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SIM: A dynamic multidimensional visualization method for social networks

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ABSTRACT

Visualization plays an important role in social networks analysis to explore and investigate individual and groups behaviours. Therefore, different approaches have been proposed for managing networks patterns and structures according to the visualization purposes. This paper presents a method of social networks visualization devoted not only to analyse individual and group social networking but also aimed to stimulate the second-one. This method provides (using a hybrid visualization approach) both an egocentric as well as a global point of view. Indeed, it is devoted to explore the social network structure, to analyse social aggregations and/or individuals and their evolution. Moreover, it considers and integrates features such as real-time social network elements locations in local areas. Multidimensionality consists of social phenomena, their evolution during the time, their individual characterization, the elements social position, and their spatial location. The proposed method was evaluated using the Social Interaction Map (SIM) software module in the scenario of planning and managing a scientific seminars cycle.

This method enables the analysis of the topics evolution and the participants' scientific interests changes using a temporal layers sequence for topics. This knowledge provides information for planning next conference and events, to extend and modify main topics and to analyse research interests trends.

Keywords: *Social network visualization, Spatial representation of social information, Map based visualization.*

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1. Introduction

The interest in social networks visualization has been used to promote social networking and to improve the “belonging feeling” of social networks elements, as well as to provide several methods of structural analysis aiming to explore and investigate individual and group’s behaviours.

Visual representation is a very useful and relevant aspect of social networks. A social network is a group of people linked by social relationships. Studying a social network implies the study and knowledge of connections and dependences between elements and groups that belong to it, (i.e. family connections, work links, friendship relations, sharing political or cultural aspects, having some common characteristics such as sex, age, and so on). The wide use of Internet, the diffusion of the Web 2.0 and the revolution produced by the use of mobile devices are all factors that have produced the emerging of virtual social networks.

The diffusion of this phenomenon has facilitated individual and groups behaviour analysis and has stimulated visualization issues. Indeed, they enable to connect and analyse persons or groups of interest, their connections and their spatial and temporal evolution. Usually, the purpose of the social network analysis concerns three different levels: the overall network, group of elements and single actors. The classifications of networks and sub-networks properties are generally discussed according to the purpose of the analysis of groups of elements. If the goal is to examine elements, the analysis focuses on the single actors’ properties, links among them and incidences, which represent actors’ connections in the network. However, a social network can require to adequately represent abstract connections (for example people sharing work and/or study interests). In particular, starting from a social network existing connections, it could be useful to highlight and share some common actors’ characteristics, such as work and/or study interests, even if such an actor had never been connected with any other by e-mail, face to face or using any other possible connection. Indeed, sharing these abstract connections enables to identify the potential connections and, consequently, their evolution, and could improve the social network expansion velocity and the social-ability of the involved people.

Collected data about a social network can concern work interests of the social network elements, their favourite music, movies, books, their local positions, and so on. These data can be used to improve functionalities connected with social networks because they allow to foresee users' behaviour and to plan new services that users could need.

An example of functionalities is represented by people detection and visualization devoted to facilitate interactions anytime and anywhere according to their interests about work, study, hobbies and so on. Indeed, many people work at distance and require information about people and organizations profiles for labour recruitments, partnering, etc. Therefore, their work can be facilitated by sharing information and organising social networks. If some people with the same interests are located in the same area, then the collected data can be used to provide functionalities promoting the people face-to-face knowledge and the social networking development, providing local services according to people needs. This aspect can stimulate the belonging feeling of each social network element to the group and her/his social ability; moreover it can change the social network egocentric perspective (usually adopted) in a group approach.

The literature has discussed some methods to support the analysis of social systems visualizing interactions between social elements and groups monitoring their dynamics. Three main relevant approaches are defined to visualize social networks: the *graph-based*, the *matrix-based* and the *map-based* one. The visualization that uses graphs provides a node-link based representation of networks structure; each node can represents an actor, single or group, or a topic and each link (arc) represents the connection between couples of actors or topics. For example connections can represent e-mail messages exchange, chats and other communication tools. The matrix-based approach associates the network actors with rows and columns; the matrix cell values identify social connections between actors. The map-based visualization is suitable to show and organize large volumes of data and complex social networks data structures emphasizing textural or conceptual features of the visualization by shading, colours, labelling and icons. This visualization uses the cartography metaphor in order to communicate information about the relationships and distances between social entities. All the existing approaches have some advantages and disadvantages, according to the different social networks features.

In this paper we are proposing an approach for social networks visualization, which provides an integrated visualization devoted to explore the social network structure and to analyse social aggregation and/or individuals. The approach we are presenting introduces different dimensions: the *spatial dimension*, the *temporal dimension* (used to describe the dynamic of the social network) and the *interests dimension* that is represented by coloured areas and it is related with the group's or the individual's interests. The user can have a dynamic visualization of the social network to discover topics (for example scientific interests), their evolution as a global phenomenon, people that share that interests, their evolution as individual, and people closely located with their interests and needs. Moreover the proposed method facilitates service sharing for people that are in the same area at the same time. The feasibility and usefulness of the method have been evaluated by developing a software prototype (SIM, Software Interaction Map), and using it for planning and managing a scientific seminar cycle. This is a real context of use, meaningful enough to asses the method, even if the amount of managed data is not very large. Before introducing this approach, the paper provides an overview of the main social networks visualization systems underlining how the networks patterns and structures are managed, and describing the different kinds of information and types of visual metaphors used. This discussion will underline how the three different approaches proposed by the literature (graph based, matrix based and map based) are suitable for different visualization purposes. In addition, mobile systems for the visualization will be presented underlying how they manage problems connected to the visualization on small screens and issues about the low resolution. Moreover dynamic systems will be analysed pointing out how they represent the evolution of the networks over the time.

The paper is organised as follows: Section 2 presents the main methods proposed in literature to visualize social networks. Section 3 describes the main features of the multidimensional and dynamic visualization method that integrates in a hybrid approach the proposed manner to visualize interests/topics of individuals and/or groups; moreover, it introduces the *SIM* (*Social Interaction Map*) software prototype used to evaluate the proposed approach. Section 4 provides an evaluation of the proposed method, whose results are explained in Section 5. Section 6 concludes the paper.

2. Related works on social networks visualization

Information and data visualization is a field where statistics, graphics, tables and maps are relevant to satisfy the need to analyse and understand problems, to solve them in a minimum time and in an intuitive and natural way.

The use of visual representation to show important data features has been well suited to the social network analysis (Moreno, 1932). Indeed, visual representation provides a synthetic and simple description of the focal features representing information and/or data about interrelations of individuals, groups and their social linkage patterns.

In the literature, as suggested in the introduction, social networks are visually represented mainly using the following three different approaches: the *graph-based*, the *matrix-based* and the *map-based* representation.

Graphs are the most natural solution used to visually represent a social network. They simply and intuitively present all connections between the network elements. However, when managing a large amount of data, matrix visualization can be more useful, since it can produce a lower user's cognitive overhead. If social network data and structure are complex and can be organized and visualized according to different points of view and different detail levels, it could be better to use a cartographic map representation. Indeed, this representation can support multiple granularity levels and viewing models.

The literature provides such systems, described below, which uses the social network visual representation according to the previous cited approaches.

Considering the graph-based visualization, it was pioneered in the construction of social networks by Moreno (1934). The author has introduced direct graphs and colours to draw multigraphs, variations of point shapes to define characteristics of social actors and variation of point locations to focus on structural data features.

Several systems for the network drawing and analysis have been developed (Freeman, 2000). For example, MultiNet (Richards & Seary, 2003) can provide two or three-dimensional images of the net; it allows users to rotate the images and to colour the points. In particular, integration of networks analysis and their visual exploration is well obtained in NetMinerII (Cyram, 2004), which provides a graph-based networks visualization using various options underlying networks patterns and structures. The graph-based visualization is also used to explore online social networks, providing awareness of community structure; moreover this visualization is used to support the discovery of people and connections among each person and communities. An example of this visualization is provided by Vizster (Heer & Boyd, 2005); it is a system that visualizes a network through a node-link representation, where each node identifies a member using a name and his/her representative image or picture. The graphic information is integrated by textual information about personal profile; the system offers the possibility to define direct search over profile text.

The social networks visualization at the level of its members has been also developed in Visione (Brandes & Wagner, 2003). This system focuses the analysis on vertices (members) providing a measure of their structural importance through indexes connected to them. Indexes define if a vertex is central or has a high status in the social network. Visione allows users to explore data using attribute-based selection mechanisms on vertices. Starting from an egocentric (individual) point of view it could be interesting to provide social network visualization according to topics characterizing the network, its elements and their connections. A topic maps visual representation that uses graphs is given in a paper by Thomas, Brecht, Bode and Spekowius (2007); they developed TMchartis, a system that proposes different visualizations according to the focused task; for example if the goal is to overview the net or to find a specific information, it allows the user to navigate on the topic map, zooming and searching for topic nodes.

To support the users' knowledge about the social networks and their emails archives, Viégas and Donath (2004) propose two visualizations. The first one is based on a network graph that considers email connections as links among nodes. The second representation uses matrices that have people associated with rows and columns. Cell values represent connections between people. This visualization highlights temporal features of interaction between each user and her/his connected elements and it highlights clusters of links obtained from email archives; moreover it enables to show different features of the social network elements.

Two different representations are presented by MatrixExplorer (Henry & Fekete, 2006) that provides visualizations based on node-link diagrams and matrices for exploring social networks. The node-link diagrams are more intuitive than matrices, and this representation is synchronized with the matrix-based one for allowing users to easily switch from one to another. Usually, the matrix-based visualization allows organizing, clustering and filtering graphs in order to provide exploration of complex social networks. Indeed, the graph representation is not always appropriate for large or dense data social networks because of their complexity. In fact, graphs are hard to interpret when there is a high probability of nodes occlusion due to their great number and the tight clusters. Moreover in a graph structure often it is not so easy to understand nodes connections inside clusters.

Issues connected with wide amount of data and information can be managed using the map metaphor for their visualization. Maps allow visualising each social network element in a 2D plane. In particular, features of the map, which can be usefully applied to the social networks maps, are the adaptive zooming and the multiple viewing modes (Viégas & Donath, 2004). Map based networks members' representations are provided in ContactMap (Nardi, Whittaker, Isaacs, Creech, Johnson & Hainsworth, 2002) that visualizes a person's social network, defining the central or peripheral position of each contact to her/his work and personal interests. This system provides a visual map of contacts and groups of contacts in the domain of the e-mail communication defining the user's personal social network. In this visualization contacts are collected in groups that are differently coloured and positioned in the map; it is similar to a geographic map where the spatial positions represent relationships among contacts. The system offers communication functions and enables the user to retrieve current and archived information associated with contacts. An example of map-based methods for social network visualization is Sociomapping (Bahbouh & Warrenfeltz, 2004); it visually expresses information captured by a social map. In this visual representation each actor has different features according to the goals of the visualization and she/he is represented as a point in the map. The point height in the map can identify the level of communication, the social position or the importance of the element in the social structure. The distance between two elements represents the level of the relationship; finally, the quality of the relationship is identified by a set of contour lines or other visual parameters.

Visualizing data and information using mobile devices can produce several restrictions with respect to the use of desktop computers, according to issues connected to the small screens low resolution. To overcome this limitation several systems include scroll and zoom functions that allows user to navigate through parts of the visualization (Adar & Tyler, 2003). In addition, the current available tools for visualization on mobile devices have low-level or limited graphics libraries. An example of map-based visualization on mobile devices has been developed by Chittaro (2006). This system displays a database of geographic points of interests and assigns a specific icon to each category of points of interest on a map. The icons positions and their distances reflect their spatial relations. This system provides selection algorithms, which satisfy a set of user-provided constraints, integrated with a coloured vertical bar for each point of interest. This bar shows the number of constraints each point satisfies; if all constraints are satisfied by one point then the bar is green. In addition, to overcome limitations due to the small screen of mobile devices, this system defines detailed information on map magnifying the more useful areas and compressing the less useful one.

In the social network visualization could be also focal to understand how the network changes over the time. Dynamic visualization allows representing topics movements and social distances and changes in a social network over the time. Dynamic visualization refers to visualize dynamic data and information about the network that concern relations between network nodes and when these relations occur (Moody, McFarland, & Bender-deMoll, 2004). The temporal visualization of social network has been presented by McFarland and Bender-deMoll (2004) using animated graph structures. This system models and animates representations of social interactions over time constructing meaningful layouts of social interaction. Dynamic systems allow analysing information concerning e-mail logs, mailing lists, phone logs and chats of social networks members, as provided in TecFlow system (Gloor & Zhao, 2004). This system visualizes both dynamic and static representations of communications among the network members. It allows users to statically visualize the communication networks in a chosen time period, while the dynamic representation provides an interactive movie that represents the evolution of the communication network over the time.

3. The dynamic multidimensional visualization method and the SIM system

Starting from the visualization methods and systems for social networks previously discussed, this section presents a *hybrid*, *multidimensional* and *dynamic* visualization method that integrates different perspectives of individuals and/or groups of individuals, considering both the egocentric and the social group point of view. It adopts a graph based representation approach integrated with a map based one (hybrid). The *multidimensionality* of this method consists of the opportunity it offers to define visualizations according to coordinates associated with the involved social variables describing phenomena such as classes *of interests* (topics) represented by colours, *spatial dimension* providing the social network elements positions in term of local coordinates (with the aim to promote face-to-face contacts when possible, and consequently the socialability of the elements), the *temporal* dimension that gives the evolution during the time.

The spatial dimension identifies each social network element position according to a local/global coordinate system on a 2D space and the different needs of visualization, while colours identify classes of interest. The temporal dimension provides to visualize the social network temporal evolution and to plan individual and group services; this last goal can be viewed as a common temporary issue.

Moreover, the proposed method allows visualizing groups or individuals classes of interests using a multidimensional social map. Two dimensions attain to a 2D virtual representation of coloured areas connected to classes of interests. The size of each area is directly proportional to the number of people of the social network involved in the identified class of interests. A third dimension has been introduced to represent the *importance* of each member of the social network according to their classes of interests, given by the number of his/her connections with the other elements of the social network with respect to the specific class of interests. All points of the ovoid with the same height define an isoline identifying people with the same importance in the social network according to the identified class of interests. Each class of interests circle is centred in the point that identifies the colour for the specific interest on the colour wheel (Figure 1). Similar colours represent the interests semantic similarity computed using the Edge Counting approach introduced by Slimani, Ben Yaghlane and Mellouli (2006).

This representation facilitates social networking because it shows the members' social importance, i.e. the social role of each element; it is a very relevant information for stimulating social networking according to the users goals.

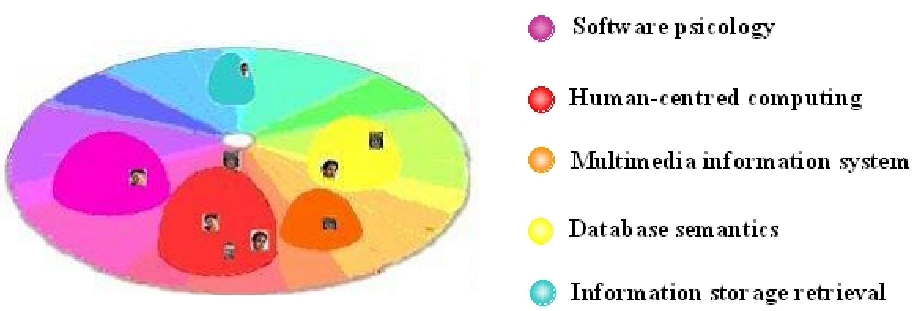

Figure 1. Interests visualized by coloured circles

The fourth dimension of the proposed model is *time.* It is visualized as an alternative to the *importance*, and gives the *evolution* of the social network, describing its dynamic by visualising the transformation of the interests during time. The temporal dimension allows to evaluate and to foresee the classes of interest evolution and the social network dynamic.

The proposed visualization method is discussed considering the scientific conference/seminars-cycle scenario. Moreover, we discuss how visualizing data/information about the social network according to the proposed method can help to improve the conference services quality and efficiency, and to monitor the evolution of participants' interests for stimulating new connections by the possibility to have an explicit visualization of all the participants and groups of interest during and after the conference running.

Indeed, the proposed method can allow, for example, visualizing people's interests in a conference/seminar location enabling users to detect people that share the same work interests to establish a direct connection with them creating a shared awareness. The idea is spawned to the fact that scientific conferences/seminars can play the important role to facilitate establishing links among people with specific common interests. However, frequently, the necessary information can be not available in real time, participants can be located in different rooms and each one could ignore important information to meet the other ones.

Handling a system that supports a map-based visualization that adopts the proposed approach can offer the possibility to improve the frequently used tools and methods to keep in touch with other people.

In order to achieve this goal it is necessary not only to provide a representation of relationships among the conference participants; it is also necessary to visually represent their interests, their potential evolution and the dynamic of relations among the conferences participants. In this scenario, people interests are collected by the system and they are shown using a very natural visual representation.

Section 3.1 gives a more detailed description of the visualization method and Section 3.2 presents the SIM system, giving an example of use.

3.1 The proposed visualization method

The proposed social networks visualization method aims to provide and integrate different visualization perspectives according to the user's goal. In particular, it offers the possibility: i) to visualize the spatial location and scientific interests of each user in a map (Figure 2); ii) to cluster users depending on their interests and to visualize them on a map according to the landscape metaphor (Figure 5); iii) to provide a visual representation of the temporal evolution of the people scientific interests (Figure 6).

In particular, each person's interests are classified and each class is associated with a colour in the visual representation. Let us consider:

- the set U of users where:

$$U = \{u_1, u_2, \ldots u_i \ldots u_I\} \text{ with } i=1...I$$

- the set S of users classes of interests:

$$S = \{s_1, s_2, .. s_i .. s_n\} \text{ with } i=1...n$$

Each user u_i is defined by name, contacts, list of interests and location that she/he has in a specific area in a given time period (p_{ui} (Δt_k)).

Each user directly selects name, contacts and list of classes of interests. The area where the user is located provides the user's location.

In our approach we use a local coordinate system where coordinates are referred to the users' positions in the specific area where she/he is.

For example, in the conference/seminars organization and management scenario local coordinates are defined considering the set of rooms of the building B where the conference is located:

$$B = \{r_1, \ldots r_i \ldots, r_b\} \text{ with } i=1...b$$

Each user's position is defined by the room r_j where she/he is located in a given time period Δt_k:

$$p_{ui} (\Delta t_k) = (r_j,)$$

Let us consider the following set of classes of interest:

S = {Software psychology, Human-centred computing, Multimedia information system, Database semantics, Information storage retrieval}

Figure 2 shows people attending a conference, sharing scientific interests; it visualizes the people locations in the seminar building according to their interests *S.* Users having more than one interest are represented as circles with partially overlapped colours.

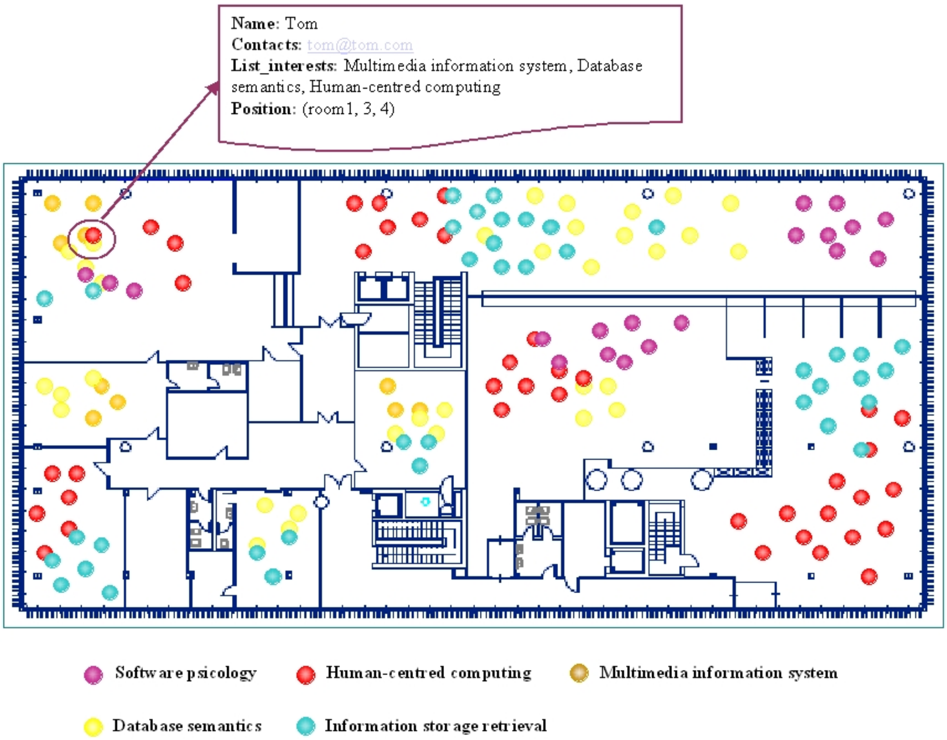

Figure 2. Real-time visualization of users' location

The knowledge about the users, their locations, their interests and their needs can be used to provide location-based services. Each user can choose services she/he needs among a set K of services:

$$K = \{k_1, k_2, \dots k_i \dots k_j\} \text{ with } i=1 \dots j$$

For example, it could be useful to provide participants with services based on their need to call a taxi, so that they can share the taxi if they need it at the same time and, if they partially or totally share the path. This example will be discussed in Section 3.2.

If the visualization perspective changes from the users' locations to the conference/seminars scientific classes of interests, it is possible to visualize topics using the 3D half-ovoid solids representations having circular horizontal sections (Figure 5). This section provides the 2D topics representation (see Figure 6 and Figure 7). Each topic area is proportional to the number of people that share the specific class of interests.

The proposed method visualizes coloured areas that represent the different topics and each person with respect to them can be represented in a given interest region.

In detail, the method defines a map according to data about the classified interests. Topics considered in the scenario of conference/seminars cycle organization and management have been classified using the top-level categories for the ACM Computing Reviews taxonomy (ACM, 2006); they have been represented using colours that are closer for more similar topics. Their semantic similarity is computed using the similarity measure proposed by Wu and Palmer (Slimani, Ben Yaghlane, & Mellouli, 2006). As shown in Figure 1 ovoid colours appear closer according to more similar interests on a 3D map.

Figure 3 shows the hierarchical structure of the topics belonging to the set *S* of interests according to the ACM Computing Reviews taxonomy.

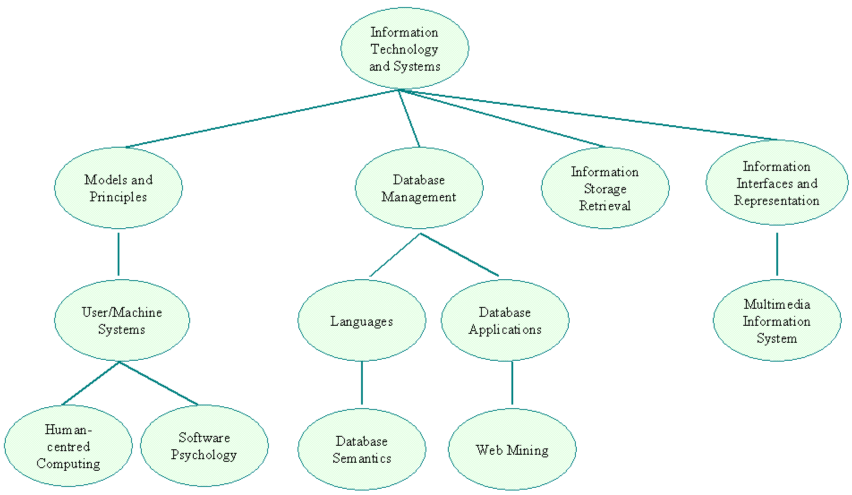

Figure 3. Hierarchical structure of the elements

The similarity measure (*sim*) between two elements is (Slimani et al., 2006):

$$sim = \frac{2N}{N_A + N_B}$$

where N, N_A and N_B are the depth levels represented in Figure 4.

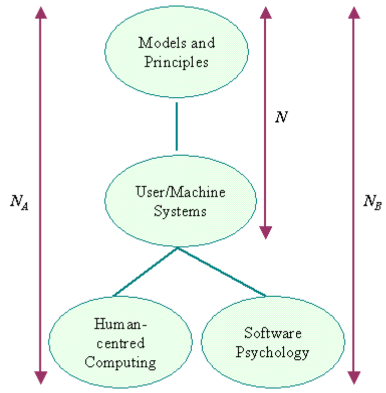

Figure 4. Depths levels in the hierarchical structure of the elements

Figure 5 shows the visual representation using the 3D space of the set S of interests. The radius of the circular horizontal section is defined by the numbers of users (n_i) that share the class of interests (i) normalized with the total number of users proportionally to $radius_{MAX}$, which is the maximum radius that a circular horizontal section can have in the plane. For example, the radius of the circular horizontal section for the class of interests *Multimedia information system* $radius_{Mult}$ is given by the following formula:

$$radius_{Mult} = \frac{n_{Mult}}{\sum_i n_i} radius_{MAX} \quad (1)$$

for i = *Software psychology, Human-centred computing, Multimedia information system, Database semantics, Information storage retrieval*

The height of the position associated with each user on the ovoid reflects the people's importance in the different classes of interests. Isolines in the landscape identify levels of importance of people in the classes of interests.

Figure 5 shows five users that are interested in *Human-centred computing*. The person that has the maximum number of connections with other people interested in *Human-centred computing* is located on the higher position on the solid visualizing that topic. Connections with other people having the same interest are shown using black edges. Moreover each person can be involved in more than one class of interests. For example the user in the higher position in *Human-centred computing* is also interested in *Multimedia information system* and *Database semantics* (visualised using orange edges).

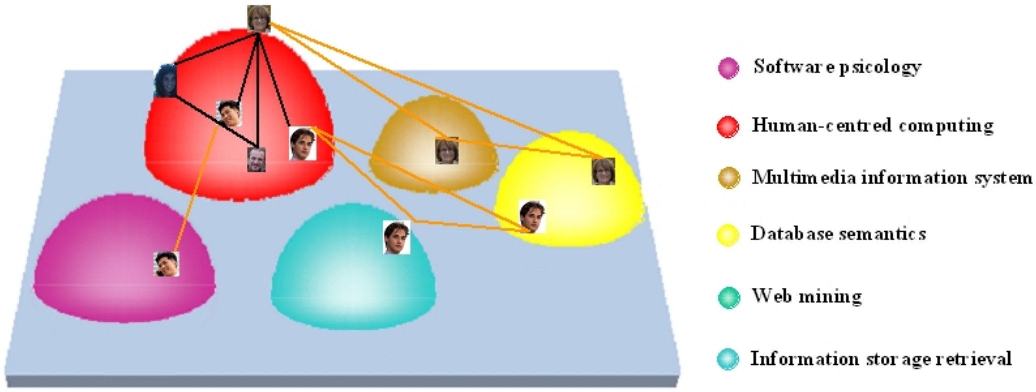

Figure 5. User profiles positioned in different points according to their interests and their importance in the class of interests

When a person is attending at a conference/seminar, usually she/he needs to get in touch with other participants according to their scientific interests and goals. If she/he does not know the other participants, she/he can browse the network (see Figure 5) choosing someone with the required features starting from the topic visual representation. Moreover she/he needs to visualize all information that enable to establish a contact, such as e-mail chat addresses and their real time locations in the conference. Therefore each participant can communicate and interact with others using e-mail, chat or face-to-face communication. The e-mail and chat are represented as directed arcs in the visualizations.

A different point of view can be considered in order to take account of the time when one person is interested in a visual representation of the social network dynamic. In this scenario, for example, the organisers of scientific conference/seminars have to plan their future events. Indeed, they can need information about the scientific interests evolution of single person and groups in order to analyse trends and to intercept the arising scientific topics.

To represent the dynamic it is necessary to consider time; the third dimension of the static representation in Figure 5, which represents the importance of the user’s profile, is removed and the temporal axis is added. 2D layers represent topics of interests in the conference/seminar at different time instants (Figures 6 and 7). This representation visualises the evolution over time of the communication network and the topics conference dynamics. The visualization consists of the topic variations on the map. In particular, it presents the topic map at the chosen time instants set. For example Figure 6 visualizes the topic map transformations (to identify mechanisms through which such changes occurs) at times t_1, t_2, and t_3.

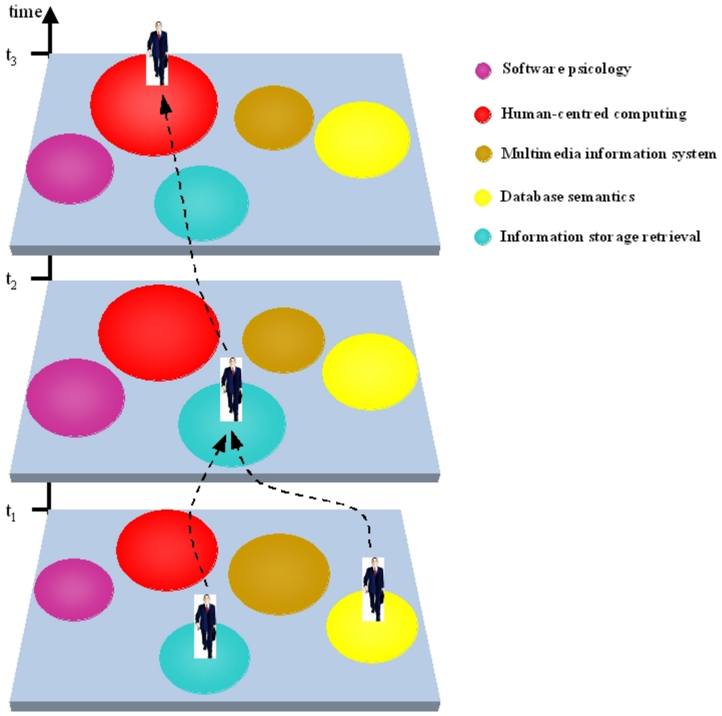

Figure 6. Interests map at the time t_1, at the time t_2 and at the time t_3

The dimension of each circle in Figure 6 is connected to the number of people that share the same class of interests (each circle is the base of half-ovoid solid representing the interests in Figure 5).

The temporal layer of Figure 6 at time t_3 is linked to the layout at time t_2 and time t_2 is linked to the layout at time t_1 considering interests changes during the time. In detail, Figure 6 shows that a person, who at time t_1 is interested in *Database semantics* and in *Information storage retrieval*, is only interested in *Information storage retrieval* at time t_2 and changes her/his interest to *Human-centred computing* at time t_3. The dynamic of people interest transforms the interest map, according to the fact that each circular area in each temporal layer is proportional to the number of people involved. In detail, the radius of each circle connected to classes of interests is given by the formula (1) previously defined. Let us suppose that the organizers of one conference/seminar are interested in the evolution of the participants' scientific interests. At time t_1 the set of main classes of interests S_{t1} in the conference is:

S_{t1} = *{Software psychology, Human-centred computing, Multimedia information system, Database semantics, Information storage retrieval}*

At time t_2 the set of main classes of interests is the same but the number of participants at the conference that share each class of interests changes with respect to the numbers at time t_1; and at time t_3 this number is different again, and the set of main classes of interests S_{t3} in the conference changes as follows:

S_{t3} = {Software psychology, Human-centred computing, Multimedia information system, Database semantics, Information storage retrieval, Web mining}

Figure 7 shows the three temporal layers underling the evolution of the participants' main classes of interests at the conference over the time. It detects the emerging of the new class of interests *Web mining* at time t_3.

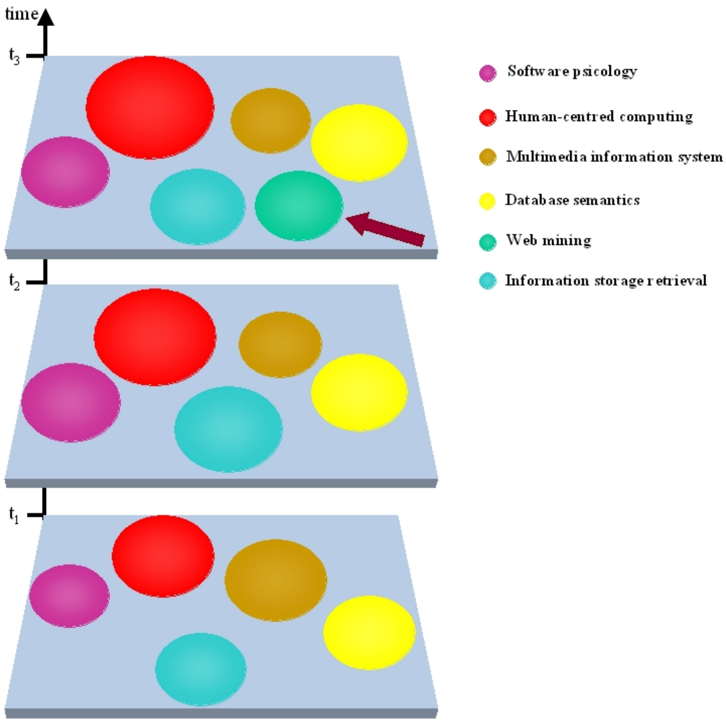

Figure 7. Evolution of the conference topics

The temporal layers sequence enables the conference/seminars organizers to analyse the topics participants evolution and to opportunely organise and plan future events (i.e. special sections, and so on). For example, considering the dynamic visualized in Figure 7, the conference/seminars organizers can decide to extend the next conference or seminars cycle topics with *Web mining,* previously not included in the conference, planning a special session on the emerging topic.

The meaningful changes between temporally adjacent network slices are visualised by interpolation techniques, which allow following changes in the topic map structure over the time. In detail, the dynamic visualization is given by a linear interpolation of the dimensions of the areas connected to interests from one resting position to the next.

3.2 SIM: the visualization system

In this section we describe the use of SIM, a software prototype based on the proposed social networks visualization method, used in the conference/seminars organization and management scenario to carry out tests with users.

For explaining its functionalities let us consider the scenario of a scientific international conference with its organizers and its participants.

Conferences/seminars organizers usually provide participants with the conference program, transport and accommodation services, list of participants, contact persons, and so on. SIM gives people with an on-line cooperative and interactive system that provides services enabling people to share and optimise information about them. It provides a spatial visualization of conference/seminar organizers and participants on a map that represents the conference. In addition a representation of interests map is provided for analysing the evolution of the topics for the seminar/conference. Let us suppose that one person needs to explore the conference/seminars members' scientific interests in order to find partners for a new project. In this scenario the system provides people with a visualization of scientific interests as in Figure 5 where it is possible to visualize people that share her/his interests in order to get in touch with them. According to this goal the system shows locations of people that share selected interests.

Each user is represented by a coloured circle whose position represents the person location in the building where the conference/seminar is running. Circles have all the same radius. Their colours visualise the people scientific interests according to the specific pattern specified in the legend. If a person has more than one interest the system visualises partially overlapped circles, having different colours, for each person. In this case problems about occlusion can arise due to the great number of circles; as SIM can be used on laptop and mobile devices too, the screen dimensions can be another critical factor. This perceptual issue can be overcome using an alternative visualization of each room in which people, represented in their locations, are grouped according to their interests. The level of interests clustering, which is applied to optimise the users' cluster visualization, is obtained using the K-means cluster algorithm (Hartigan & Wong, 1979); in fact, in order to have a clearer visualization it could be necessary to reduce the number of interests that are represented providing a more abstract representation aggregating the most similar topics.

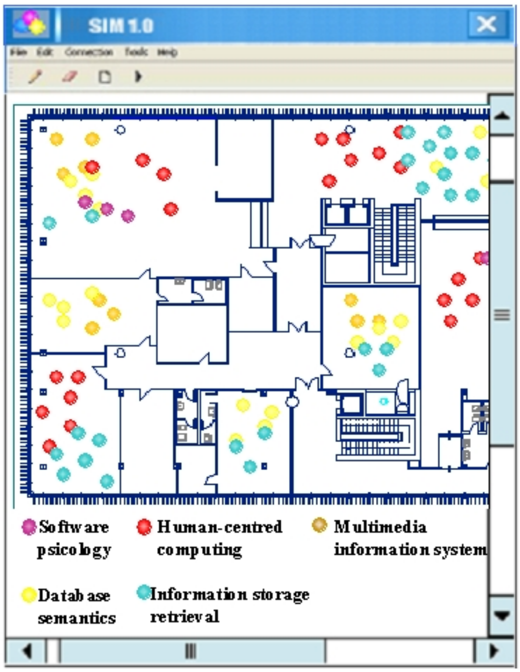

Figure 8. Visualization of the conference participants in the local area according to their interests

This representation is displayed in Figure 9 that. A circle represents a class of interests and its radius is proportional to the number of people in the room that share that specific interest.

Usually, during conferences and seminars events, participants need to such services.

Let us suppose that one participant needs to take a taxi for the airport and she/he wants to know if she/he can share it with other people. The system provides the set of K services offered in the conference/seminars organization. For example we suppose that at 10 a.m. the Prof. Rossi, which is attending the conference/seminar, selects the service for booking a taxi at 4 p.m. of the same day. Consequently the system provides him with a screenshot that shows the positions of people that have required a taxi close in time with the Prof. Rossi's request (Figure 10). In this representation circles represent people and the colour of each circle is connected to temporal gap between the time selected by the Prof. Rossi and the time selected by other people. The green colour is associated with the Prof. Rossi's services request. Services requests by other people for taxi are represented using colour that starting from green to shade of yellow referring to following time respect to 4 p.m., while if the reservation time come before then the colour of the circle is a shade of blue (Figure 10). Additionally, if the user selects circles in the map the system shows information about destinations, date and hours of the reservation of the taxi (Figure 10).

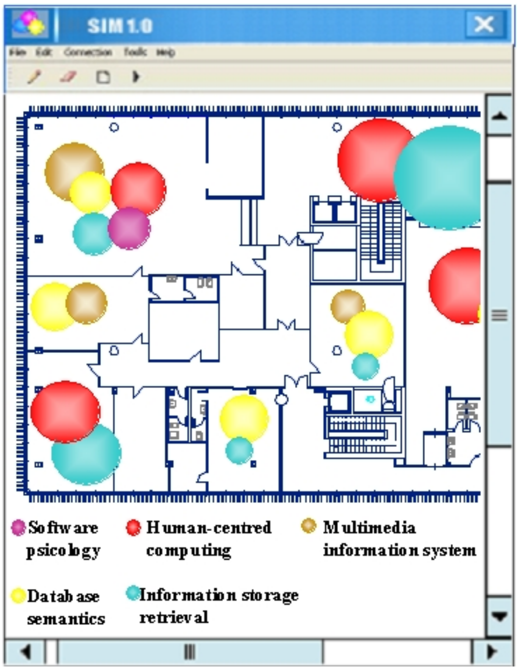

Figure 9. Aggregate visualization of the conference participants according to their classes of interests and their location

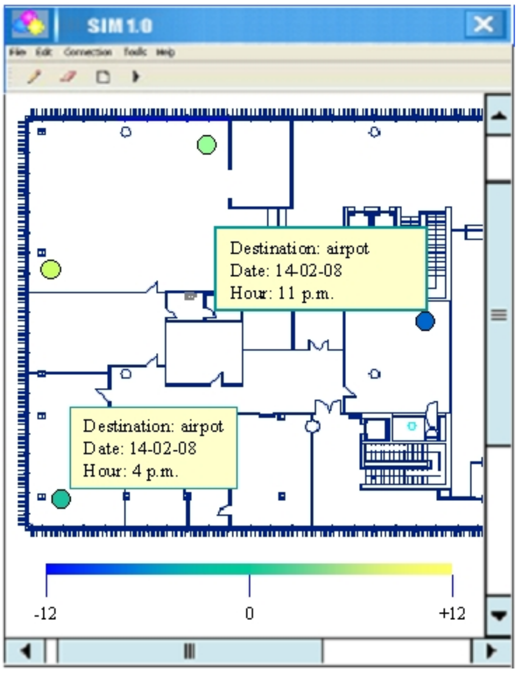

Figure 10. Services needs visualization

Therefore the user can choose people to contact. The system provides their locations in the building, their e-mail and chat addresses for allowing them to establish a connection promoting the services optimisation.

Let us suppose now that the conference/seminars organisers are interested to visualise the interests' evolution along the time in order to plan future scientific events. The system offers the possibility to change visualization from a location-based representation to the representation of classes of interests of the conference and their evolution in the last years.

Therefore, we suppose that the set of classes of interests of the conference is:

S = {Software psychology, Human-centred computing, Multimedia information system, Database semantics, Information storage retrieval}

The system visualizes three temporal layers referred to 2006, 2007 and 2008; each layer presents five coloured areas representing classes of interests. The visualization of the temporal evolution of each class of interests can be more effective connecting the same interest areas for the different temporal layer with a linear interpolation as shows Figure 11.

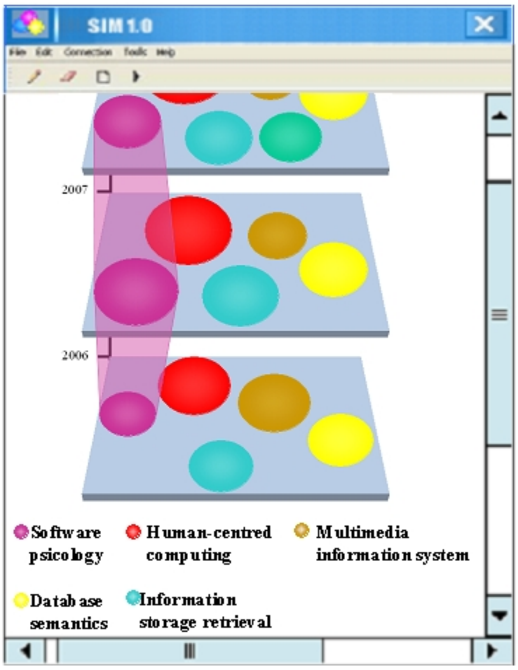

Figure 11. Temporal evolution of class of interests "Software psychology"

4. User's evaluation of the proposed visual model

In this section we aim to evaluate the proposed social network visual representation with respect to its usefulness in stimulating social ability and social networking among people and, with respect to the users' satisfaction. To evaluate the visual model introduced by this paper we have to answer the following question:

How the proposed visual model is consistent with people's natural mental models about social networks and their management activities and services?

Providing an answer to this question means to verify if the model enables to reach its goals and, consequently, to test: 1) its *effectiveness* in stimulating social networking, the connected activities and potentially new services, and 2) the *users' satisfaction* due to the proposed visualization model.

According to these purposes we have carried out a test devoted to highlight how the use of this model can improve the number of engaged people in social networking, how it can give a visual support to define the decision-makers' strategies, and how it can support services management and fruition. Finally the test provides the users' evaluation of the proposed visualization approach in term of user's satisfaction.

The test was carried out during two cycles of scientific seminars at IRPPS-CNR for a time-period of eight months, cycle A and cycle B. The test involved 77 people, 35 for the cycle A and 42 for the cycle B, with ages from 25 to 65. Each seminars cycle was organised in parallel sessions. The participants to the cycle A of seminars (A-group) were provided with the SIM prototype, supporting the defined model of visualization. The second group (B-group) did not use any system for social networking, but they were provided with the list of participants and their scientific interests.

Some people among the participants have had frequent face-to-face or virtual (e-mail, chat and so on) links with other ones before seminars beginning, and they were part of a social network (11 persons from the first group and 18 from the second one). Other people had not had any link with participants to the seminar. Consequently they had a strong need to share information and services, typically available among members of social networks.

All the participants in both groups had to answer to a questionnaire before the beginning of each seminar.

Moreover, each people could access to the list of participants of the current and previous seminars in order to give such a measure of her/his linking and social networking with the other participants in her/his questionnaire answers.

Starting from information collected by the preliminary questionnaire, we have obtained some important evaluation effectiveness factors. In particular, each seminars cycle consisted of 20 seminars, organised in 4 parallel seminars per cycle. The total number of the participants to the cycle A was of 40, while the total number of the participants to the cycle B was 47. Five participants were in common between the two cycles and they have been excluded by the experimental observation due the need to consider bipartite sets for the A-group and the B-group. Comparing answers collected with the questionnaire for the two groups we have obtained an implicit evaluation of the model effectiveness.

Let us consider the number *N.link* of frequent connections of each participant to each group. Comparing these values permits to evaluate the influence of visualization in stimulating social networking.

The preliminary questionnaire has involved both, the A-group and the B-group. In particular, the *social networking trend* for the participant *i* to the A-group seminars is given considering the evolution of the number of links from the j to the j+1 seminar. The social networking trend is similarly computed for the participants to the B-group seminars.

The social networking trend for each participant *i* to the A-group and each participant *k* to the B-group, can be computed respectively considering the differences ($\Delta^{A}_{i,\ j+1}$,, $\Delta^{B}_{k,j+1}$) between the number of links in the *(j+1)* and the *j* seminar sessions, for each participant (identified by the *i* and *k* indexes respectively) for all the n=5 parallel sessions of seminars. Their formulas are:

$$\Delta^{A}_{i,\,j+1} = \text{N.link}^{A}_{i,\,j+1} - \text{N.link}^{A}_{i,\,j} \qquad \text{with i=1, 2,..I and j = 1, 2, n-1}$$

$$\Delta^{B}_{k,\,j+1} = \text{N.link}^{B}_{k,\,j+1} - \text{N.link}^{B}_{k,\,j} \qquad \text{with k=1, 2,..m and j = 1, 2, n-1}$$

Let $P^{A}_{j,\ j+1}$ and $P^{B}_{j,\ j+1}$ be the total number of participants in the j and j+1 seminars, respectively for the A-group and the B-group.

The average increment of the links number on the total number of participants enables a qualitative evaluation of the proposed visualization approach, as it gives the difference of social networking for people that use this approach respect to other people. The average increment of the links number is expressed by the following formulas:

$$\Delta\lambda^{A} = \frac{\sum_{i=1}^{l}\Delta^{A}_{i,j+1}}{P^{A}_{j,j+1}}$$ with $j = 1, 2, n-1$ and $0 < P^{A}_{j,j+1} < l+1$

$$\Delta\lambda^{B} = \frac{\sum_{k=1}^{m}\Delta^{B}_{k,j+1}}{P^{B}_{j,j+1}}$$ with $j = 1, 2, n-1$ and $0 < P^{B}_{j,j+1} < m+1$

Similarly with the previous values, another way to evaluate the advantages in using the proposed model is to consider the average increment of the number of links for each scientific interest (topic) *s* on the total number of participants for that interest. It is expressed by the following formulas:

$\Delta^{A}_{s,i,j+1} = N.link^{A}_{s,i,j+1} - N.link^{A}_{s,i,j}$ with i=1, …, l, j = 1, …, n-1 and s= 1, …, t

$\Delta^{B}_{s,k,j+1} = N.link^{B}_{s,k,j+1} - N.link^{B}_{s,k,j}$ with k=1, …, m, j = 1, …, n-1 and s= 1, …, t

Indeed, sharing scientific interests is generally a reason of great improvement of social networking. Starting from the two last formulas, we have considered the average increment of the links number on the participants' total number for the scientific interest *s*; it is expressed by the following formulas:

$$\Delta\lambda^{A}_{s} = \frac{\sum_{i=1}^{l}\Delta^{A}_{s,i,j+1}}{P^{A}_{j,j+1}}$$ with $j = 1, \dots, n-1$, $0 < P^{A}_{j,j+1} < m+1$ and $s = 1, \dots, t$

$$\Delta\lambda^{B}_{s} = \frac{\sum_{k=1}^{m}\Delta^{B}_{s,k,j+1}}{P^{B}_{j,j+1}}$$ with $j = 1, \dots, n-1$, $0 < P^{B}_{j,j+1} < m+1$ and $s = 1, \dots, t$

The second step of our test was devoted to investigate the *users' satisfaction* on the proposed visualization method in order to express a qualitative evaluation. This step consisted of a short interview that involved all the participants at the end of the A-group seminars cycle. The experiment consisted of displaying to each participant all the different visual representations proposed by the method (as discussed in the previous sections) and available in SIM, and asking her/him to comment and discuss that representation. The most relevant questions that the seminars participants answered are:

a) *Is the visualization method adopted by SIM useful for you, and why?*

b) *Do you think the proposed method could adopt such a better visualization? If yes, how?*

c) *Give us any suggestion to improve the visualization method and the SIM prototype.*

d) *Are you satisfied in using the SIM prototype? (Express your satisfaction level using a value from 1 to 10).*

5. Results and discussions

The social networking trends for each participant *i* to the A-group and each participant *k* to the B-group, given by the differences ($\Delta^{A}_{i,\,j+1}$, $\Delta^{B}_{k,\,j+1}$) between the number of links in the *j+1* and the *j* seminar sessions, for each participant (identified by the *i* and *k* indexes respectively) for all the n=5 parallel sessions of seminars are the following:

$\Delta^{A}_{1,\,2} = 7$ $\Delta^{B}_{1,\,2} = 2$

$\Delta^{A}_{2,\,3} = 5$ $\Delta^{B}_{2,\,3} = 4$

$\Delta^{A}_{3,\,4} = 8$ $\Delta^{B}_{3,\,4} = 3$

$\Delta^{A}_{4,\,5} = 6$ $\Delta^{B}_{4,\,5} = 4$

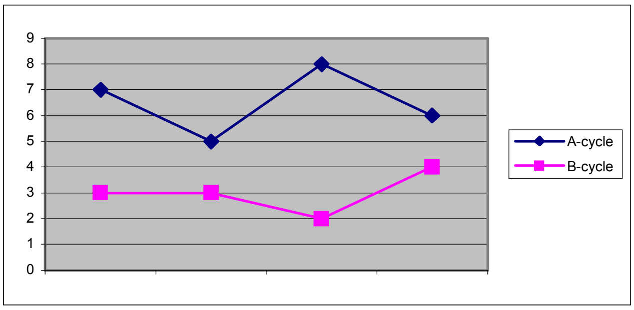

Figure 12. Social networking trends for participants to the A-group and the B-group of seminars

The average increments of the number of links on the total number of participants for the A-group and the B- group computed according to formulas introduced in the previous section and here shortly reminded are:

$$\Delta\lambda^{A} = \frac{\sum_{i=1}^{l} \Delta_{i,j+1}^{A}}{P_{j,j+1}^{A}} \qquad \Delta\lambda^{A} = \frac{28}{35}$$

$$\Delta\lambda^{B} = \frac{\sum_{k=1}^{m} \Delta_{k,j+1}^{B}}{P_{j,j+1}^{B}} \qquad \Delta\lambda^{B} = \frac{13}{42}$$

the $P^{A}_{j,\,j+1}$ and $P^{b}_{j,\,j+1}$ values are respectively 35 and 42 because we did not take into account of people participating to both, the A and B cycle of seminars (it could be quite difficult to identify what relation is stimulated by seminars of group A and seminars of the group B).

These data show the greater average increment of social networking for the group that uses the proposed visualization method.

The interviews carried out to evaluate users' satisfaction highlighted that:

- it was a widely shared opinion that the adopted visualization method gave to the seminars participants the opportunity to have a clear picture of the other people scientific interests and the possibility to get in touch with them, even if they participated to a previous seminar of the cycle;
- the proposed visualization method permits to each person to have a good orientation among information and data about other people or their interests, facilitating the each-other links and, consequently, social networking;
- the proposed visualization method could be improved in its effectiveness using such an animation when the use of images produces problems of cognitive overhead;
- people suggested evolving the SIM software prototype providing a visualization approach adaptable to the different devices and with users' preferences.

Finally, the user's satisfaction directly expressed by each people giving a value from 1 to 10 for the described visualization method returned us an average value of 7.

The evaluation of the proposed method for visualizing social networks produced very satisfactory results both, in term of stimulating social networking and in term of users' satisfaction.

All people's suggestions produced by the evaluation process will be considered in order to evolve the visualization method and the SIM software prototype.

6. Conclusions

This paper has presented a hybrid and multidimensional method to visualize data and information about social networks and their dynamics considering *space*, *time* and coordinates involving *classes of interests*.

The work has been focused on social networks visualization approaches according to their different perspectives, their use to promote social networking and individual and group activities planning. We have presented an overview of the main methods proposed in the literature to visualize social networks, while an extension toward geo-visualization will be considered for a future work, integrating the SIM module with more sophisticated location-based service systems. Three main approaches have been considered here: the *graph-based* method that provides a visual representation that uses nodes and arcs; the *matrix-based* one that represents the networks elements on rows and columns, while matrix cells values define connections between individuals; finally, the *map-based* approaches use the cartography metaphor in order to represent information about the social network elements, their relationships and distances. Each one of these approaches has some advantages and limitations at the same time. For this reason they are usually combined in a hybrid use as in the case of some systems discussed in the literature and cited in this paper.

Starting from these visualization approaches, we have defined a hybrid, multidimensional visualization method, which uses graph, maps or both, according to the users' needs and can provide users with, an egocentric as well as a global view of social network data and information. The method was based on the idea of stimulating social networking and facilitating the information management according to the different goals and needs.

Considering these issues, the proposed approach integrated different visualizations considering *interests dimension,* related with the group's or the individual's interests (topics), their evolution during time, combined with the elements' locations of the social network on a local area.

This approach has provided a spatial representation of individuals or groups of individuals that share specific interests in order to support people during the creation of personal social networks to accomplish their works. Moreover, this method has allowed exploring information about the changing of interests of the conference/seminar's participants and the evolution of the topics in a conference comparing the sequence of temporal layers. That information supports conferences and seminars organizers to plan special sessions in the next conference or to extend its main topics. Note that each element of the social network has to register herself/himself and has to express the consensus to provide and share her/his data.

The proposed method has been tested and evaluated in the scenario of scientific seminars participation, organization and management. The evaluation highlighted that the proposed visualization method is a stimulus for social networking because it allows to each social network element to improve his/her connections, even if he/she doesn't know anybody; this facilitates a transition from a general to an egocentric view. Moreover, the evaluation expressed a high user's satisfaction level in using SIM.

Finally, the evaluation process suggested us to carry out tests considering different scenarios respect to the tested one, and involving a larger amount of people in order to develop an adaptable visualization system.

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