Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 100 (2013) 127 – 143

Procedia
Social and Behavioral Sciences

8th Conference on Applications of Social Network Analysis – ASNA 2011

On visualizing knowledge flows at a university department

Florian Windhager[a], Michael Smuc[a], Lukas Zenk[a], Paolo Federico[b], Jürgen Pfeffer[c], Wolfgang Aigner[b1]

[a]*Department for Knowledge and Communication Management, Danube University Krems, Krems A-3500, Austria*
[b]*Institute of Software Technology and Interactive Systems, Technical University Vienna, Vienna A-1040, Austria*
[c]*CASOS Center, Institute for Software Research, Carnegie Mellon University, Wean Hall 4103, USA*

Abstract

The analysis of dynamic network data has become an increasingly relevant research issue, showing a high potential for applied use in organizations. To unlock its potential also for the target user group of non-domain experts, we introduce a software prototype, which provides different views on network dynamics, intertwining network analytical measures with options of visual exploration. To demonstrate, how this approach can provide new access to questions of knowledge management and accessibility, a case study of a university department will be discussed. By combining multi-relational data of communication networks with attribute data of individual knowledge domains, we show how essential knowledge and change management issues can be reframed from a social network perspective and further developed towards integrated applications in organizations.

© 2013 The Authors. Published by Elsevier Ltd.
Selection and/or peer-review under responsibility of Dr. Manuel Fischer

Keywords: social network analysis; network dynamics; visual analytics; knowledge management.

[1] Corresponding author. Tel.: +43-2732-893-2338; fax: +43-2732-893-4335.
E-mail address: florian.windhager@donau-uni.ac.at.

1877-0428 © 2013 The Authors. Published by Elsevier Ltd.
Selection and/or peer-review under responsibility of Dr. Manuel Fischer
doi:10.1016/j.sbspro.2013.10.704

1. Introduction

Division of labor, which is a necessary precondition for organizational performance, means from the management perspective: the challenge to constantly control and coordinate actors with specific skills and specific knowledge. At least, this is how the classical (i.e. the heroic) management perspective is used to tell the story (Handy, 1991). From a cognitive science perspective, knowledge originates from an actor's expectation, addressed to environmental objects, issues, structures or processes (Johnson-Laird, 1980). Interaction with such entities can lead to the development of mental models or representations, which help to manipulate and cope with relevant parts of an actor's environment. Expectations or conjectures which continually prove themselves in practice can attain the state of "knowledge" - in terms of appropriate expectations and representations - but still have to undergo a constant process of collective evaluation and adaption (Harms, 2004).

Due to naturally restricted task and information processing capacities of individual actors, social collectives show a general tendency to differentiate or distribute their various aims on different (groups of) actors –hence developing ever refining subgroups of specialized knowledge and expertise (Boyd & Richerson, 2009). Given the ability to share specific knowledge via inter-actor-communication, social collectives can cultivate high standards of collaborative problem solving by developing highly differentiated trees and bodies of expert knowledge (see Figure 1).

Organizations, as socio-technical units which bundle specialized actors and tools to pursue common organizational aims (e.g. producing microprocessors, providing heart surgery, attacking or granting national security, transporting people, or mediating knowledge), hence have to solve the problem of (re-) integration and coordination of heterogeneous expertise by functions of communication and management (Hatch, 2006).

The classical "heroic" approach to such challenges of high diversity always has been – in a figurative sense – to counteract the tree of evolution by turning it upside down (i.e. transforming it into an organizational chart) and putting a manager on the top. This is the background, against which the network perspective makes those patterns visible, which build the factual infrastructure of collaboration by informally and pragmatically connecting the hierarchical branches of vertical hierarchies wherever need is given (Brass, Galaskiewicz, Greve, & Tsai, 2004). The associated "postheroic" approach to management is thus fostering notions of flat hierarchies and self-organizing networks of coequal actors for a long time (Handy, 1991; Etcher, 1997; Pearce & Barkus, 2004; Balkundi & Kilduff, 2005) (see Figure 2).

While this – in the meanwhile – is commonly accepted and widely practiced, we want to put the focus of the following considerations on challenges which arise from scenarios where such transitions have already taken place or are currently happening. When the structures of informal communication networks are crucial for collaborative performance, then their patterns and dynamics should be accessible also for non-experts in network analysis (Zenk, Windhager, Ettl-Huber & Smuc, 2011). When governing hierarchies or strict rules of communication are reduced, skills and technologies are gaining importance, which help the actors to operate and optimize their connectivity by themselves (Tenkasi & Boland, 1996).

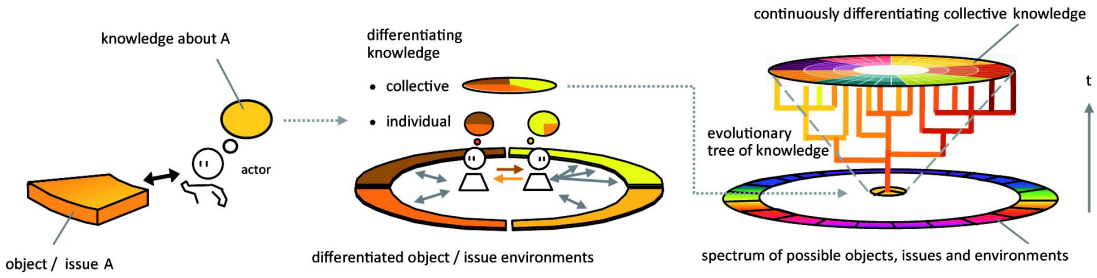

Fig. 1. Acquisition of individual knowledge via actor-object-interaction (left), knowledge differentiation and communication (center), evolutionary perspective on the social differentiation of knowledge (right).

What gains specific relevance in knowledge intensive organizations are means and methods to cope with coordination issues with respect to their highly diversified and distributed intellectual capital – meaning all areas of individual knowledge and skills which are on hand and have to be developed and connected anew to assure innovation and adaptivity to changing environments (Alavi & Leidner, 2001). Such entering the area of knowledge management (KM), we want to focus on the question, how methods of organizational network analysis can be adapted to provide assistance in mastering the dynamic challenges of knowledge intensive communication.

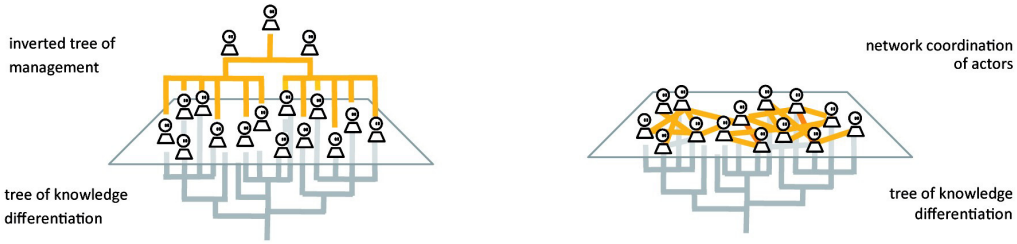

Fig. 2. The hierarchical versus the network approach to deal with differentiated knowledge by organizational structures of communication, collaboration and management.

In this context we want to discuss recent developments of the research project ViENA (Visual Enterprise Network Analytics), which is dedicated to both: unlocking dynamic network analysis for experts and non-expert users in organizations and doing this primarily on a visual level (Windhager, Zenk, & Federico, 2011). In chapter 2 we introduce its conceptual framework and the software prototype which has been developed. In chapter 3 we show results of a case study of knowledge communication at a university department and in chapter 4 we discuss options how to enrich the given framework of network analysis to integrate issues which are often delegated to isolated applications of knowledge management systems until now.

2. The ViENA framework and prototype

Visual Analytics "is the science of analytical reasoning facilitated by interactive visual interfaces" (Thomas & Cook, 2005). This field of study systematically works on intertwining the remarkable human abilities of visual perception and pattern recognition with the advanced capabilities of machine computation to enable users to visually explore and make sense of large and complex data (Keim et al., 2008). As far as network analysis builds on visualizations, it could be reconstructed as part of the visual analytics domain since its early beginnings. Still, the role of visual representations is not undisputed and some research strands – especially towards network dynamics – put most of their efforts on computing stochastic models (Breiger, Carley, & Pattison, 2003; Sniders, Steglich, & van de Bunt, 2010). In contradistinction to these procedures, which presuppose high skills in data handling, formal thinking, and reasoning, the ViENA project is working on options to make dynamic network data accessible from a visual perspective (Windhager et al., 2011).

The strategic aim of this methodical readjustment is twofold: dynamic network experts shall be enabled to use such methods and tools for the purpose of early data exploration and the detection of salient patterns. On the other hand also other users, which may not necessarily be network experts (e.g. employees, managers or consultants) will be provided with the option to visually explore and evaluate (their own) organizational communication dynamics by a lowered threshold of analytical preconditions. As such, the functional architecture of the ViENA project is designed to provide experts and organizational actors the possibility to continuously evaluate (changes of) communication patterns from a network perspective (see Figure 3).

To identify visual analytical features and functionalities, which would provide relevant insights within an organizational context of dynamic network analysis, we conducted a user and task analysis by the means of semi-structured interviews. Based on the answers of 11 persons (SNA experts and business consultants), we assembled a list of general tasks (at the network level) and specific tasks (at node level), all focused on dynamic aspects. A general task would be to understand the structure of an entire network or its subgroups - and their evolution over time. Examples of tasks at the node level are the identification of key players and their increasing or decreasing levels of involvement, as well as the evaluation of transitions between leaving actors and their successors. Most prominently, analyses on general and specific levels should help to do both: support the planning of change management measures and enable the evaluation of their effects based on empirical data.

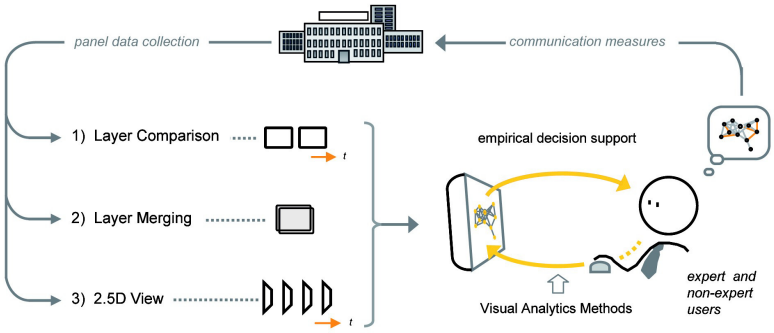

Fig. 3. The ViENA framework and functional architecture within organizational analysis.

The requested feature of displaying structural change over time - including before/after comparisons as basic data set with two time points - could be provided by various methods. A common solution is to map time to time, i.e. choosing animation or morphing for the visualization of structural change (McGrath & Blige, 2004).[1] A second approach is to map time to a spatial dimension by arranging snapshots of network change chronologically side by side, i.e. layer comparison or juxtaposition (Andrews, Wohlfahrt, & Wurzinger, 2009). A third option is to merge temporal layers for seeing shifts of nodes or edges as positional deviations marked by different colors, i.e. layer merging or superimposition (Brandes & Corman, 2003). A fourth option is to stack temporal layers as a pile and view it from various angles – the so called 2.5D view (Dwyer & Gallagher, 2004). Despite the fact, that each of these views on network dynamics shows different kinds of strengths and weaknesses (Windhager et al., 2011) existing SNA software is used to offer only one of them. To put the user into the position of deciding, which one would fit or support her analytical tasks best, we brought three of them together (layer comparison, layer merging and 2.5D) and allow to switch between them at any given point of an analytical procedure (see Figure 4). To preserve an orientation guide for the time oriented exploration, the change between the three views happens via smoothly animated transitions, so that the shifting or maintaining alignment of the timeline could be easily followed.

Regardless of the chosen view on a dynamic network graph, a crucial challenge is the preservation of the mental map (Eades, Lai, & Sugiyama, 1991), i.e. minimizing unnecessary changes to increase comprehension and comparability over time. Conversely, empirical studies pointed out that for certain data and tasks, too much preservation is not needed and might be counterproductive (Purchase, Hoggan, & Görg, 2006). This involves the necessity to find a balance between chronologically shifting layouts and their approximate preservation. Alike the choice of the appropriate view, the fine-tuning of this balance between inter-node layout consistency and inter-time layout stability was consigned to user control (Federico, Aigner, Miksch, Windhager, & Zenk, 2011). Governed by this meta-variable, a continuously running force-directed algorithm (Heer, Card & Landay, 2005) computes the dynamic graph layout for each time slice, operating on a GraphML data input format. Basic visual interaction options like zooming, panning, and rotating allow for the selection of graph overviews or details.

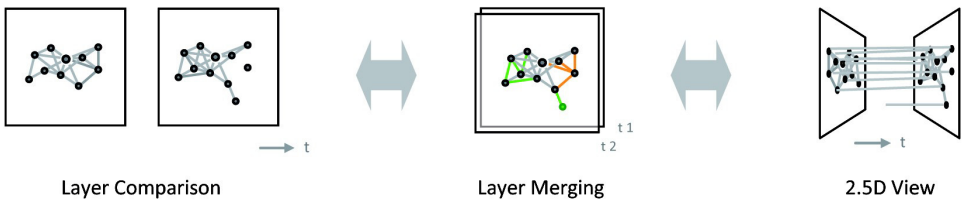

Fig. 4. Dynamic Views offered by the ViENA prototype for dynamic network visualization.

[1] The disadvantage of this method to produce artifacts of intrapolation and to allow for the detailed comparison of network layers only by the means of a viewer's memory, led to the decision to leave it initially aside.

To incorporate the established benefits of static network analysis, common node centered measures and metrics (e.g. degree, betweenness, closeness, and eigenvector centrality) are computed and visualized on request (e.g. as node color, size, etc.). This integration of computational and visual techniques supports the analysis by enriching the node-link diagrams with global and topological properties and enables the visualization of node and network trends from a dynamic perspective (Moody, McFarland, & Bender-DeMoll, 2005). Finally, to support the task of visually analyzing ego-networks and their evolution, we developed two different modes of highlighting. Hence the temporal evolution of the social embeddedness of selected single actors or groups can be traced over time. In the 2.5D view, this task can be performed by additionally visualizing the trajectories of selected nodes and their neighbors, showing the trends of personal communication performance by expanding or decreasing bundles of traces (see Figure 7). Moreover, colors are blended along trajectories, reflecting the trends of node centered measures. To demonstrate and evaluate the outlined features, field data had to be collected and analyzed.

3. Case study: knowledge communication at a university department

The case study, which will be discussed to illustrate the potentials of visual analytical methods on empirical data, focused on knowledge communication at a university department. This type of organization has been chosen due to its broad range of individual tasks, competencies and expected knowledge communication processes. We introduce some of the main results - to assure anonymity by basing our description on renamed actors and knowledge areas.

3.1. Context information on the organization and data collection

The analyzed department focuses on research and education in various areas of social sciences. We gathered multirelational network data by four consecutive surveys conducted during the time period of 14 months by the means of online questionnaires. Every 3-4 months organizational members were asked about their knowledge communication to continuously measure the interpersonal network ties. At first, the department was structured into three organizational units, while a restructuring process was altering the initial compartmentalization between the third and fourth data collection. The number of the department staff varied between 33 and 34, with a total of 38 different persons considering the turnover.

Relational questions included relations of contentual and technical advice, intense collaboration, awareness of individual knowledge, knowledge substitution, discussion of new ideas and suggested communication that should be intensified. Further data collection focused on various demographic attributes and especially on given areas of individual knowledge and practical experience. To capture the shape of individual knowledge profiles, seven different knowledge categories were established, which were seen necessary for the collective pursuit of strategic tasks of the department (cf. Figure 14). These categories got further differentiated into 44 single knowledge domains, wherein all actors had to classify their personal skills as nonexistent, elementary (basic knowledge) or advanced (expert knowledge). Whereas these attribute data served for advanced network analysis, which will be introduced in the fourth chapter, the following section presents selected insights into the interpersonal knowledge networks as evolving infrastructure, along which skills and ideas have been exchanged and communicated.

3.2. Visually analyzing knowledge communication dynamics

A) Overview and Detail - Intense Collaboration Dynamics - Layer Comparison: Intense collaboration within projects or daily routines is to be seen as one of the most important generative factors of shared

knowledge. These networks could be read as the knowledge distributing backbone of the organization. Driven by a spring embedder layout (Barnes & Hut, 1986), Figure 5 shows three relatively well distinguished clusters from the overview perspective (actors colored by degree centrality) which mirror the formally established organizational units. The top row shows the evolution of the whole network, while the bottom row focuses on the single actor Christian (Ch, highlighted in red) and the decrease of his intense collaboration (ego-network, yellow) when leaving the organization for individual re-orientation.

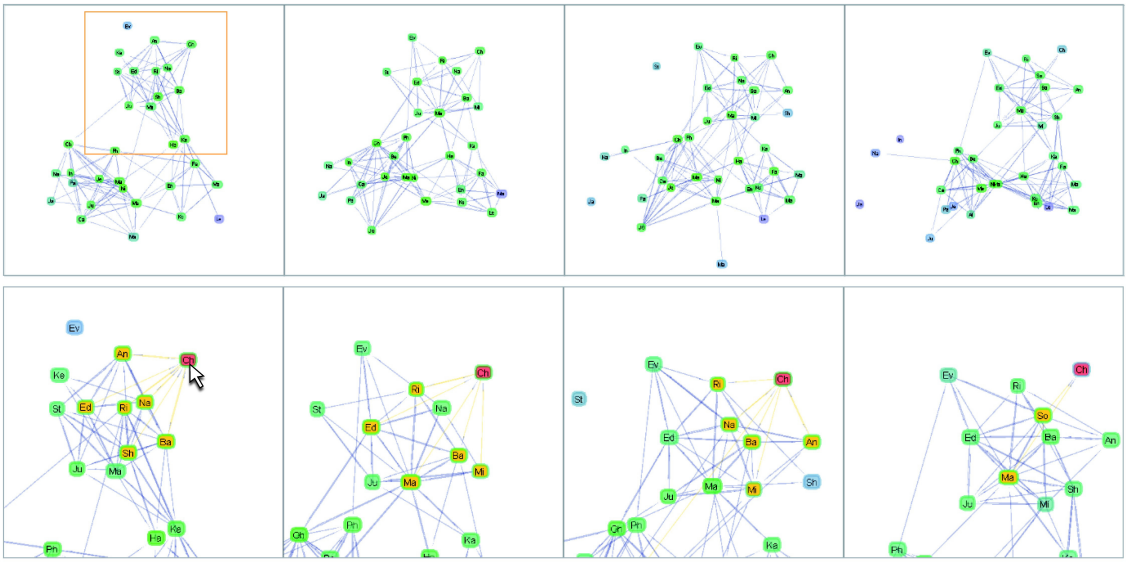

Fig. 5. Layer Comparison view (spring embedder layout) on total collaboration dynamics, showing the evolution of three collaborative clusters (at the top) as well as the evolution of a subgroup (at the bottom), with one actor highlighted (Ch, red) to track his decreasing collaborative ties (ego-network, yellow) when leaving the team.

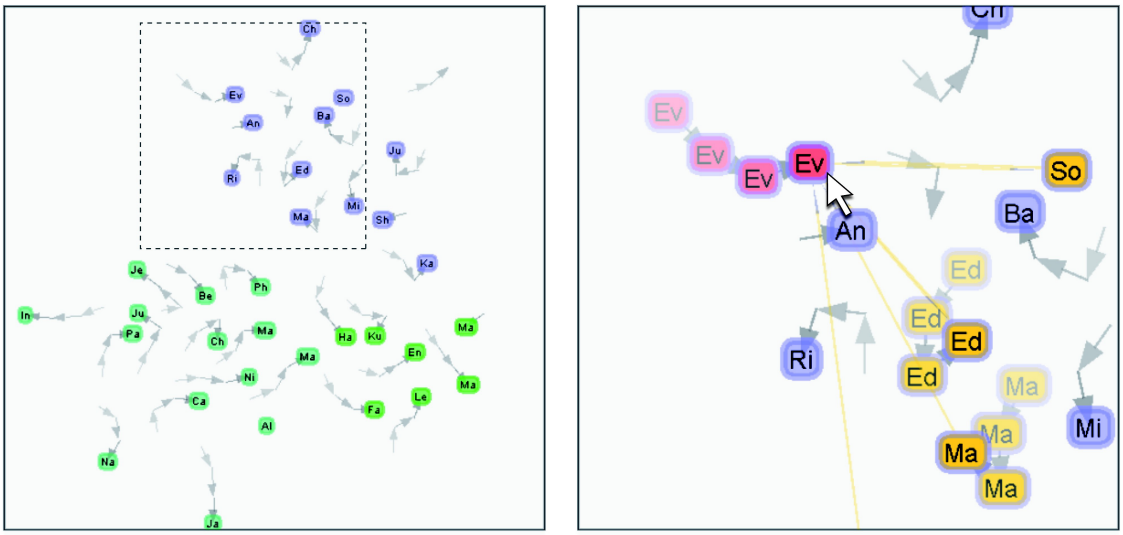

Fig. 6. Layer Merging view (spring embedder layout, hidden ties, shifting node positions shown as temporal trajectories) on total network dynamics (left) and on the evolution of a subgroup (right) and a selected actor (Ev) with his temporal track (red) and his current ego network (yellow).

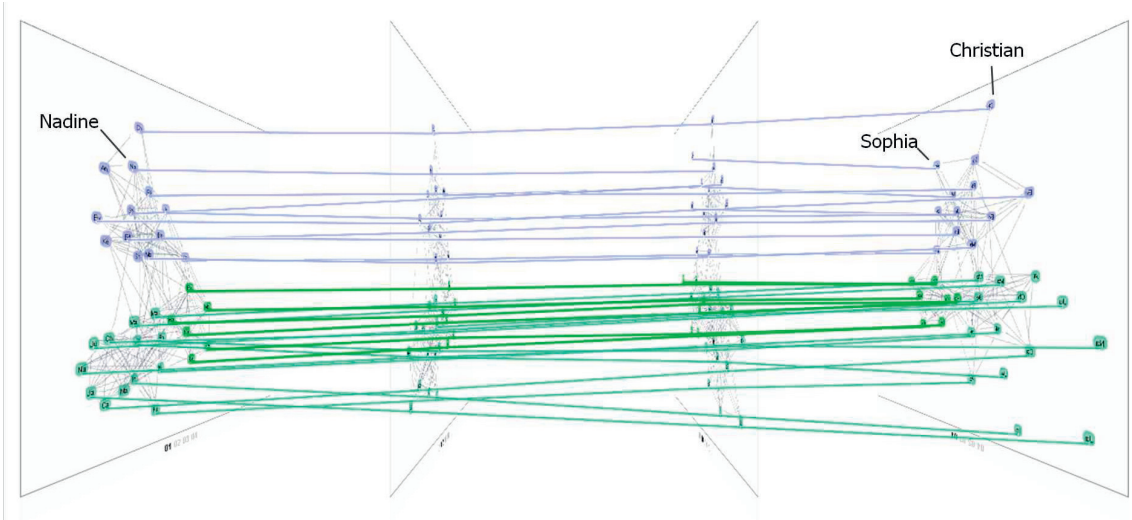

Fig. 7. 2.5D view (spring embedder layout, node trajectories colored by affiliation to one of the three organizational units) on the total network dynamics of content related advice dynamics.

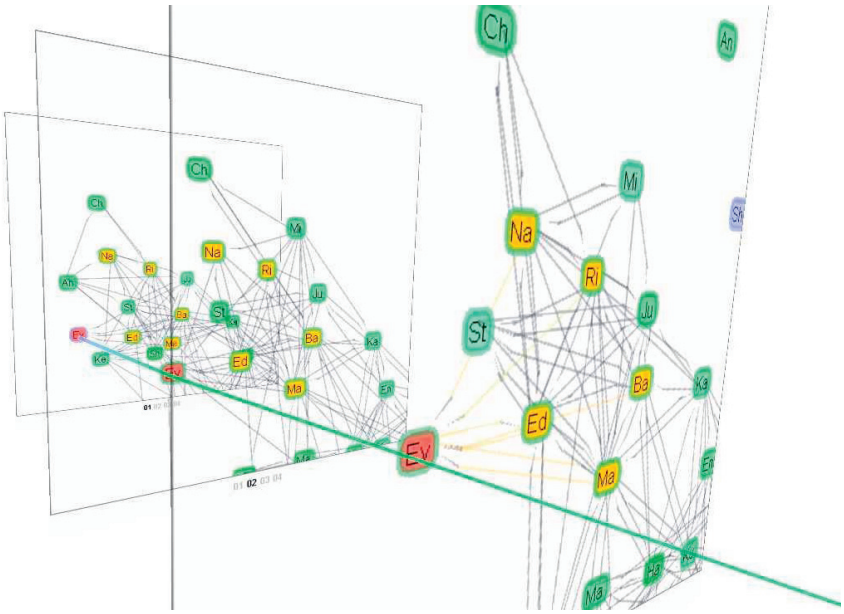

Fig. 8. 2.5D close-up on the involvement evolution of Evans (Ev, red), visualizing his increasing closeness centrality on his trajectory, changing from blue (low) to green (high closeness).

B) Overview and Detail - Layer Merging: The same network could be visualized from the layer merging perspective to accentuate strong shifts or changes of positions – like those near the bottom edge of the image (see Figure 6, left) (actors are colored by units). A close-up on the blue subgroup shows the highlighting of an actor Evans (Ev, red), whose track leads from the periphery towards the clusters core, due to his return from an organizational leave (contacts in yellow).

C) Overview and Detail - Content Related Advice - 2.5D View: The network of content related advice shows again three well distinguished clusters and a quite stable structure over time - illustrated by parallel trajectories, which indicate the maintenance of given structures (see Figure 7). Exceptions are the already known actor Christian at the top, whose trajectory is segregating from the main bundle due to reduced reachability and a handful of actors of the subgroup colored in bluegreen at the bottom of the layers, who departed from the organization due to a restructuration process. Other salient information provided by the 2.5D view are leavings and recruitings - like the second and third trajectory at the top, which show the entrance of the actor Sophia, substituting the leave of the actor Nadine. The option to zoom and rotate the 2.5D view enables the closer examination of specific structural components and their development over time, e.g. by mapping increasing or decreasing centrality measures onto single trajectories (see Figure 8).

3.3. Enhancing communication on communication by means of empirical data

With respect to the first part of the case study results, the main function of visual network analysis could be summarized as extension of network exploration options to be performed by experts as well as non-experts. While the former user group gains options of rapid data inspection and pattern detection, the latter could gain the opportunity for reflecting their own performance from a network view for the first time at all. Hence the interpretation of network visualizations by involved actors could benefit from existing knowledge about actors, groups and relevant events which happened in between two time points. Also the deduction or alignment of change management measures could be based on the complementing day-to-day perspectives from inside the organization, which are usually missing on sides of external experts. The same holds true for the evaluation of implemented measures or the effects of critical events, which could be collectively interpreted and discussed (e.g. whether the relational patterns are unexpected or got visible as expected, whether they could be affirmed or criticized, developed or optimized). As such, the potential of involved tool use lies in the options to initiate communication about existing communication and to facilitate its self-evaluation.

Yet, this might only lay ground to an extended assessment of organizational communication dynamics. While the preceding section focused on interpersonal knowledge communication the following considerations are expanding the analytical scope to individual attributes and the exploration of personal knowledge domains.

4. Reframing knowledge management from a network perspective

The aims and endeavours of knowledge management (KM) approaches are manifold and have led to a highly differentiated field of discourse, developments and a broad array of applications (Prusak, 1997; Dalkir & Liebowitz, 2011; Hislop, 2009; Maier, 2003). With regard to the given context, we want to reframe some of their basic questions from a network perspective.

4.1. Exploring individual profiles of knowledge:

Among the major issues of knowledge management, the challenge of orientation within an organization's intellectual landscape is an ever recurring and major concern (Maier & Lehner, 2000; McDonald & Ackerman, 1998). How can members of an knowledge intensive organization know, which knowledge is on board altogether, how is it distributed, how far is it away from an ego perspective and who should be asked to find what one is looking for? Conceptual solutions, which react to these questions, are "yellow page" applications: a catalogue (or database), filing actors according to their areas of knowledge or expertise (Alavi & Leidner, 1999).

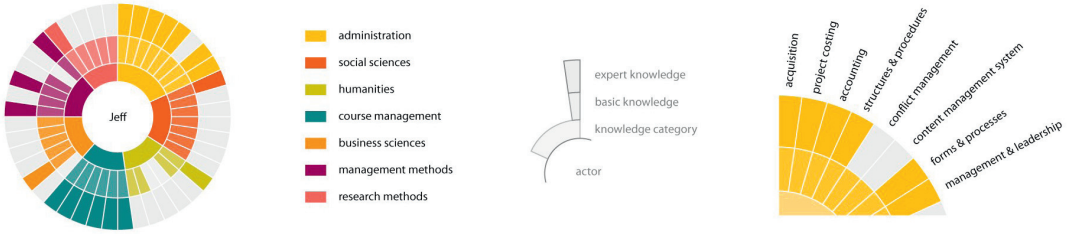

Fig. 9. Sunburst diagram of an actor's aggregated knowledge, showing the specific distribution as radial sunrays, levelled from general categories to basic and expert knowledge.

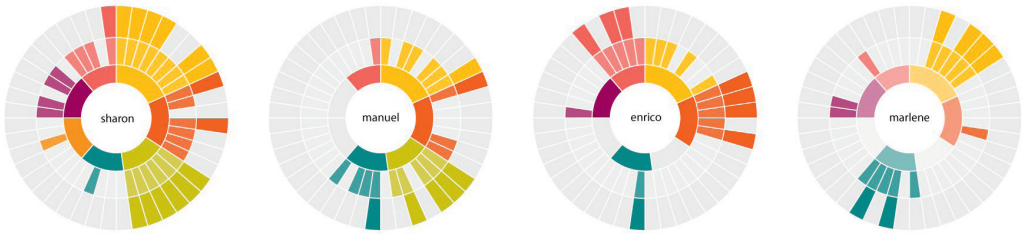

Fig. 10. Comparing different actor's individual distributions of knowledge and expertise.

From our perspective, the integration of this individual (actor-centered) perspective with the interpersonal network perspective can help a lot to understand the day-to-day interdependencies of both (see also Ibarra, Kilduff, & Tsai, 2002). To visually analyze knowledge as attribute data of embedded actors, we take on sunburst diagrams (Chuah, 1998; Stasko, Catrambone, Guzdial, & McDonald, 2000), as they are capable to display categories in a radial and hierarchical style, visually arranging themselves around actors as attribute carriers. For the knowledge data collected within the context of the case study, the function principle of this kind of diagram is explained in Figure 9.

This kind of diagram not only allows for the detailed visual analysis of individual attribute data (see Figure 10), it could also be integrated into network visualizations, being displayed as peripheral information visualization, surrounding single actors (see Figure 14).

4.2. Exploring the interpersonal distribution of knowledge

Building on the notion of knowledge about knowledge (Cross, Parker, Prusak, & Borgatti, 2001), which is located in individual actors, the possible flows of specific knowledge within organizations can be analyzed on a new level of detail. Taking on these extended exploration options, the structural position of experts and their knowledge could be re-evaluated to ensure appropriate knowledge accessibility in the network.

In the following, two knowledge domains (Course Administration and Process Management) will be selected to demonstrate the domain specific visual exploration of the advice network data. These knowledge domains were identified as being crucial for the day-to-day work and hence should be accessible to all of the employees. About half of the actors stated to be an expert in CA, but only one actor stated to be an expert in PM. To analyze the structural reachability of experts, employees were asked whom they turn to, if they need content related advice. Building on this relational infrastructure, the structural distribution and individual accessibility of various knowledge domains could now be visually explored.

In Figure 11 and 12, the respective advice networks are visualized by a force directed layout to show the possible flows of knowledge of the selected domains. If a person A asks a person B for advice, knowledge flows from person B to person A, indicated by an arrow from B to A. The color saturation of the actors are based on their knowledge levels concerning the specific domain (saturated color: expert knowledge, desaturated color: basic knowledge, gray: no knowledge in this domain). The colors of the relations are based on the actor who gives advice to visualize the possible knowledge accessibility.

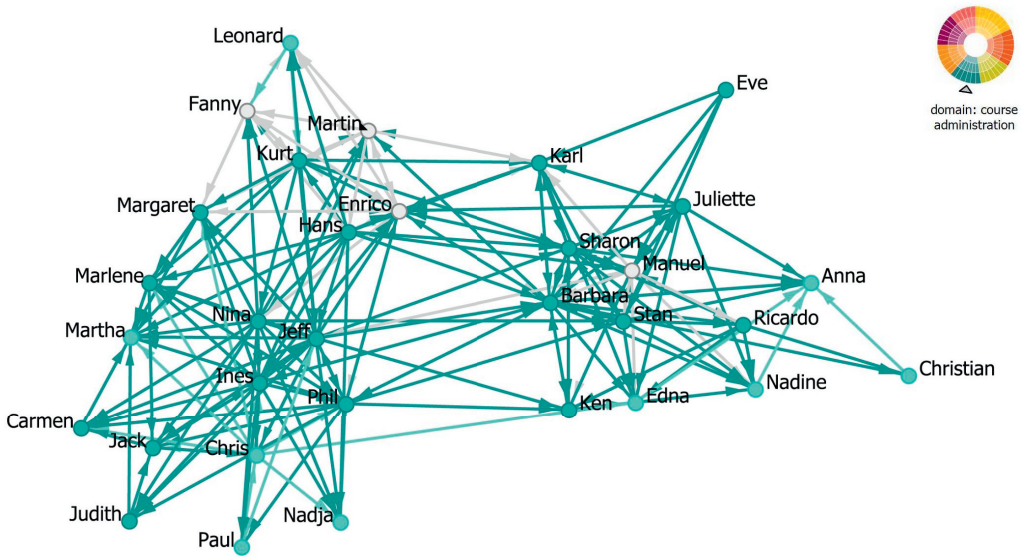

Fig. 11. The distribution and accessibility of the specific domain “course administration” (CA) in the advice network (spring embedder layout) saturated color: expert knowledge, desaturated color: basic knowledge, gray: no knowledge in this domain).

In Figure 11 the knowledge of course administration is spread throughout the organization. Most of the employees are experts in this field and persons who are not experts can connect directly to an expert to seek advice. As opposed to this, the knowledge distribution of process management is visualized in Figure 12. There is only one expert (Nina) who is positioned on the left side of a dense subgroup and all direct contacts but one are also located in this group. Only one actor (Stan) from another subgroup is directly connected to this expert and he does not have basic knowledge in that domain. This means, that the knowledge flow of this domain is restricted to a specific subgroup of the advice network, without the opportunity to be immediately shared within the organization.

Regarding relational knowledge management over time, two interventions could be planned to optimize the distribution of crucial knowledge. From an actor-based perspective, actors could be identified who should be trained in a specific knowledge domain in order to allow employees to directly contact experts in the field. These new experts should be positioned centrally (closeness centrality) to enable others to efficiently seek advice. Referring to Figure 12, this person should be located on the right side of the advice network in which no expert is located and the person should be close to many other actors in this area (e.g. Manuel instead of Christian). From a relation-based perspective, the knowledge flows could be optimized by encouraging additional interpersonal communication patterns. Nina, as the only expert in PM, is positioned on the left side of the network and there is only one connection to the right side. Making Nina directly accessible for the actors on the other side of the advice network would enhance the distribution of her knowledge (e.g. by regular meetings concerning this domain or a weekly internal consultation-hour). To evaluate whether or not these interventions have an effect on the knowledge distribution, the dynamic features of network analysis – including before-after comparisons – come into play again.

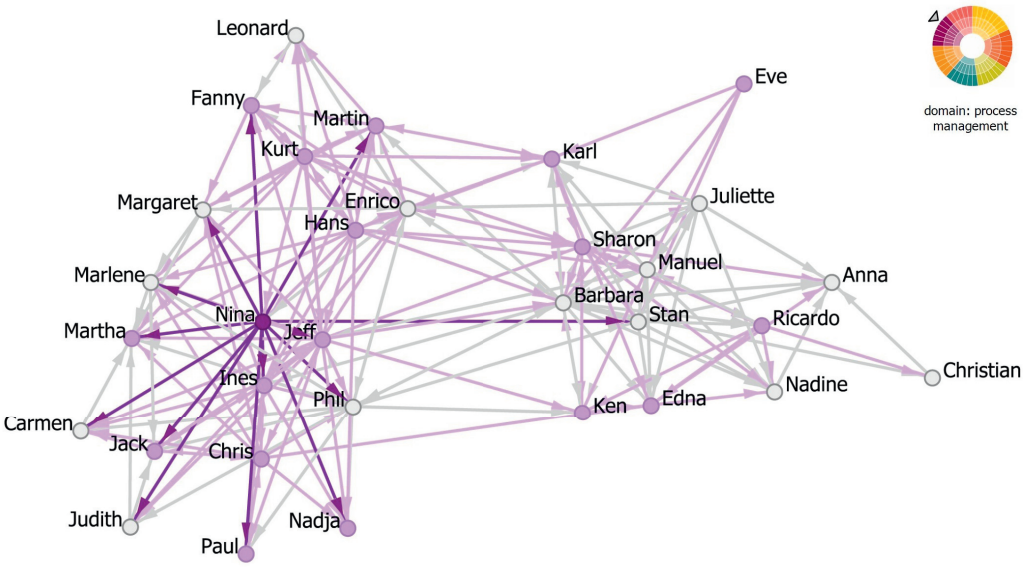

Fig. 12. The distribution and accessibility of the specific domain “process management” (PM) in the advice network.

4.3. Exploring the collective knowledge space

So far, we showed how to visualize the distribution of organizational knowledge domains from the perspective of an individual actor (4.1) and how to visualize the knowledge flows throughout the organization from the perspective of specific knowledge domains (4.2). To analyze the distribution of all knowledge domains from all actors, we will show the similarity of actors based on their expertise. As mentioned earlier, some knowledge areas are widely distributed throughout the department (e.g. course administration). In our data each pair of actors shares at least one knowledge area. When transforming this 2-mode network (actors and knowledge) into a 1-mode network (actors and actors) a fully connected graph will be the outcome. From the perspective of network visualization, the force-directed layout algorithm (Barnes & Hut, 1986) may not produce an appropriate image to visually understand the underlying structure of the network if no network manipulation (e.g. line reduction based on a given threshold) is performed.

To tackle this challenge, we use multidimensional scaling (MDS) to visualize the collective knowledge space by positioning actors with similar knowledge close to each other (Torgerson, 1952). For the input matrix of the MDS we calculate a knowledge distance between every pair of actors as the sum of the absolute knowledge differences, e.g. if we assume three knowledge categories X, Y, and Z and two actors A with knowledge {1,0,2}, and actor B with knowledge {2,1,2}, then the knowledge distance between actor A and B is 2. The resulting MDS should therefore position actors nearby each other when their knowledge, but also their lack of knowledge, is similar.

In Figure 13 a two-dimensional plot (on the left) and a three-dimensional plot (on the right) are visualized. The axes in the two-dimensional plot represent the dimensions (i.e. eigenvectors), the colors represent the three different units of the department. Due to the fact that the data is based on a fully connected graph, the ties are not drawn in this network. One result to mention in the two-dimensional plot is that the person with the largest amount of knowledge categories (Ines, the outer left actor) is located in a peripheral position because her knowledge distance is, of course, larger compared to the other actors. This is a counter-intuitive result, as from network visualization experiences one would expect such actors being positioned in the center of the visualization. Looking at the colors of the actors based on units, we see separated groups of all three teams and overlapping areas. Using a third eigenvector to visualize a three dimensional space, results in a visualization shown on the right side of Figure 13. The lines in this

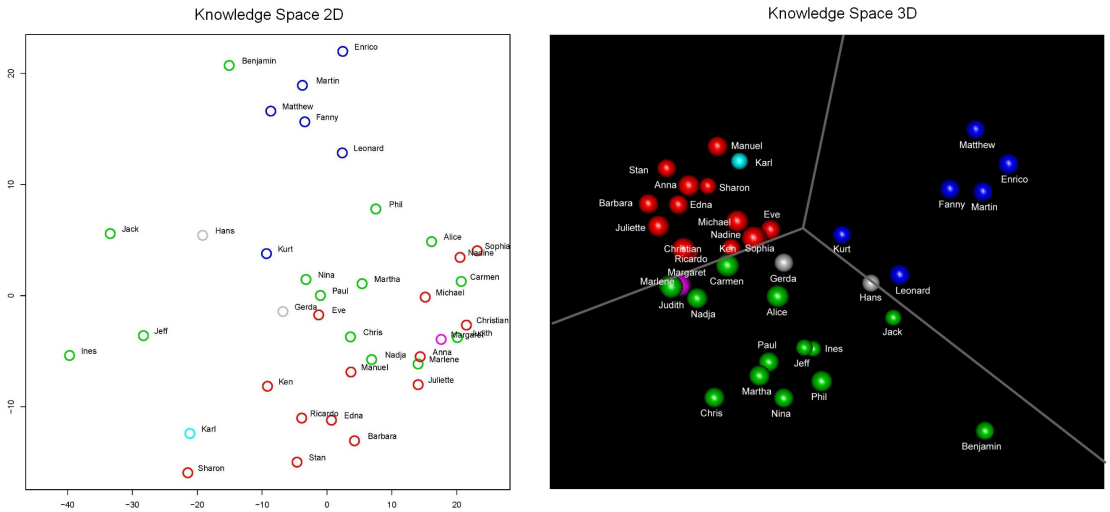

Fig. 13. MDS visualization of actors - closeness indicating similarity of their expertise - in 2D (left) and 3D (right), units are colored red, blue, and green, gray actors are in no units, other colors in more than one unit.

visualization do not represent axes but auxiliary lines to show the different groups. Hence it is possible to cluster the actors according to their affiliation by visually exploring the 3-dimensional image.

To bring individual knowledge back into the network based MDS-view of the knowledge space (Figure 13, left), we used a reduced version of the sunburst diagrams (i.e. ring charts) to show expertise in seven categories and implemented them into the diagram (see Figure 14). Even if the positioning of the nodes is based on the detailed knowledge categories and the ring charts show just the seven top-level categories, the grouping of similar knowledge - as well as lack of knowledge - is obvious. On a group level, the green unit shows the highest expertise diversity, followed by the red unit and the blue unit. Also on the level of functional analysis, the visualization shows coherent groupings of similarity, which reassemble clusters of roles and responsibilities within the organization.

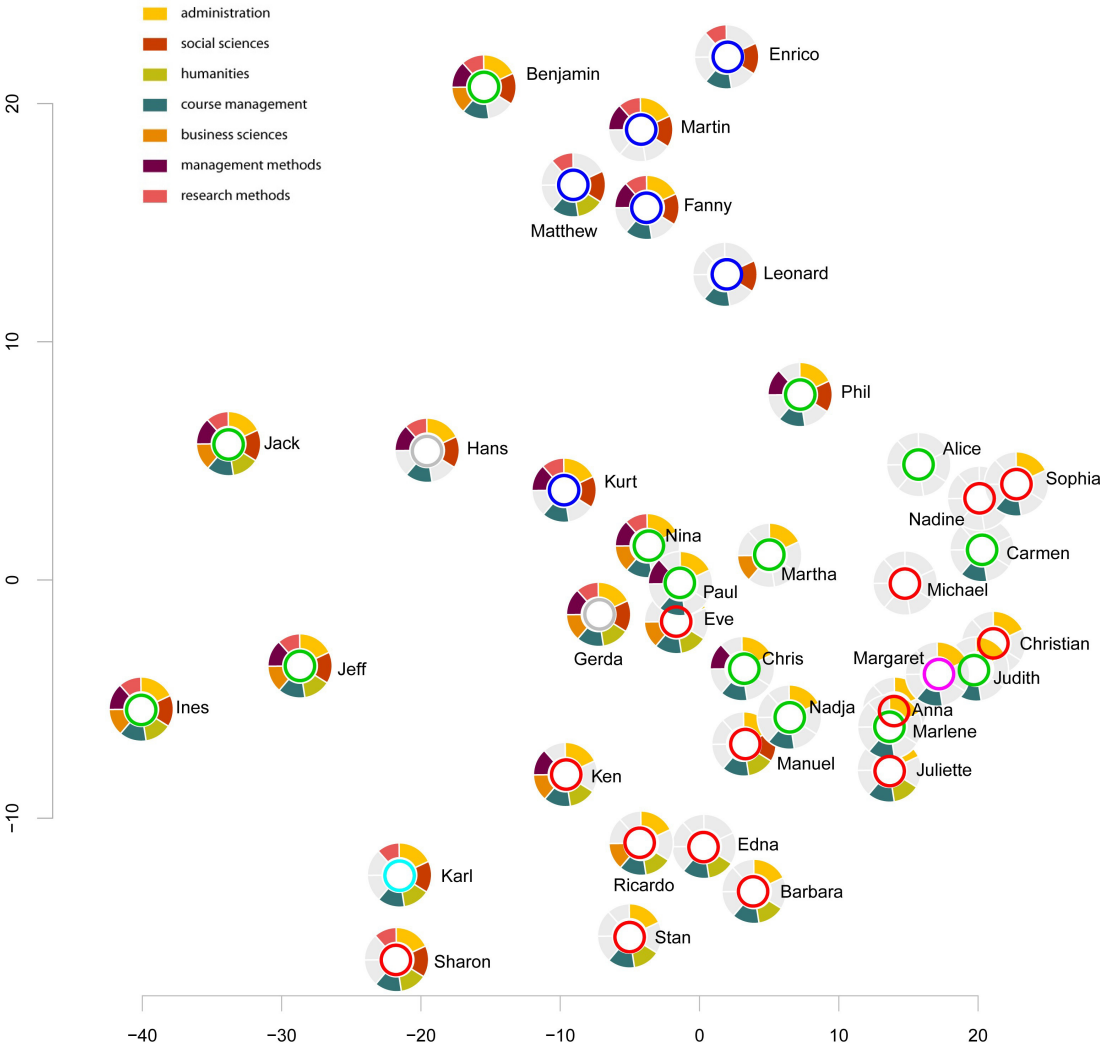

Fig. 14. MDS visualization of knowledge similarity in 2D, combined with the visualization of advanced knowledge within seven knowledge categories – displayed by ring charts (colored segments showing existing expertise).

4.4. Further options to integrate KM issues into a relational perspective

Building on the re-evaluation and optimization of communication networks, which can arise out of dynamic network monitoring outlined in chapter 3 and extended approaches of knowledge and network exploration described in this chapter, further options to integrate organizational data into dynamic network models can be conceptualized.

Due to the basic tenets of the paradigm of process management (PM), organizational knowledge is not only located in individual actors and their knowledge communication networks, but also in their daily activities, which are structured by processes and projects as chronologically specified chains of (future) activities (Kohlbacher, 2010). As these processes and projects could be explicated and, in fact, get widely modelled and mapped (Madison, 2005), a long term aim of the research project ViENA is to integrate the process and network perspective as two complementary paradigms of visualization (Windhager et al., 2011). As a conceptual mock-up, Figure 15 shows how process chains (in terms of activity streams or process logs) could visually be incorporate into the 2.5D view on network dynamics. Along the given trajectories of single nodes, various events (like individual operations, social collaborations and other performance data) can be noted and linked. In conjunction with business management systems such embedded process logs can serve as chronologically growing attribute data repository of individual actors and help to enrich their knowledge profiles, to be explored by other actors in search for specific process expertise.

5. Conclusion and outlook

In this paper we have presented a dynamic network approach to knowledge and communication management. Building on a newly developed software prototype for the visual analysis of network change, we showed on basis of the case study of a university department, how the exploration of network data can provide insights into existing communication and collaboration structures. In contrast to purely static analyses, a major benefit of the outlined dynamic approach is the opportunity to visually analyze and evaluate structural change, including individual or organizational performance, personal turnover, or the effect of already implemented change management measures over time. By further enriching dynamic network models with actor and attribute data, we showed how the intra- and inter-individual distribution of organizational knowledge domains can be visualized. In contrast to largely individualistic, actor-centred methods of human ressources management, this integrated approach also allows for an ongoing evaluation and development of the social accessibility of crucial skills and areas of expertise.

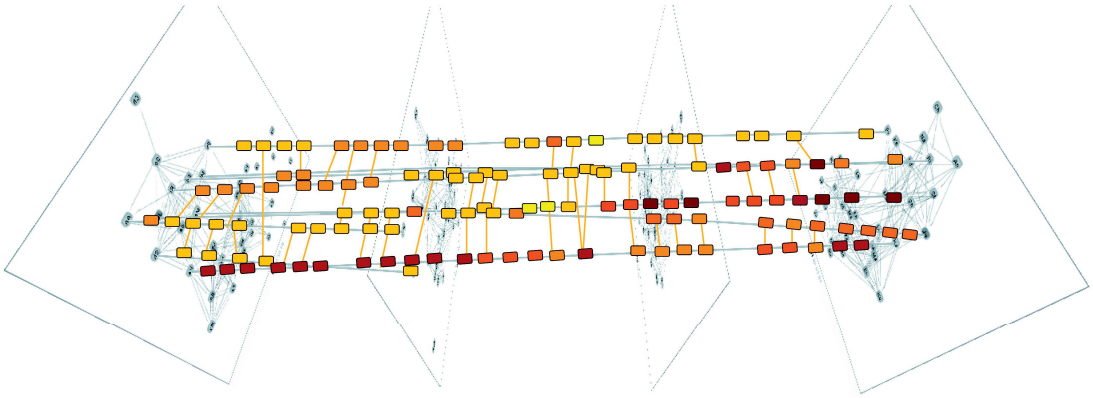

Fig. 15. Integrated dynamic network perspective (2.5D) on organizational processes and activities.

To bridge a structural gap towards process oriented modelling paradigms and to overcome various limitations of relational data collection, we want to address further research towards integrated approaches of network and process data exploration. From an inter-operational perspective, the resulting question is how to take advantage of existing project and process models to develop appropriate tools for visually supporting the long term developments, as well as the daily processes of organizational learning and change.

Acknowledgements

This research was supported by the Austrian FFG research program FIT-IT Visual Computing (No. 820928, Research project ViENA, Visual Enterprise Network Analytics, http://fitit-viena.org).

References

Alavi, M., & Leidner, D. E. (1999). Knowledge management systems: issues, challenges, and benefits. *Communications of the AIS, 1*(7) 1-28.

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS quarterly*, *25* (1), 107–136.

Andrews, K., Wohlfahrt, M., & Wurzinger, G. (2009). Visual graph comparison. In *Proceedings of the 13th International Conference on Information Visualization (IV09)* (pp. 62 – 67). Los Alamitos, CA: IEEE Computer Society.

Balkundi, P., & Kilduff, M. (2006). The ties that lead: A social network approach to leadership. *The Leadership Quarterly, 17*(4), 419-439.

Barnes, J. & Hut, P. (1986). A Hierarchical O(N Log N) Force Calculation Algorithm. *Nature, 324*(4), 446-449.

Boyd, R., & Richerson, P. J. (2009). Culture and the evolution of human cooperation. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*, 3281 -3288.

Brandes, U. & Corman, S. R. (2003). Visual unrolling of the network evolution and the analysis of dynamic discourse, *Information Visualization, 2* (1), 40 – 50.

Brass, D. J., Galaskiewicz, J., Greve, H. R., & Tsai, W. (2004). Taking stock of networks and organizations: A multilevel perspective. *Academy of Management Journal*, *47*(6), 795-819.

Breiger, R., Carley, K., & Pattison, P. (Eds.). (2003). *Dynamic Social Network Modeling and Analysis*. Washington D.C.: The National Academies Press.

Chuah, M. C. (1998). Dynamic Aggregation with Circular Visual Designs. In G. Wills & J. Dill (Eds.) *IEEE Symposium on Information Visualization (InfoViz '98)* (pp. 35-43). Los Alamitos, CA: IEEE Computer Society.

Cross, R., Parker, A., Prusak, L., & Borgatti, S. P. (2001). Knowing what we know: Supporting knowledge creation and sharing in social networks. *Organizational Dynamics 30*(2), 100-120.

Dalkir, K. (2011). *Knowledge Management in Theory and Practice* (2nd ed.). Boston; MA: The MIT Press.

Dwyer, T., & Gallagher, D. R. (2004). Visualising changes in fund manager holdings in two and a half-dimensions. *Information Visualization, 3* (4), 227 – 244.

Eades, P., Lai, W., Misue, K., & Sugiyama, K. (1991). Preserving the mental map of a diagram. *Proceedings of COMPUGRAPHICS 91*, 34-43.

Etcher, J. P. (1997). Post-Heroic Leadership: Managing the Virtual Organization. *Performance Improvement, 36*(2), 5-10.

Federico, P., Aigner, W., Miksch, S., Windhager, F., & Zenk, L. (2011). A visual analytics approach to dynamic social networks. In S. Lindstaedt & M. Granitzer (Eds.) *Proceedings of the 11th International Conference on Knowledge Management and Knowledge Technologies* (i-KNOW '11) New York, NY, ACM Press.

Handy, C. (1991). *Gods of Management*. Oxford: Oxford University Press.

Harms, W. F. (2004). *Information and Meaning in Evolutionary Processes*. Cambridge: Cambridge University Press.

Hatch, M. J. (2006). Organization Theory: Modern, Symbolic, and Postmodern Perspectives (2nd ed.). Oxford, UK: Oxford University Press.

Heer, J., Card, S. K., & Landay, J.A. (2005). prefuse: a toolkit for interactive information visualization. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '05), (pp. 421-430). New York, NY, ACM Press.

Hislop, D. (2009). *Knowledge Management in Organizations* (2nd ed.). Oxford: Oxford University Press.

Ibarra, H., Kilduff, M., & Tsai, W. (2005). Zooming In and Out: Connecting Individuals and Collectivities at the Frontiers of Organizational Network Research. *Organization Science*, *16*(4), 359–371.

Johnson-Laird, P. N. (1980). Mental models in cognitive science. *Cognitive science*, *4*(1), 71–115.

Keim, D., Andrienko, G., Fekete, J.-D., Görg, C., Kohlhammer, J., & Melançon, G. (2008). Visual Analytics: Definition, Process, and Challenges. In A. Kerren, J. T. Stasko, J.-D. Fekete, & C. North (Eds.), *Information Visualization, 4950*, (pp. 154-175). Berlin: Springer.

Kohlbacher, M. (2010). The effects of process orientation: a literature review. *Business Process Management Journal*, *16*(1), 135-152.

Madison, D. (2005). *Process Mapping, Process Improvement and Process Management*. Chico, CA: Paton Press.

Maier, R., & Lehner, F. (2000). Perspectives on knowledge management systems theoretical framework and design of an empirical study. In H.R. Hansen, M. Bichler, H., Mahrer (Eds.). *Proceedings of the 8th European Conference on Information Systems – ECIS 2000*, (pp. 685-693).

Maier, R. (2010). *Knowledge Management Systems: Information and Communication Technologies for Knowledge Management* (3rd ed.). Berlin: Springer.

McDonald, D. W., & Ackerman, M. S. (1998). Just talk to me. *Proceedings of the 1998 ACM conference on Computer supported cooperative work - CSCW '98*, 315-324.

McGrath, C. J., & Blythe, J. (2004). Do you see what I want you to see? The effects of motion and spatial layout on viewers' perceptions of graph structure, *Journal of Social Structure*, *5*(2).

Moody, J., McFarland, D. A., & Bender-DeMoll, S. (2005). Dynamic network visualization: Methods for meaning with longitudinal network movies. *American Journal of Sociology 110*, 1206-1241.

Pearce, C. L., & Barkus, B. (2004). The Future of Leadership: Combining Vertical and Shared Leadership to Transform Knowledge Work. *The Academy of Management Executive*, *18*(1), 47-59.

Purchase, H. C., Hoggan, E., & Görg, C. (2006). How important is the "mental map"? An empirical investigation of a dynamic graph layout algorithm. In Proceedings of the 14th International Conference on Graph Drawing. GD'06, (pp. 184 – 195). Berlin/Heidelberg, Germany: Springer.

Prusak, L. (Ed.). (1997). *Knowledge in organizations*. Boston, MA: Butterworth-Heinemann.

Snijders, T. A. B., Steglich, C. E. G., & Van de Bunt, G. G. (2010). Introduction to actor-based models for network dynamics. *Social Networks*, *32*, 44-60.

Stasko, J., Catrambone, R., Guzdial, M., & McDonald, K. (2000). An evaluation of space-filling information visualizations for depicting hierarchical structures. *International Journal of Human-Computer Studies*, *53*(5), 663-694.

Thomas, J. J., & Cook, K. A. (2005). *Illuminating the Path: The Research and Development Agenda for Visual Analytics*. Los Alamitos, CA: IEEE Computer Science.

Torgerson, W. S. (1952). Multidimensional scaling. Theory and Method. *Psychometrika 17*, 401–419.

Windhager, F., Zenk, L., & Federico, P. (2011). Visual Enterprise Network Analytics - Visualizing Organizational Change. *Procedia - Social and Behavioral Sciences*, *22*(0), 59-68.

Zenk, L., Windhager, F., Ettl-Huber, S., & Smuc, M. (2011). Kommunikationsflüsse im Bild: Dynamische Netzwerkvisualisierung in der internen Organisationskommunikation anhand des Fallbeispiels eines Universitätsinstituts. *Medien Journal 35*(2), 50-61.