qualitative effect: this represents the influence on the choice of the action to be taken by an agent ;
- a quantitative effect: this represents the influence on the parameters (such as the position, the strength, the frequency, the latency, the duration, etc.) of the action, while the nature of the action remains unchangeable;
- a qualitative and/or quantitative indirect effect: this represents the influence on the action result. This influence indirectly affects the way the action will be taken and its result, are a consequence of the changes made to its environment.

Let us consider the case of adding a resource to a personal library, where an agent could choose a tag from his/her own vocabulary list. If this resource doesn't exist in the system, the personal tag will be added to the resource. But if the resource does exist in the system, with multiple dominant tags, the user will probably choose one of these tags. The actions that have already been taken by previous users will be affected by the result of the current agent's action. The resource will be reinforced by the dominant tag, which will affect the actions of future agents. This is a case of passive stigmergy. The mechanism of stigmergy allows the environment to structure itself through activities that agents take in the environment.

The spatial organization in form of sub-communities of resources is affected by this change, leading to a restructuring of the environment. This restructuring will have an effect on the spatial position of the agent in the physical environment that is materialized by the network of resources. This position influences the choice of the action to be taken by the agent. Consequently, the agent could choose to play the role of Resource Tagger, Resource Searcher or Knowledge Expert. He could also choose to be, for instance, the creator of a new community of users, etc.

An agent's behaviour and the role it will play are greatly affected by its position in the spatial organization. Its position is also affected by its actions and the roles it plays in the social organization and by the different activities in the environment (pheromone presence, etc.). The coupling between the social organization and the spatial organization is retroactive and is expressed in the graph topology. Figure 3 shows a cycle of evolution between the social and spatial organizations.

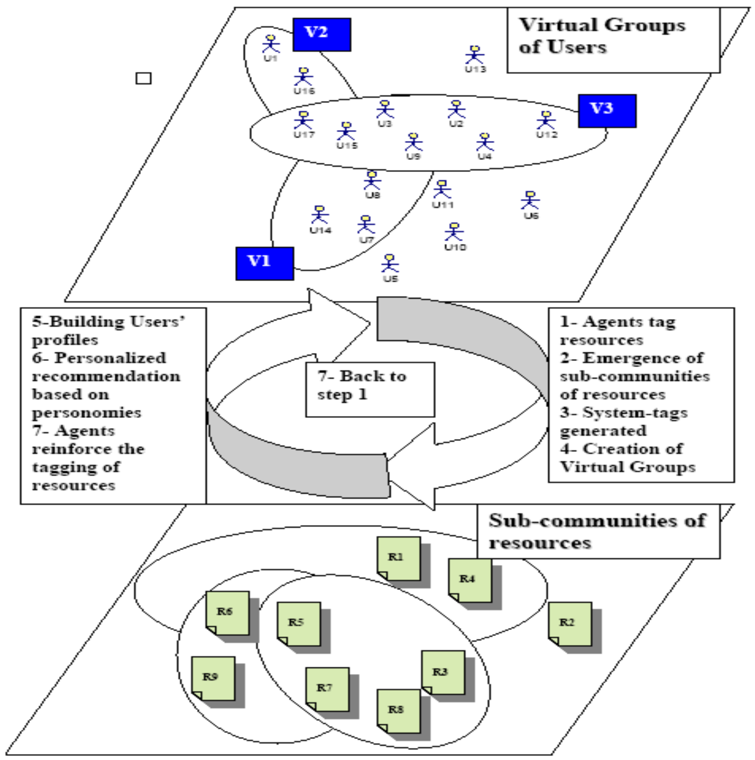

Figure 3. Evolution cycle

4.3. Functionalities of the collaborative tagging system

The purpose of our research is to complement existing tagging systems with new features that enhance the tagging experience while taking into consideration the complex characteristics of these systems. The co-evolution of the spatial and social organizations of agents paved the way for the emergence of new properties. Users or agents leave their traces on the physical environment (tags and reinforcement of tags). As a result of this tagging behavior, sub-communities of resources eventually emerge. This is viewed as the stigmergy mechanism, where the influence of persisting effects in the environment of past behaviours affects future behaviours.

Our collaborative system was created based on the organizational multi-agent system model. The main functionalities of our tagging system that enhance the users' experience are listed below:

- Enhancing the search by tag by having a kind of hierarchical classification from the formation of sub-communities of resources. Searching a tag like 'design' with the option to cluster the results will return in our system sub-communities such as 'web design", "home design" etc.. The advantage of belonging implicitly to a virtual group will allow each member of the group to access and view more quickly any new resource tagged within the group. The member will also have a chance to interact with other users who share his same interest. Most users in current tagging systems do not explicitly form or join social groups.

- A member may decide to become a group leader and create a physical group and send invitations to members of the virtual group to join the new group. (building communities and forming social relationships becomes easier as the group leader is aware of all the potential members)
- Integrating the personomy in the application as a tool for calculating the similarity rate between two users of the same group. Users can compare themselves to other users and find those who share more interests with them.
- This similarity is used to build user profiles that support the integration of web page recommendation systems, as these systems will have a better understanding of the interests of the users and be able to recommend more specific bookmarks to users.
- The system-tags generated by the system improve the tag vocabulary of users in terms of consistency.

These functionalities have emerged as a result of the coupling of the social organization and spatial organization. This self-organizational aspect at the spatial and social levels, as well as the mutual retroactive effect, could be expressed in our application as follows:

The evolution of the spatial organization (sub-communities of resources) has a direct effect on the evolution of social organization (formation of our virtual groups). The reinforcement of the resources by the users has a direct effect on spatial organization. The more users leave their traces, the more traces will be reinforced by other users. This is a kind of pheromone that is deposited in the environment.

The social presence of individuals affects their behavior in their social networks. Users will therefore increase their annotations and contributions. This is the direct effect of social organization.

5. CLUSTERING RESOURCES AND EXTRACTING USERS' PROFILES

5.1. Clustering resources

We used the spectral clustering for grouping sub-communities of resources that share similar content. We adopted the algorithm used in [16] for the emergence of sub-communities of resources by calculating the weight between two resources R1 and R2, as follows:

$$w_{R_1,R_2} = \frac{\sum_{t \in T_1 \cap T_2} \frac{\min(f_t^1, f_t^2)}{f_t}}{\sum_{t \in T_1 \cap T_2} \frac{\max(f_t^1, f_t^2)}{f_t} + \sum_{t \in T_1 - T_2} \frac{f_t^1}{f_t} + \sum_{t \in T_1 - T_2} \frac{f_t^2}{f_t}}$$

The numerator is the sum of the minima of normalized frequencies for the tags used in both resources (intersection of sets T1 and T2).

T1 (respectively T2) is the set of tags associated with R1 (respectively R2), (respectively) is the frequency of occurrence of tag t in T1 (respectively T2) and is the global frequency of tag t or the total number of times that tag t was used in all the resources.

The formed similarity matrix W could be considered as the adjacency matrix of a complex weighted network in which it is possible to assign to the arcs of the graph a weight that is proportional to the intensity of the connections between the network elements.

In order to visualize the different sub-communities of resources that emerge from the set of all resources related to a particular topic, some necessary transformations of the rows and columns of this matrix were needed. Consequently, the matrix was transformed into a matrix Q as follows:

Q = S – W where Wij = (1-δij) ( ) and

S is a diagonal matrix in which every element equals the sum of the corresponding elements of the row of W.

We study the spectral properties of matrix Q, and determine the number of emergent semantically distinct sub-communities of resources from the number of smallest distinct non-trivial eigenvalues. Figure 4 shows the sorted eigenvalues of the matrix Q. The presence of the first 4 non-zero well separated eigenvalues indicates the existence of at least 4 well defined sub-communities of resources.

The Laplacian matrix L of the graph G (also called the Kirchhoff matrix) is defined as being the difference between the degree matrix D and the adjacency matrix W. L = D – W

Let us consider the first smallest eigenvalues of the Laplacian matrix L. The number of these well separated eigenvalues can indicate the number of possible emerging communities. A study of the first eigenvectors that correspond to these eigenvalues reveals the structure of these communities.

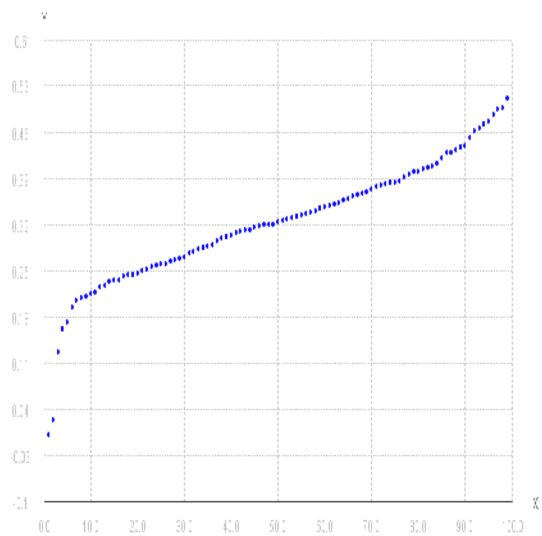

Figure 4. Sorted eigenvalues of Matrix Q. The presence of at lease 4 well separated non zero eigenvalues shows the presence of at least 4 different clusters

To partition the graph by the eigenvectors of matrix Q, the number of clusters from the eigenvectors of Laplacian matrix were detected by studying the correlation between two nodes, as both resources that belong to the same community will be strongly correlated [18]. We calculated the correlation matrix Cij between two nodes i and j based on the following formula:

$$C_{ij} = \frac{\langle x_i x_j \rangle - \langle x_i \rangle \langle x_j \rangle}{\sqrt{[(\langle x_i^2 \rangle - \langle x_i \rangle^2)(\langle x_j^2 \rangle - \langle x_j \rangle^2)]}}$$

in which xi and xj are the components of the first few nontrivial eigenvectors, the notation represents the average of these components. The correlation coefficient cij measures the proximity between two nodes i and j. Based on the analysis of this matrix, clusters of resources were retrieved.

When searching for resources that are assigned a specific tag, our system clusters these resources into sub-communities. For example, if the user searches for resources tagged with ‘programming’, the system will arrange the resources into sub-communities as follows: ‘web programming’, ‘java programming’, ‘ajax programming’, etc., while the existing systems display resources that are associated with the tag ‘programming’. Our system significantly improves the results of a search by tagged resources.

Once the system applies the clustering algorithm described above to a particular set of resources, these resources will be assigned system tags composed of the combination of the topic-subtopic (i.e. ‘web’ and ‘programming’, or ‘java’ and ‘programming’).

The system tags are auto-suggested to new users who are about to tag a resource that is already assigned system tags. This application of a suggested tag is viewed as a pheromone used to reinforce traces left by the agents when coming across a particular resource.

5.2 Virtual groups of users

A virtual group is a set of users sharing the same interest in a particular topic. Users are grouped into virtual groups based on their tagging history. Newly added resources are categorized into virtual groups based on users’ early tagging behaviour. This provides an advantage to users as they become aware of the social network earlier, and they can choose to interact with the network and add more tags and resources to share within the virtual groups. For each sub-community of resources, corresponding users who have already tagged these resources will be grouped into ‘virtual groups’ based on the topic of the sub-community resources. For example: all users interested in resources related to ‘Web Design’ belong to the same virtual group ‘Web Design’. Figure 5 shows an example of a user who belongs to 2 groups “Web Design” and “Home Design”

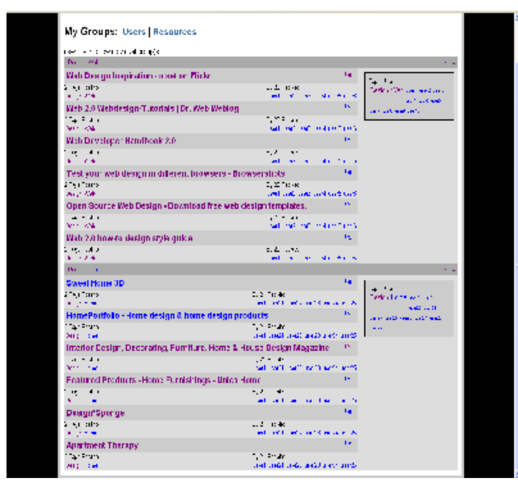

Figure 5. 2 groups “Web Design” and “Home Design”

5.3. Analysis of the similarity degree between 2 users and building users' profiles

The purpose of this analysis is to determine whether two specific users are strongly or slightly similar.

Definition: Two users are defined as strongly similar if they tag many resources that are semantically non-similar. For example: if two users tag in the same way (use similar tags) resources that are related to programming, it will be interesting to analyze how these users have tagged resources related to cooking or the Vancouver Olympic games for instance.

If the two users who belong to the same virtual group are strongly similar, the resources added by one of them will be suggested to the other user and vice versa. In this case, the results of the search by tag will be customized based on the interests of each user.

In each virtual group of users, we will cluster users with high similarity degree, whereas other users in the same group will have slight similarity degree. This creates several clusters in the same group. It is important that every user become aware of other strongly similar users, and consequently will have direct access to the resources added by these users to their libraries. In the sub-communities of resources this situation is reflected in the information that will be displayed to the user. The sub-communities of resources will in turn be customized and refined according to the user's interests. Given this direct and rapid access to those resources that have been tagged by users with a high degree of similarity to a particular user, the particular user will have the tendency to tag the same resources. This will create a building of such resources in the community quite similar to the pheromones.

For example, suppose we have 2 users, namely User1 and User 2 both interested in "web design", therefore tagging the same resources with the "web design" tag. Suppose they are also both interested by the resources related to the same city "Vancouver". In our system, User1 and User2 will be highly similar.

The customized recommendation for User1 will display the resources tagged by highly similar users (User2 in this case). When User2 tagged a new resource which is a "web design" company in "Vancouver", this resource was recommended only to User1 based on the high similarity score between these 2 users. These resources are of special significance to User1 because they come from a user who shares the same interests.

It is very probable that User1 considers tagging the resources that the system recommends to him. Therefore theses tags and resources will be reinforced in the system.

6. CONCLUSION

In this paper, we propose to introduce more sociability in collective tagging systems. Our work is aimed to contribute to the effort of the emerging web science, where one objective is to propose new principles and underlying architectures of future social machines over the social web. We made explicit the linkage between social activity of tagging and its effect on emerging clusters of resources and virtual groups of users. This was modeled by a multi-agent systems with a social organization (practices and activities) and a spatial organization (effects on resources), coupled in a retro-active way. This coupling allows the co-evolution of clusters of resources (tagged with similar tags) and virtual groups of similar users. The emergence of clusters of resources is obtained by the adaptation of a spectral clustering algorithm. This clustering allows the definition of a hierarchical organization of tags, using system tags suggested after the emergence of a cluster of resources and an associated virtual group of users (taggers). Finally, these virtual groups of users and their associated clusters of tagged resources were used to propose resources recommender system, based on the cross-fertilization of the tagging activity of the members of the virtual groups that emerged from the tagging activity. In future work, we intend to consider the effect of considering social networks properties and their effects in the context of collective/social tagging systems.

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