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Augusto Celentano, Piero Mussio, Fabio Pittarello

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The Other Side of Technology

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Editorial Preface

Maps are visual depictions of a subject, highlighting relationships characterizing the subject through a space based representation. As noted by Kuhn¹, "space is not just any domain of experience, but the most important one, and as such uniquely qualified as a metaphor source." Hence, maps permit the communication and sharing of knowledge and are used as boundary objects for cooperative activities. Born as media for representing, communicating and reasoning on geographic phenomena, maps evolved to represent knowledge about systems developing in space but also abstract subjects, schematizing intangible relationships through a geographical metaphor. Today, maps can also be the expression of a general social 'mood' of a part of the environment, bridging geographical metaphors with information visualization.

In the Web 2.0 age, maps become new media for knowledge creation, accumulation, distribution and sharing. They evolve to digital interactive and pro-active tools, whose content develops in time and whose physical appearance can be determined on the fly at use time. Users themselves may become coauthors of the map, directly contributing to its evolution.

Cooperative computing traditionally has been focused on collaboration for solving specific tasks; social systems extend the use of computer supported communication and collaboration for promoting friendship, for communicating thoughts and feelings to people that share common interests, and for enhancing the exploration of the social environment.

In social networking maps can greatly improve the users' perception of the social environment through the visual representation of other people's social features and of the relations inside a community. Maps improve also interaction among users, who are able to visually identify and relate each other through the perception of location, distance and grouping. Maps are useful as a real-time representation of the social environment dynamics, and for localizing events such as meeting, entertainment, public places, that can affect the virtual community evolution.

A large literature has addressed social networks and virtual communities. At our knowledge their representation with map metaphors has only been addressed for display purposes, leaving interaction related issues a field still to be analyzed.

The MapsNet workshop, Map Based Interaction for Social Networks, was held on September 10, 2007 at Rio de Janeiro, Brazil, in conjunction with INTERACT2007, 11th IFIP TC 13 International Conference on Human-Computer Interaction. It aimed at discussing the issues related to the use of maps as active mediators between the users and the social environments, and among the users of a social environment. Several open questions were proposed and debated at the workshop, here briefly recorded with hints for an answer.

How can a map representation communicate social parameters to the users?

Social networks as seen through the Web 2.0 applications do not exhibit formalized organization and structure. Free tagging and spontaneous convergence of keywords seem to characterize several communities whose users are able to self-organize their vocabulary and to coordinate themselves to gain a general understanding of their interests. Maps

¹ Kuhn W. (1996, August). Handling Data Spatially: Spatializing User Interfaces. Presentation at the 7th Int. Symposium on Spatial Data Handling, SDH'96, *Advances in GIS Research II*, IGU

can provide a firm shared ground for anchoring information related to users and coming from users, acting as a common layer all the users can agree upon for reasoning and for adding their interpretation.

How can individual parameters be integrated and interpolated in a map to visualize a social "mood" of the network?

Often the social or affective mood evaluation can be reached through a cooperative evaluation process, for example by exploiting map annotation techniques, through which users express and compare their views, comment and ranks, summarized, for example, by tags and emoticons.

How can a map facilitate the human use of the net?

Semantic web is aimed at obtaining machine inter-operability of web resources, which must be translated into a human manageable form to be consumed by human users. However, human manageable forms are not unique, because signals are interpreted by humans according to their different cultures, skills and situations. Through localization, involving not only the language of words but also the languages of symbols, layout and interaction map based representations may become an intercultural way to represent and share content.

Which is the role of maps in dealing with people physical and emotional neighborhood?

Social maps may have a direct emotional impact on users, because they may precisely relate the presence of humans, associated to information such as their profile, to the territory. The impact is augmented whenever such maps are consulted on the field, e.g., with a mobile device, in a situation where the physical limits of the user are directly related to the environment.

How can novel visualization and interaction techniques improve the user perception of the social environment?

Interactive maps can offer to the users the opportunity to have a real-time perception of the evolution of their social environment, deriving from their input, from actions of other components of the social network, even from external factors. Geographic interactive maps add the awareness of the physical locations of the social network components, permitting new interaction opportunities in the real world.

How is the development of context-aware and ubiquitous systems contributing to improve the map based interaction to discover and access social services?

Ubiquitous systems and context awareness are tightly related since the dawn of this area. In context aware systems, location has been considered for long time a privileged context descriptor, also due to the ease to acquire measures and compute spatial coordinates and discrete locations. The human ability to relate oneself to the surrounding space and the space-based nature of most human activities has boosted location awareness to its full exploitation.

The four papers collected in this special issue are extended versions of selected papers presented at the MapIsNet workshop. They respond to these questions from complementary perspectives, exploring the themes of social networks representation and interaction through maps in different application areas. Collectively they provide an ample coverage of the main issue of the workshop: the ability of map based interaction to make clear and self evident the information related to social phenomena, services and mood.

The first paper "A Design Framework for Mapping Social Relationships" by Alistair Sutcliffe describes a design framework for representing spatial data

related to social phenomena on maps and diagrams, illustrating the design approaches for social data representation. In two case studies the author pro-poses map based visualizations to compare organizational structures with social relationships and to interpret cause-effect relations in the analysis of health care data for a population.

The paper “Social Interaction through Map-based Wikis” by Andrea Marcante and Loredana Parasiliti Provenza introduces the notion of map-based wiki, a collaboration metaphor that allows users to interact each other and with information through a digital map by multimodal and localized digital annotations. The authors face also the issue of affective knowledge, introducing a set of multi-modal signs that are used for expressing the perception of the quality of the environment and that are localized according to different cultures.

The paper “Nurturing Learners’ Communities by Creating and Sharing Maps” by Sosuke Miura, Pamela Ravasio and Masanori Sugimoto presents a system that integrates outdoor and classroom activities related to the exploration of urban and nature environments with a map based approach to data creation, analysis and interaction. The authors aim at promoting, through maps, collaborative activities among the children, involving also teachers and parents as components of learning communities.

Finally, the paper “SIM: A dynamic multidimensional visualization method for social networks” by Maria Chiara Caschera, Fernando Ferri and Patrizia Grifoni describes a method of social networks visualization devoted not only to analyse individual and group social relationships, but also aimed to stimulate an active social participation. The authors analyze, in the context of a conference management scenario, the participants’ social relations along several dimensions: the individual characterization, their social position,

the spatial location, the evolution along time, providing information for interaction between users, service design and event planning.

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In addition to the articles addressing the topic of the special issue, PNJ 6(3) includes a paper by Thomas Hoff and Andreas Hauser, entitled “Applying a Cognitive Engineering Approach to Interface Design of Energy Management Systems”. The authors illustrate the ergonomic issues in designing a grid management system, and organize the suggested constraints according to the cognitive level involved (skill-, rules-, and knowledge-based control).

The Editors-in-Chief

A Design Framework for Mapping Social Relationships

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ABSTRACT

This paper describes a design framework for representing social-spatial data on maps and diagrams and then illustrates the design approaches for representing social data in two applications. One derives from a project which compared social relationships, organisational structures and social networks of organisational members. The second project produced visualisation tools to support epidemiological investigations of obesity. The mapping approaches for different types of social data are illustrated with case studies.

Keywords: *visualization, social data, representational design.*

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1. Introduction

Mapping social data poses new challenges in representing data in visual formats. While data visualisation has been extensively researched and several set of guidelines exist for designing and choosing appropriate representations in charts, diagrams and maps (Bertin, 1983; Spence, 2001; Tufte, 1997; Ware, 2000), social phenomena have grown in importance in recent years and design of socio-spatial representations has not been explicitly addressed in the literature. Representations have been oriented towards social network analysis (Martino & Spoto 2006), where diagrams are automatically generated to show relationship connections between individuals (Freeman, 2006). Alternatively, cartographers have represented social and economic data in maps and geographic information systems for many years. However, the complexity of social data, particularly when relationships, social

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networks and groups are considered in a spatial context, challenges existing designs. This paper explores the design space for representing socio-spatial data, proposes a design framework and illustrates its use in two projects.

The first project, TESS (Theory for Evolving Socio-technical Systems) project** is investigating the relationships between people in social networks and the role of interpersonal relationships within groups. The motivation is to analyse how social networks contribute towards group effectiveness and how people identify with groups and collective aims. Small Group Theory (Arrow, McGrath & Berdahl, 2000) predicts that one of the desiderata of effective groups is a well developed social network, which can help coordinate individual action as well as developing trust between members to work collaboratively (Fukuyama, 1995). However, there is little firm data on the contribution of individual relationships to group success. This paper reports a preliminary analysis supported by visualisation of social networks and group working in charities.

The second project, ADVISES (Sutcliffe et al., 2007) is developing software to facilitate geographical visualisation in epidemiology and public health decision-making. Epidemiologists investigate the distribution and determinants of diseases and other health-related states in defined populations. Within epidemiology, many of the simpler causes of disease have been identified, leaving today's epidemiologists the difficult task of finding more subtle causal associations, which may involve complex, interacting networks of factors that determine health and disease. The interactions may operate across different scales of organisation, for example: molecular/genetic; environmental; and social lifestyle factors. One approach to investigating complex conditions is to use data-driven hypothesis discovery methods as a complement to hypothesis-driven experimentation (Wilkinson, 2005). Since much data is social and spatial in nature, visualisation and map-based representations are a key to discovery-based methods.

The aims of this paper are twofold: first to propose and illustrate a visual mapping approach for the analysis of inter-organisational as well as interpersonal relationships; and secondly to report experience in developing and applying a design approach to socio-spatial data visualisation in research on social relationships and epidemiology of social influences on obesity.

** <http://informat.web.man.ac.uk/research/groups/isd/projects/dtess/>

2. Mapping Social Information

Many guidelines have been produced for designing cartographic representations (Bertin, 1983; Tufte, 1997); however, most data which has been represented in geographic information systems has not involved social relationships. The first question concerns defining the types of information involved in social data. The prime distinction is between data relating to socio-economic attributes of the individual, social relationships between individuals, relationships between individuals and large entities, i.e. groups, organisational units, and finally population-level data describing attributes of groups, tribes or whole societies.

Examples of data at each level are:

- Individual social attributes: socio-economic class, social attitudes.
- Social relationships: individuals involved, relationship strength, type.
- Group relationships: membership, role in group, measures of identity with the group.
- Group attributes: average age of members, gender distribution, group goal, performance.

Social data is therefore either attributional or relational at both individual and group levels and can be reduced to the basic form:

- Individual entity <attributes>
- Relationship <entity 1..n, type, attributes>

2.1 Mapping Social Data to Visual Forms

Visual coding of such data can be realised either by network diagrams to show relationships by charts with distributions of individuals according to one or more attributes, e.g. frequencies of people in an area by socio-economic status. When spatial data is added, representation in a geographic area is necessary. This increases the complexity of the design problem, since graphics have to be overlaid on a map. In the case of entity-attribute data either the data has to be coded as points or areas on the map, or graphic elements have to be added to maps; for instance, histogram bars can be placed in map areas to show frequencies of people in different socio-economic classes. The disadvantage of graphical overlays is that the scales in the graph are difficult to add to the map without distortion or obscuring cartographic detail, hence understanding the representation can become error prone. The alternative of coding data directly on the map is increasing the learning burden on the

reader who has to understand new coding conventions, and secondly the limitation in the number of variables that can be represented. Possible choices for representing social data standalone and associated with maps are summarised in Table 1.

When relationship data is mapped, the design problem is confounded by possible clashes between the topography of the network and the topology of the map, so if people are related within one area or in adjacent areas it is simple to overlay a diagram on top of the map, but when relationships are separated by distance then there is an inevitable compromise between scale of the map and representing the network diagram faithfully. A small scale map (zoom out) is a partial solution as it can show people who are related in distant areas.

Data type	Non-geographic representation	Representation on maps
Individual social attributes	graphs, histograms, scatterplots	data points, icons, area coding for means
Social relationships	hierarchy or network diagrams	networks overlaid on map areas
Social group attributes	graphs, histograms, scatterplots	data points, icons, area coding for means

Table 1. Cartographic and non-cartographic representation choices

Social data representation is determined partly by the data type, and partly by the task. For individual data points (see Table 2) the choice is use of colour, shape, and size to code up to three attributes. Shape can be used as a symbol set to denote categories (e.g. squares, triangles, circles) or icons for more mnemonic representations. More detailed design guidelines for visual coding can be found in Spence (2001), Ware (2000) or Wilkinson (2005). Relationships represented by arcs can be code attributes by line thickness, line type (dotted, etc.), or colour. Group area coding is limited to colour and texture, hence only two attributes can be shown at once. More might be represented, for example by 3D effects (area thickness or histogram bar overlays), but this increases visual complexity and reading accurate values in 3D representations in not easy (Ware, 2000).

Data type	Visual representations
Individual data points	size, shape (icons), colour
Relationships	size (width), texture (shading, line thickness), colour
Groups (area/means)	colour, texture, overlays, 3D bars, etc.

Table 2. Visual representation of data types on maps

2.2 Design Space

The broader perspective of design for social maps needs to be assessed using cognitive criteria to judge trade-offs when matching design options to users' needs. The cognitive criteria for judging the effectiveness of maps and any complex visual displays are:

- *Learning costs*: if information is coded visually using colour, symbols, etc., then the user has to learn the coding convention to understand which variables and values have been shown. More complexity in coding increases the learning burden, so this criterion favours simple displays.
- *Information volume and complexity*: this will be determined by the domain and task. For complex analyses the connection between many different datasets may need to be made. This presents a trade-off between displaying a large quantity of information concurrently, or spreading the information across several screens and thereby reducing complexity.
- *Working memory*: given the limited capacity of working memory (Baddeley, 1986), spreading information across many screens increases the probability of losing the thread of the argument while paging between windows. Taking notes is one remedy but this takes time. In contrast, concurrent representation of different types of information on one screen allows rapid scanning to see associations between different datasets; however, crowding more information on one screen increases complexity and this can also lead to working memory loss.
- *Interaction costs*: if complexity is reduced by spreading information across more screens, this increases interaction costs as users page between screens. This cost also applies to dynamically configurable displays in which the information display is under user control by invoking filters to determine which sub-set of data is displayed or overlaid on a map.

The criteria pose conflicting demands so there is no optimal design for all contexts. The design space is summarised in Figure 1. Tiled displays minimise learning and working memory problems, but they are prone to information crowding, which can mitigate any gains as complexity rises. Sequential displays impose more interaction costs and possible forgetting due to working memory burdens. Overlays increase complexity, but may be unavoidable for complex datasets and tasks. These design choices need to be driven by a sound analysis of the users and their tasks to assess trade-offs between learning and interaction costs with the objective of reducing

working memory burden where possible. This prompts the next topic in the framework: the tasks and types of analysis people might want to carry out on socio-spatial datasets.

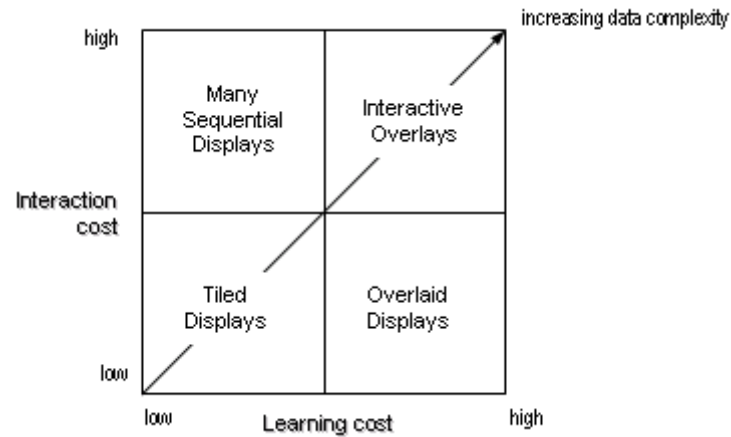


Figure 1. Design space trade-offs

2.3 Tasks and Questions

Several taxonomies of tasks relevant to visualisation analysis have been produced (see Casner, 1991; Wehrend & Lewis, 1990); however, these are not directly relevant for the needs of social data analysis. From our analysis of social networking and epidemiological research there are four key data analysis tasks:

- *Finding associations*: between individuals, groups and between people and areas on maps. Associations are driven either by discovery of common characteristics or attributes, or by relationship formation.
- *Difference*: between individuals, groups, etc.; the inverse of association.
- *Comparing individuals, relationships and groups*: in a geographic context, comparisons are between areas or regions; in non-geographic contexts between groups of individuals.
- *Discovering trends*: trend analysis usually connotes analysis over time; however, in geographic contexts, trends can be spatial gradients over distance and area.

To refine the task analysis, a set of generic question types are proposed for frequently asked socio-spatial questions. These can be used as a checklist when assessing visualisation requirements. Relationship network datasets imply specialised questions related to connectivity which have motivated analyses common in social network analysis research, e.g.

- *Connectivity*: degree to which one individual is connected to others in the network. This may be calculated by the number of relationships per individual or the overall link density for the whole network.
- *Centrality*: degree to which one individual is connected to others in the network compared to other individuals; a measure of how much one person is the hub of a network.
- *Distance*: between two individuals by counting the shortest relationship path between them
- *Bridging*: the degree to which one individual connects other networks. This question is usually answered by visual inspection rather than calculating metrics.

When geography is considered, social data can be analysed with the following generic questions:

- *Where*: in terms of location of an individual, group or set of relationships.
- *Proximity*: of individuals, etc. to a location; area which depends on interpretation of what proximity means in terms of distance.
- *Distance*: questions about proximity which expect a distance value as the answer.
- *Adjacency*: of individuals or groups to a location or area, assuming the location of the individuals is known.
- *Pathway*: are individuals, groups, or relationships linked in a spatial contiguous pathway; as well as for relationships, a network pathway.
- *Spatial trend*: do individuals, groups, etc. form a continuous gradient across an area.
- *Clustering*: do individuals, groups etc show an uneven distribution with clumps in certain areas. The inverse of this question is sparseness.

The question types and tasks are used to analyse users' requirements for socio-spatial mapping and the interactive support in terms of filters and controls for querying social map representations. The design process progresses from task/questions analysis to consider the high-level design trade-offs using Table 1, and the dimensions in Figure 1 before planning the visual data coding using Table 2 and specifying interactive controls for data display and querying. The following sections illustrate how the design framework was applied to design interactive visualisations of social map data in two projects: the TESS project which researched social networking and group relationships, and the ADVISES project which is producing visualisation

tools to support epidemiological research into social factors influencing childhood obesity, and other topics.

3. Social Networking Case Study

The data comes from two studies: one on not-for-profit organisations in State College, Pennsylvania, USA in May-June 2007; and the other taken from analysis of social relationships in an inter-organisational collaboration in UK charities. Not-for-profits, or charities in the UK, are good test cases for studying the intersection of social and organisational relationships. People tend to work for charities because of a deep personal commitment to society, a community or a cause, so their work becomes more than a commercial job. Individuals who work for charities tend to share similar interests and world views, hence there is a good chance that they will be members of the same social networks.

Data was collected from five organisations via interviews with 12 key personnel in those organisations, by attending meetings, and by documentation analysis from websites and other public sources of information on the charities and their personnel.

3.1 Organisational Mapping

CASE (Community for Arts, Society and Education) is an umbrella charity which aims to create a multi-tenant not-for-profit facility, so several charities can share the building, office staff, IT support facilities and business functions. Approximately 120 such shared facilities exist in the USA and Canada. The organisation map for CASE is illustrated in figure 2.

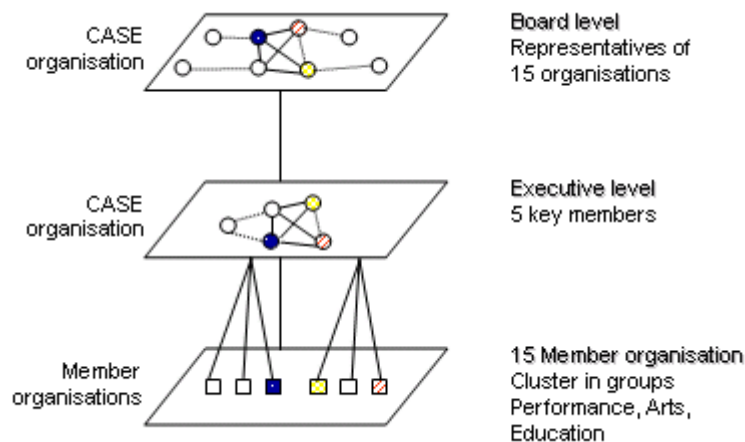


Figure 2. Organisation map of CASE showing organisation structure and member organisations. Four individuals were members of both the board and the executive team

This representation uses network diagrams to show social relationships with contour boundaries to delineate different layers in the organisation. This enables social and working relationships in a peer-peer community to be compared with the organisations which they represent. Colour coding is used to show which individuals participated in different layers of the organisation. The organisation structure of CASE is more complex than a standalone charity since it aims to serve many charities. In common with other charities it has a board which is responsible for policy and strategic management; however, in CASE the board is also composed of representatives from the client organisations as well as the prime organisers of CASE itself. The executive is composed of five individuals who are the main contributors to and organisers of CASE itself. Four of the executive team are also board members. As all members of the CASE board and executive are also members of client charities, there is a potential conflict of interest between CASE and its clients. However, personal relationships within the board membership could also reduce the need for governance between CASE and its client charities, and hence save money by reducing transaction costs, e.g. legal fees for contracts.

3.2 Relationship Mapping

The individual relationship map for one charity which was involved in provision of free health care to the poor is illustrated in Figure 3. Network and hierarchy diagrams are used to depict social relationships and organisational structures respectively, with width coding on relationship arcs to denote stronger relationships, and colour/shade coding for roles (e.g. chief executive).

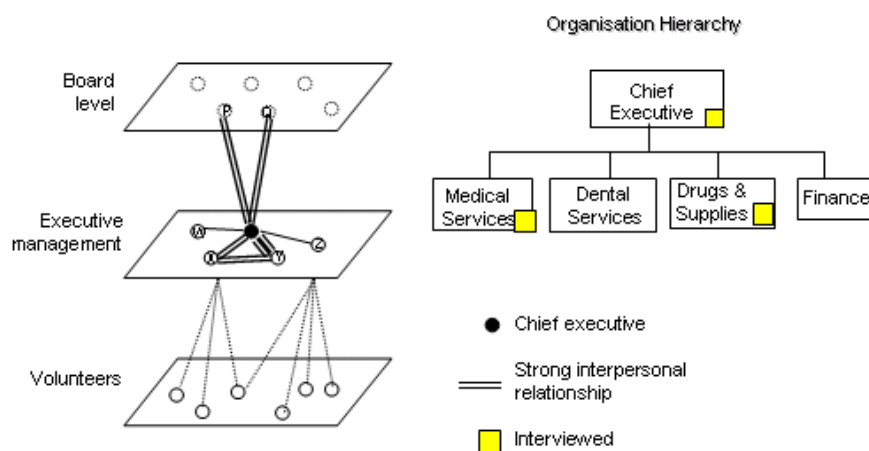


Figure 3. Community Healthcare organisation chart and relationship map

Individuals and relationships are set in the perspective of areas to depict layers in the organisational hierarchy. Analysis tasks are to discover associations between individuals and their connections between organisational layers.

The relationship map of the chief executive is illustrated. She interacted with two colleagues, X, Y, who also held managerial positions coordinating volunteer doctors and provision of medicines and supplies. She also had close relationships with the chair of the board and another key board member. All these relationships were characterised as mixed social and professional, with the relationships between the two colleagues at the executive level being rated as very close. The chief executive and her colleagues also knew many of the volunteers personally. Hence the chief executive's relationships provided a social and organisational glue not only to ensure smooth functioning in the core business but also between the executive team and members of the board. The close relationships spanned only part of the organisational hierarchy; however, medical supplies and drug suppliers were the most important business functions, and these were underpinned by personal relationships. These relationships helped the Community Healthcare organisations to function effectively without formal monitoring and line-management control procedures, because problems were anticipated and solved by frequent interpersonal communication. While most communication was face to face, frequent e-mail contact also played a part, especially between the executive members and the board as well as the volunteers.

The individual relationship map for the CASE charity, at the executive level, is shown in Figure 4.

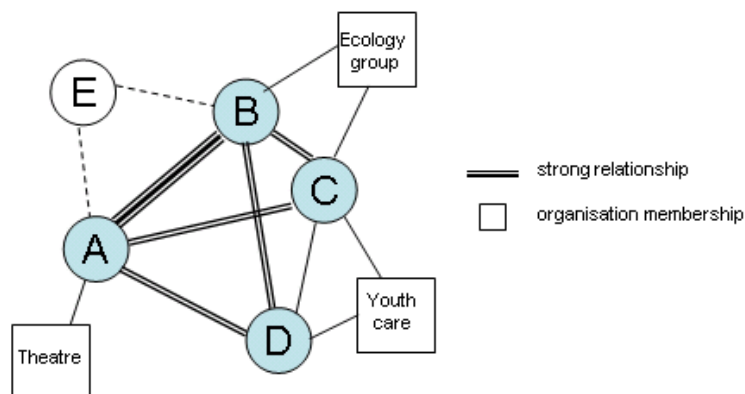


Figure 4. Individual relations and organisation affiliation for CASE: executive level

Network diagrams were the natural choice for social relationships with coding on the arcs for strength. Organisational memberships of the individuals was added to the diagram so the connections between individuals and different organisations could be traced. Four executive team members had close individual relationships which were mixed social and professional (shown with shading in Figure 4), although the one member of the executive team who was not interviewed, did not appear to be included in this social network. For two executive board members their relationship also appeared in the client charity in which they were both board members. Inter-individual networking was common among board members in most of the charities as the same individuals appeared on several boards, and this became more apparent when the history of board membership was considered.

When geography is added to the analysis (see Figure 5), it can be seen that the social relationships might be correlated with spatial distribution.

Although several CASE board members were also on the boards of two or more charities, the relationships between CASE board members, apart from the inner executive team, was less clear. One client organisation board member did not appear to work closely with any members of the CASE team and no particular relationship was reported. In this case, membership was seen as a simple business proposition for lower costs in the parent organisation. This dissonance between the individual relationship network and organisation may pose problems for CASE in the future. The inner executive team all work closely together and have developed trust, which bodes well for delivering their objectives. However, some of the client organisations may have a more tenuous link with CASE. The network diagram was overlaid on the map to facilitate analysis of social relationships and spatial distribution; and the spatial isolation of one board member (E in figure 4) suggests a possible cause for his poor integration: distance matters. Figure 5 illustrates some of the problems inherent in integrating representations. Network links on the map cause distortion of the original network diagram in figure 4, and some relationship arcs have been omitted to reduce clutter on the map. Furthermore, the organisational membership of the board members has been omitted for a similar reason. While the location of the organisations could be shown in a separate view, figure 5 illustrates a general design problem in map overlays. Adding more information aids the interpretation of a spatial context, but at the penalty of obscuring some detail on the map and making dense images such as maps even more complex.

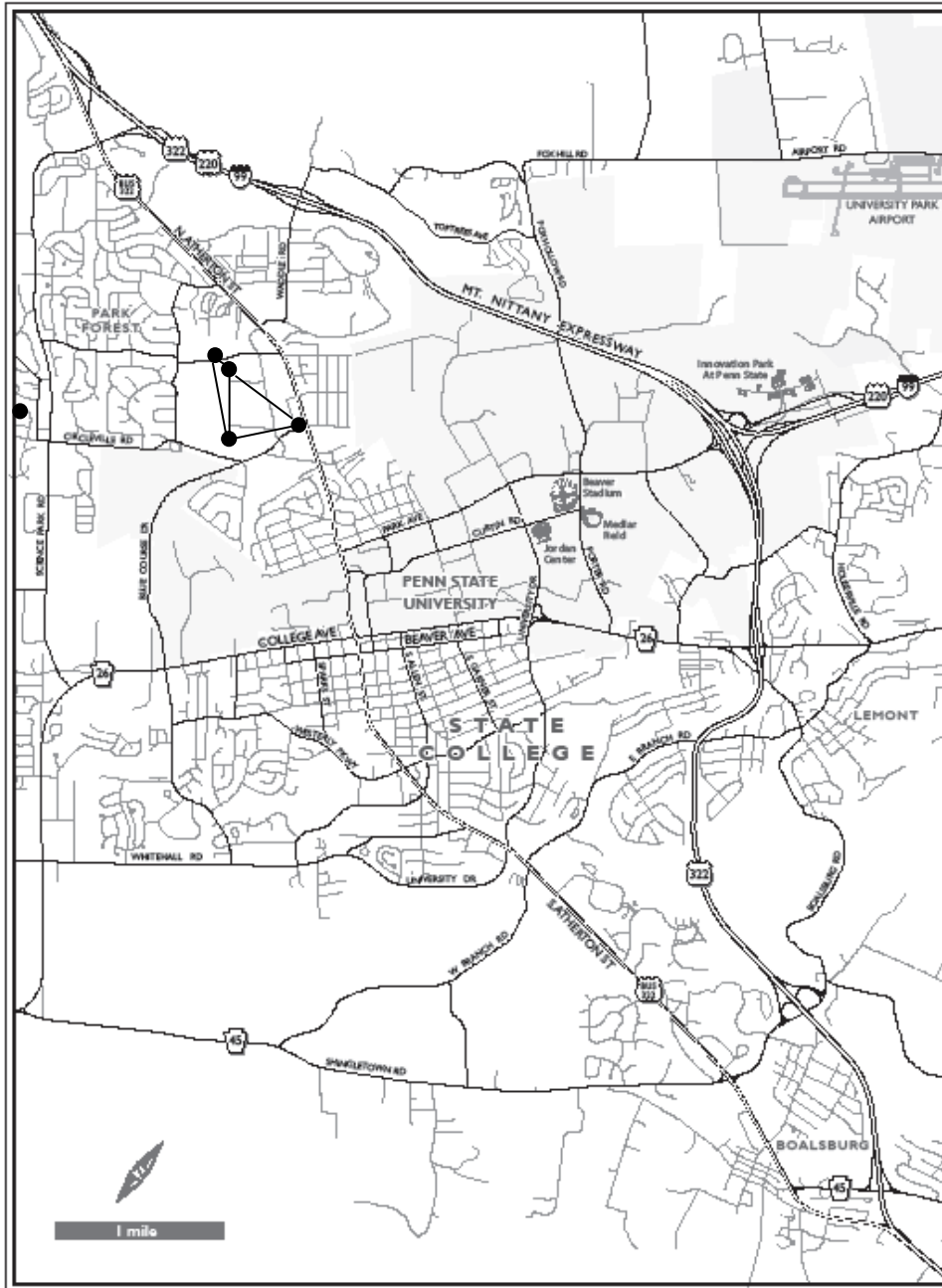


Figure 5. Map overlaid with social relationships in CASE showing the locations of board members' primary work location.

3.3 Mapping Relationships and Roles

Advanced Life Support Group (ALSG) is a medical education charity that specialises in providing training courses in the immediate care of critically ill and injured patients, particularly in developing countries. The charity also produces standard medical

textbooks in the area of trauma medicine, which have earned them a worldwide reputation as an authority for research and expertise in this field. As a result, ALSG is concerned to maintain the high standard of their courses and medical texts, and exercises a stringent quality control procedure. The charity has numerous relationships with other organisations, including NHS Trusts and other charities. The actor and goal dependencies between members of the charity-based alliance are illustrated in Figure 6.

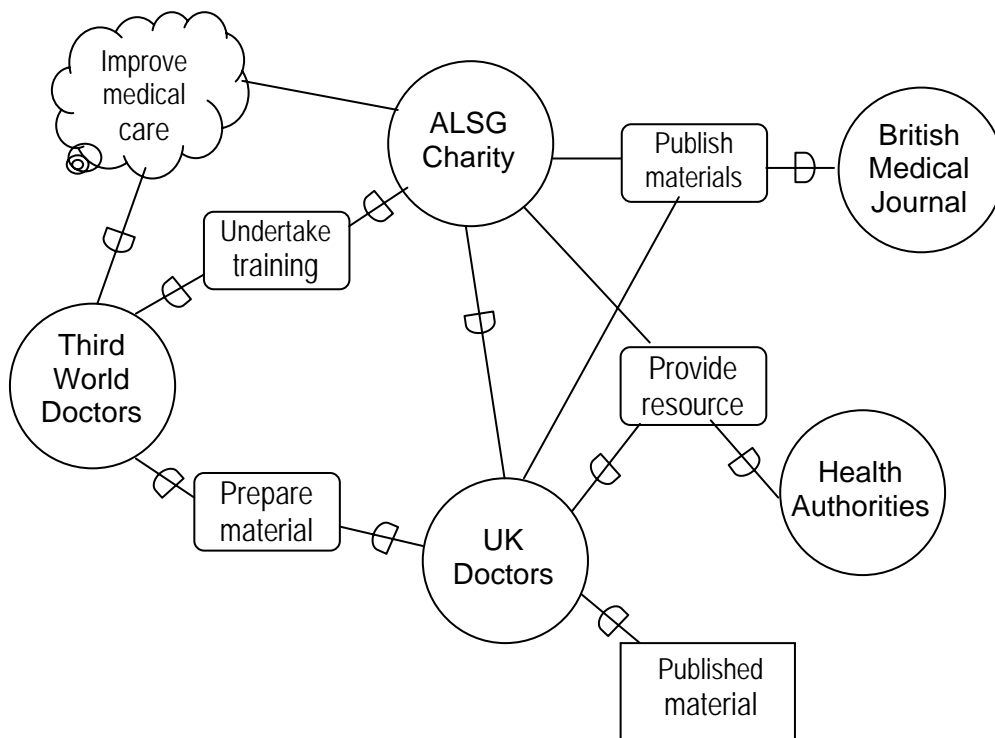


Figure 6. Strategic dependency model for the ALSG alliance using the i* modelling language

In the previous examples, simple diagram formats which have intuitive or easily learned meanings were used. While this lowers the learning cost for these representations, it limits the sophistication of the information that can be represented. In Figure 6 a formal diagram notation is used which requires more learning. Shape is used to code types of nodes. Circles represent actors who may be individual people, or groups or organisations as in this case (Doctors, Health Authorities). Squares represent resources or materials, while rounded boxes denote intentions or goals owned by the actors. Finally the cloud symbol is used for quality criteria, called soft goals in the i* star notation (Yu 1994). To read the diagram you have to know that the

arcs denote dependency between actors to deliver a goal, so Third World Doctors depend on the ALSG charity to provide training (not exclusively of course, but in this modelled world) and UK doctors to prepare training material. The direction of the relationship Dependee (recipient), Depends on (provider) is denoted by the direction of the Ds on the arc. The notation is complex, but the payoff is the ability to represent several complex associations on one diagram, i.e. social and work relationships between actors, goals and intent, as well as how resources and activities (not shown) fit into the model.

Four organisation-level actors in the alliance were the doctors in the Third World who were recipients of the medical training material donated by the ALSG charity. The charity depends on UK medical professionals to donate their time in creating training material and to give courses. However, most of the training material is already subject to copyright agreement with medical journals, hence the charity also depends on the good will of the *British Medical Journal* which publishes the material. Furthermore, it depends on health authorities who employ doctors to give them leave so they can undertake training in the Third World. These dependencies are reflected in the goals “provide resources”, “undertake training” and “prepare materials”, which contribute to the soft goal of improved quality of medial care. While the dependency analysis gives some understanding of the inter-organisational relationship it does not uncover the tensions between the partners.

The association has not been without its problems. An examination of one incident illustrates an interesting aspect of the relationship between a prestigious international journal and a comparatively small not-for-profit organisation. The Director of ALSG described a “supply chain” problem that directly affected the quality of the works. In order to cope with the increasing demand for publishing services by ALSG, the *BMJ* employed a new printer who did not have sufficient resources to do a quality job. The result was that the newest medical textbook emerged from the printers full of textual errors. This created the frustration of extra work for the Director and her staff, in proof-reading the text and correcting errors. However, the greater potential for damage was to the relationship of trust that has built up between the charity and the *BMJ*, and to ALSG’s much valued reputation as a fund of medical expertise.

Analysis of commitments and trust shows how the power asymmetries in the relationships are counter-balanced (see Figure 7). Further symbols (shape coding) have been introduced to represent the type (trust and commitment) and strength of the relationships. This refines the notation of dependency, albeit at the cost of

learning. The C convention symbols indicate commitment, with the direction denoting who is committed to whom and the dashed arcs with arrows showing trust between the trustor and trustee. The diagram notation illustrates the following relationships: the UK doctors are strongly motivated to collaborate with the charity and vice versa. This mutual commitment (denoted by 'c' on the relationship arc and bidirectional arrow) is associated with the UK Doctors altruistic commitment to Third World doctors that is strong in the medical profession. Third world doctors in turn reciprocate this commitment, although less strongly (one 'c' rather than two) by helping their UK colleagues with third research into 3rd world medical problems. Similarly the charity is strongly motivated to help Third World medical practitioners since it is their *raison d'être*, and the developing world doctors are very supportive of the charity. The strong commitment counter-balances the power asymmetries and vulnerabilities between medical practitioners and the charity. However, commitment between the charity and medical journal on the one hand and doctors and their employers on the other was less strong so no explicit commitment relationship is shown. The medical journal and health authorities are trusted by the health authorities and the *BMJ*, but the relationship is one-way. These organisations had fewer incentives to collaborate since they had little to gain apart from possible improved external image for being seen to help charitable causes, so their trust in others and commitment were neutral at best.

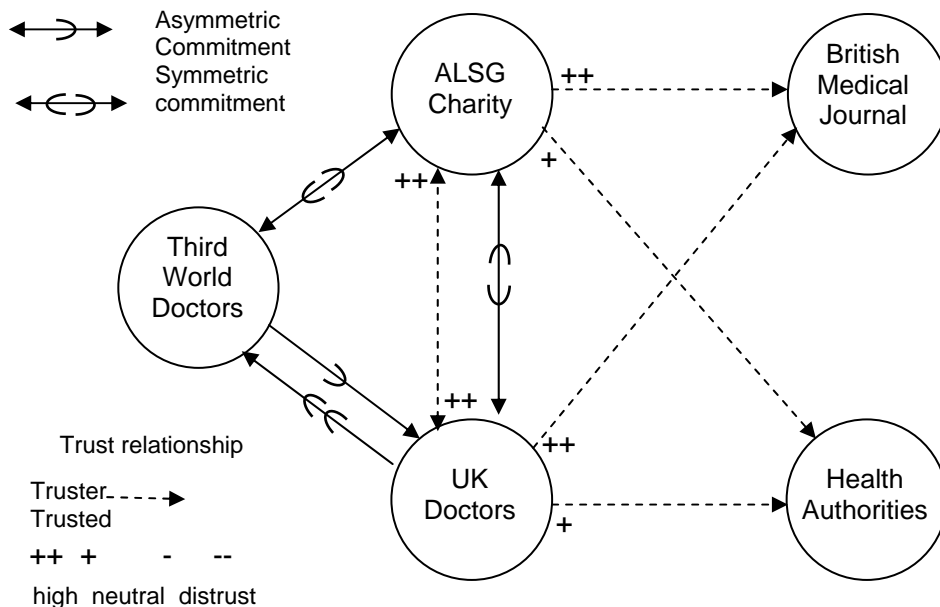


Figure 7. Actor model: trust and commitment dependencies

The two representations can be viewed in juxtaposition to compare inter-actor dependencies, commitment and trust. While it is possible to include all the relationships in one diagram, this makes the resulting representation very complex, leading to increased learning and working memory burdens. Following the principle of separation of concerns, we believe it is more effective to keep the representations separate but view them concurrently to reduce working memory loss.

4. Mapping Social Causations in Epidemiology

The representations reviewed in previous sections have been paper-based illustrations for scientific analysis using conventional software tools. In this section the design of computer-based interactive visualisations is reviewed. The ADVISES (ADaptive VISualisation of E-Science) project is developing tools to support the use of geographic visualisation in epidemiology and public health decision making. Epidemiologists investigate the distribution and determinants of diseases and other health-related states. Geography is often a factor in epidemiological investigations, whether comparing the distribution of a disease within two populations, or considering ease of access to health services across a Primary Care Trust. Despite this, GIS tools are underused in epidemiology due to their complexity for non-GIS expert users.

We used scenarios to explore ways the system could support users' research questions. Scenarios were based on research questions, and we imagined how the system could support investigation and exploration of data, for example:

- *What are the characteristics of the GP Registered Population in the North-West?* A scenario describing how a user could explore a map of patients registered to Primary Care Trusts in the North West, stratifying the population by location, gender and ethnicity.
- *Is there an association between the number of people reporting runny noses versus weather conditions and levels of electrostatically charged particles?* A complex question, requiring the system to support mapping of cases of runny noses, weather conditions, wind direction and power line locations, over a six-month period.

Scenario creation was not a technique that came naturally to our users; they initially constrained themselves to simple research questions and found it hard to think of questions that would stretch the requirements for the new system; however, as the

technique became more familiar we were able to develop increasingly complex scenarios.

During the ADVISES requirements process we used several pictorial approaches for requirements exploration, ranging from simple storyboards for exploring initial ideas, through paper prototypes, up to web-based prototype implementations. The various prototypes encouraged users' involvement in the decision-making processes. They were able to imagine the steps they would work through and the accompanying statistics they would need to interpret the map. Figure 8 shows the progression of a storyboard from a sketch to a PowerPoint slide and then to a functioning prototype. The first pencil drawing shows a distribution graph split into quintile fractions of the range, with the geographic regions coloured according to which quintile the regional mean corresponds to. This feature was originally suggested by a user, who then responded to this storyboard by elaborating on the original idea, requesting movable quintile boundaries, with the map colours updating as the boundaries change. The storyboards support the development of requirements by providing realistic illustrations, and easy modification and development of ideas.



Figure 8. Progression of the interface design

The design adopted a tiled layout to facilitate scanning multiple datasets and avoid working memory problems and the interaction costs of paging between different representations. Colour and texture coding was used to represent value ranges for two attributes by area (e.g. age and obesity, socio-economic status and obesity) with histogram and line graphs to show the data distributions in more detail.

The task and question types analysis indicated that the number of high-level question types in epidemiology is limited, essentially to pattern identification (e.g. what is the distribution of diabetes in population X), association-causation (e.g. is there a link between asthma and obesity?) and comparison between populations, over time and spatial distribution. Hence the query interface was designed with menu

picking-lists of terms, (<association, asthma, obesity> for the above example), driven from the variables in the chosen dataset. However, complexity arises in a large space of possible associative combinations between variables, in exposing population structure variation and in eliminating confounding effects; for instance, “Is there a link between smoking and obesity once the variation in age, exercise and other illnesses have been eliminated?”. The answer to this question is not a simple database query; it requires complex statistical analyses to be invoked. The requirement for processing complex questions came from the knowledge management workshops and led to developing interpreters for high-level concept keywords in queries. An example from our ontological analysis was “deprivation”. In population datasets this might be measured as income range, socio-economic class from census data, or status of housing and the local environment in a GIS. Our query processor needed to read the metadata from the selected datasets and then interpret the best fit to “deprivation” to execute the query. Alternatively, if several measures were available the system needed to ask the user to select their choice.

Another visualisation illustrates association between different variables on a map, combining wind direction with area distributions, to answer the association-style questions “what is the link between wind direction, the spread of pollution and the incidence of asthma in children?”. The storyboard illustrated in Figure 9 shows use of arrow symbols to show wind direction that enables the spatial relationship of factories (and implicitly pollution) and location of asthmatic patients to be interpreted. This illustration could be overlaid by diffusion models for the spread of pollutants

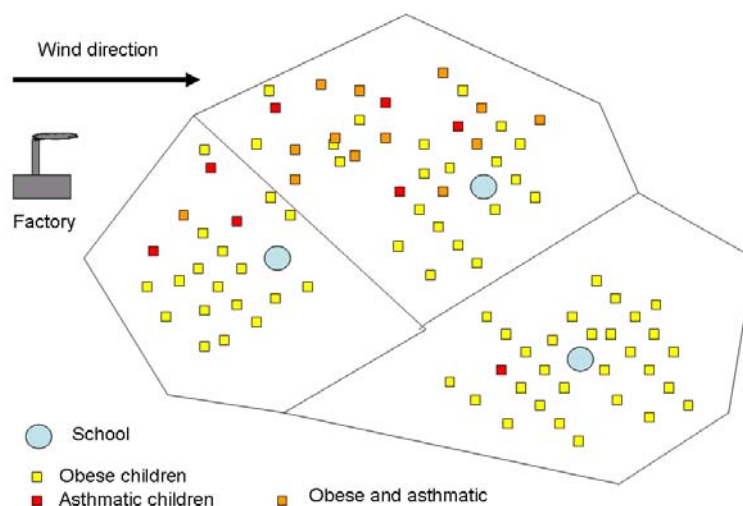


Figure 9. Map prototype for analysing the association between pollution and asthma given the direction of the prevailing wind

Experience of representing socio-spatial data in ADVISES did not concern social relationship data as this was rarely available; however, representing group and individual attributes posed considerable challenges for deciding which data to code explicitly on maps, how to code the data for areas and individual data points and then design query controls to allow multiple variables to be analysed, even though this imposed a penalty of sequential analysis. Annotation facilities provided a partial remedy for working memory problems.

5. Conclusions

There are three main contributions following from this paper. First is a visualisation design and evaluation framework which explicitly considers cognitive criteria to assess which design should be more effective. The second contribution is to apply the criteria, such as reducing working memory burden by increasing the role of representations as external memory. This criterion was applied in the juxtaposed diagrams and map overlays enabling more information to be gained from one display. The visualisation design framework helped design in different applications by focusing attention on the trade-offs that needed to be made. This extends previous visualisation design frameworks (Card, Mackinlay & Shneiderman, 1999; Shneiderman, 1996; Wilkinson, 2005) with explicit consideration of socio-spatial data. The overlay of social networks on maps facilitated understanding about how distance may influence relationships, but it also showed inherent limitations. The combination of maps and diagram representations illustrated the problem of increasing complexity and the topographic clash with networks and spatial distributions are shown concurrently.

Social networks analysis also needs to be linked to algorithms for centrality and connectivity of individuals as well as providing diagrams for inspection; however, such single viewpoints do not illuminate the associations or potential clashes between organisational structures and inter-personal relationships (Moody & White, 2003). While network representations can afford inspection of central or peripheral membership of groups, network diagrams need to be juxtaposed with organisational hierarchies to understand how organisational design helps or hinders working relationships. Then social relationships are overlaid on geographic maps to locate where individuals live, and thus investigate how distance may affect relationship

formation and maintenance. Multiple-view mapping as illustrated in this paper can provide further insights into the links between organisational structures and social relationships. The diagram notations we chose were either intuitive networks and hierarchies or built upon established conventions for representing socio-technical systems such as *i** (Yu, 1994; Sutcliffe, in press). These provide more sophisticated means of coding social relationships than more limited notations such as Entity Relationship diagrams, which are also prone to many notational variants.

The lessons learned from the ADVISES project showed that task question part of the framework was invaluable in focusing attention on design trade-offs for visualising socio-spatial data. Considering the representation in tandem with the types of questions that might be asked by the user can reduce the worldview and rationale gaps (Amar & Stasko 2004), when users have difficulty in relating the representation to properties of the underlying dataset, and the meaning coded in the representation design (e.g. the denotation of colours, texture, symbols, etc). The design framework provides some guidance which was useful for human-computer interaction experts who could use it in conjunction with source references to produce effective designs. However, for novice end-user developers, the framework provided insufficient guidance. In our future work we are developing design rules for an automated visualisation expert. The system has to select appropriate ways to code data in maps and graphical displays, according to the user's research questions and metadata; for example, using texture, shading and colour coding so a map can be scanned to detect patterns of association between obesity and social deprivation by postcode area.

Experience so far has only started to address the problem of designing tools for effective analysis of socio-spatial data. The framework needs to be elaborated with design rules and guidelines, which we have started to address in the visualisation expert in the ADVISES project. More fundamentally, many of the trade-offs in the visualisation design space are based on intuitions drawn from cognitive psychology and limited experimental evidence. Systematic investigation into the limits of effective human information processing in multi-view displays has yet to be carried out. Furthermore, understanding social data analysis from a task perspective to inform design also requires considerable further research.

6. References

- Amar, R., & Stasko, J. (2004, October). A knowledge task-based framework for design and evaluation of information visualisations. Presented at the *IEEE Symposium on Information Visualization 2004, InfoVis'04*, Austin, Texas, USA.
- Arrow, H., McGrath, J.E., & Berdahl, J.L. (2000). *Small groups as complex systems: Formation, coordination, development and adaptation*. Thousand Oaks, CA: Sage Publications.
- Baddeley, A.D. (1986). *Working memory*. London: Oxford University Press.
- Bertin, J. (1983). *Semiology of graphics: Diagrams, networks, maps*. Madison: University of Wisconsin Press.
- Card, S.K., Mackinlay, J.D., & Shneiderman, B. (1999). Information visualization. In Card, S.K., Mackinlay, J.D., & Shneiderman, B. (Eds.), *Readings in information visualization: Using vision to think* (pp. 1-34). San Francisco: Morgan Kaufmann Publishers.
- Casner, S. (1991). A task-analytic approach to the automated design of graphic presentations. *ACM Transactions on Graphics*, 10(2), 111-151.
- Freeman, L. (2006) *The Development of Social Network Analysis*. Vancouver: Empirical Press.
- Fukuyama, F. (1995). *Trust: The social virtues and the creation of prosperity*. New York: Free Press.
- Martino, F., & Spoto, A. (2006). Social Network Analysis: A brief theoretical review and further perspectives in the study of Information Technology. *PsychNology Journal*, 4(1), 53 – 86.
- Moody, J., & White, D.R. (2003). Structural cohesion and embeddedness: A hierarchical concept of social groups. *American Sociological Review*, 68, 103-127.
- Shneiderman, B. (1996). The eyes have it: A task by data type taxonomy for information visualization. In *Proceedings of IEEE Symposium on Visual Languages*, 96 (pp. 336-343). Los Alamitos CA: IEEE Computer Society Press.
- Spence, R. (2001). *Information visualisation*. Reading MA: Addison Wesley.
- Sutcliffe, A.G., Thew, S., Venters, C., de Bruijn, O., McNaught, J., Procter, R., & Buchan, I. (2007). ADVISES Project: Scenario-based Requirements Analysis for e-Science Applications. In *Proceedings of UK e-Science All Hands Meeting 2007*. Nottingham, UK.
- Sutcliffe, A.G. (in press). Modelling Human Activity Systems with i*. In E. Yu, J.

- Mylopoulos, P. Giorgini, & N.A.M. Maiden (Eds.), *Social Modeling for Requirements Engineering*. Cambridge, MA: MIT Press.
- Tufte, E. (1997). *Visual explanations: Images and quantities, evidence and narrative*. Cheshire, CN: Graphics Press.
- Ware, C. (2000). *Information visualization: Perception for design*. San Francisco: Morgan Kaufmann.
- Wehrend, R., & Lewis, C. (1990). A problem-oriented classification of visualization techniques. In *Proceedings of First IEEE Conference on Visualization* (pp.139-143). Los Alamitos, CA: IEEE Computer Society Press.
- Wilkinson, L. (2005). *The grammar of graphics*. 2nd ed. New York: Springer.
- Yu, E. (1995). *Modelling strategic relationships for process reengineering*. Unpublished doctoral dissertation, University of Toronto, Department of Computer Science.

Social Interaction through Map-based Wikis

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ABSTRACT

This paper introduces the notion of map-based wiki, a wiki that allows users to interact with each other and with information through a digital map. The map, either geographic or conceptual, becomes a medium for creating knowledge through digital annotations. Annotations may be multimodal. Audio or icon notes set the mood for perceiving map space, while text or graphic notes create information space. We analyze examples to gauge map-based wikis' potential, then focus on Banco Territorio, a map-based wiki designed for information and emotional spaces, which localizes both spaces to overcome cultural misunderstanding in social interaction through digital maps.

Keywords: *map-based wiki, digital annotation, social interaction and communication, knowledge sharing, emotional mood.*

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1. Introduction

Maps are one of the most ancient and useful tools for organizing and displaying knowledge, starting with their primary use as a medium for geographic information. For this purpose, maps depict areas of the Earth's surface that involve *generalization* (pictorial representations show only some of the features that matter to a cartographer) and *symbolization* (certain features are represented by symbols: a town may be shown as a dot, for example (Freeman, 2007)). Maps have been used both as information-storage medium and as information-display medium. Reading a map generally yields information beyond geography *per se*. Of course it tells distance, latitude, longitude, elevation or borders, but also gives ancillary information, which may include advertisements, notes on tourist attractions and so forth. Furthermore, maps can be

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used to represent historical data, not only as data related to a specific geographic area (the map of a certain country at a certain time) but also as historical events represented spatially (i.e. a timeline). In any event, all these kinds of information are static, expressed once for all. When information changes a new map is needed.

In the electronic era, maps become *dynamic* and *interactive*. They are *dynamic* in that maps display data from a database. If these data change, map visualization changes accordingly. Maps are *interactive* in that different users working on the displayed map can add to, reorganize or change the information to be displayed. This feature makes the map, on the one hand, a common knowledge base for a community of interest and, on the other hand, a social medium for human interaction.

These characteristics are not independent from one another. The ability to modify a knowledge base is the necessary premise for a social medium. Maps act as common knowledge bases because they are the virtual space where data and information can be easily collected, organized, and displayed. When maps are accessible to others and available online, many people can jointly manage the information associated with a map and, by interacting with it, interact with other users of the map. The map thus becomes the perceptible part of a social medium, the boundary object through which different users interact (Giaccardi, 2007).

This social aspect is conveyed not only by geographic maps, but also by concept or mind maps. By 'concept maps', we mean diagrams that show the relationships among concepts, with concepts connected by labeled arrows in a downward-branching hierarchical structure. Mind maps are diagrams used to represent words, ideas, tasks or other items linked to and arranged around a central keyword or idea without any formal restriction on the kinds of link to be employed.

In this work, a digital map is considered a social medium if it meets the following conditions:

1. It displays information stored in a related knowledge-management system;
2. Users can access and modify the information associated with the map;
3. Users can share additional information related to the map;
4. Users can act on the information added by other users;
5. Interaction among users and interaction between users and information is enabled through the map.

These features define a *map-based wiki*.

This paper is organized as follows. Section 2 presents some examples of social interaction among users through map-based wikis available online or recently proposed

in literature. Section 3 starts from the preceding examples to discuss the different kinds – or ‘flavors’ – of knowledge that are created or shared through map-based wikis. Observation of these examples shows digital annotation to be the main tool that supports creating and sharing knowledge. Section 4 describes the Banco Territorio system, a map-based wiki that capitalizes on the features analyzed in section 3. Banco Territorio allows users to express and share both cognitive and emotional knowledge, which is localized to user culture, language and system of signs. Finally, Section 5 draws some conclusions and directions for future work.

2. Social Interaction through Digital Maps

Google Maps has dramatically changed the way we use and see digital maps. Geographic information systems (GIS) first introduced virtual maps as displays for information located in databases and managed by complex systems. They allow complex operations to be performed on the information in the map’s layers. The problem is that these systems are designed for communities of geoinformatics experts. Generic users are often unable to interact usefully with such systems. Moreover, these systems were not originally designed for the web.

Google Maps gives generic web users the chance to interact with a map through simple operations for planning a trip or searching for a place, for example. The ‘MyMap’ functionality allows a user to annotate a map by adding text, images or video and then share the map with other users s/he chooses by sending them the map’s URL (the map is thus private). If the private map’s creator allows the users s/he shares the map with, this community of users can modify the annotations on the map. Google’s ‘MyMap’ feature has been used as a basic operation in many systems that exploit Google Maps’ API, which can be considered map-based wikis in that they are wikis (Leuf & Cunningham, 2001) for collaborating to create and develop knowledge related to digital maps.

The WikiMapia project allows registered users to select interesting places by drawing polygons: then a user can add a text note about the place, as well as images. Other users can see that the place has been selected and they can read the note and see the images by clicking on the polygon that identifies the area. Registered users can add new information or edit the annotation that refers to the place. Information is thus transformed by editing or addition. Registered users can also vote for an annotation. If

the annotation has more than one vote against it, it is deleted. This parameter, which WikiMapia uses to control the correctness of annotations, is a typical feature in a social network, where peers who belong to the network (in WikiMapia they are the registered users) approve or reject information. In Figure 1, the open window in the middle of the map displays a description of the place written by a registered user. The menu items display the operations that the user can perform on the map.

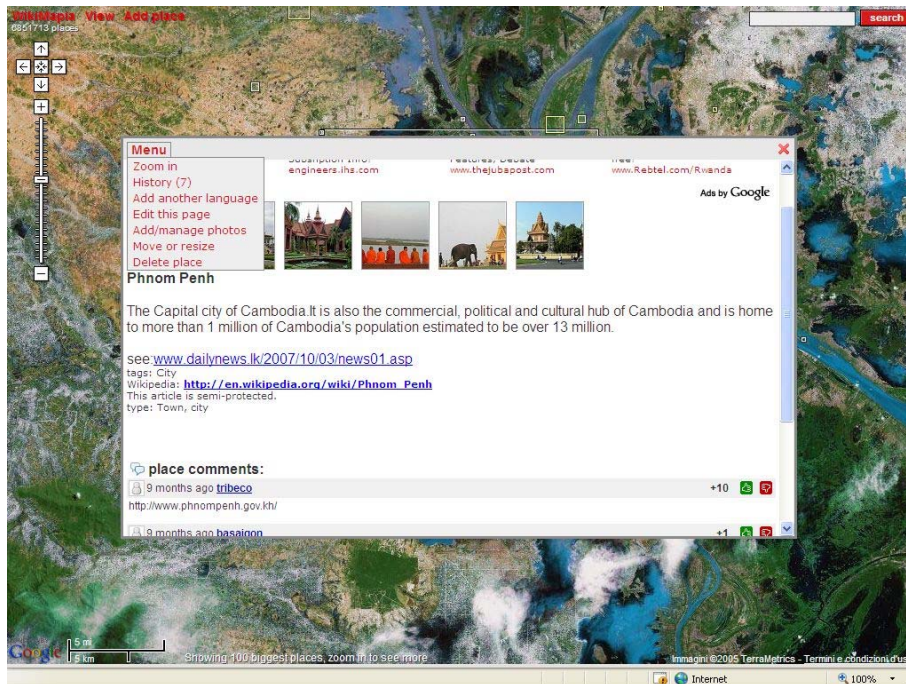


Figure 1. WikiMapia: an annotation on the digital map of Phnom Penh, Cambodia. In the upper left corner, menu items show the operations that may be performed on the map and on the current annotation. The box at bottom center displays comments.

YourHistoryHere and PlaceOpedia are two other interesting map-based wikis based on the Google Maps API. They were developed by mySociety, a charitable organization aimed at building websites to support civic and community aspects of people's lives. YourHistoryHere is similar to WikiMapia: it enables users to mark a place with a flag and to add, at the flag, a textual annotation telling the history of the specific and, in the developers view, 'unusual' place. Other logged users can comment on the history. PlaceOpedia links places to related articles in Wikipedia by adding notes, again by exploiting the Google Maps API. What is interesting is that the aim of both these wiki sites is to create an *"underlying system for collecting and sharing geographic annotations in an open syndicated format"* (as in the home page of both sites). There are no registered users. When a user writes a history or a response, s/he simply has to leave her/his name and email address. A specific response requires

users to state if they consider the history 'abusive'. If so, they have to give reasons for their opinion. Unlike WikiMapia, no voting mechanism is used, but the conversation among users determines the reliability of the information displayed. In all these examples, users who comment on or edit annotations constitute informal groups, characterized by common interests or common knowledge, e.g. about a same place. In this case, their common ground is a geographic map.

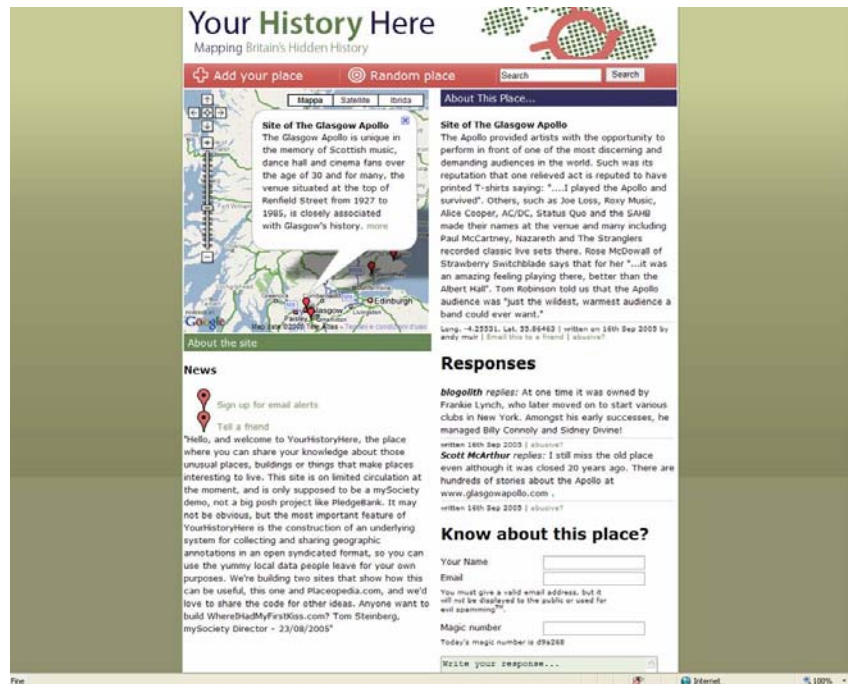


Figure 2. In YourHistoryHere, the map is displayed at the upper left of the page. Clicking on a flag in the map displays part of the history. Clicking again loads the full history on the right. Below the history, comments and a form to add comments or history are shown.

Other map-based wikis employ a mind-map representation to define the relationships among members of an interest group. An example is FOAFnaut, which is based on a graph that defines the closeness of the users signed in on the FOAFnaut tool, a sort of mind map of people involved in one of the FOAF projects (FOAF). Relationships among people are displayed through arrows that link interactive icons and through pictures: each icon represents a person and pictures show the two connected persons. Two persons are linked if they know each other and, in this case, they are co-depicted in the same picture (as in Figure 3). The annotation box on the screen displays metadata about the person represented by the selected icon and shown in the photo. By signing in, a member can add some pictures and information about her/himself and build relationships that specify who s/he knows in the network.

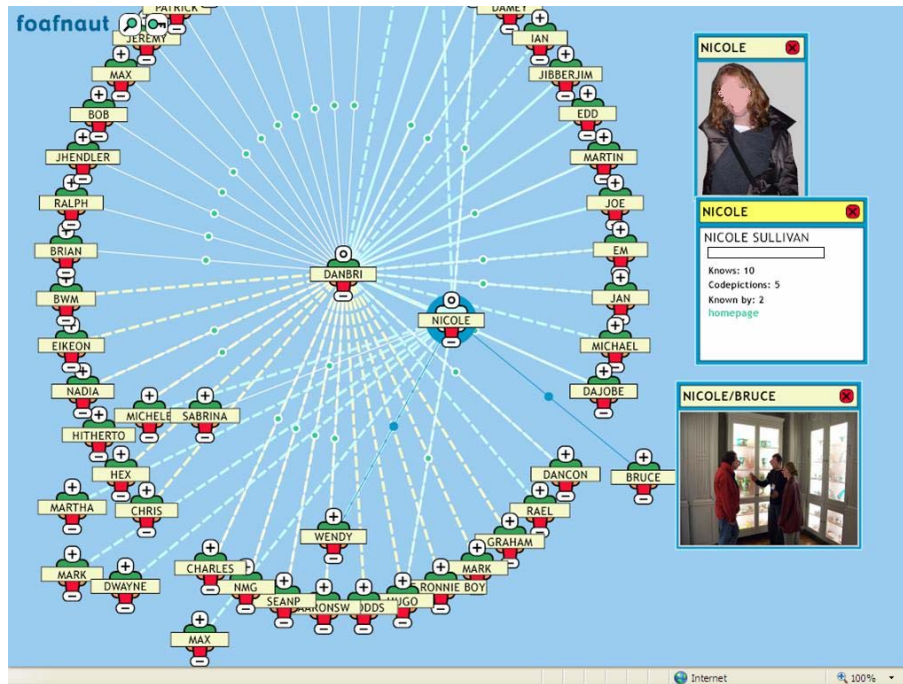


Figure 3. FOAFnaut shows relationships among its members. The blue line shows the co-depiction of two persons. Clicking on the blue circle on the line displays a picture of the related persons (Nicole and Bruce). An annotation box containing information about Nicole is also displayed because Nicole is the original selected person on the map.

Regardless of its specific use, the FOAFnaut experiment is interesting because the mind map displayed is the result of the application of metrics such as centrality, closeness, density, and cohesion, characteristics taken from social-network analysis (Martino & Spoto, 2006; Moody & White, 2003).

Several map-based wikis have been proposed in the literature to collectively create and manage new knowledge related to a digital map (Teranishi, Kamahara & Shimojo, 2006; Chen, Lee & Chang, 2006; Priedhorsky, Jordan & Terveen, 2007). GMapWiki is an example of a map-based wiki proposed by Teranishi, Kamahara and Shimojo (2006) as a ubiquitous collaboration environment where users in virtual environments and in the real field can collaboratively create new knowledge related to digital maps. Remote users in the real field – through portable devices, such as PDAs and mobile phones – can easily add links and images of objects in the ubiquitous environment or edit existing ones, and collaborate with other users to manage and enrich the knowledge related to digital maps. Fotowiki is a further example of a map-based wiki designed to collaboratively enrich a geographic area with up-to-date visual and textual information (street-level photos of the surrounding sub-areas and related descriptions, along with 360-degree virtual tours) (Chen, Lee & Chang, 2006).

A further example of a map-based wiki is the 'Silence of the Lands' project (Giaccardi, 2007). Silence of the Lands is a virtual museum of natural quiet where geographic maps are enriched with sound annotations. Sound annotations express in a more emotional way than textual annotations the experience of the natural heritage through the sounds directly captured from nature.

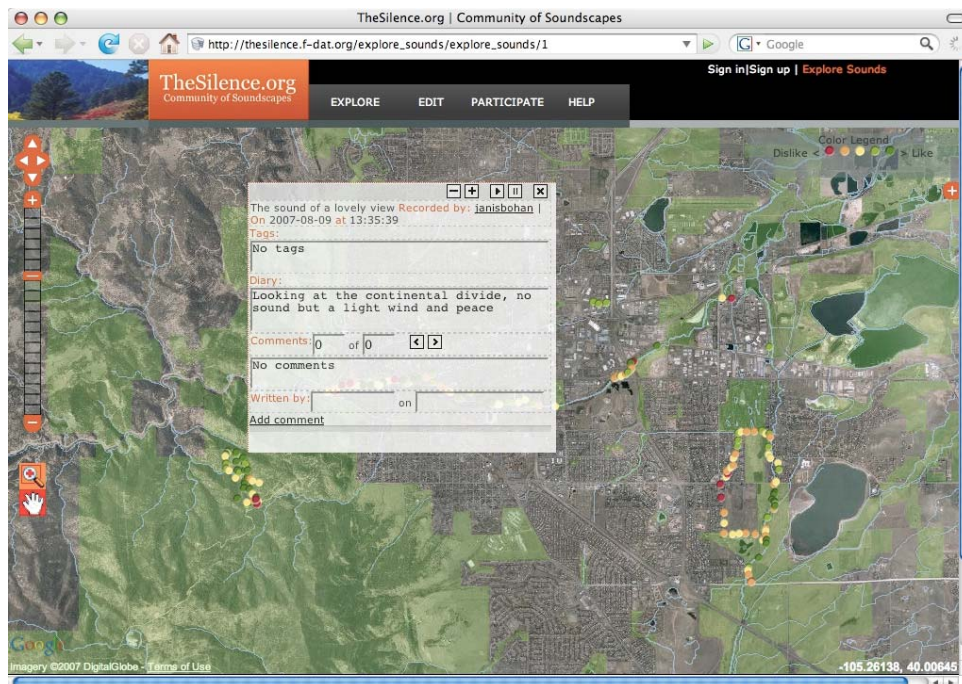


Figure 4. A screenshot of the Silence of the Lands website.

In the center, a written annotation describes a sound captured on the field that can be heard by clicking on the related dot on the digital map.

Members of and stakeholders in the Boulder, Colorado, local community – indeed people from anywhere in the world – can collect sounds from the natural environment and automatically associate them, through PDAs, with a precise time and place for display on a GIS or Google map. They can then access their own sound annotations through the Silence of the Lands website (see Figure 4) and describe the recorded sounds through various descriptors. An interesting descriptor is a colored dot that marks on the map the place where a sound was recorded, as well as visually conveys the user's mood related to the sound in that place, where dot colors are chosen according to a scale of liking. It is also possible to add a written note. A 'soundscape' is thus produced by adding descriptors and sounds, accessible through the web. Participants and occasional visitors can access the interactive soundscapes and compose their own soundscape in the public space through a computational table or through the website.

3. Wiki Knowledge through Digital Annotations

In this section, we focus our attention on the different kinds – ‘flavors’ – of knowledge managed by the map-based wikis analyzed so far and on their use of digital annotation as the basic tool for knowledge pooling and social interaction.

3.1 Flavors of Knowledge

In a map-based wiki, maps are the ‘doors’ through which users access existing knowledge; they are also the framework for creating new knowledge. Different kinds of knowledge can be identified on the basis of content, of the physical support used to convey the knowledge, and of how users perceive and interpret such knowledge. The combination of these three features in different ways leads to different flavors of knowledge, which we discuss in the following with respect to the systems presented so far.

In a map-based wiki, a map depicting a geographic area may provide several informative contents – as in the case of Wikimapia or YourHistoryHere – from geographical data or notes to historical narrations, to folk tales created by wiki users and so forth. This information is mostly conveyed by written signals and can be backed up by pictures illustrating the places related to the knowledge content. This information primarily involves human cognitive capacity, thus setting up an information space associated with the map. Humans read and write textual information about the place and, if necessary, cognition is supported by exemplifying pictures.

A concept or mind map depicting an abstract or metaphorical concept allows us to detach from real spaces. The case of FOAFnaut focuses on the cognitive level of knowledge by proposing a mind map of the relationships among FOAF members. Stressing (and perhaps shifting) the notion of ‘conceptual metaphor’ (Lakoff & Johnson, 1980) a map can be considered a visual metaphor where distances are built according to sociological metrics: places denoted by nodes represent human members, distances visualize the relationships among members and indicate common interests occurring among the members, while pictures exemplify these occurrences. In FOAFnaut, as in Wikimapia and YourHistoryHere, users perceive the content by visual signals and interpret it by associating written notes with geographical or metaphorical spaces.

The knowledge represented in the Silence of the Lands project has a different flavor: the aim of this project is to build emotional paths that describe a real environment.

Knowledge is no longer cognitive but emotional and the signals to support this kind of knowledge can no longer be written: sounds and colors are the evocative bits of information that allow users to explore a real environment.

The sounds a visitor collects from the natural environment indeed represent an intimate aspect of visitor's perception and experience of the environment. While the map identifies the boundaries of the area where sounds have been caught, sounds permit to expand the map's perception (and knowledge) beyond their natural boundaries. A further spatial dimension is thus introduced beyond the 2-D map, and the sound duration also permits to create a time-sited experience. Geographic maps enriched with such a flavor of knowledge can thus be conceived as 'affective geographies' (Giaccardi & Fogli, 2008), that is maps that elicit and visualize the affective meaning users ascribe to places in the maps. Written texts are minor additions, captions that do not change the emotional knowledge of the places. Colored dots associated with the places where sounds have been caught permit to represent visually the positive or negative feelings inspired by the sounds. Sounds and colors enable building a map that is not understood but rather experienced according to different emotional moods.

3.2 Digital Annotation as a Tool for Social Interaction

Written texts, pictures, sounds and colored flags or dots are all elements that make up a digital note. Digital annotation is the tool that enables social interaction in the map-based wikis under consideration. In different ways, a digital annotation allows users to start a 'dialog' by sharing information and feelings. Digital annotations can be shared by the members of a community of interest and may evolve to create new knowledge.

Annotations associated with a map can be multimodal in order to support different kinds of interaction and knowledge. Textual and graphical annotations set up an information space, which is dynamic in that it may be enriched or evolve through new annotations. The use of sound and icon annotations, on the other hand, sets up an emotional space in that they represent different emotional moods in perceiving the map space.

However, both the information space and the emotional space are local to the user culture, language, and system of signs (De Souza & Barbosa, 2006). Languages and symbols are culture-oriented. In different cultures a same color or graphic sign may represent different emotions or moods. Cultural hurdles and misunderstandings can

thus arise. In creating a network to support social interaction through digital maps, one challenge and opportunity is to overcome such cultural boundaries.

One solution, currently adopted by several systems, is to use a single language (both textual and visual) to express shared knowledge, in some cases defining a sort of universal icon language; Google itself seems to prefer this approach. As Google, big web brands usually design or try to impose their language as universal (a sort of globalization effect). However, this solution requires too much effort for a non-native user who has to interpret and manipulate information represented through textual and icon signs that are alien to her/his culture and language. This may lead to ambiguity and misunderstanding when users of different cultures and languages collaborate to build new knowledge. WikiMapia supports many national languages; however the icon language is the same.

A different strategy to overcome cultural hurdles is to localize the whole language, not only the spoken (or written) language but also the icon language, with respect to the user culture and system of signs, by translating colors and symbols as well. In this way, not only cognitive information but also feelings and emotional moods can be easily interpreted by each wiki user.

4. Localizing Cognitive Knowledge and Emotional Moods in Banco Territorio

The Banco Territorio is introduced here to illustrate a solution for localizing cognitive and emotional knowledge. Banco Territorio is a wiki based on tourist maps that allows generic users to collaboratively build and associate with digital maps not only cognitive but also emotional knowledge through colored emoticons, i.e. stylized facial expressions that visually denote human emotions and attitudes (Costabile, Piccinno, Mussio & Parasiliti Provenza, 2007). Banco Territorio also allows users that are experts in different disciplines (e.g. as geology, history etc.) to jointly enrich the knowledge base with certified information in the form of specialized annotations, which illustrate relevant topics referring to the maps.

4.1 Cognitive Knowledge Arising from Interactive Annotation

In Banco Territorio, generic users can annotate their suggestions, comments or useful remarks with regard to a specific point on the map, by creating, as WikiMapia, text or multimedia annotations to share with other users. Banco Territorio users can also associate annotations with paths they depict on the map. In Figure 7, a user, 'Giovanna', has annotated her opinions on the different legs of her trip through Milano (the selected path in red from Duomo to Policlinico). Annotated paths enrich the information space related to the map with knowledge paths on different topics. Figure 7 also shows that an annotation associated with a map can become a starting point for a discussion. Users can recursively annotate an existing annotation entered by another user, providing their points of view on the annotation's content. A thread of annotations is thus created recursively. The thread leads to knowledge enrichment through discussion, which could completely change the original point of view. Specifically, new points of view can be identified as well as new ways to approach an interesting topic related to the environment shown on the map.

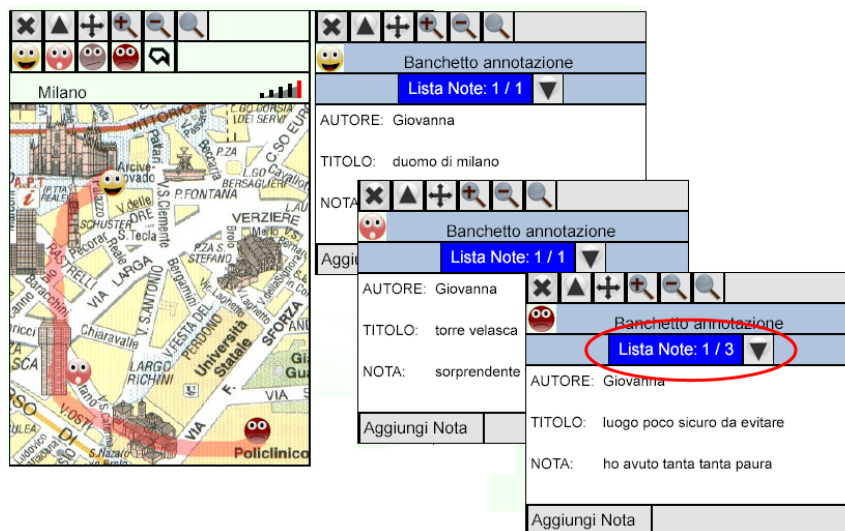


Figure 7. A path on the map of 'Milano' and its related annotations. The note on the right is the first in a thread of notes.

Social interaction among users also permits to add 'certified' knowledge when users are experts on the topic being discussed. Expert users feed the existing knowledge base with specialized content that is discussed and approved among them. They enhance the informative material and give users new material to comment on. An expert user can define two different types of specialized annotations: i) *descriptions*, i.e. textual and multimedia annotations; ii) *narrations*, i.e. multimedia annotations

enriched with sets of metadata. The set of metadata in the narration (the 'context' of the narration) is used to dynamically obtain links to related (even external) resources, with the aim of describing different aspects of the situation, activity or general subject under consideration, e.g. wine production, the history of the place, etc. (Valtolina, Mazzoleni, Franzoni, & Bertino, 2006). The context is described by a query, unwittingly and easily defined by expert users, on a set of distributed databases: the result of the context query is a set of documents, such as images, that refer to the annotation content written by the expert. In Figure 8, an annotation added by an expert user is shown.



Figure 8. A recursively expert annotation: the annotation includes pictures of relevant monuments in the country.

4.2 Sharing Emotional Moods through Digital Annotation

Unlike the purely document nature of text and graphic annotations, icon and sound annotations allow the user of a map-based wiki to enrich perception of the map space with an emotional layer, thus associating the map with an emotional space.

In Banco Territorio, the emotional space is set up through particular visual markers – i.e. colored emoticons – that immediately evoke the notes' emotional nature, each emoticon referring to a particular place and summarizing, for example, the experience of a visitor in that place at a specific time. As shown in Figure 7, Banco Territorio provides users with four emoticon types, which visually express four different emotions: appreciation, surprise, disappointment, and sense of danger. The path on the map depicted in Figure 7 is annotated with three emoticons. Each emoticon

provides users with an immediate visual indicator of the particular mood the entity being annotated inspired in the author of the note. The first emoticon above, near *Duomo*, denotes a positive feeling related to that leg of the path. The subsequent emoticons denote different feelings, from surprise to completely dissatisfaction. If interested, readers can select a specific emoticon and access the correspondent annotation content, which clarifies the reasons for the emotional state visualized on the map. The use of colored emoticons, along with the possibility to attach a sound to them, makes the annotations multimodal and provides a sort of synesthetic method for sharing information about places on a map.

Whenever different users associate different emotional states with a same point on the map, the resulting emotional state will be displayed as a synthesis of them all. In this way, a common emotional level is achieved from a plurality of different users' emotional states.

4.3 Facing Cultural Challenge

Banco Territorio has been designed and developed according to current internationalization and localization techniques (Esselink, 2000) so as to be easily adapted to different cultures and conventions – by taking into account the different materialization properties (localization components) of each culture (Barricelli, 2007; Barber & Badre, 1998; O'Hagan & Ashworth, 2002).

The Banco Territorio depicted so far is localized to Italian culture: behind the Italian texts, the emoticon buttons – which express appreciation, surprise, disappointment, and sense of danger – are displayed according to the colors and facial expressions of Italian culture and conventions. Figure 9 shows the Banco Territorio presented in Figure 5 localized for a Japanese male user, where both textual and visual signs are displayed differently according to the Japanese language and system of signs. Specifically, behind text translations, the icon language, and in this case, the emoticon buttons are translated by using colors and graphic signs typically adopted in the community of Japanese male people. This is indeed an example where representing a same emotion also depends on the user gender (O'Hagan & Ashworth, 2002). As shown in Table 1 the four emoticons for Japanese female users should be stylized by graphical signs that are different from the Japanese male ones, while colors are the same since they convey the same information – colors and shapes in Table 1 are derived by current literature (Barber & Badre, 1998; O'Hagan & Ashworth, 2002).

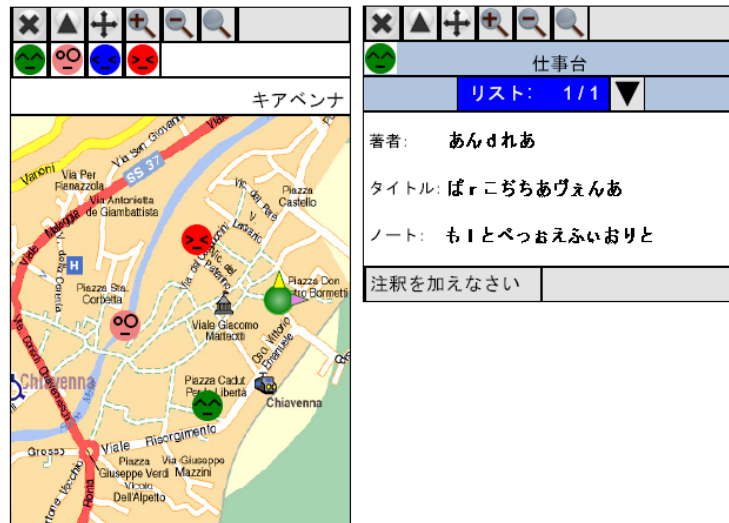


Figure 9. Banco Territorio localized for Japanese male users. Compare this to how the same information appears in Figure 5.

By adopting this approach, a same emotional state is correctly visualized by taking into account the culture and, in the case at hand, also the gender of the specific user. This solution pays special attention to the affordance and firstness of icons, which must be the right ones for the particular user to avoid misunderstanding and ambiguities.

To conclude, localization allows cultural hurdles to be overcome very broadly: the interactive system – internationalized and subsequently localized to different cultures – enables users of different nationalities to interact with the map-based wiki and with one another, each of them through her/his own language and system of signs.

SCALE OF LIKING					
Emotion	Italian colors	Italian Shape	Japanese colors	Japanese male shape	Japanese female shape
Appreciation	Yellow		Green		
Surprise	Lightcoral		Lightcoral		
Disappointment	Gray		Blue		
Sense of danger	Red		Red		

Table 1. Shape and color localization in the emoticon case (Barricelli, 2007)

4.4 Implementation Issues

In this section, we provide an overview on the different specifications of a Banco Territorio system and then we briefly discuss the Banco Territorio architecture.

Banco Territorio specification. Banco Territorio is characterized by four-specification levels, one for each different aspect of an interactive system: (i) content and organization; (ii) localization; (iii) materialization; (iv) interaction dynamics (Fogli, Fresta, Marcante, & Mussio, 2004).

The functional components – entities – of Banco Territorio, together with their logical structure, are specified through an XML-complaint language, the *interaction multimodal markup language* (IM²L). IM²L has been introduced in (Fogli et al., 2004) to describe interactive systems and its schema has been recently refined to provide an internationalized specification of the abstract entities that make up an interactive system independently from its materialization. These entities define the goals, scope, operational structures and functionalities of the system under construction apart from their materialization and consequently from their localization components. As an example, the row of emoticon buttons visible in all the Banco Territorio shown in previous figures, are described as an *operatorSet* entity that contains four *operator* entities, the emoticons – one for each different emotion to be associated with a note. Generally, the *operator* entity denotes a widget through which the user can interact to activate a function. According to IM²L each *operator* is characterized by a name, a type, an identifier, the other entities it is related to, as well as its current state, the function associated, together with – as in the case of emoticon operators – the emotion the entity has to convey. This abstract and internationalized specification of an interactive system permits to describe the system without taking into account how it will be materialized based on the user's culture. As an example, the Banco Territorio in Figure 5 and 9 are different materializations of the same Banco Territorio, whose abstract and internationalized content is described by the same IM²L document. For more details we refer the interested reader to (Barricelli, Fresta, Marcante, Mussio & Parasiliti Provenza, 2008).

When materializing the abstract entities of an interactive system, some materialization properties (also called localization components) strictly depend on users' culture, language and system of signs¹. Geometry, topology, color representation, shapes and text are some example of these components. To specify

¹ They also depend on the activity to be performed and on the work context as well as user physical capabilities.

the localization aspects of Banco Territorio, we have defined a second XML-complaint language, the *localization markup language* (LML), which permits to specify for each IM²L entity its localization components (e.g. shape, color, orientation, order, thickness) given a specific locale (e.g. culture, gender). In the case of emoticon *operators*, the LML Banco specification for a given locale (e.g. the Italian one) sets the shapes and colors adopted, as reported in Table 1, based on the emotions that characterize the different *operators*.

To describe the materialization aspect of Banco Territorio (independently from its localization aspect) a *template language* (TL) is specified. TL is built upon the specific language chosen for system materialization (e.g. XHTML and SVG). The current prototype of Banco Territorio is materialized according to the W3C scalable vector graphics (SVG) to strengthen a window-icon-menu-pointer interaction and direct manipulation on the web. Consequently, the current TL consists of SVG documents that specify the materialization templates of the entity types to be localized during the instantiation process based on the LML Banco specification at hand.

Finally, the interaction dynamics of Banco Territorio is specified through the ECMAScript language and PHP scripting documents.

The different levels of system specification permits to easily localize the abstract and internationalized description of the Banco Territorio according to user culture, language and system of signs.

Banco Territorio architecture. Banco Territorio is realized according to an AJAX-like architecture (Garrett, 2005) as shown in Figure 10. The user accesses the system through a Banco log-in web page, which loads from the Banco specification database: (i) the ECMAScript engine specification; (ii) the IM²L content description; (iii) the current SVG templates; (iv) and, on the basis of the user profile (her/his culture, the activity and work context), the correspondent LML specification of the system. These specifications are thus interpreted by the browser, which coordinates the activities of its XML processor, the ECMAScript interpreter and the SVG viewer – the Adobe SVG Viewer plug-in, in our case. Given the IM²L Banco specification, the Banco engine thus localizes the SVG templates according to the LML document. It then produces the initial state of the Banco Territorio system localized to the specific user and manages, on the client side, the interaction between the user and the system. On the server side, a PHP module is responsible to enrich the knowledge base with the new knowledge (i.e. annotations and narrations) associated with the maps. More details can be found

in Barracelli (2007), and Barricelli, Fresta, Marcante , Mussio & Parasiliti Provenza (2008).

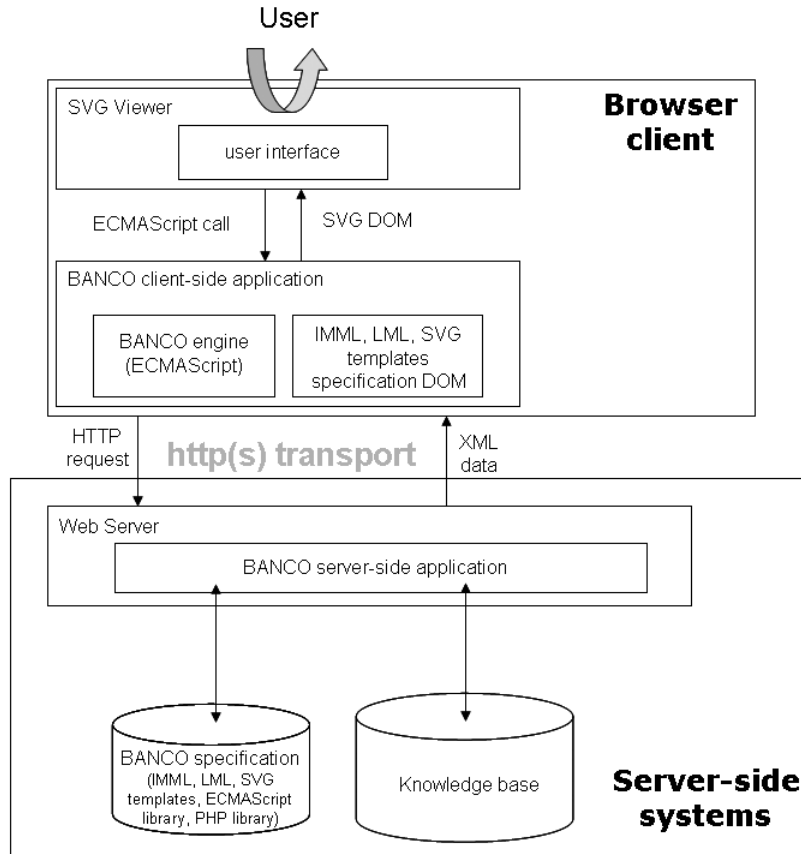


Figure 10. The Banco Territorio Architecture.

5. Conclusions

The ability to map space for cognitive knowledge and emotional moods, directly or metaphorically, and to localize this representation in such a way as to create a multicultural social network are interesting topics that merit further and deeper exploration.

The notion of map-based wiki introduced in this paper aims at defining tools to 'materialize' these efforts as emerging from virtual interaction. In map-based wikis, a map is the perceptible part of a social medium. Operations on the map allow users to interact with one another to create a social network.

Multimodal digital annotation appears, from the examples discussed, to be a powerful functionality of map-based wikis for conveying cognitive and emotional knowledge

(cognition and feeling) in a sharable shape, the external form of the knowledge. This external form can be described by adopting internationalization techniques, such as in the Banco Territorio, so as to be localized for specific cultural domains.

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7. References

- Barber, W., & Badre, A. (1998, June). Culturability: The Merging of Culture and Usability. Presented at the *4th Conference on Human Factors & the Web 1998*, Baskin Ridge, NJ.
- Barricelli, B.R., Fresta, G., Marcante, A., Mussio, P., & Parasiliti Provenza, L. (submitted). *BANCO: a Web Architecture Supporting Unwitting End-User Development*.
- Barricelli, B.R. (2007). *Sistemi per la costruzione e la gestione cooperativa di contenuti: un approccio basato sugli standard del Semantic Web*. Unpublished Master's thesis, University of Milan, Italy.
- Chen, W., Lee, B.N., & Chang, E.Y. (2006). Fotowiki: distributed map enhancement service. In *Proceedings of the 14th Annual ACM international Conference on Multimedia* (pp.803-804). New York, NY: ACM Press .
- Costabile, M.F., Piccinno, A., Mussio, P., & Parasiliti Provenza, L. (2007, June). End-User Visual Languages as Guiding Lights to avoid Turing Tar Pit and its inverse. Paper presented at *CHIItaly'07*, Padova, Italy.
- De Souza, C.S., & Barbosa, S.D.J. (2006). A Semiotic Framing for End-User Development. In H. Lieberman, F. Paternò, & V. Wulf (Eds), *End User Development* (pp. 401-426). Dordrecht: Springer.
- Esselink, B. (2000). *A Practical Guide to Localization*. Amsterdam: John Benjamins.
- FOAF project. Retrieved July 8, 2007, from <http://www.foaf-project.org>

- Fogli, D., Fresta, G., Marcante, A., & Mussio, P. (2004, May). IM2L: A User Interface Description Language Supporting Electronic Annotation. Presented at the *Workshop on Developing User Interface with XML: Advances on User Interface Description Languages, AVI 2004*, Gallipoli, Italy.
- Freeman, H. (2007). On the problem of placing names on a map. *Journal of Visual Languages and Computing*, 18(5), 458-469.
- Garrett, J.J. (2005). *Ajax: A New Approach to Web Applications*. Retrieved April, 20 from <http://www.adaptivepath.com/ideas/essays/archives/000385.php>
- Giaccardi, E. (2007). Cross-Media Interaction for the Virtual Museum: Reconnecting to Natural Heritage in Boulder, Colorado. In Y. Kalay, T. Kvan, & J. Affleck (Eds.), *New Heritage: New Media and Cultural Heritage* (pp. 112-131). Oxford, UK: Routledge.
- Giaccardi, E., & Fogli, D., (2008, May). Affective Geographies: Toward Richer Cartographic Semantics for the Geospatial Web. In *Proceedings ACM Int. Conf. on Advanced Visual Interfaces 2008* (pp. 173-180). New York, NY: ACM Press.
- Google Maps. Retrieved April 20, 2008, from <http://maps.google.com>
- Lakoff, G., & Johnson, M. (1980). *Metaphors We Live By*. Chicago: University of Chicago Press.
- Leuf, B., & Cunningham, W. (2001, April). *The Wiki Way: Quick Collaboration on the Web*. Boston, MA: Addison-Wesley Longmann.
- Martino, F., & Spoto, A. (2006). Social Network Analysis: A brief theoretical review and further perspectives in the study of Information Technology. *PsychNology Journal*, 4(1), 53-86.
- Moody, J., & White, D.R. (2003). Structural Cohesion and Embeddedness: A Hierarchical Concept of Social Groups. *American Sociological Review* 68(1), 103-127.
- MySociety. Retrieved April 29, 2008, from <http://www.mysociety.org>
- O'Hagan, M., & Ashworth, D. (2002). *Translation-mediated Communication in a Digital World - Facing the Challenges of Globalization and Localization*. Clevedon, UK: Multilingual Matters.
- PlaceOpedia. Retrieved April 27, 2008, from <http://www.placeopedia.org>
- Priedhorsky, R., Jordan, B., & Terveen, L. (2007, October). How a personalized geowiki can help bicyclists share information more effectively. In *Proceedings of the 2007 international Symposium on Wikis* (pp. 93-98). New York, NY: ACM Press .

Teranishi, Y., Kamahara, J., & Shimojo, S. (2006). MapWiki: A Ubiquitous Collaboration Environment on Shared Maps. *Joho Shori Gakkai Shinpojiumu Ronbunshu*, 19, 414-419.

WikiMapia. Retrieved April 27, 2008, from <http://www.wikimapia.org>

YourHistoryHere. Retrieved April 27, 2008, from: <http://www.yourhistoryhere.org>

Valtolina, S., Mazzoleni, P., Franzoni, S., & Bertino, E. (2006). A semantic approach to build personalized interfaces in the cultural heritage domain. *Proceedings of AVI 2006* (pp. 306-309). New York, NY: ACM Press.

Nurturing Learners' Communities by Creating and Sharing Maps

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ABSTRACT

We present the SketchMap system, which integrates outdoor and classroom activities to support children's collaborative learning. Individual children create maps near their school in an outdoor environment using a SketchMap client. The maps are uploaded to the SketchMap web server for sharing among the children, who have created maps of different areas. Children can edit or add new information to the maps in their classroom or in their home. The goal of the SketchMap project is to investigate whether integrating outdoor and classroom activities, and sharing children's experiences through the maps can actually promote their collaborative learning and nurture learning communities including teachers and parents. The SketchMap system has been used in "Safety Map" and "Nature Exploration" classes in a Japanese elementary school. Evaluation of the SketchMap system is in progress, and issues found through the educational practices are described.

Keywords: *Outdoor learning, collaborative learning, tablet PC, GPS, safety map, nature exploration map.*

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1. Introduction

We have been developing systems to support collaborative learning (Kusunoki, Sugimoto & Hashizume, 1999; Sugimoto, Kusunoki & Hashizume, 2002; Sugimoto, Kusunoki, Inagaki, Takatoki & Yoshikawa, 2003) in elementary school education. The underlying philosophy of our research project is that learners should be regarded as active creators of information and knowledge, rather than passive recipients (Fischer & Sugimoto, 2006). To make children active learners, our systems have been used to enhance their learning experiences (Sugimoto, 2008). The system proposed in this paper also shares this philosophy and purpose with the previous systems.

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In this paper, a system called SketchMap (Enjoji, Ravasio & Sugimoto, 2006; Ravasio, Tschertter & Sugimoto, 2006; Sugimoto, Ravasio & Enjoji, 2006; Miura, Ravasio & Sugimoto, 2007) for supporting children's outdoor collaborative learning is described. SketchMap is used: (1) to allow children to easily record what they have found during their fieldwork; (2) to enhance their further learning using their maps; and (3) to support their knowledge-sharing and construction processes by sharing individual children's experiences through the maps.

In SketchMap, children are asked to create a map near their school. A tablet PC is used for this task, to retain the natural feeling of a sketch using a pen and a paper, and to overcome the difficulties of pen–paper-based sketches; for example, it is not easy to change a scale of a map on paper, but it is not difficult to modify the computer map. Children draw a street with a stylus pen, or place an icon that represents a landmark by selecting it from an icon list. A tablet PC with SketchMap is augmented with a GPS receiver and a USB camera. Children can capture an image, a sound, or a video through the attached camera, and easily arrange it anywhere on the tablet PC display. During the map creation tasks, all the manipulations on the tablet PC by the children are logged, with time and location data captured through the GPS receiver. As the tablet PC is always connected through its wireless internet card to a server computer, a map being created by children can automatically be uploaded to the server.

When children return to their school or their home, they can access the web server where the uploaded maps are presented. The children can edit their own map or add new information to other children's maps.

Evaluations using the SketchMap system have been conducted in collaboration with a Japanese elementary school. Children used SketchMap for creating safety maps and nature exploration maps near their school. Using results gained through the evaluations, the effects of integrating outdoor and classroom activities and sharing their experiences through maps are investigated. We discuss some lessons learned and suggest future work.

2. Related Works

The use of a mobile device, such as a PDA, to individualize tuition in educational environments has rapidly led to the transfer of widely known, effective pedagogical methods to this novel medium. Examples are the MapIt and PicoMap applications for

concept mapping (Chan & Sharples, 2002) and Cooties projects for science classes (Soloway, Norris, Blumenfeld, Fishman, Krajcik & Marx, 2001). A mobile butterfly-watching system (Chen, Kao, Yu & Sheu, 2004) uses content-based image retrieval and allows individual learners to retrieve information on a butterfly after capturing its image using a camera built into the handheld device in an outdoor environment.

The range of existing collaborative educational systems covers topics as diverse as participatory simulations (Wilensky & Stroup, 1999; Colella, 2000; Benford et al., 2005), classroom communication systems (Dufresne, Geracce, Leonard, Mestre, & Wenk, 1996), and problem-based learning (Cuartiellas, Malmborg & Schlaucher, 2003).

Individual and collaborative practices can be integrated into a single system. Ishizuka Horita, Takada, Ishihara, Ogawa, Moriya et al. (2004) compared the achievements of pupils using web-based training systems in combination with PDAs in the "integrated study" classroom, outdoors, and in a social education facility. Deguchi, Yamaguchi, Inagaki, Sugimoto and Kusunoki (2006) described a system for use in the integrated study class, to encourage pupils to collaborate in the design of a town and experience the relevant environmental implications. Yatani, Sugimoto and Kusunoki (2004) developed a system in which pairs of pupils collaborated to solve a knowledge quiz about the individual insights they gained from the science exhibition they were visiting, while Takenaka, Inagaki, Kuroda, Deguchi and Ohkubo (2006) proposed a system that allows elementary school children to collaboratively create and share a virtual botanical garden by using a mobile phone equipped with a camera. Finally, the purpose of the Ad Hoc Classroom project (Chang & Sheu, 2004) is to develop a wireless platform so that teacher and students can establish a classroom dynamically, irrespective of location and time limitations (that is, any time and anywhere).

There have been proposals for systems that aimed to enhance the use and application of geospatial data and tools in the context of other knowledge domains. An example is the e-MapScholar project (Jones, Blake, Davies & Scanlon, 2003), which, together with others, provides teaching case studies from varying areas of expertise, such as archaeology, civil engineering, or forestry. In the WebPark project (Dias Beinat, Rhin & Scholten, 2004), a mobile information system that provides visitors to nature reserves and parks with information about their surroundings was constructed, using smart phones and a GPS receiver that is equipped to access the information in the system.

Environmental Detectives (Squire, 2007) helps students learn about the potential contamination of a local water supply using a PDA that provides learners with location-

sensitive visualization and supports them in their socially situated scientific practices. JAPELAS and TANGO (Ogata & Yano, 2004) are context-aware language-learning support systems, especially for assisting foreign students in Japan to learn polite Japanese expressions through interactions with real-world objects. DIGITAL-EE (Okada et al., 2003) supports learners conducting fieldwork in an outdoor environment and those in a classroom in sharing the virtually augmented fieldwork and enhances their collaboration. CyberTracker (CyberTracker, 2000) is a PDA application designed for data collection in conservation biology. It is used in the BioKIDS curriculum (Parr, Jones & Songer, 2002) to enhance inquiry learning in an outdoor environment. Ambient Wood (Rogers, 2005) uses pervasive technologies to augment woodland digitally in a contextually relevant manner, to enhance the physical experiences of children exploring the outdoor world. In (Chipman, Druin, Beer, Fails, JGuha & Simms, 2006), a system that supports children to enhance their collaborative inquiry by allowing them to link digital information with real world objects using RFID tags and tablet PCs is discussed, and evaluated in a US National park. The literacy fieldtrip (Halloran, Hornecker, Fitzpa, Fitzpatrick, Weal, Millard et al., 2006) is aimed at supporting children's writing skills. The system consists of PDAs, GPS receivers, and RF beacons for providing children with visual/auditory information of historical exhibits and for recording their location and audio/text messages. The logged data is used for their creative story writing after the fieldtrip. HyConExplorer (Bouvin, Brodersen, Brodersen, Hansen, Iversen & Nørregaard, 2005) was developed based on the "browsing with your feet" concept, which is similar to a car navigation system and allows to children to conduct digital annotations by using a camera and a GPS receiver while exploring a town.

Although there are similarities between these predecessors and SketchMap, it differs from them in the following ways.

- The basic objective of SketchMap is that children's experiences are augmented by their articulation and recognition of the real world, and by expressing their experiences in a map.
- SketchMap enhances conventional children's fieldwork by using a tablet PC that retains the features of pen-based interaction.
- To share individual children's outdoor experiences, enhance their reflections, and use them for their further learning, SketchMap allows the children to edit and annotate the maps through the server.

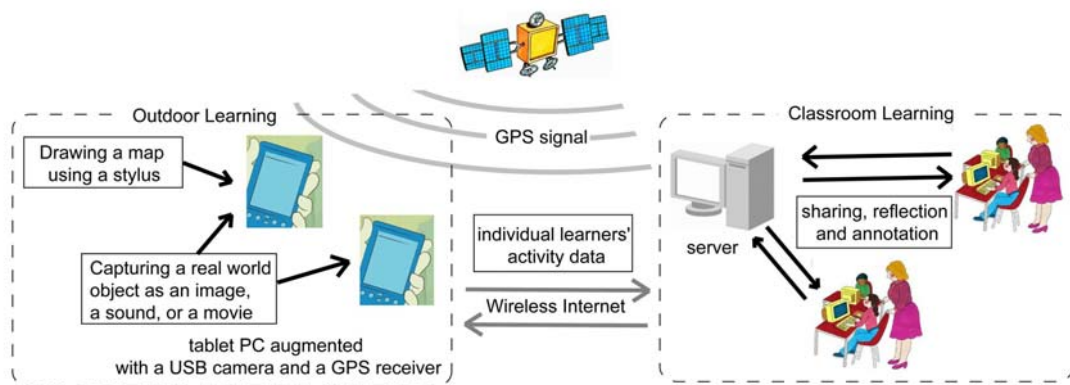


Figure 1. An overview of the SketchMap system

3. Configuration of SketchMap

3.1 Overview

As shown in Figure 1, SketchMap consists of multiple client computers and a server computer. The client computer is used to support children as they create a map in an outdoor environment, and the server computer is mainly used for supporting children's individual and collaborative learning using the maps in their classroom.

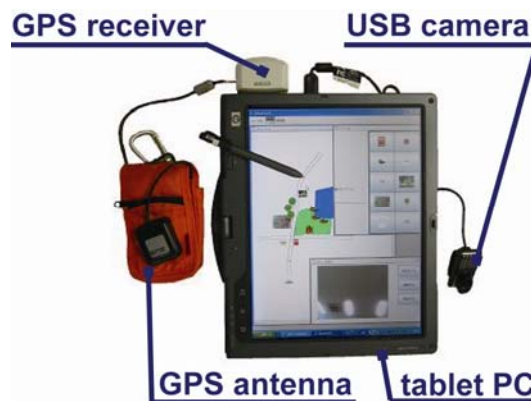


Figure 2. A map creation support system of SketchMap

3.2 SketchMap Client

The client side of SketchMap consists of a tablet PC (HP Compaq tc4400), a USB camera (Logitech Qcam for Notebooks Pro), and a GPS receiver (IO DATA CFGPS2), as shown in Figure 2. Children carry the system and create a map with a stylus pen. A user interface of the system is shown in Figure 3. When children draw a street or place a landmark icon such as a hospital or a municipal office on the canvas (Figure 3(A)),

they tap the menu in the upper part of the user interface (Figure 3(B)) and select the corresponding item. A USB camera attached to the tablet PC is manipulated through the buttons in a popup window (Figure 3(C)). Children can capture an image, a sound or a video with the camera. When the capture is completed, an icon that represents the captured image (thumbnail icon), sound (microphone icon), or video (thumbnail icon) is automatically added to the palette as shown in Figure 3(D). Then, children can drag the icon from the palette to anywhere they like on the map. They can easily enlarge or shrink an image or a video, or replay a sound by tapping the corresponding icon.

Before starting the design of the SketchMap client, we investigated numerous commercial software packages that could support children's map creation. Our investigations showed that most of the packages prepare a blank map and ask children to complete it by placing landmark icons on it (e.g., a police station or a fire department). However, consider how we might create a map on a blank piece of paper. We must first decide what should be placed or drawn on the paper. From an epistemological point of view, this is closely related to our articulation process, namely, how we recognize the three-dimensional real world, how we select a limited number of objects, such as roads, buildings, and shops, from an unlimited number of objects, and how we represent and arrange the objects on the paper as a two-dimensional map. This map creation task requires greater cognitive capability or effort than tasks that require children simply to place a ready-made icon corresponding to a real-world object (because the world is already "articulated"). One of the main goals of the SketchMap project is to enhance learners' experiences and reproduce them for their further learning, so a map creation task that requires a higher level of articulation, based on the individual child's viewpoint, is inevitable. In the same vein, we decided not to implement a function for tracking children's locations and automatically drawing streets on their tablet PC by using GPS records. These design decisions were made through discussions with schoolteachers. Finally, we designed and developed a SketchMap client that allows children to create a map on a white canvas while receiving moderate assistance, as shown in Figure 3.

While individual children are creating a map in an outdoor environment, the SketchMap system always receives GPS data. Children's usage data and GPS data are automatically logged in the format (*time, latitude, longitude, user manipulation, item information*). *User manipulation* represents the manipulations conducted by children using SketchMap, such as capturing an image, moving an icon on the canvas, and so on. *Item information* is written in the SVG/XML format that describes a type of an item

(such as street, park, or icon) and its graphical information (e.g., shape, x - y coordinate values of points). These log data are uploaded to the server through the wireless internet and managed by the server for sharing and annotating the maps, as described in the next section.



Figure 3. The user interface of the map creation support system

3.3 SketchMap Server

To utilize the maps created by the children in an outdoor environment for their collaborative learning, the SketchMap system on the server computer provides children with the following functions, which are available through a web browser.

A function for supporting reflection. SketchMap allows children to replay their map creation processes using the log data described in the previous section. Figure 4 shows the user interface of the replay module. The slider at the bottom of the figure represents the time elapsed during map creation. Children can change the position of the slider and visualize the map that was created at the corresponding elapsed time. The replay module is used to remind children of what they discovered during their fieldwork through their reflection; by viewing the map using the module, children can easily recall when and where they drew a map, took a picture, and so on.

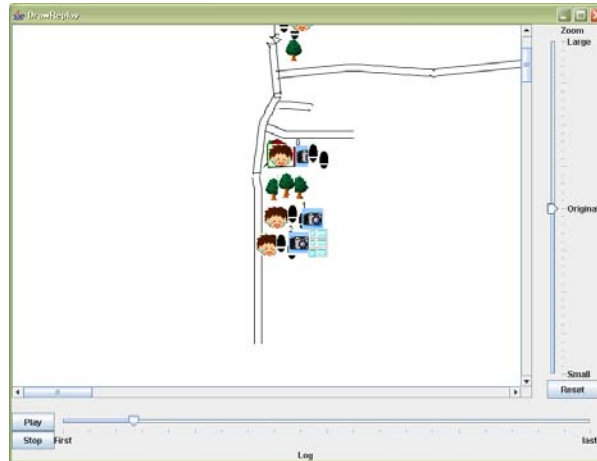


Figure 4. A user interface for replaying map creation processes

A function for annotating maps. SketchMap allows children to add new information related to what they have learned after their outdoor activities, or their experiences, to their maps. As all the children can view the map or information annotated by the other children, they can collaboratively construct and share information and knowledge on the area near their school.

A web interface for editing and annotating a map is shown in Figure 5(A). When children click the hand-drawn map in the left window, a comment box with images, videos, or sounds recorded in an outdoor environment appears in the right window.

The web server is accessible not only in the children's classroom, but also in their homes or any other place where a public internet service is available. This allows children to add photos, sounds or videos that have been captured while they commute, and moreover involves their parents with the knowledge sharing and collaborative construction processes by annotating the maps.

Figure 5(B) is an example of a Google map interface that also shows the results of children's map creation tasks. A red icon representing that children recorded an image, a sound, or a video in an outdoor environment is placed on the map based on the GPS output. As a map created by individual children is often inaccurate in its scale or orientation, it may be difficult for other children, teachers, or parents to understand the map. In this case, they can use the Google map interface for their annotation tasks.



Figure 5. A web interface for editing and annotating maps

The current version of SketchMap was developed using the Java language (J2SE5.0), an XML database server (eXist), and a web server (Apache), and is executable on Microsoft Windows XP.

4. Evaluations

4.1 Overview of educational practices

We have studied educational practices using the SketchMap system in collaboration with a local elementary school (Chiba prefecture, Japan) since February 2006. Evaluations of the SketchMap system have been conducted three times during 2006 (February, June, and October) and twice during 2007 (February and June). To date, more than 200 children have used the SketchMap system.

The purposes of the evaluations are to investigate the usability of the client for children in an outdoor situation and to see how outdoor activities motivate children for their knowledge construction in their classroom or homes.

Safety Map Class. Recently, the number of brutal crimes against children has increased and preserving their safety while commuting is one of the most critical issues in Japanese elementary schools (Japanese Ministry of Education, 2006a). One of the countermeasures for protecting children from such crimes is to create a safety map from children's viewpoints: individual children create a map by using pen and paper, taking a photo with a digital camera, and complete the map after they returned to their classroom (Japanese Ministry of Education, 2006b). By using SketchMap, which supports pen-based interaction with a tablet PC enhanced by a camera and a GPS

receiver, it seems possible to clarify differences from the conventional paper-and-pen-based method.



Figure 6. Children in the safety map class

In the safety map class, as shown in Figure 6, sixth-grade children (aged 11 to 12 years) were divided into groups of five. Each group was given one SketchMap client, and was asked to create a map of a specified area near their school, by drawing a street, taking a photo, and by placing an icon that represented an “empty street” or a “blind spot” (these icons denote a danger sign), as well as by recording interviews with residents. The task took approximately 90 minutes. After the children returned to their classroom, using their map uploaded onto the SketchMap server, each group presented to the other groups what they had found during their outdoor activities.



Figure 7. Children in the nature exploration class

Nature Exploration Class. The purpose of a nature exploration class is to increase children’s interest in living things, such as insects or plants, by creating a map near their school. In this class, fourth-grade children (aged 9–10 years) were divided into groups of five. Each group was asked to create a map of a specified area near their

school using the SketchMap system (Figure 7). The task lasted about 60 minutes. As with the safety map class, children reflected on their activities, and finally presented what they had found by using their map when they returned to their classroom.

We mainly show experimental results from the safety map class here. This class was conducted from the second week of June to the first week of July in 2007 with the following schedule:

- one day for outdoor fieldwork using a SketchMap client
- three successive weeks for reflection and collaborative map annotation using the SketchMap server

Seventy-five sixth graders divided into 15 groups participated in this experiment, in which the purposes of the evaluations were: (a) to investigate the usability of the SketchMap client for children outdoors; and (b) to investigate how outdoor activities motivate children to undertake collaborative learning and knowledge sharing and construction in their classrooms or homes.

Children's outdoor activities were performed on their commuting routes selected by their schoolteachers for individual groups. All the routes started from their school and returned there via several landmark places (e.g. parks, shopping streets, and heavily trafficked intersections). The length of each route was approximately 800 to 1200 meter.

In this class, a public wireless internet service that allows each SketchMap client to upload a map automatically was not used; instead, the maps were uploaded immediately after the children returned to their school. The children's activities outdoors and in the classroom were videotaped and we administered post-experimental interviews and questionnaires to the children and their teachers.

4.2 Overview of educational practices

Usability of SketchMap client. The results of the post-experimental interviews (Figure 8) show that children's responses were positive. Children could enjoy creating a map by using SketchMap and its usability was satisfactory.

Table 1 shows the statistics on the usage of SketchMap by the fifteen groups. The average numbers and standard deviations of four different icons (landmark icons, sound icons, image icon, and video icons, as shown Figure 3) in the final version of their maps are given.

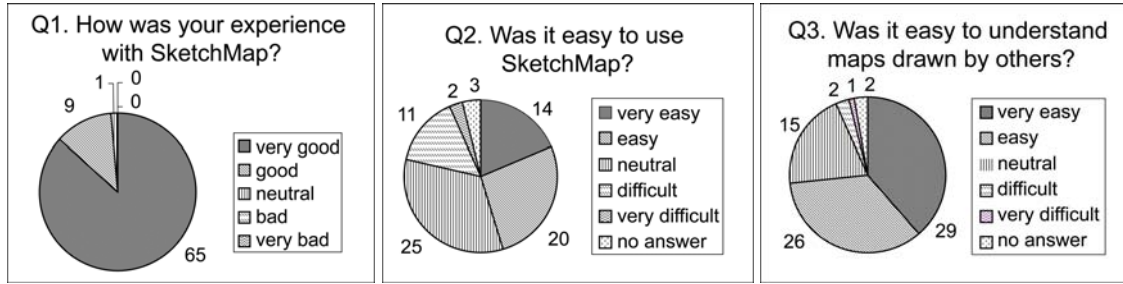


Figure 8. Results of post-experimental interviews

One interesting finding through this statistics is that there are differences among groups in their icon usage preferences --- some groups who frequently used sound icons did not use image icons so frequently and vice versa. It is guessed that these groups tried to collect and record safety information through interviews to people they met during the fieldwork rather than take photos.

Icon	average	S.D.
Landmark	34.3	7.7
Microphone	2.5	2.1
Image	9.5	2.9
Video	5.2	1.9

Table 1. Statistics on icon usage by children groups

Video analyses during children’s outdoor activities clarified several issues related to the advantages and disadvantages of the current SketchMap system. Some of them are summarized as follows.

- The five children in each group voluntarily discussed and allocated their individual roles, e.g., capturing with a camera, drawing a map, discovering an object to be captured, and managing individual tasks, and changed them halfway through their task, although they were not asked to do this beforehand. This division of roles allowed children to conduct their map creation smoothly. Children could easily use the SketchMap system. During the fieldwork, to record what they were interested in, they frequently used a camera to take a photo (e.g., unfrequented spots), capture a sound, or a video (e.g., a bulldozer working at a construction site).
- Children frequently checked their map being drawn and asked each other if they found questions. The following episode shows how one child (A4) and the other children (A1, A2, and A3) constructed shared understanding of the

meaning of an item on their map through discussions (Phrases and sentences within the brackets have been added by the authors to clarify the meaning of the comments).

A1: What is this [on the map]? Where is it?

A2: This is ... well, well, the agricultural cooperative office [at the corner]. Hey, you said, this corner must be very dangerous! But I didn't understand why [it is] so dangerous?

A3: Let's see, yeah, I saw a Mercedes there, Mercedes!

A2: No, no, the Mercedes was not there. It was bit a head [from there].

A4: 'Cause, it seemed difficult to see [from the street] even if something dangerous happens.

A1: Hmm ... I see! Let's check it again [when we return to the school].

- The remarkable difference between SketchMap and the conventional map creation method is that children can draw a street, and then immediately put a photo, a sound, or a video on their map. For example, if they do not like a photo on their map, they can immediately take a new photo and easily replace the old one. However, when they use the conventional paper-based method, it is impossible for children to place photos, videos, or sounds on the map and confirm if it is acceptable during the fieldwork. Comments from the teachers revealed that children seemed more motivated and engaged in the tasks by using SketchMap than by using the conventional method.
- Using a tablet PC in an outdoor environment was sometimes difficult for children because of the weather. In the safety map class, the weather was cloudy, and children could easily recognize what was shown on their tablet PC display. However, in the nature exploration class, the weather was sunny, and children could not easily recognize the displayed information and draw a map. To solve the problem, it may be better to use a tablet PC with a low-reflection display.

How outdoor activities motivate children for collaborative learning and knowledge sharing/construction. During the reflection time and presentation time in the classroom after the outdoor fieldwork, children could actively discuss what they found through the fieldwork and exchange their experiences and knowledge. Using the replay module

reminded the children of what they had done using SketchMap (e.g., drawing a street, taking a photo, or putting an icon on their map), which became clues for their discussions. This indicated that to enhance and share outdoor experiences was useful for activating discussions and interactions among children.

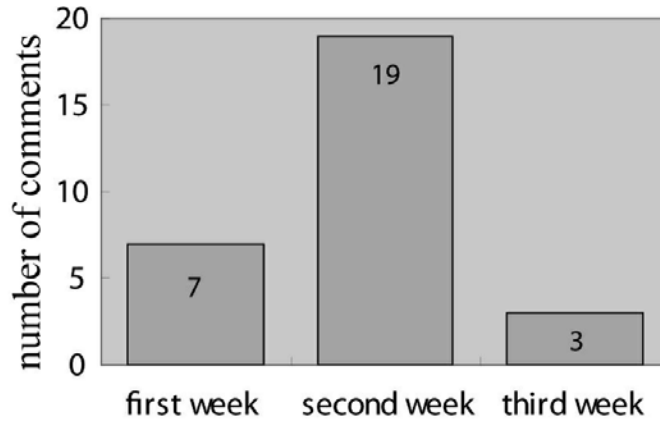


Figure 9. Number of comments during the three-week experiments

Figure 9 shows the number of comments made by children on the SketchMap web server during the three successive weeks. The total number was 29, which appeared relatively small. One of the main reasons was that the teachers did not use the SketchMap server in their classes. The teachers expected the children to access the server voluntarily, and to edit or provide comments on their maps whenever and wherever they liked, such as in their free time before, between, or after classes in their school, or while they were at home.

The following is an example of a series of comments made by four children (C1, C2, C3, C4) and one teacher (T1) on the SketchMap server. They tried to enumerate potentially dangerous places by referring to a certain part of the map and photographs on the server. (Phrases and sentences within the brackets have been added by the authors to clarify the meaning of the comments.)

C1: This parking lot seems dangerous, because suspicious individuals can easily hide behind cars. We might be attacked while commuting.

T1: A location behind the step of the apartment house [next to the parking lot] is also dangerous, because it is dark and difficult to recognize.

C1: There are a bush and a hut [around the parking lot] that allow suspicious individuals to hide.

C2: Suspicious individuals can easily enter these places, and we cannot recognize them when it becomes dark.

T1: This photograph [on the map] shows the parking lot taken from a distant location.

C3: I think it is very dangerous because cars parked there make it difficult to identify suspicious individuals.

C4: That location [behind the steps of the apartment] seems dangerous because it is dark and [the wall of the apartment is] covered with graffiti.

In this case, C2 and C4 walked by the parking lot and found information that they had not found during the fieldwork. Active discussion among the children happened because they really (re)visited and recorded to create a map in their fieldwork, and, therefore, had a certain level of knowledge about the places.

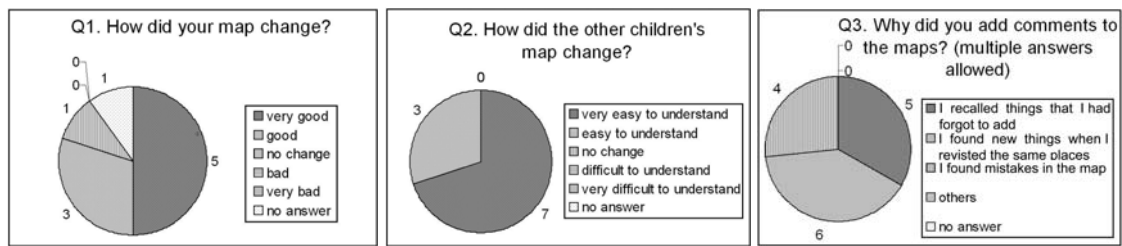


Figure 10. A questionnaire survey on the SketchMap server

A questionnaire survey after the three-week experiments was conducted by asking 10 children who used the SketchMap server. Their responses to the questions (e.g. Q1. How did your map change through discussions and comments on the web?; Q2. How did the other children's maps change through discussions and comments on the web?) were overall positive as shown in Figure 10. These results indicated that: (1) children who accessed the SketchMap server and added comments on the map could increase the level of their understanding of the map; and (2) they could share more information and knowledge with the other children.

4.3 Lessons Learned

The evaluations of SketchMap indicated that the integration of outdoor and classroom activities could motivate children's learning and also clarified several issues to be investigated in our future work.

More participation by the children is necessary. In this experiment, the teachers neither used the SketchMap server in class nor strongly suggested that the children use it in their schools or homes, which reduced the number of children involved with the annotation. In the next experiments, a curriculum that utilizes the SketchMap server will be designed to make children actively participate in the annotation and relate their classroom activities to their outdoor activities.

Role of teachers. The role of teachers was very important for discussions saved on the SketchMap server. Teachers provided suggestions or clues to activate the children's discussions and often moderated them by deleting inappropriate comments, such as defamation of other children. Every time a comment was added to the map, an email notifying a teacher that children had annotated the map on the SketchMap server was automatically sent. Although some teachers told us that such notification emails were useful in allowing easy and prompt checks on the children's comments, others said that they sometimes interrupted the teacher's other activities.

User interface of the SketchMap server. Before the experiments began, the teachers and the authors thought that children might not be able to understand a map created by other children (Figure 5(A)) and therefore prepared a map (Figure 5(B)) that was more accurate than the hand-drawn maps. However, the children did not use the map frequently, apparently because they had sufficient knowledge about the vicinity of their school, and photographs and icons attached by children to the hand-drawn maps helped the other children to identify their physical locations.

Parents' participation. In this experiment, contrary to the teachers' and authors' expectations, the children's parents did not participate in annotating the maps. The reason for this is still to be investigated thoroughly, but the following two issues can be suggested: (a) parents were not well informed about the experiment or the server's URL, as they only knew about the experiment from their children; and (b) parents hesitated to add comments because they did not want to make their comments visible to the other children and parents. A method for effectively promoting parents' participation must be explored.

Reflection of outdoor activities. Using the replay module reminded the children of what they had done using SketchMap, e.g., drawing a street, taking a photo, or putting

an icon on their tablet PC. Some children found clues for starting discussions or were motivated to revisit a place after their fieldwork through reflecting on their outdoor activities.

Can maps be a substrate for nurturing communities? The evaluations of SketchMap proved that children could share their experiences through the maps. Theoretically, as people such as children's parents or other residents in the area of the maps individually see and hear what happens in their neighbourhood, they can relate their experiences to the maps. Therefore, SketchMap can allow stakeholders (children, their teachers and parents, or local residents) to asynchronously communicate and collaborate through the maps by mutually exchanging their own information and knowledge. We believe that SketchMap has possibilities to nurture learning in communities by creating and sharing maps. Our most important task in the future should be to investigate this hypothesis further.

5. Conclusions and Future Works

This paper describes a system called SketchMap that integrates outdoor and classroom activities to enhance children's learning experiences. Children use a tablet PC augmented with a GPS receiver and a USB camera to create their maps in outdoor environments. The SketchMap system allows children to share and annotate the maps for collaborative learning and has been used in classes in a Japanese elementary school. Evaluations of SketchMap proved that children's responses were positive and indicated that it could promote children's collaborative knowledge sharing and construction through their outdoor learning experiences. However, as the number of children and parents who participated in the discussions on the SketchMap server was small, more investigations are necessary. Consequently, in future, it will be important for us to undertake further educational trials using the SketchMap system, to derive more conclusive results to prove its effectiveness. The purpose of the SketchMap is to nurture learning communities, so the challenge of the project is to conduct larger-scale evaluations with the involvement of their parents and local residents.

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7. References

- Benford, S., Rowland, D., Flintham, M., Drozd, A., Hull, R., Reid, J., Morrison, J., & Facer, K. (2005). Life on the Edge: Supporting Collaboration in Location-Based Experiences. In *Proceedings of CHI 2005* (pp. 721–730). Portland, OR: ACM Press.
- Bouvin, N. O., Brodersen, C., Brodersen, Hansen, F.A., Iversen, O. S., Nørregaard, P. (2005). Tools of Contextualization: Extending the Classroom to the Field. In *Proceedings of IDC2005* (pp. 24-31). Boulder, CO: ACM Press.
- Chan, T., & Sharples, M. (2002, August). A Concept Mapping Tool for Pocket PC Computers. Presented at the *IEEE WMTE 2002*, Vaxjo, Sweden.
- Chang, C., & Sheu, J. (2002, August). Design and Implementation of Ad Hoc Classroom and eSchoolbag Systems for Ubiquitous Learning. Presented at the *IEEE WMTE 2002*, Vaxjo, Sweden.
- Chen, Y., Kao, Y., Yu, G., & Sheu, J. (2004, August). A Mobile Butterfly-Watching Learning System for Supporting Independent Learning. Presented at the *IEEE WMTE 2002*, Vaxjo, Sweden.
- Chipman, G., Druin, A., Beer, D., Fails, J.A., Guha, M.L., & Simms, S. (2006). A Case Study of Tangible Flags: A Collaborative Technology to Enhance Field Trips. In *Proceedings of IDC 2006* (pp. 1-8). Tampere, Finland: ACM Press.
- Colella, V. (2000). Participatory Simulations: Building Collaborative Understanding through Immersive Dynamic Modeling. *Journal of the Learning Sciences*, 9(4) 471-500.
- Cuartielles, D., Malmberg, L., & Schlaucher, P. (2003, June). Components for a Ubiquitous Learning Environment. Presented at *HCI International*, Crete, Greece.
- CyberTracker (2000). *CyberTracker*. Retrieved June 2007, 2008, from <http://www.cybertracker.co.za>

- Deguchi, A., Yamaguchi, E., Inagaki, S., Sugimoto, M., & Kusunoki, F. (2006). CarettaKids: A System for Supporting Children's Face-to-Face Collaborative Learning by Integrating Personal and Shared Spaces. In *Proceedings of IDC 2006* (pp. 45-48). Tampere, Finland: ACM Press.
- Dias, E., Beinat, E., Rhin, C., & Scholten, H. (2004). Location Aware ICT in Addressing Protected Areas' Goals. *Research on Computing Science, Special Edition on e-Environment, 11*, 273-289.
- Dufresne, R., Geracce, W., Leonard, W., Mestre, J., & Wenk, L. (1996). Classtalk: A Classroom Communications System for Active Learning. *Journal of Computing in Higher Education, 7*, 3-47.
- Enjoji, H., Ravasio, P., & Sugimoto, M. (2006, July). A Collaboration Support Tool for Cartography Learning in the Open Air. Presented at *CollabTech 2006*, Tsukuba, Japan.
- Fischer, G., & Sugimoto, M. (2006). Supporting Self-Directed Learners and Learning Communities with Sociotechnical Environments. *Research and Practice in Technology Enhanced Learning, 1*(1), 31-64.
- Halloran, J., Hornecker, E., Fitzpa, Fitzpatrick, G., Weal, M., Millard, D., Michaelides, D., Cruickshank, D., & Roure, D. (2006). The literacy Fieldtrip: Using UbiComp to Support Children's Creative Writing. In *Proceedings of IDC 2006* (pp. 17-24). Tampere, Finland: ACM Press.
- Ishizuka, T., Horita, T., Takada, K., Ishihara, K., Ogawa, M., Moriya, K., Mori, K., Nishimura, Y., Yamada, T., & Morishita, S. (2004, November). Development and Practical Study on Mobile Learning Environment using Personal Digital Assistants for Elementary School Children. Presented at *ICCE 2004*, Melbourne, Australia.
- Japanese Ministry of Education, Culture, Sports, Science and Technology (2006a). Retrieved September, 2006, from http://www.mext.go.jp/b_menu/houdou/17/12/05120900.htm (in Japanese).
- Japanese Ministry of Education, Culture, Sports, Science and Technology (2006b). Retrieved September, 2006, from http://www.mext.go.jp/b_menu/houdou/17/12/05120900/007/{005,020,021,024}.pdf (in Japanese).
- Jones, A., Blake, C., Davies, C., & Scanlon, E. (2004). Digital Maps for Learning: Review and Prospects. *Computers and Education, 43*, 91-107.
- Kusunoki, F., Sugimoto, M., & Hashizume, H. (1999, December). A System for Supporting Group Learning that Enhances Interactions. Presented at *CSCL '99*, Palo Alto, CA.

- Miura, S., Ravasio, P., & Sugimoto, M. (2007, September). Nurturing Learners' Communities by Creating and Sharing Maps. Presented at *INTERACT 2007 Workshop on Map Based Interaction in Social Networks (MapIsNet '07)*, Rio de Janeiro, Brazil.
- Ogata, H., & Yano, Y. (2004, March). Context-Aware Support for Computer-Supported Ubiquitous Learning. Presented at *IEEE WMTE 2004*, Taoyuan, Taiwan.
- Okada, M., Yamada, A., Tarumi, H., Yoshida, M., & Moriya, K. (2003). DigitalEE II: RV-Augmented Interface Design for Networked Collaborative Environmental Learning. In *Proceedings of CSCL 03* (pp. 265-274). Dordrecht: Kluwer Academic Publishers.
- Parr, C. S., Jones, T., & Songer, N.B. (2002, October). CyberTracker in BioKIDS: Customization of a PDA-Based Scientific Data Collection Application for Inquiry Learning. Presented at *ICLS 2002*, Seattle, WA.
- Ravasio, P., Tschertter, V., & Sugimoto, M. (2006, July). SketchMap: A Collaborative Tool to Learn Basic Cartographical Concepts. Presented at *COOP '06*, Carry-le-Rouet, Province, France.
- Rogers, Y., Price, S., Randell, C., Fraser, D. S., Weal, M., & Fitzpatrick, G. (2004). Ubi-learning Integrates Indoor and Outdoor Experiences. *Communications of the ACM*, 48(1), 55–59.
- Soloway, E., Norris, C., Blumenfeld, P., Fishman, B., Krajcik, J., & Marx, R. (2001). Handheld Devices are Ready-at-Hand. *Communications of the ACM* 44(6), 15-20.
- Squire, K., & Klopfer, E. (2007). Augmented Reality Simulations on Handheld Computers. *The Journal of the Learning Sciences*, 16(3), 371-413.
- Sugimoto, M., Kusunoki, F., & Hashizume, H. (2002). Design of an Interactive System for Group Learning Support. In *Proceeding of DIS 2002* (pp. 50-55). London, UK: ACM Press .
- Sugimoto, M., Kusunoki, F., Inagaki, S, Takatoki, K, & Yoshikawa, A. (2003). Design of a System and a Curriculum to Support Group Learning for School Children. In B. Wasson, L. Ludvigsen, & U. Hoppe (Eds.), *Designing for Change in Networked Learning Environments* (pp. 303–312). Dordrecht: Kluwer Academic Publishers.
- Sugimoto, M., Ravasio, P., & Enjoji, H. (2006, December). SketchMap: A System for Supporting Outdoor Collaborative Learning by Enhancing and Sharing Learners' Experiences. Presented at *ICCE Workshop on Design and Experiments of Mobile and Ubiquitous Learning Environments*, Beijing, China.
- Sugimoto, M. (2008) A Support for Learning by Enhancing Experiences. *Journal of Japanese Society for Artificial Intelligence*, 23(2), 237–242.

- Takenaka, M., Inagaki, S., Kuroda, H., Deguchi, A., & Ohkubo, M. (2006, June). Fieldwork Support System Using Mobile Phones: Evaluations of Information Sharing in the Second Grade's Life Environment Study. Presented at *ED-MEDIA 2006*, Chesapeake, VA.
- Wilensky, U., & Stroup, W. (1999, December). Learning Through Participatory Simulations: Network-based Design for Systems Learning in Classrooms. Presented at *CSCCL '99*, Stanford, CA.
- Yatani, K., Sugimoto, M., & Kusonoki, F. (2004, March). Musex: A System for Supporting Children's Collaborative Learning in a Museum with PDAs. Presented at *IEEE WMTE 2004*, Taoyuan, Taiwan.

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 assess 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.

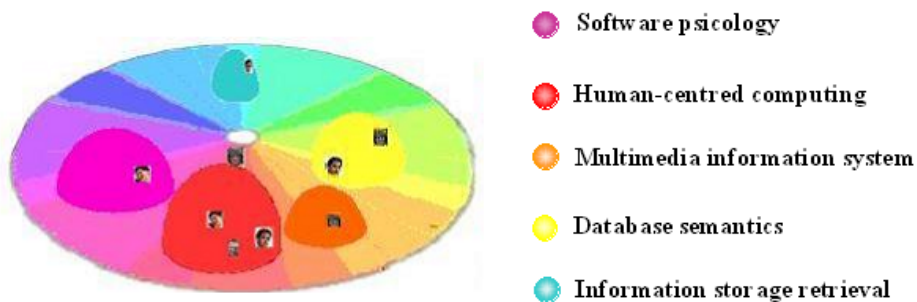


Figure 1. Interests visualized by coloured circles

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:

$$U = \{u_1, u_2, \dots u_i \dots u_l\} \text{ with } i=1\dots l$$

- the set S of users classes of interests:

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

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 ($p_{ui}(\Delta t_k)$).

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:

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

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:

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

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.

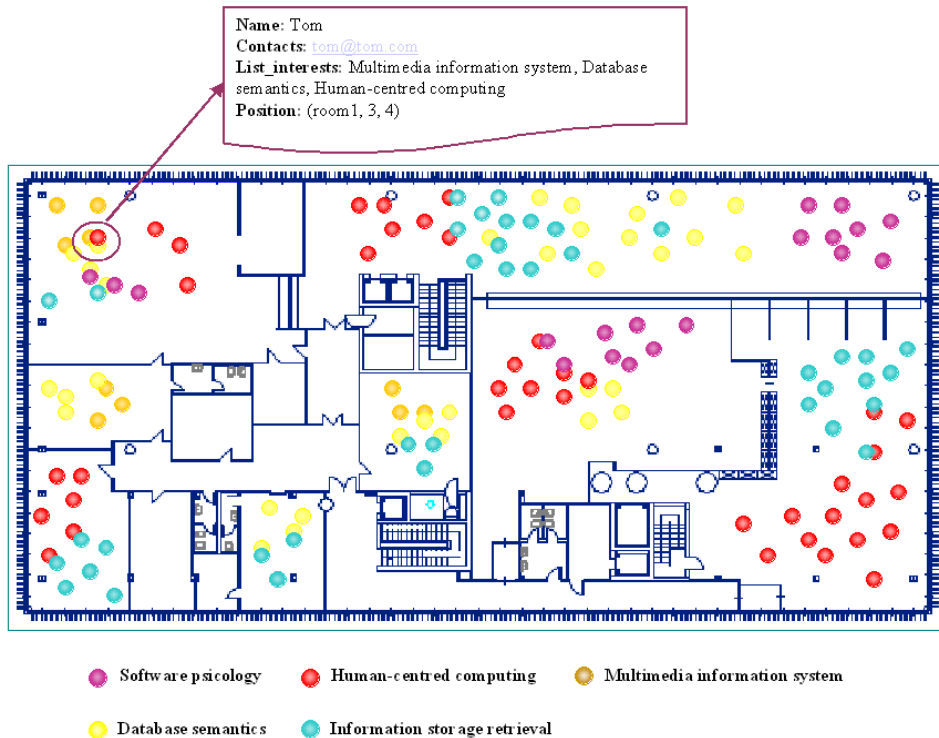


Figure 2. Real-time visualization of users' location

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.

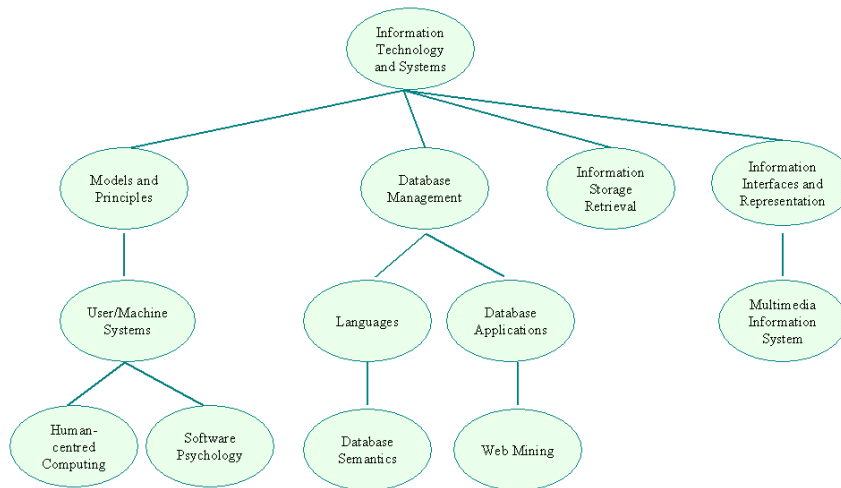


Figure 3. Hierarchical structure of the elements

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.

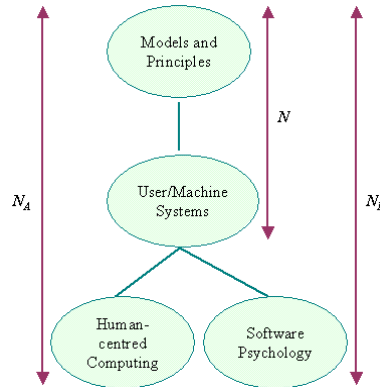


Figure 4. Depths levels in the hierarchical structure of the elements

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 $i = \textit{Software psychology, Human-centred computing, Multimedia information system, Database semantics, Information storage retrieval}$

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).

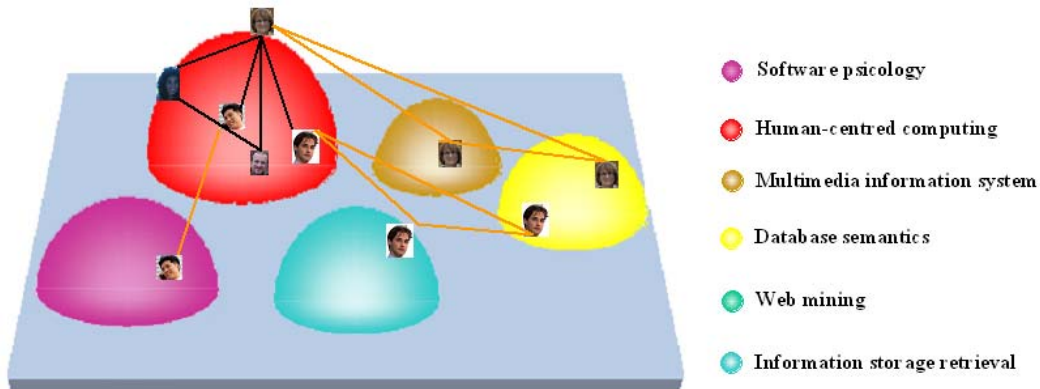


Figure 5. User profiles positioned in different points according to their interests and their importance in the class of interests

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 .

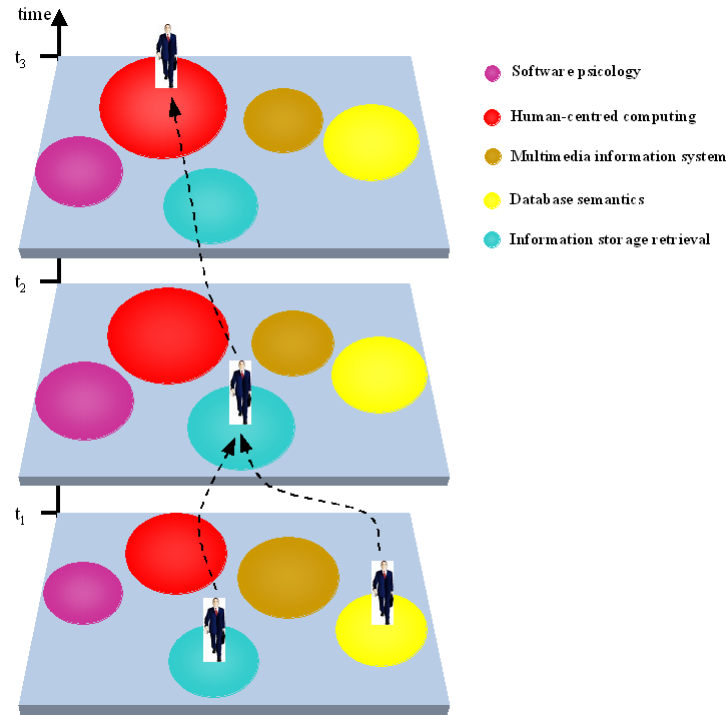


Figure 6. Interests map at the time t_1 , at the time t_2 and at the time t_3

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_{t_1} in the conference is:

$$S_{t_1} = \{\textit{Software psychology, Human-centred computing, Multimedia information system, Database semantics, Information storage retrieval}\}$$

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_{t_3} in the conference changes as follows:

$$S_{t_3} = \{\text{Software psychology, Human-centred computing, Multimedia information system, Database semantics, Information storage retrieval, Web mining}\}$$

Figure 7 shows the three temporal layers underlying 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 .

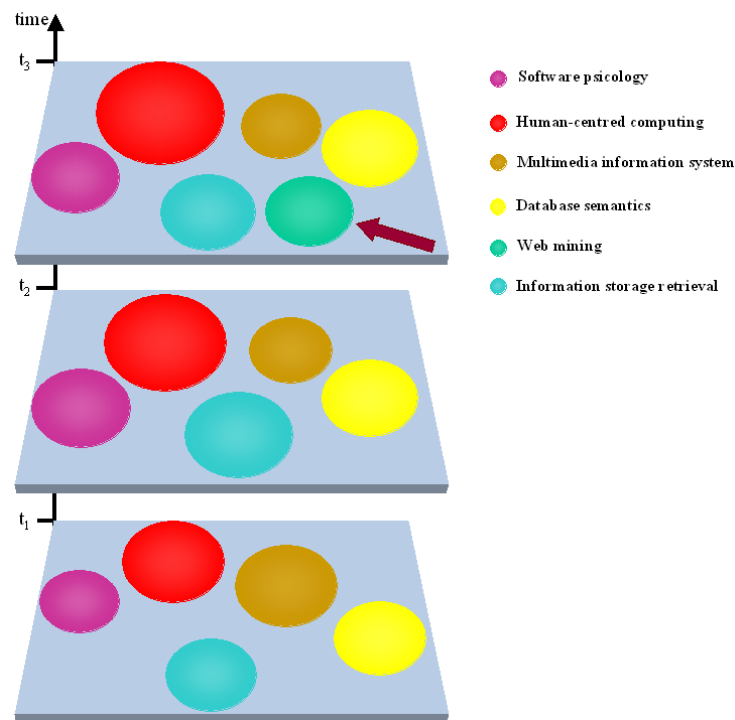


Figure 7. Evolution of the conference topics

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.

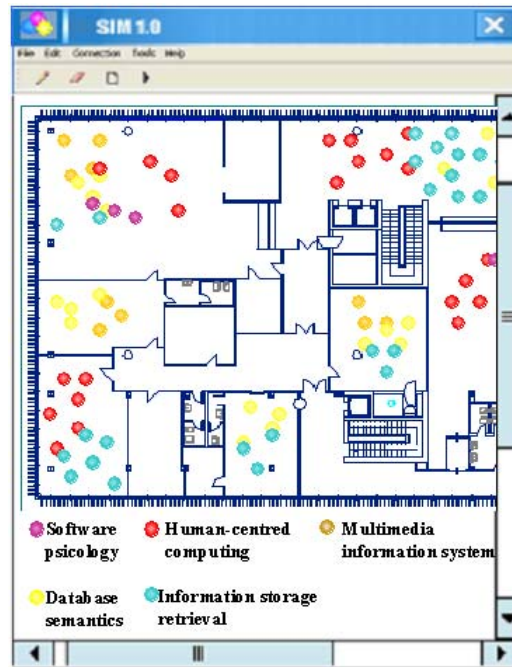


Figure 8. Visualization of the conference participants in the local area according to their interests

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).

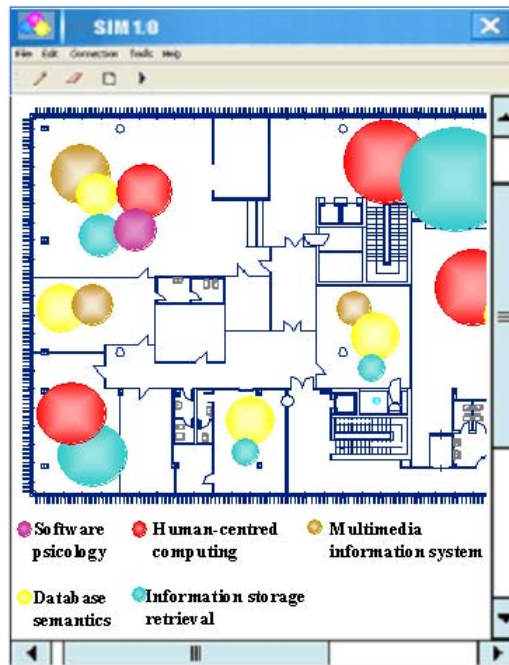


Figure 9. Aggregate visualization of the conference participants according to their classes of interests and their location

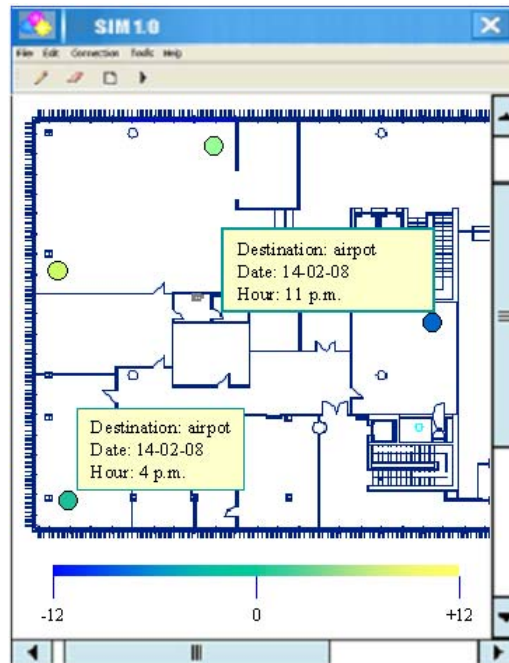


Figure 10. Services needs visualization

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:

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

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.

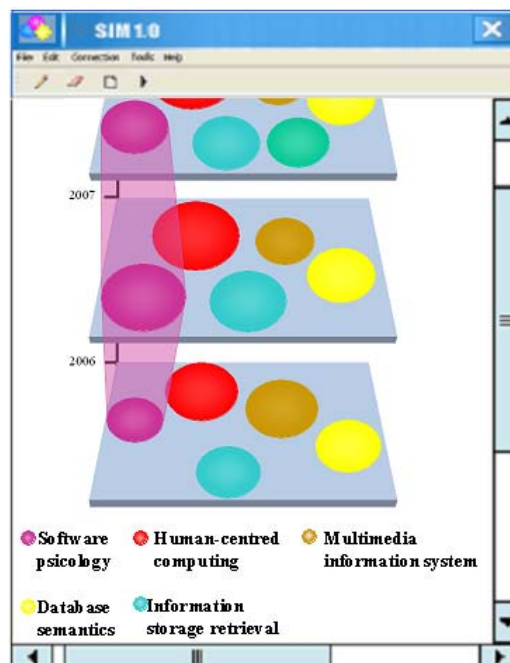


Figure 11. Temporal evolution of class of interests “Software psychology”

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:

$$\Delta^A_{i,j+1} = N.link^A_{i,j+1} - N.link^A_{i,j} \quad \text{with } i=1, 2,..l \quad \text{and } j = 1, 2, n-1$$

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

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:

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

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

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:

$$\Delta_{s,i,j+1}^A = N.\text{link}_{s,i,j+1}^A - N.\text{link}_{s,i,j}^A \quad \text{with } i=1, \dots, l, j = 1, \dots, n-1 \text{ and } s= 1, \dots, t$$

$$\Delta_{s,k,j+1}^B = N.\text{link}_{s,k,j+1}^B - N.\text{link}_{s,k,j}^B \quad \text{with } k=1, \dots, m, j = 1, \dots, n-1 \text{ and } s= 1, \dots, t$$

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:

$$\Delta\lambda_s^A = \frac{\sum_{i=1}^l \Delta_{s,i,j+1}^A}{P_{j,j+1}^A} \quad \text{with } j = 1, \dots, n-1, 0 < P_{j,j+1}^A < m+1 \text{ and } s= 1, \dots, t$$

$$\Delta\lambda_s^B = \frac{\sum_{k=1}^m \Delta_{s,k,j+1}^B}{P_{j,j+1}^B} \quad \text{with } j = 1, \dots, n-1, 0 < P_{j,j+1}^B < m+1 \text{ and } s= 1, \dots, t$$

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:

$$\begin{array}{ll} \Delta^A_{1,2} = 7 & \Delta^B_{1,2} = 2 \\ \Delta^A_{2,3} = 5 & \Delta^B_{2,3} = 4 \\ \Delta^A_{3,4} = 8 & \Delta^B_{3,4} = 3 \\ \Delta^A_{4,5} = 6 & \Delta^B_{4,5} = 4 \end{array}$$

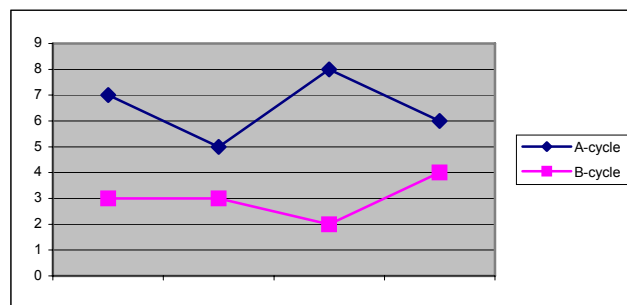


Figure 12. Social networking trends for participants to the A-group and the B-group of seminars

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:

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

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

the $P_{j,j+1}^A$ and $P_{j,j+1}^B$ 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.

7. References

- ACM (2006). *Top-Level Categories for the ACM Taxonomy*. Retrieved July, 2006 from: www.computer.org/portal/pages/ieeecs/publications/author/ACMtaxonomy.html
- Adar, E., & Tyler, J. (2003). *Zoomgraph*. Retrieved November 11, 2008, from www.hpl.hp.com/research/idl/projects/graphs/zg2003.pdf
- Bahbouh, R., & Warrenfeltz, R. (2004). *The Application of Sociomapping to Executive Team Development*. Retrieved November 11, 2008, from <http://www.hoganassessment.com/hoganweb/documents/ApplicationOfSociomapping.pdf>
- Brandes, U., & Wagner, D. (2003), visone - Analysis and Visualization of Social Networks. In M. Jünger & P. Mutzel (Eds.), *Graph Drawing Software* (pp.321-340). Perugia: Springer-Verlag.
- Chittaro, L. (2006). Visualizing Information on Mobile Devices. *IEEE Computer*, 39(3), 40-45.
- Cyram (2004). *Cyram NetMiner II*. Version 2.4.0. Seoul: Cyram Co., Ltd.
- Freeman, L. (2000). Visualizing Social Networks. *Journal of Social Structure* 1(1). Retrieved November 11, 2008, from: <http://www.cmu.edu/joss/content/articles/volume1/Freeman.html>

- Gloor, P., & Zhao, Y. (2004). TeCFlow - A Temporal Communication Flow Visualizer for Social Networks Analysis. *ACM CSCW Conference*, November 6-10, Chicago, Illinois, USA.
- Hartigan, J.A., & Wong, M.A. (1979). A K-Means Clustering Algorithm. *Applied Statistics* 28(1), 100-108.
- Heer, J., & Boyd, D. (2005). Vizster: Visualizing Online Social Networks. *IEEE Symposium on Information Visualization (InfoVis 2005)*, October 23-25, Minneapolis, Minnesota, USA.
- Henry, N., & Fekete, J. (2006). MatrixExplorer: a Dual-Representation System to Explore Social Networks. *IEEE Transactions on Visual Computer Graphics* 12(5), 677-684.
- McFarland, D. A., & Bender-deMoll, S. (2004). Classroom Structuration: A Study of Network Stabilization. Paper presented at the *Annual Meeting of the American Sociological Association*, San Francisco, CA. Retrieved November 11, 2008, from http://www.allacademic.com/meta/p110224_index.html
- Moody, J., McFarland D., & Bender-deMoll, S. (2004). *Dynamic Network Visualization: Methods for Meaning with Longitudinal Network Movies*. Retrieved November 11, 2008, from http://www.sociology.ohiostate.edu/jwm/NetMovies/Sub_CD/dynamic_nets_public.html
- Moreno, J.L. (1932). *Application of the Group Method to Classification*. New York: National Committee on Prisons and Prison Labor.
- Moreno, J.L. (1934). *Who Shall Survive?* Washington, DC: Nervous and Mental Disease Publishing Company.
- Nardi, B., Whittaker, S., Isaacs, E., Creech, M., Johnson, J., & Hainsworth, J. (2002). ContactMap: Integrating Communication and Information Through Visualizing Personal Social Networks. *Communications of the ACM*, 45(4), 89-95.
- Richards, W.D., & Seary, A.J. (2003). *MultiNet. Version 4.38 for Windows*. Burnaby: Simon Fraser University.
- Slimani, T., Ben Yaghlane, B., & Mellouli, K. (2006). A New Similarity Measure based on Edge Counting. *World Academy of Science, Engineering and Technology*, 17, 232-236.
- Thomas, H., Brecht, R. B., Bode, S., & Spekowius, K. (2007). TMchartis- A Tool Set for Designing Multiple Problem-Oriented Visualizations for Topic Maps. In L. Maicher, & L.M. Marshol (Eds.), *Scaling topic maps* (pp. 36-40). Leipzig, Germany: Springer.

Viégas, F. B., & Donath, J. (2004). Social Network Visualization: Can We Go Beyond the Graph? *ACM CSCW Conference*, November 6-10, Chicago, Illinois, USA.

Applying a Cognitive Engineering Approach to Interface Design of Energy Management Systems

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ABSTRACT

This article presents a case study of the user interface design of a grid (energy) management system. The theoretical backdrop of the case study is cognitive engineering, with its focus on supporting three levels of cognitive control, namely skill-, rules-, and knowledge-based control, respectively. In this design case study, the interface of the grid management system is divided into three hierarchical levels, each corresponding to a type of cognitive control. Details of the prototype system (the Compact System State Display) are introduced, as a reference to readers familiar with the particular challenges of designing energy management systems. The article also discusses the basic assumptions regarding human cognition and behaviour that engineers and designers might utilize in the design process, including the pros and cons of these assumptions.

Keywords: *Ecological psychology, abstraction hierarchy, cognitive work analysis, energy management systems*

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1. Introduction

During the past decades, a lot of effort has gone into improving the human-machine system interface of nuclear reactor control rooms. In the same period, almost nothing has been done in order to systematically improve the human-machine system interface of grid control. Even though effort has been put into improving single aspects and subsystems (e.g. Mitsui & Christie, 1997; Mahadev & Christie, 1994; Sprenger, Stelzner, Schäfer, Verstege, & Schellstede, 1996; Kobayashi et al., 1996; Bacher, 1995), there has been no overall theoretical framework present to guide the design

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process. In this paper we wish to introduce a cognitive engineering, or more precisely, an ecological approach to the design of energy management systems (EMS). In order to demonstrate how a unified EMS – system might look like if one take the theoretical position presented in this paper as the starting point, we introduce a compact system state display (CSSD). The article presents the CSSD system as a case study. This means that focus lies on presenting aspects of ecological interface design that might be useful for practitioners. At this point, we have not carried out research to empirically establish the extent to which this type of interface outperforms traditional interfaces. Also, the case study focuses primarily on the interface design as such, not on the social impacts for everyday work. For a discussion of social work implications of novel EMS interfaces, see Hoff (2004).

1.1 Mental models or ecological information?

It is common among developers of EMS – systems to state that the interface of the system should be compatible with the operator's mental model of that system. As traditional human factors and human-computer interaction are built on the reminiscence of the information processing approach, this comes as no surprise.

However, one can never be sure that the operators' mental model of the system is correct, in particular when the system in question is complex. Mental models are dynamic, and will change if the external events are not compatible with the current mental model. Hence, mental models can be incomplete or even plain wrong. Additionally, there is often no one correct mental model of a system – several mental models might be just as correct. To develop a true mental model of a Joint Cognitive System (JCS) will be far beyond the capabilities of the operator. This does not mean that we should not include user models in user interface design. Indeed, one need to model both the system as such, as well as the operator as an extended model of the system. For a detailed discussion of this, see Øvergård, Bjørkli and Hoff (submitted). But one need to differentiate between system and operator models, and the latter should not be used as the primary means of design. Vicente (1999) gives a detailed discussion of this fact, and states that "if workers are generally not aware of the deficiencies in their mental models, and if designers use these models as the basis for the interface design, then these deficiencies are almost sure to be transferred to the resulting interface" (p. 55).

During the past decade, the ecological approach has presented an alternative theoretical framework. The main difference between a cognitive and an ecological

approach is that the cognitive, or information processing approach, states that cognitive phenomena such as perception, language, memory etc. are the result of information processing of discrete symbols (Fodor, 1983; Gardner, 1985). These symbols imply a representation of the real world in the head, whereas the ecological approach states that meaning can be perceived directly, without the need for such representations (Gibson, 1979; Michaels & Carello, 1981).

Cognitive constraints (memory limitations, speed of processing, attention, mental models etc.) and ecological constraints (the physical, social or cultural factors that shape human behaviour) contribute together and constitute the total action space. What is important is which of these should be given primacy to. Simon's (Vicente, 1995) parable about an ant on the beach gives a clue: "Viewed as a geometric figure, the ant's path is irregular, complex, hard to describe. But its complexity is really a complexity in the surface of the beach, not a complexity in the ant" (p.55). To understand and model human behaviour, we need to model the "beach", that is, all the factors that human behaviour is determined by, such as physical and social constraints. If one starts in the other end, one might erroneously conclude that the complexity of behaviour is something that belongs to the actor and not to the factors that shape such behaviour. Given this insight, work analysis has to start with the environmental constraints, not the cognitive ones.

Environmental constraints inherent in the system are descriptions of the existing possibilities for action, and are more a description of what actions that can be ruled out, rather than a prediction about behaviour per se. In process industry, there are always physical constraints that need to be respected in order to control the system. For EMS-systems such constraints might be e.g. minimum and maximum voltage level, frequency level, the amount of time deviation, outages in the grid, generator statics etc. Behaviour is also constrained at higher levels, e.g. the purpose for which the system was built or law regulations.

Rasmussen, Pejtersen, and Goodstein (1994) introduced the abstraction hierarchy as a means of representing the relevant ecological constraints in a psychologically significant manner for complex systems. The abstraction hierarchy differs from other types of hierarchies in that it is explicitly related to goals, because there is a means-end relation between the levels. Although the different levels describe the same system, every level has its unique set of terms, concepts and principles (Vicente & Rasmussen, 1992). The fact that inherent constraints are represented in a means-end relationship, knowledge of the system functioning will increase, because it is possible to move

between the different levels. By moving up the hierarchy, the representations give a deeper understanding with respect to the overall system goals, whereas moving down the hierarchy the information becomes more detailed, and says something about how these goals can be achieved.

1.2 Control mode and the SRK-taxonomy

Rasmussen (1983) identified three levels of cognitive performance; the skill, rules and knowledge taxonomy. Knowledge-based behaviours are slow, serial, bottom-up activities, in which progress is made through processing performed at a structural level, i.e. on the basis of input of symbolic information, based on the operator's mental model of the system. Skill- and rule-based behaviour on the other hand, is based on "perceptual processing", which refers to the fast, parallel and effortless thinking of normal activity. These heuristics are twofold: rule based behaviour represents if-then associations between perceptual cues in the environment and the procedures triggered by this cue, whereas skill-based behaviours "represents sensory-motor performance during acts or activities which, following a statement of an intention, takes place without conscious control as smooth, automated, and highly integrated patterns of behaviour" (p.258).

It is critical to note that complex and dynamic systems elicit all types of behaviours (i.e. skill-, rules- and knowledge based behaviour), depending on e.g. the time available for performing the operation, the available information at a certain time, and the amount of mental workload involved. Such factors are tightly coupled to the degree of control the operator experiences at a given time. Hollnagel and Woods (2005) have developed a contextual control model to describe how control constrains cognition, and suggests four different control modes: A scrambled control mode is characterized by zero control over the situation. Due to panic, actions are taken at random, and there is no rational reasoning or reflection involved. An opportunistic control mode is characterized by being determined by the salient features of the current context. There is little or no planning, because the context is not fully understood, or because the situation is chaotic. According to Hollnagel and Woods, the opportunistic control mode is a heuristic one that is applied when the constructs (knowledge) are inadequate, due to inexperience, lack of knowledge, or an unusual state of the environment. Hollnagel and Woods go on to state, rather worryingly, that many cases of controlled air carrier landings are carried out in this control mode. The tactical control mode is typical for cases in which the operator follows a known procedure or rule, but there is still little

planning or reasoning involved. However, the operator's time horizon goes beyond what is currently critical. The strategic control mode corresponds to situations in which the operator has full control over the situation and is capable to make decisions based on higher-level goals, rather than salient features of the moment. The strategic control mode is of course the optimal mode for the operator, but this state of awareness is rare for operators of joint cognitive systems.

External disturbances affect the operator's experience of control and influence what control mode the operator operates within at a given time. The operator exhibits qualitatively different cognitive heuristics in different control modes, and the system should ideally accommodate these variations by supporting different cognitive heuristics, and not only the strategic control mode (which tend to be the case in most complex systems). It is of critical importance to design the decision support system in a way that makes it possible for the operator to deal with unanticipated events in a scrambled control mode.

1.3 Direct perception: Invariants in the optic flow field

Traditional EMS – systems gives the impression of supporting lower-level knowledge-based behaviour, because of the amount of detail in the information presented. However, in order to use this information efficiently, the operator needs to have a clear idea of the general system state. What is often the case is that when something suddenly goes wrong (as in the case of an outage) the operator is overwhelmed by alarms indicating that individual variables have reached set-point values. Even though this problem might be somewhat reduced by thorough advance off-line predictions of revisions and bottlenecks within the grid, there is a crying need for higher-level information that supports the operator in making predictions of grid behaviour, and subsequently supporting the operator in making better use of lower level information.

In searching for theoretical support for the construction of higher levels of information representation, it seems viable to attend to Marr's (1982) computational level (what there is to be processed), rather than to the algorithmic level, which is the main target of analysis in cognitive psychology. The reason for this is that we need an account of the type of information that operators actually use. In the words of Neisser, "if we do not have a good account of the information that perceivers are actually using, our hypothetical models of their information processing are almost sure to be wrong. If we do have such an account, however, such models may turn out to be almost unnecessary" (Neisser, 1987, pp. 11-24).

A thorough framework for describing the computational level is James Gibson's ecological approach to visual perception. Gibson (1979) states that there is no need for information processing of stimuli on the retina (much to the contrast of Marr, it should be said). In fact, perception is, in this perspective, not about stimulation at all, but rather the pickup of information from the optic flow field. To perceive something, the light has to be structured. The potential information that can be picked up, is invariant, that is, it provides a stable relation between the perceiver and the object. During evolution, humans have developed together with, and have adapted to this kind of invariant information. This approach is different from psychophysics (e.g. Fechner, 1860, 1966), because they chose to adopt Newtonian physics as the source of potential processable information. Gibson introduced ecological physics, which is information of higher order, i.e. invariant information scaled to human proportions and physiological makeup. For empirical findings, see Lee's (1993) Tau – paradigm, Carello and Turveys' inertia tensor – paradigm (Cooper, Carello & Turvey, 2000; Turvey, 1992), and Flach's (1990a) active psychophysics.

In Gibson's terms, we are lowered into a pool of potential information. What is lacking from graphical user interfaces however, are exactly the invariants the real world is full of. The situation is turned upside down; instead of detecting invariants, the designer has to artificially design invariants. This fact is both a problem and an advantage: Before the introduction of digitalized interfaces, analogue (mechanical) displays often conveyed information in adequate terms, whereas digital information removes most of the relevant semantic relations within the system. Consider Woods and Watts' (1997) description of the evolution of control centres. The old hardwired case represents a design that is directly visible in the layout of controls, displays, status panels and annunciators. In the digitalized control room, all you can see are the computer screens, but the actual complexity is hidden; behind what is actually shown, there are thousands of displays that could be called up depending on the context. In the previous designs, navigation involved moving physically around, touching the interface, and moving the head and eyes. The new trend of creating graphical user interfaces that forces the operator to statically navigate by means of menu options, in which all knowledge resides "in the head" of the operator, supports an information processing view of humans. This is because it triggers a knowledge based cognitive mode (Rasmussen, 1983), which is unnecessary as operators tend to favour a skill based cognitive mode. However, the common user interface design described above neglects the insights gained from ecological psychology, which states that a poor interface is one where

ambiguities cannot be resolved by the activity of the observer, where assumptions, computations and inferences are required (Flach, 1995). From an ecological point of view, there is a need in order to design decision support systems for joint cognitive systems like EMS-systems to support online decision making, to show the intrinsic constraints by way of designing invariants which the operator can get attuned to (meaning that there are representations in the interface that the operator can act on, as opposed to information that depends on the operator to perform inferences based on the data. The ecological interface (EID) paradigm by Vicente and Rasmussen (1992) is one way of achieving this.

This general introduction has reflected some of the theoretical issues regarding interface design in complex systems today. We now move towards the more specific problem of how to design a new generation of interfaces for energy management systems. We do not believe that the present interface resolves all of the problems previously discussed. On the contrary, it should be looked at as an early attempt to change the focus of interface design within this domain.

2. EMS Interface Design

According to the introduction, the aim of our research presented in this paper is to extend existing representations by two additional display levels. The aim is to achieve a user interface that supports skill-, rule-, and knowledge-based behaviour. According to the control mode of the operator at any time, he/she can choose to switch between the different levels of interface representations. This will give the operator improved flexibility in problem solving activities, regardless of contextual variation and operator control mode. The three levels of representations will together constitute the CSSD. The well-known single-line diagrams (useful particularly at the knowledge based level in strategic operator control mode) are used at the bottom level of the CSSD.

2.1 The hierarchical approach

The top display level visualizes the global power system state and, therefore, includes a great amount of data. Hence, there is a low degree of information detail and a high data compression rate in this level. The main purpose of the top display level lies in the fact that it shows the operator whether the system is in a desired operating state or not. It shows the global system state and enables the operator to discern the global system

state at a glance (what Woods and Watts (1997) has termed "the longshot"). Fig. 1 and 2 illustrates the hierarchical approach presented here.

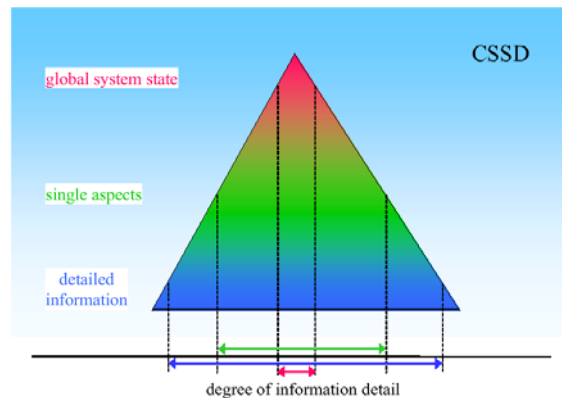


Figure 1. The hierarchical approach

Additionally it gives the operator – in case of a non-desired operating state – an idea about the amount of deviation from the desired operating state. It also gives the operator an indication of which aspects of the system state a deviation is found. This gives the operator a sense of direction, i.e. where to look next for further information. For this purpose the system state is subdivided into nine aspects. These are the bus voltage situation (BV), line flows (LF), results of contingency analysis (CA) and short circuit calculation (SC), interchange transactions (IT), optimal power flow (OPF), quality of load forecast (FOR), and state estimation (SE), as well as the state of interchange lines (IL). In general, these aspects show whether a desired state within an aspect is kept or not. For some aspects the desired state is defined through single desired values such as bus voltages that should be kept as a result of the OPF. For other aspects the desired state represents a situation with no off-limit conditions like line loadings smaller than a warning or overload level. All data related to these nine aspects are accessible at all three levels of information presentation. The idea, however, is to provide a 'longshot' display, where higher-order information is presented in a unified display. Detailed information about the aspects and their indices will be given in the paragraph regarding the numerical data compression.

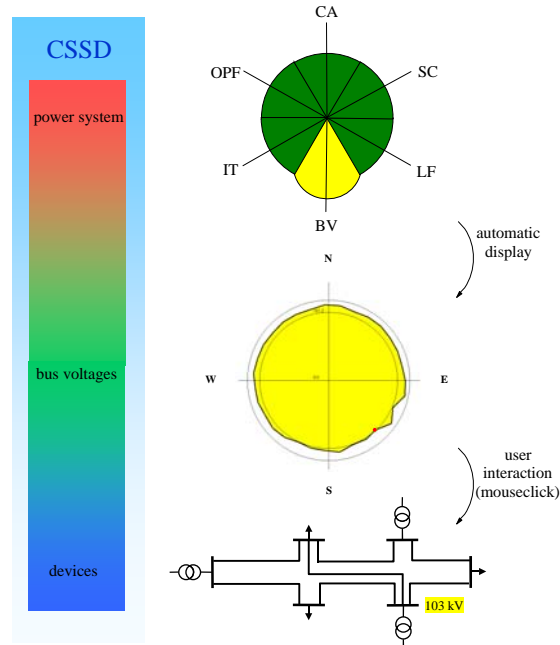


Figure 2. Hierarchical visualization system

An integral (highly compressed) display is used for the top level of the hierarchy in order to show all indices simultaneously. This is intended as an artificially designed invariant, which the operator will get attuned to during interaction with the system over prolonged periods of time. In the same manner, as in a natural environment, these invariants also give the operator a sense of direction in the evolving perceptual experience. The integral displays at the top level will be discussed together with graphical data compression methods.

The displays of the middle level are mainly used in case of a deviation from the desired system operating state. If the deviation is greater than a given value, the corresponding displays of the middle level will appear automatically. The operator can also request these displays manually. The main purpose of the displays in the middle level is to show the operator the essential and high-level information about relevant aspects of the system state mentioned above. This can also be achieved by using integral displays, which allow a certain kind of graphical data compression. Each display of the middle level visualizes one aspect of the power system state. Hence, there is a smaller amount of data included in the middle than in the top display level, and the degree of information detail is higher.

The operator uses the displays at the bottom level if he wants to consult detailed data regarding particular devices of the power system. The well-known and already used

single-line diagram is an example of the displays in the bottom level, where the highest degree of information detail within the CSSD can be found.

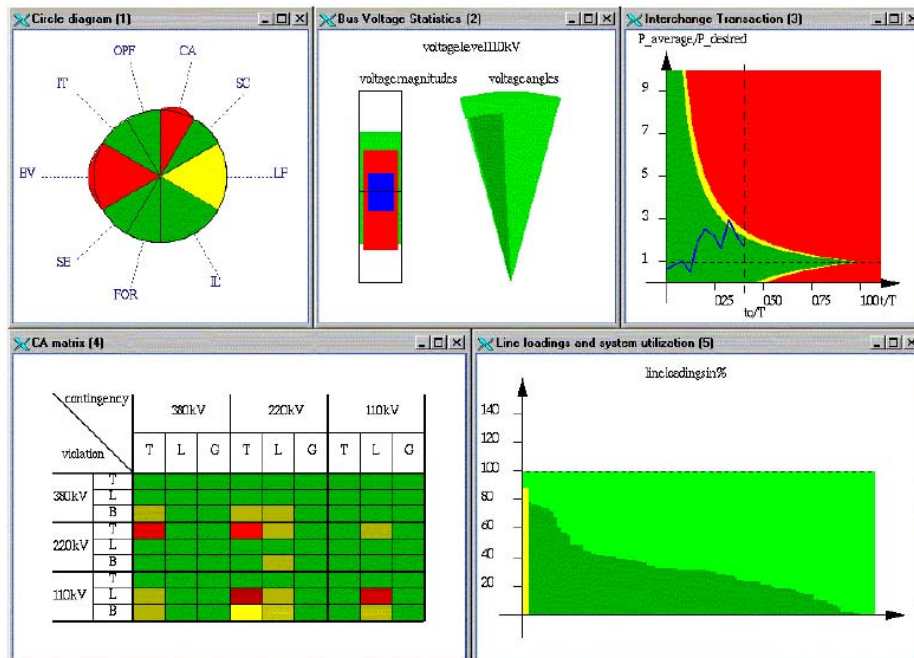


Figure 3. Examples from the hierarchical visualization system

Fig. 3 shows an example of the visualization system to get an idea of the applied approach. The global system state is visualized through a circle diagram in the top left hand side of fig. 3. The red circle segment for the BV aspect indicates some off-limit conditions which can be seen in the bus voltage statistics diagram of the 110 kV voltage level next to the circle diagram (top line, middle visualization). In the same way, off-limit conditions within the results of the CA are visualized through a smaller red circle segment and a matrix diagram. A warning condition within the LF aspect is indicated by a yellow circle segment and a yellow bar in the line loadings and system utilization diagram. Furthermore, this example shows a diagram for the state of a single interchange transaction. Some of the displays in fig. 3 are explained in detail below.

2.2 Numerical Data Compression

Numerical data compression methods are used in the top level of the CSSD to calculate the indices of the nine aspects of the system state. The crucial information at this abstraction level is the degree to which there are off-limit conditions. Additionally, the information should reflect how close the operating values are to their limits. The calculated indices must include all this information and must increase in an analogue fashion with advancing dangerousness of system deviations.

All indices of the CSSD can be interpreted in a similar way. An index of 1.0 stands for a desired state within the aspect of the system state, i.e. there are neither off-limit nor warning conditions and/or deviations from the desired values. The value of the index increases from 1.0 up to a given parameter value K_g if there are warning conditions, such as bus voltages near but within the limits or line loadings greater than a warning load level and/or deviations, e.g. between the past values of the load forecast and the actual load. If there is at least one off-limit condition and/or deviations greater than an acceptable amount, the index is equal or greater than K_g , and increases with more off-limit conditions and/or deviations.

The index OPF indicates whether or not the results of the OPF module of the EMS are kept. For this purpose the current operating state has to be compared with the one calculated by the OPF. The relevant information for the index OPF depends on the criteria used by the OPF module. E.g., active power losses for the current and optimal power flow as well as the cost of generation for both operating states are needed, if their minimization is used as OPF criterion.

$$OPF = 1 + (OPF_g - 1) \cdot \left[\frac{\sum_{i=1}^{n_K} w_i \cdot \frac{|K_{cur,i} - K_{opt,i}|}{K_{opt,i} \cdot A_i}}{\sum_{i=1}^{n_K} w_i} + \operatorname{sgn} \left(\sum_{i=1}^{n_K} B_i \right) \right] \quad (1)$$

with:

$$B_i = \begin{cases} 0 & ; \quad |K_{cur,i} - K_{opt,i}| < K_{opt,i} \cdot A_i \\ 1 & ; \quad \text{else} \end{cases} \quad (2)$$

OPF_g : index value if every criterion i has reached its acceptable normalised deviation

A_i

n_K : number of criteria used for OPF

w_i : weight factor for each criterion

$K_{cur,i}$: current objective function value of criterion i

$K_{opt,i}$: optimal objective function value of criterion i

A_i : acceptable normalized deviation for criterion i

Thus, the index OPF is calculated according to (1) the normalized deviations of the current and the optimal objective function value of each criterion used for the OPF. The remaining indices are calculated in a similar way. For LF, the line loadings are taken

into account if their values are greater than a given e.g. 80% threshold-parameter x_{thres} . Line loadings in the range of x_{thres} and an f. ex. 100% overload-parameter x_{over} are interpreted as warnings for those greater than x_{over} as overloads (Hauser & Verstege, 1999). The index BV is calculated out of normalized bus voltages using a desired value $U_{\text{des},i}$, upper $U_{\text{up},i}$, and lower off-limit value $U_{\text{low},i}$ for each bus i . Therefore, deviations from $U_{\text{des},i}$ and violations of the permissible voltage range are included in this index (Hauser & Verstege, 1999). For the indices CA and SC, the number of off-limit conditions within the results of the security analysis is taken into account. A number of off-limit conditions less than a given acceptable number is interpreted as a warning and a greater number as an alert. The index FOR is calculated out of the normalized deviations of the past values of the load forecast and the actual load and, therefore, represents the quality of the load forecast. In a similar way, the results of the state estimation are used to calculate the index SE to indicate e.g. bad data. For the index IL, the free capacity of the interchange lines are taken into account, which have to be greater than a minimum value to ensure that there will be no overloaded interchange line in the case of a power plant outage. The index IT for the state of interchange transactions is calculated out of two normalized deviations for each transaction. The first deviation is built out of the running average power and its desired value which is given through the energy and time period of the contract. The second one is calculated out of the current power and its maximum and minimum limits. Therefore, the index IT describes the fulfilment of the interchange transactions regarding energy and power conditions of the contracts.

2.3 Graphical Data Compression

Graphical data compression methods are used in the top display level, as well as in the middle display level of the CSSD. Integral displays - a special kind of analogue visualization - are applied for this purpose. By "analogue information" we refer to the non-inferential nature of mechanical devices (for example the arms of a wrist watch) due to perceptual invariants as opposed to the inferential nature of numerical information (for example a digital/numeric wrist watch). Note also that such information is more than a differentiation in the level of detail; it is also possible to represent relations at a different level of description that cannot be reduced to an atomistic level of representation.

High-level information is defined here as the relationship of single values either with each other or with a desired value. They serve mainly as a basis for showing the

operator the next step regarding system operation. Examples of high-level information are "heavy power flows from west to east of the supply system", "balanced voltage profile", and "power system in a desired state".

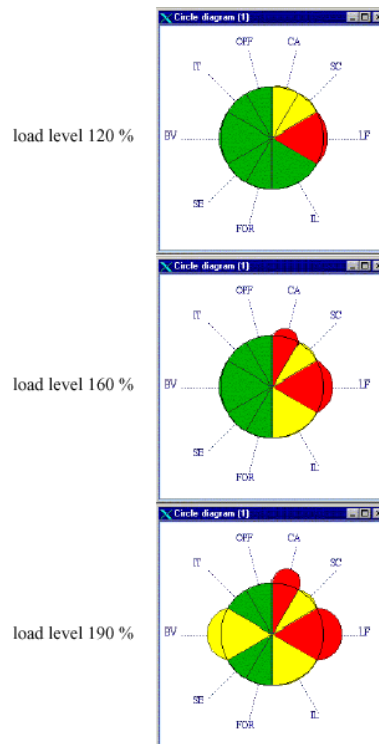


Figure 4. Circle diagram for global system state

One example of an integral display in the top display level of the CSSD is the circle diagram, which is shown for three different load levels in fig. 4. In this circle diagram, geometric shapes are used to represent operating states within several aspects of the system state. A segment of the circle and an axis for the corresponding index is used for each aspect. The colour of a segment shows the operator whether there are neither warnings nor alerts (green), at least one warning but no alert (yellow), or at least one alert and maybe warnings (red) in an aspect of the system state.

The distortion (deformation) of each segment of the circle is proportional to the corresponding index value. Therefore, it is a qualitative indicator of the deviation in the aspects of the system state. The aspects BV, LP, and IL are represented with bigger segments of the circle due to their higher importance for the operator (fig. 4). Thus, the influence of these three aspects, on the impression of the whole diagram regarding the global system state, is higher than any one of the other aspects. If all indices have their desired values of 1.0, the diagram will show a green coloured circle. Otherwise, a

diagram with distorted and yellow, and/or red coloured segments appears in order to indicate deviations from desired values. The distortion and the portions of green, yellow, and red of the whole diagram represents the deviation of the global system state from the desired system state. The circle diagram represents, in a straightforward way, what we mean by "invariant information", and "analogue visualization". Once the operator has established an association between the represented (the nine subdivisions) and its representation (the circle diagram), he/she is able to directly infer the system status by reference to the geometric symmetry of the figure. Integral displays are also used in the middle display level, and some of the most important displays are presented next.

2.4 Mid-level displays, geographical information

The global power system state can be visualized through the circle diagram with indices for nine aspects of the system state, as mentioned above. Therefore, deviations within the power system state can be assigned to the corresponding indices and aspects respectively. But there are no geographical information passed on to the operator that may help him/her to quickly find places of warnings and/or alerts within the grid. For this purpose, the iso-line diagram in fig. 5 as additional display for the global power system state with included geographical information, has been developed. An iso-line diagram is a 2-dimensional representation of a 3-dimensional surface, which contains a given set of vertices (Hauser & Verstege, 1999). The vertices used for the iso-line diagram in fig. 5 are indices that describe the state of devices in the network, such as bus bars and lines at their geographical place. Since lines cannot be described by only one geographical place, the centre of the beginning and the end of a line is used in this diagram. The calculation of the indices is done similar to the one of the indices in the circle diagram, but includes only the data of the corresponding device (Hauser & Verstege, 1999; Hauser, 1999). Places of devices with neither warnings nor alerts are represented by a green colour, those with at least one warning but no alert by yellow colours, and those with at least one alert, and maybe some warnings by red colours, respectively. Therefore, geographical regions with their corresponding system state can be easily discerned.

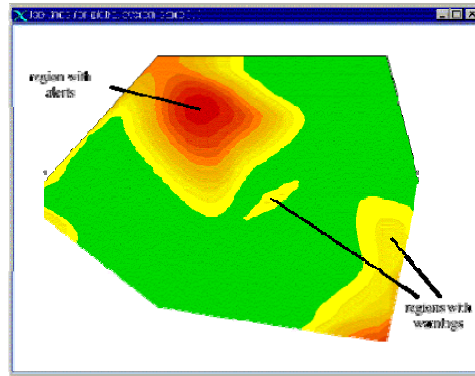


Figure 5. Iso-lines for global system state with geographical information

2.5 Other aspects of the system state

Several integral displays are used in the middle display level of the CSSD to show the essential and high level information about aspects of the system state. These are e.g. the matrix diagram for the results of the contingency analysis and the bar diagram for line loadings and system utilization, which are shown in fig. 3 and explained in Hauser and Verstege (1999), Hauser (1999). A similar bar diagram for free line and system capacities is shown in fig. 6. The bars representing the lines of the network are sorted according to their free line capacities in MVA. The lowest bar in the diagram shows the minimum possible load increase if there are no current overloads. In case of current overloads, they are shown as negative free line capacities, visualized with red bars in the diagram. In this case, a minimum possible load increase cannot be given without taking detailed information into account, e.g. the place of injection and take-over of a transit and the resulting load flow situation. The structure of the whole diagram and the distribution of the bars in the diagram give an idea of free capacity within the power system.

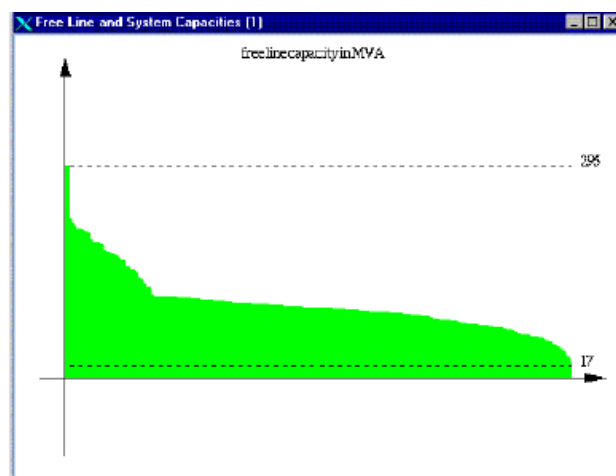


Figure 6. Free line and system capacities

Figure 7 shows an example display with runny colours for visualizing line flows and their changes due to a transit of 100 MW. The width of the runny colour bars represents the amount of active power that flows from the lower towards the upper colour saturation of the bars. The green part of the bars represents the active power flows without the transit, and the turquoise one represents the changes as a result of the transit. The turquoise part will surround the green one if there is an increased active line flow. There is a vice versa situation in case of a decreased active power flow. Furthermore, generation centres are indicated with node's surroundings of low color saturation and load centres with high colour saturation. With this kind of visualization the effect of transits on the line flow situation can be seen easily.

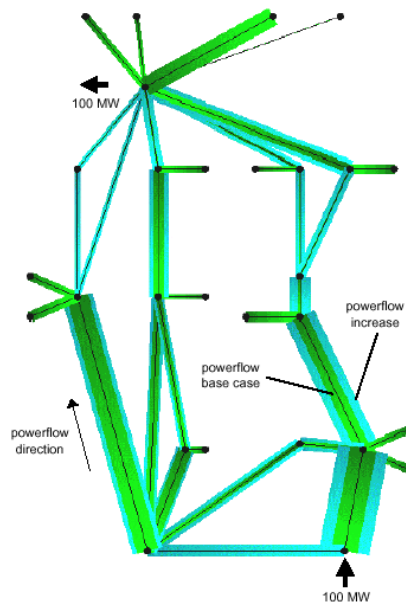


Figure 7. Line flows represented with runny colours

The state of interchange transactions can be visualized through the diagram in fig. 8. The diagram has three coloured areas, green, yellow and red. It shows the running average power from the beginning of the interchange transaction until the current moment. The fulfilment of the transaction at the end of the contract period is only possible if the average power remains in the green or yellow area of the diagram. If it reaches red at least once, the transaction cannot be fulfilled regardless of further energy interchange. The yellow area represents a warning level to indicate a potential violation of the interchange contract.

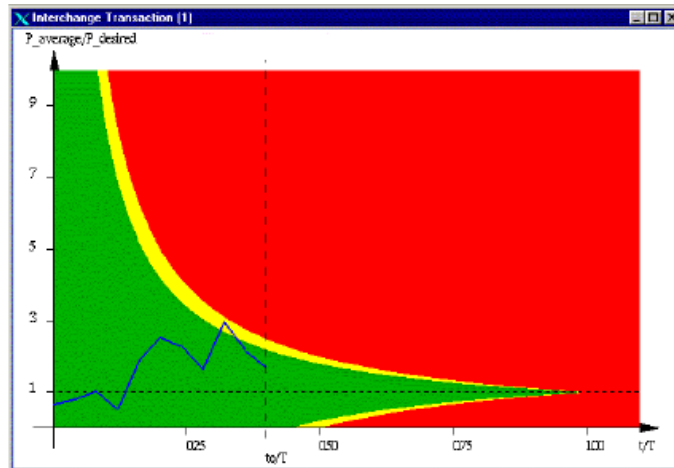


Figure 8. State of interchange transaction

In fig. 9 the bus voltage situation for two voltage levels is shown through two different display types.

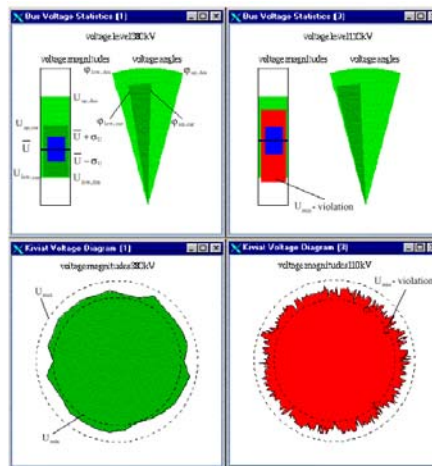


Figure 9. Displays for bus voltage situation

The first display type in the top of fig. 9 visualizes statistical values of the bus voltage magnitudes and angles. The statistical values of the voltage magnitudes are the mean value, standard deviation as well as the current and desired upper and lower bus voltage magnitude. With this kind of display, it is easy to see the balance of the voltage profile as it is indicated through the range of the standard deviation around the mean value. The current voltage range and the closeness to the off-limit values can easily be seen as well. For the bus voltage angles only the current and desired upper and lower

values are shown because they can be used as an indicator for the amount of active line flows and system stability. The Kiviat diagrams in the bottom of fig. 9 show the bus voltage magnitudes, their minimum and maximum limits as well as limit violations. It is easy both to get an idea about the voltage profile and also to discern limit violations with this kind of display.

3. Discussion

The belief that system safety can be improved by post hoc analysis of human error (which accounts for about 80% of all major accidents) and subsequently correcting the one factor that led to that accident rests on the assumption that operators can, and do, follow normative instructions of how to perform work, and that it is possible to predict up front how the operator might behave in certain situations. This is a problem of confusing hindsight with foresight. In retrospect it is always possible to find violations to certain procedures and to conclude that this causally led to the accident. When one looks in the microscope, and study human behaviour in situ, one finds that even for highly constrained tasks, operators tend to adjust their actions in order to adapt to the requirements put forth by the particular context at hand (Hutchins, 1995; Woods, 1996; Vicente & Burns 1996). For joint cognitive systems like the operation of electrical power systems one cannot predict operator behaviour, because a) the initial conditions will vary, b) there is often more than one correct strategy for solving a particular problem (different operators might use different strategies, or one operator might use different strategies at different times), and c) unforeseen disturbances require compensatory action (Vicente, 1999). Control theory has shown in formal mathematical models that operator behaviour cannot be predicted as long as the system has one or several of these characteristics (Flach, 1990a). The implications of these facts are that behaviour actually needs to vary in order to keep the outcome constant.

In chaotic systems (Kelso, 1995; Thelen & Smith, 1995), the one variable that causes a behavioural phase shift (the control parameter), cannot be predicted. What cause a phase shift are the perturbations in the dynamic system, not in the control parameter per se. Given this fact, there is no meaning in improving a system by changing the one cause that led to the accident. On the contrary, the fundamental design issue is, according to Rasmussen (1999), not to fight individual causes of human error but to

create a work environment for operators that make the boundaries to failure visible and reversible.

For joint cognitive systems, one of the main design challenges is to support the operator when rare and unanticipated events occur. It is under these situations that major accidents tend to happen (Perrow, 1984). Because neither operator behaviour nor system variation can be predicted, it becomes difficult to use traditional approaches to system design. Normative approaches, e.g. task analysis (Kirwan & Aintsworth, 1992), tend to focus on "the one best way" of performing work, that is, how the system should behave. These tayloristic approaches suffer from the fact that they cannot accommodate unanticipated events. The moment an event occurs that the system was not designed for, the operator is left unaided. Thus, such systems provide the least information at the one critical point where it is needed the most.

Phenomenological approaches have, much in the same manner as the ecological approach, evolved as a reaction to the notion that human behaviour is characterised by logic reasoning based on information processing of discrete symbols (Newell & Simon, 1972; Churchland, 1996). Characteristic of descriptive approaches is to study cognitive phenomena as they happen in real-life situations. Important contributions have been made in the study of expertise (Dreyfus & Dreyfus, 1986), navigation (Hutchins, 1995), decision making (Klein, Orasano, Calderwood & Zsombok, 1997) and problem solving (Rasmussen, 1974). Although these contributions have had a significant influence in fundamentally changing the perspective of how cognition should be studied, the practical implications of such an approach within human-machine systems research remains somewhat unclear. The field that most explicitly uses a descriptive approach to system design, is Russian activity theory (Nardi, 1996; Bødker, 1990). Nardi (1996; Vicente, 1999) states that activity theory is more of a descriptive tool rather than a strongly predictive theory.

The user-centred design tradition (e.g. scenario-based design, rapid prototyping and usability testing), might also be considered descriptive, as it takes contextual observations of the users as its starting point. Although it is a very appropriate tool for systems of low to medium complexity, they are of limited value when it comes to the design of joint cognitive systems. The reason is that current practice depends on the devices the operators have available to them. That is, there are many currently unexplored possibilities of performing work (for a detailed discussion of this, see Vicente, 1999). Because people adapt their behaviour in order to meet even the slightest change in variation, the introduction of new features based on existing devices

leads to new ways of interacting with the system. Hence, the task-artefact cycle (Carroll, 1991) weakens user-centred design as an omnipotent tool for complex systems.

It follows from this discussion that what the designers need in order to support the operator of EMS-systems is not a prescription of how they should behave in certain situations, or just a description of how the operators actually behave. On the contrary, what is needed is a system that is flexible enough to accommodate variations both in operator behaviour and in the system itself, which is not based on current practice. This can be achieved by identifying the relevant constraints of the system, and to represent these constraints in a way that is compatible with human cognition. This is what Vicente (1999) has termed a formative approach to system design.

We have, with the development of the CSSD – system, not carried out an ideal predictive cognitive work analysis, and it is not clear to us what such an ideal process should look like. The main challenge is, that in practical product development (as opposed to the micro-worlds of science), it is almost impossible to gather a project group that both understands the principles of the ecological approach, as well as understands the basic functioning of the system, at a time when no presumptions of the interface or the operators have been made. Although neat in theory, the ideal prescriptive approach difficult to carry out.

What we have done, however, is to ensure that ecological (body based) information is represented in the interface, and ensured that a hierarchic display of information is readily accessible. Depending on the operator's current overview of the situation (the degree of cognitive control), he/she can access information at several layers, and assist the operator in regaining cognitive control. Additionally, the visual displays represent the constraints (boundaries) of the system, rather than as serial information. Constraint based information empowers the operator, because he/she can act flexible in the face of external disturbances, rather than being a passive agent that carries out stepwise if-then corrections. This is what differentiates predictive from normative approaches.

4. Conclusion

In the development of the CSSD, we have explicitly aimed at exploiting theoretical advances in the field of ecological psychology, particularly with respect to Rasmussen's

Skill-, Rules- and Knowledge-based model. Traditional EMS tend to be based on a low level conception of human cognitive functioning; that is, the conception that humans process information from the bottom up, on the basis of the basic structural elements of the thought process. Traditional displays, such as the single-line diagrams, taps a task humans are not very good at – namely to perform pure mental inferences, in this context in order to derive a conclusion about the total system state. Being extremely mentally laborious, this task leaves no mental space for the task human operators are very good at; namely to solve problems at hand by creative adaptation based on years of experience with similar cases (so called context conditioned variability).

It can be argued, from an ecological point of view, that what is lacking in traditional displays are the invariants which we are perceptually attuned to during hundred thousands of years of co evolution between the organism and the environment that surrounds it. In Gibson's (1979) terms, we do not perceive the world by mentally reconstructing it. Rather, we are able to directly pick up information, because the information is already structured in invariant ways. For visual perception, the invariant arise because the light travels in fixed angles. For instance, when you move your head to the right, the perceptual world moves in the opposite direction. All perceptual experiences are perceived as being continuous; there are no pauses or leaps in the stream of information. This is not because the brain is a fast processor, reconstructing retinal snapshots in a rapid fashion, making it look as though the information is continuous. Rather it is continuous because our senses are tuned by way of evolution to pick up certain kinds of invariant information in the optical (or perceptual) flow field.

In the process of developing the CSSD we have pursued the task of creating such invariants, because no invariants can exist in a virtual medium without having graphically recreated them (mimicking the invariants of the real world). There is, according to Woods (1997), "...nothing inherent in the computer medium that constrains the relationship between things represented and their representations".

We have constrained the relationship between the represented and its representation by adding two more levels of abstraction to the traditional displays. They both contain information that cannot be directly perceived from low level displays. All the displays at the two top levels carry invariant information, as the graphical displays vary their shape and colour in an invariant relation to what happens "out there" in the world of power flow patterns and their changes, transits, interchange transactions and their fulfilment, loads and generations, system utilization, and results of the security analysis describing the global system state.

In this sense, we have attempted to support the online problem solving activity of the operator by moving the quality of the interaction on a indirectness to directness continuum, e.g. from effortful serial processing of discrete variables to ecological pick-up of direct information conveyed by the graphical interface. In Rasmussen's (1983) terms, we have moved from tapping knowledge-based knowledge to tapping skill-based knowledge.

To represent as many relevant constraints as possible, and to represent these in a way that support skill-, rules-, and knowledge behaviour, is the only way we see it possible to support the operator when rare and unanticipated events occur. Because these events cannot be predicted, one can do nothing but to represent the information available in a sensible manner. For the rest of the job, one has to rely on the expertise of the operator.

5. References

- Bacher, R. (1995). Graphical Interaction and Visualization for the Analysis and Interpretation of Contingency Analysis Result. In *Proceedings of the 1995 Power Industry Computer Applications* (pp. 128-134). Salt Lake City, USA: IEEE Power Engineering Society.
- Bødker, S. (1990). *Through the Interface – A Human Activity Approach to User Interface Design*. Hillsdale, NJ: LEA.
- Carrol, J.M., Cellogg, W.A., & Rosson, M.B. (1991). The task-artifact cycle. In J.M. Carrol (Ed.), *Designing interaction: Psychology at the Human-Computer Interface*. Cambridge, MA: Cambridge University Press.
- Churchland, P.M. (1996). *The Engine of Reason, the Seat of the Soul. A Philosophical Journey into the Brain*. Cambridge, MA: MIT press.
- Cooper, M.M., Carello, C., & Turvey, M. (2000). Perceptual independence of whole length, partial length, and hand position in wielding a rod. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 74-85.
- Dreyfus, H.L., & Dreyfus, S.E. (1986). *Mind Over Machine. The Power of Human Intuition and Expertise in the Era of the Computer*. New York: The Free Press.
- Fechner, G.T. (1966). *Elements of Psychophysics*. New York: Holt, Rinehart & Winston.

- Flach, J.M. (1990A). Control with an eye for perception: Precursors to an active psychophysics. *Ecological Psychology*, 2, 83-111.
- Flach, J.M. (1995b). The Ecology of Human-Machine Systems: A Personal History. In J.M. Flach, P.A. Hancock, J. Caird, & K. Vicente (Eds.), *Global Perspectives on the Ecology of Human-Machine Systems*. Hillsdale, NJ: LEA.
- Fodor, J.A. (1983). *The Modularity of Mind*. Cambridge, MA: MIT Press.
- Gardner, H. (1985). *The Minds New Science: A History of the Cognitive Revolution*. New York: Basic Books.
- Gibson, J.J. (1979). *The Ecological Approach to Visual Perception*. Hillsdale, NJ: LEA.
- Hauser, A.J. (1999). Visualization of Global Power System States in a Compact and Task Oriented Way. In *Proceedings of the 13th Power Systems Computation Conference* (pp. 413-419). Trondheim, Norway: IEEE Power & Energy Society.
- Hauser, A.J., & Verstege, J.F. (1999, June). Compact and Task Oriented Visualization Techniques Displaying Global Power System Operating States. Presentation at *1999 CIGRE Symposium Working Plant and Systems Harder*, London, United Kingdom.
- Hoff, T. (2004). Comments on the Ecology of Representations in Computerised Systems. *Theoretical Issues in Ergonomics Science*, 5(5), 453-472.
- Hollnagel, E., & Woods, D.D. (1995). *Joint Cognitive Systems: Foundations of Cognitive Systems Engineering*. Boca Raton, FL: CRC Press.
- Hutchins, E. (1995). *Cognition in the Wild*. Cambridge, MA: MIT press.
- Kelso, J.A.S. (1995). *Dynamic Patterns*. Cambridge, MA: MIT press.
- Kirwan, B., & Ainsworth, L.K. (1992). *A Guide to Task Analysis*. London: Taylor and Francis.
- Klein, G.A., Orasano, J., Calderwood, R., & Zsombok, E. (1993). *Decision Making in Action: Models and Methods*. Ablex, Norwood, NJ: Ablex.
- Kobayashi, N., Yamada, T., Okamoto, H., Tada, Y., Kurita, A., & Sekine, Y. (1996, August). P-6 Map, Q-6-V Map and Short Circuit Current Map. Presented at the *12th Power Systems Computation Conference*, Dresden, Germany.
- Lee, D.N., Davies, M., Green, P., & Van der Weel, R. (1993). Visual control of velocity of approach by pigeons when landing. *Journal of Experimental Biology*, 180, 85-104.
- Mahadev, P.M., & Christie, R.D. (1994). Envisioning Power System Data: Vulnerability And Severity Representation for Static Security Assessment. *IEEE Transactions on Power Systems*, 9(4), 1915-1920.

- Marr, D. (1982). *Vision. A computational investigation into the human representation and processing of visual information*. San Francisco: W.H. Freeman & Co.
- Michaels, C.F., & Carello, C. (1981). *Direct Perception*. Englewood Cliff, NJ: Prentice Hall.
- Mitsui, H., & Christie, R.D. (1997). Visualizing Voltage Profiles for Large Scale Power Systems. *IEEE Computer Applications in Power*, 10(3), 32-37.
- Nardi, B.A. (1996). *Context and Consciousness. Activity Theory and Human-Computer Interaction*. London: MIT Press.
- Neisser, U. (1987). *From direct perception to conceptual structure. Concepts and conceptual development: Ecological and intellectual factors in organization*. Cambridge, MA: Cambridge University Press.
- Newell, A., & Simon, H.A. (1972). *Human Problem Solving*. Englewood Cliffs, NJ: Prentice Hall.
- Perrow, C. (1984). *Normal Accidents. Living with high-risk technologies*. Princeton, NJ: Princeton University Press.
- Rasmussen, J. (1983). Skills, rules and knowledge; signals, signs, and symbols, and Other distinctions in human performance. *IEEE Transactions on Systems, Man, and Cybernetics*, 13, 257-266.
- Rasmussen, J. (1999). Ecological interface design for reliable human-machine systems. *International Journal of Aviation Psychology*, 9, 203-223.
- Rasmussen, J., Pejtersen, A.M., & Goodstein, L.P. (1994). *Cognitive Systems Engineering*. New York: Wiley.
- Rasmussen, J., & Jensen, A. (1974). *A study of mental procedures in electronic trouble shooting*. Roskilde: Danish Atomic Energy Commission.
- Sprenger, W., Stelzner, P., Schäfer, K.F., Verstege, J.F., & Schellstede, G. (1996). Compact and Operation Oriented Visualization of Complex System States. In *Proceedings of the 36th CIGRE Session*, 39, 107.
- Thelen, E., & Smith, L.B. (1995). *A Dynamic Systems Approach to the Development of Cognition and Action*. Cambridge: MA: MIT Press.
- Turvey, M. T. (1992). Affordances and prospective control: An outline of the ontology. *Ecological Psychology*, 4(3), 173-187.
- Vicente, K.J. (1999). *Cognitive Work Analysis – Toward Safe, Productive, and Healthy Computer-Based Work*. Mahwah, NJ: LEA.
- Vicente, K.J., & Burns, C.M. (1996). Evidence for Direct Perception from Cognition in the Wild. *Ecological Psychology*, 8(3), 269-280.

- Vicente, K.J. (1995). A Few Implications of an Ecological Approach to Human Factors. In J.M. Flach, P.A. Hancock, J. Caird, & K. Vicente (Eds.), *Global Perspectives on the Ecology of Human-Machine Systems*. Hillsdale, NJ: LEA.
- Vicente, K.J., & Rasmussen, J. (1992). Ecological interface design: Theoretical foundations. *IEEE Transactions on Systems, Man, and Cybernetics*, 22, 589-606.
- Woods, D.D. (1996). Decomposing Automation: Apparent Simplicity, Real Complexity. In R. Parasuraman, & M. Mouloua (Eds.), *Automation technology and human performance*. Hillsdale, NJ: LEA.
- Woods, D.D., & Watts, J.C. (1997). How Not to Have to Navigate Through Too Many Displays. In M.G. Helander, T.K. Landauer, & P. Prabhu, (Eds.), *Handbook of Human-Computer Interaction*, 2nd edition. Amsterdam: Elsevier Science.
- Øvergård, K.I., Bjørkli, C.A., & Hoff, T. (submitted). Models and Control Strategies Used by Experienced Marine Navigators. *Cognition, Technology and Work*.