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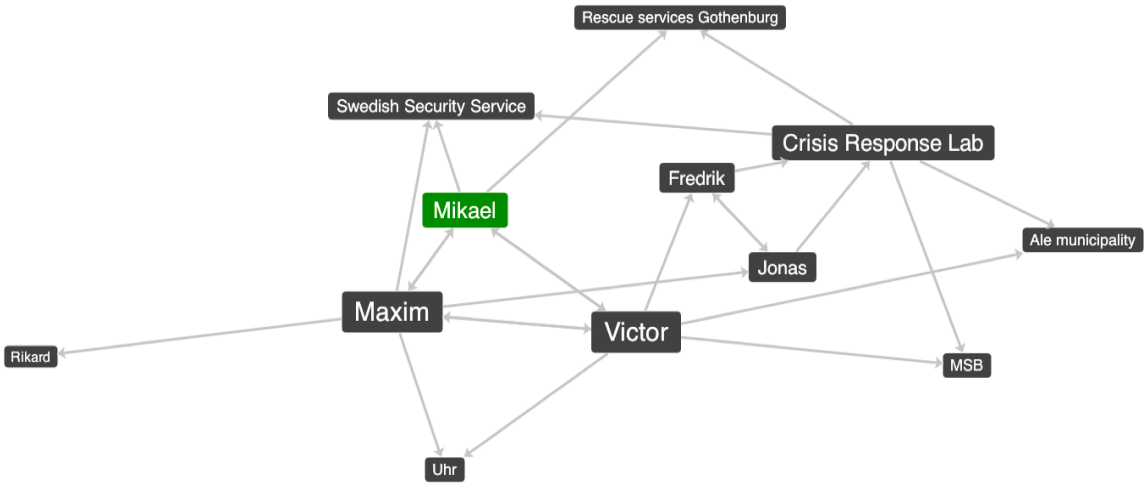

Real-Time Social Network Visualisation

Exploring the Design Space for a Multi-User Real-Time Visualisation Tool for Social Network Analysis

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Abstract

In society we handle an increasing amount of information and relations on a daily basis. To overcome the risk of information overload and to make sense of these aspects of our surroundings we employ various kinds of tools and aids. Visualisation of information is a common tool for this and can be found in most areas of society. In studying social networks, researchers often use visualisations to identify key actors and to understand the exchange of information. This typically involves time-consuming data gathering activities and answering questions in past tense. While social network analysis (SNA) contributes with valuable understandings for the future it provides little or no use for involved actors in the present. Realising the potential of SNA in real-time application to promote situational awareness and collaboration, practitioners and researchers in the emergency response field have called for the translational research and development of SNA tools for practitioners. The aim of this thesis is to explore the design space for a real-time multi-user visualisation tool for social network analysis. This is achieved by the construction and evaluation of a prototype for such a tool. For this purpose Action Design Research (ADR) is conducted, situated in the domain of emergency response. The results consist of a set of design principles manifesting key aspects needed to address when designing a real-time multi-user network visualisation tool. The prototype and the possible design solutions derived from the development and evaluation process each constitutes an example of how to design for a social network visualisation tool of this kind.

Keywords

Social Network Analysis, Real-time Visualisation, Multi-user SNA, Collaboration Technology, Action Design Research, Emergency Response Networks, Crisis Response Management, Design Principles.

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Introduction

In an age where society produces and consumes more information than ever before and where social networks have grown outside the cognitive bounds of their members, visualisation have become an increasingly used method for keeping everything intelligible (Perer, 2010).

To gain understanding of the dynamics and relations in social networks, researchers have been conducting data gathering studies and using visualisations since the early 20th century (Krebs, 2010). In the field of Social Network Analysis (SNA) researchers study, amongst other things, the exchange and control of information. By mapping this, improvements can be made to the organisational resource and information delivery routes to optimise the flow (Haythornthwaite, 1996; Brodlie, et al., 2004).

When society responds to an emergency, networks are mobilised to deal with the situation. These networks are often multi-organisational and ad hoc in nature (Landgren and Nuldén, 2007). SNA have been applied to understand these networks. While adding to the understanding they deal with the situation in past tense and their chief contribution for practitioners has been in preparing for future situations. Researchers and practitioners have started to investigate SNA as means of adding to the situational awareness during an emergency but lack the tools and methods for this real-time support (National Research Council (NRC), 2009). After discussing the research opportunity this presents, we concluded that the need for SNA tools to facilitate direct situational awareness could very likely be translated into other fields as well. The domain of emergency response thus lends itself well to be used as a case study domain for the exploration of this research opportunity.

In this study we have used Action Design Research (ADR) to explore the perceived need and opportunity. Action Design Research focuses on solving situational issues by developing artefacts within a specific context and deriving generalised design knowledge by reflecting on the process. This method views the problem of the domain as an instance of a class of problems, and demands for the results to be generalised in order to be adaptable to the problem class.
(Sein, et al., 2011).

The aim of this study is to explore the design space for a real-time multi-user tool for social network visualisation and analysis. We do this by constructing and evaluating a prototype of such a tool based on a conceptual framework. With this we aim to contribute and lay the groundwork for further research and development by presenting a set of design principles.

Therefore, our research question is:

> *What design principles can be derived from the process of constructing and evaluating a real-time multi-user visualisation tool for social network analysis?*

Conceptual Framework

In order to examine the design space for creating a multi-user visualisation tool for social network analysis (SNA), we have used a framework based on earlier literature and research in the fields related to our purpose. The main scientific field that has provided the backbone, inspiration and context for this framework, is social network analysis. We used the framework for investigate the process of how to build a multi-user real-time visualisation tool for the purpose of SNA.

Social Network Analysis

We are living in a time where informal social networks are playing an important role in our society, a part that appears to be growing (Cross, Borgatti and Parker, 2002). Reasons for this are said to be the loosening of social structures and the development of new techniques for communication, both allowing for contacts across formal borders (ibid). It is clear that social networks play an important role in many areas of modern life, both in organisational and personal contexts (Hanneman and Riddle, 2005).

The term "social network" is often used to describe patterns of collaboration and communication of individuals. In an organisational context this also describes patterns that go beyond formal organisational charts; organisations can, according to Cross, Borgatti and Parker (2002), be viewed as a combination of formal and informal networks. The definition and usage of the term ranges from including brief acquaintances to concentrating on stronger ties like family or close work relations (Tichy, Tushman and Fombrun, 1979). Haythornthwaite (1996) defines the social networks as exchange routes for resources and information between actors. According to Hanneman and Riddle (2005) the individual should not be seen as belonging to one network exclusively, but rather to be a part of several overlapped networks, often embedded in each other. For organisations, this means that several social networks exists side by side, more or less intertwined, and that the individuals occupying these networks also are a part of their own personal networks, crossing organisational borders (ibid).

Studies have shown that managers of organisations often think that they have a good understanding of the informal networks within their organisation (Cross, Borgatti and Parker, 2002). According to the same studies, the case is often that the managers understanding their own closest connections, as well as those of the five to six persons closest to them are rather accurate. After that, the level of knowledge drops substantially. Research both shows that social networks play an important role in organisations, and that the knowledge and understanding of them often are at a level that could be improved. This indicates that there is still much room for improvement for organisational awareness on the matter (ibid).

SNA is the study of resource exchange among actors, and one important resource is information. An analysis shows who the actors are and how the flows of resources between them are connected. By mapping this, an understanding is gained about which actors are exposed to information, and which actors are in control over information. Improvements can then be made to the organisational resource and information delivery routes to optimise the flow (Haythornthwaite, 1996).

Cross, Borgatti and Parker (2002) point out three areas where SNA can be especially beneficial. 1) Promoting collaboration in strategically important groups. These groups can be identified, and their information routes optimised. 2) Support critical junctions in networks. This can refer to junctions that connect different networks and part of organisations. 3) Integrate networks, in order to ensure that information and resources can flow freely to where it is most needed. By supporting these areas, knowledge can be better distributed within the organisation through enhanced communication. It is also stated that the integration of different networks can drive innovation forward by the exchange of ideas (ibid).

An interesting perspective is presented by Granovetter (1983), who points out the importance of so called "weak ties" in a network, meaning a person in the outer perimeter of a network, who has only a few connections. The centre of any network is usually is tightly coupled, and dense with internal connections, meaning that a great deal of the communication takes place within the group. Individuals who shares only a few bonds with this network are more likely to be a part of outside networks, and therefore more likely to present new ideas and different points of view. These weak ties can therefore acts as bridges between different networks, and greatly assist in the spreading of information. SNA can lead to the identification of these important bridges. In society, as well as in organisations, Granovetter (1983) states that weak ties can counterbalance fragmentation and aid in the mutual understanding and tolerance between groups.

To perform a social network analysis, the first step is to collect information about the population of interest (Tichy, Tushman and Fombrun, 1979). Data is typically attained through surveys. Apart from asking about what relationships each respondent has, more specific questions can be asked about the nature of the relationship or the communication conducted. The researcher must keep in mind that this information may be sensitive, both for the individual and for the organisations and must be handled accordingly. Depending on the situation, it may or may not be appropriate to openly display the information. A compromise can be to present the results with the names and identifying attributes of each person masked (Cross, Borgatti and Parker, 2002).

One of the most crucial aspects of the SNA process is the decision of what information to look for, and where. There are two main methods, that differs from each other both in the process and in the results they produce. The first one is the *Full network method* that tries to collect all information from all parties. This method produces an extremely rich picture of all ties within the chosen population, but is very costly in time and resources. Another problem of the method is that it by definition includes every individual, and therefore makes for a result that can be hard to read (Hanneman and Riddle, 2005).

At the other end of the spectrum, we have the *snowball method,* named after the metaphor of a rolling snowball, collecting more snow and expanding as it moves forward. In the method, one or a few entry points are decided upon, namely a number of individuals. These respondents name their relationships, who are then invited to continue the process and name their connections, and so forth until the study ends. It can either end because the researchers decide so or that no new connections appear. The typical results produced will not be as extensive and complete as those of the full network method, but may reveal a number of interesting points of interest. The snowball method can identify subgroups, point to fragmentation within the organisation and identify weak ties. However the results produced will be greatly dependent on the point of entry, and may not provide accurate information about the network as a whole. The importance of certain subgroups may be overstated, while other subgroups and individuals may be totally left out of the result data. These aspects of the method must be fully understood in order to use it

successfully. The revelation, that parts of the perceived network does not turn up in the results from a certain entry point, can offer valuable insight about inter-organisational information routes. This may be regarded as both a benefit and a problem with the method (Hanneman and Riddle, 2005).

To get a more complete picture of the network as a whole, several snowball studies can be run in conjunction. The method will then come closer to the full network method, both in the aspect of being more complete, and in being more costly to perform. One alternative approach is to ask the entry point respondents about their closest connections and their internal ties. This instantly produces a small micro network, and can be an alternative with limited resources (Hanneman and Riddle, 2005).

A factor that must be decided on in an SNA is the scale of measure for the connections. The most basic, and most frequently used is the *binary scale* that only has two values; a connection or no connection. This scale does not regard subtle shades of human relationships; the bond between parent and child is rated just the same as a once in a lifetime e-mail connection. To battle this bluntness, a *multi category scale* may be used, with a suiting number of alternatives to choose from. Another choice is the *graded ordinal measure scale,* in which the respondents grade their connections in different ways, for example from ”close contact” to ”brief encounter”. With this scale two connections can be given the same value. A *ranked scale,* on the other hand, demands the ranking of connections, where each is given a unique rank; number one, number two, et cetera. The last alternative is an *interval measurement scale,* where data is collected about the different intervals between connections, for example: “Number one is twice as frequent as number two, which is five times as frequent as number three” et cetera (Hanneman and Riddle, 2005).

All of these scales produce their own type of data and enables different levels of analysis to be made from the data-set. The binary scale and the multi category scale are the two most commonly used scales due to their relative simplicity. In most cases, the binary scale will provide sufficient information for a social network analysis. It produces a result that is relatively simple to visualise, analyse and draw points of interest from, such as: weak ties, subgroups, junctions and routes of information and resources (Hanneman and Riddle, 2005).

Concepts Related to Social Network Analysis

Data gathering and visualisation are two concepts of significant importance when designing a tool for social network analysis, and constitutes two prominent challenges in the area. Analysis can be understood as the sense-making of data, visualisation is a powerful aid in this process (Krebs, 2010), and the gathering of data constitutes the foundation of social network analysis (Sharp, Rogers and Preece, 2007). In this thesis, we have focused on the aspects of data gathering and visualisation that intersects with SNA and therefore contributes to the process of building a tool for conducting SNA.

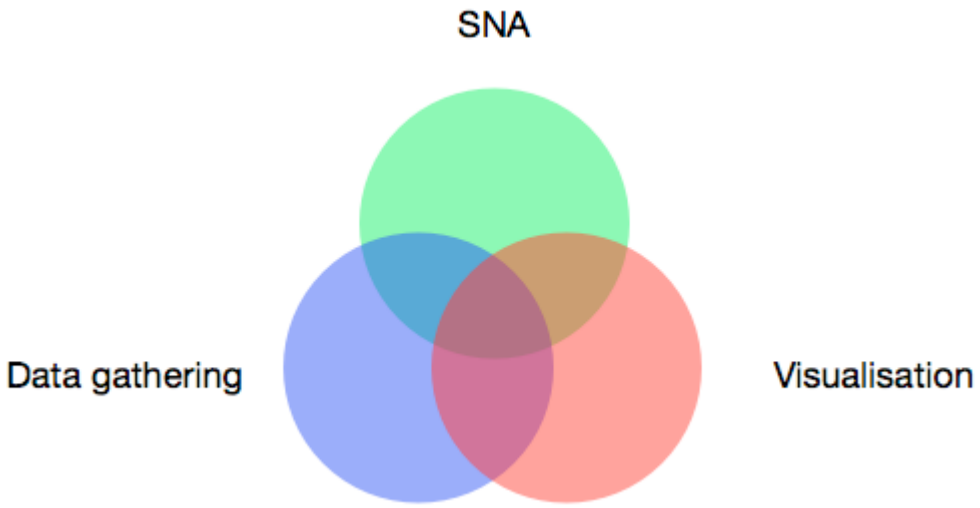

*Figure **1**. Illustrating the intersection of SNA, data gathering and visualisation fields.*

Data Gathering

The conceptual framework for this thesis is limited to the aspects of the literature on data gathering that relates to our aim of building a tool for SNA. Therefore, focus in this field is on questionnaires and more specifically on their advantages, limitations and use in SNA.

According to Sharp, Rogers and Preece (2007), questionnaires is a well-established technique for gathering opinions and demographic data. It consists of a number of defined questions, put together in a form and distributed to the desired population. This is a way of reaching large populations in cases where limitations in resources otherwise would have rendered this impossible (Sharp, Rogers and Preece, 2007). This technique is often regarded as well suited for receiving quantitative data. A great advantage, in comparison with for example interviews, is that the researcher does not have to be in direct contact with the responder. In many cases this gives the responder some freedom of choice of when and where to complete the questionnaire. The limitations of the study itself, naturally puts boundaries on this freedom; a survey on the street with a few questions handed out to pedestrians requires direct answers in a way that a longer, mail based survey does not. Another advantage of the technique is the possibility of privacy for the responder. Several studies show that responders in some cases tend to be more truthful and revealing in their answers, when not being eye-to-eye with an interviewer (Sharp, Rogers and Preece, 2007).

Questionnaires also have a number of disadvantages when compared to data gathering techniques that involves direct contact. This technique might in many cases be less suited for receiving qualitative data. The possibility for direct follow-up questions is limited compared to interviews. When there are no clarifications of the questions available, there is the potential risk of misunderstandings. Different people might have a vastly different perception of what is asked for, resulting in inconsistent or misleading data. Therefore all instructions and questions need to be precise and clearly worded to aid proper understanding (Sharp, Rogers and Preece, 2007).

Another problem is that respondents might skip questions they do not feel like answering or choose not to participate at all. The persuading effect of the meeting with the interviewer is not present, and studies show that questionnaires suffer from a big percentage of respondents ignoring it all together. Motivation therefore becomes a key issue for receiving data from large enough part of a population. Otherwise the problem of a potentially biased group of respondents arises (Sharp, Rogers and Preece, 2007).

Counterbalancing problems of motivation is an important part of success in this technique and demands a well thought-out design. The length of the questionnaire is a factor; the higher amount of work a participant must put down, the bigger the reward must be. Possible ways of motivating respondents include rewarding them with gifts, such as bonuses or gift cards. Another way is to make sure some kind of benefit is associated with the providing of data, for example the possibility to get feedback on the answers given. The questions must also be perceived as understandable and have sufficient directions provided (Follet and Holm, 2009; Sharp, Rogers and Preece, 2007).

As stated earlier, this technique is often regarded as well suited for gathering quantitative data but have some limitations in that no immediate clarifications are possible. This can however be dealt with by providing suitable answer alternatives. Closed questions, with a fixed set of alternative answers can be mixed with open-ended questions. For example, a simple “yes/no” check-box might be followed by a field for free elaboration of the answer. This can be one way of enriching the data gathered, but may make analysis and comparisons harder due to the wide range of possible answers (Sharp, Rogers and Preece, 2007).

Other ways of getting more qualitative data is to include ”rating scales” with a number of alternatives. This is often used to pinpoint opinions in specific areas. One use of this is to make a statement (for example; ”x is important”) and have the respondent make a notation on a scale rating from “totally agree” to “do not agree at all”. Another use is to rate a specific matter on a scale between two opposites, such as ”hard” and “easy”. One must be aware that both the way a question is asked, and the answer-alternatives given, have a significant affect on the answers. Different persons may also assign different values to the terms used in the questionnaire. Again, careful wording is of great importance to avoid misunderstandings (Sharp, Rogers and Preece, 2007).

Internet has provided the means to distribute questionnaires that reaches a large group of people, at a very low cost. There are two main types of questionnaires using the Internet; web-based- and email questionnaires, which both have their advantages and disadvantages. Web based simply means that the form is available at a certain URL address. The obvious downside to this is that only people who visits the site can complete the form, something that leads to an high risk of biasing, something that makes traditional sampling methods less usable. This has rendered this method much critique, even since the first trials in the childhood of the Internet at Georgia Tech

1994 (Sharp, Rogers and Preece, 2007). The upsides to this approach is the possibilities of aiding the respondent by "help" options, drop-down, pop-up menus and graphics and visualisations. Used in a good way this can enhance the user experience and heighten motivation (Follet and Holm, 2009; Sharp, Rogers and Preece, 2007).

In order to combat the problems with biasing and aid the focus on specific populations, the email-questionnaire can be used. If the email addresses to the responders are known, populations can be targeted very accurately. The limitations of an email brings some of the same issues as with a paper survey, and does not yet provide the same dynamic approach as do a web based variation. A solution to these issues is to combine the two methods; to invite the selected population to a website via an email-link. This way, the motivational aspects of dynamic content mixed with a personally directed invitation can act together to result in a higher percentage of completed questionnaires and thus avoid problems of a biasing of the population (Sharp, Rogers and Preece, 2007).

Several factors contribute to make an Internet based survey as effective as possible to reach the targeted population and get satisfying participation. One basic factor is the availability of the service, this, amongst other things, means that all web browsers should be supported and that the site shouldn't take too long to load, even with slower Internet connections and older machines. The possibility of persons responding several times and by that change the outcome must also be accounted for. One way is to remember and recognize the responders computer (i.e. IP address, browser or other) and restore the application to where they left of when they return. A pilot survey can aid the understanding of the responders reaction to the questionnaire (Sharp, Rogers and Preece, 2007). Today applications exist that can be used to map how the interaction with the site is done, and help to improve the form even further. One great advantage with web/email based questionnaires is that much of the information can be directly transferred to a database and analysed, something that can even further reduce the cost of resources and make data gathering more effective (Sharp, Rogers and Preece, 2007).

Visualising Information

In an age where we have access to more information than ever before, visualisation has become a popular method for keeping it intelligible (Steele and Iliinsky, 2010). While many of the studies that examine visualisation deal with its potential strengths, tapping the well developed and culturally spanning visual senses of humans to quickly give meaning to what we see (Perer, 2010), there are also a cautionary messages. The potentials of visualisations are great and there are many examples of very successful use, though it still remains an unwieldy ally. There are many pitfalls and while visualisations in the broad sense of the word have been around as long as human civilisation, the use of visualising large data-sets is a relatively new and uncharted territory (Steele and Iliinsky, 2010).

As the basic usage of visualisations aim to increase understanding and lessen the cognitive workload of dealing with vast amounts of information, the cardinal error could easily be summarised as anything that negates that purpose (Iliinsky, 2010). While the world of visualisation is not black and white enough to construct a do-and-do-not-list special considerations must be taken to the domain visualised, the message intended, and the target audience (Iliinsky, 2010). Going into more detail on pitfalls identified by the literature we find that the choice of visualisation type (i.e. type of graph or suchlike), what data is visualised (and likewise not visualised), and how that data is visualised, are all areas that need to be properly

addressed. Another common pitfall is to want to visualise too much data in one view. This might seem overly simplistic but to illustrate we will give a brief introduction to each area.

In our society we deal with different types of visualisations everyday. Many times they are so integrated into our everyday lives that we do not think of them as the powerful visualisations they are. Maps are a good example of visualisations that would be difficult to live without. Public transit systems (e.g. London Underground) famously takes the maps-visualisation further to guide travellers from one part of the city to another (Fry, 2003; Iliinsky, 2010). While map-based visualisations arguably are naturally connected to what they represent this kind of translation might not be as straight forward when it comes to visualising behaviours of the stock market or in a school yard. Available visualisation methods does not always lend itself to naturally visualise such data, but attempting to be creative and invent new forms might well work against its propose. The understanding of the data may be impaired as the cognitive workload of assigning meaning to the visualisation becomes too great (Steele and Iliinsky, 2010).

The graph is a technique for visualising information where entities are represented by nodes, and the relationship between these entities, are represented by edges (Fry, 2003). In the case of visualising networks the graph has been around since the early 20th century when researchers such as Jacob Moreno started to analyse social networks (Krebs, 2010; Cross, Borgatti and Parker, 2002). The question have been raised if we can go beyond the graph no compelling alternative have been presented other than using the traditional graph in conjunction with other visualisations for greater understanding (Viégas and Donath, 2004). While not being as obvious in its representation as maps, graphs are well established for the use in visualising networks (Krebs, 2010).

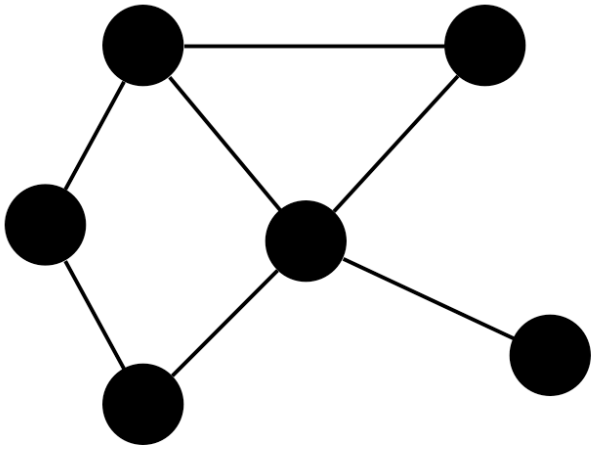

*Figure **2**. Visualising a social network with a graph.*

While visualisations allow us to easily deal with vast amounts of data there are limits to how much we can handle. It is easy to want to visualise many different kinds of data in the same visualisation. However, in instances where data-sets are large there might be a significant challenge to maintain meaning to just a few kinds of data (Fry, 2003). As with any design there is a point where too much or too little will render the product inefficient and useless (Fry, 2003).

Selecting the data to be visualised is a preamble to deciding how to visualise it. Largely depending on the type of visualisation used there will be a certain amounts of visual

representations available (Shapiro, 2010; Spears, 1999). The most commonly used visual representations are: size, colour, shape, location, networks, and time (Shapiro, 2010). In the case of graphs size, colour, and shape are the most common representations apart for the inherent representation of the network itself (ibid). Research has been conducted on using movement (i.e. animation) as a mean of visualising dimensions of data. While users tend to find animations engaging there have been inconclusive results on whether animations add to the understanding of the data (Fisher, 2010). If the data visualised is subjected to change over time, including this aspect in the visualisation may add to keeping the graph relevant and uncluttered even in large data-sets (Fry, 2003; Shapiro, 2010; Fisher, 2010; Spears, 1999).

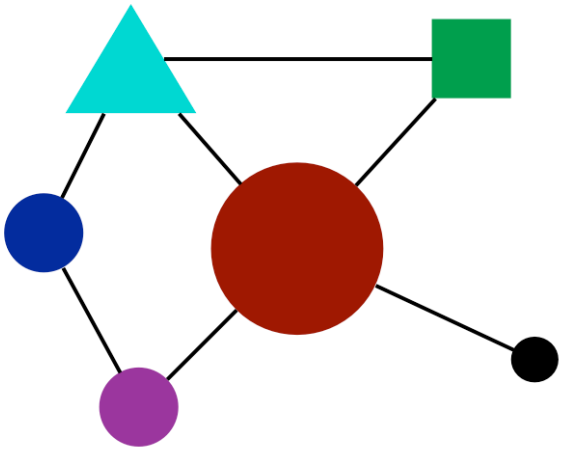

*Figure **3**. Visualising the same network as in figure **2**, but using colours, shapes and sizes to incorporate more information.*

When visualising information, one of the key considerations is to avoid taxing the cognitive faculties of the users (Sharp, Rogers and Preece, 2007; Tidwell, 2005). This means using elements, language and patterns that feels familiar to the user and allow them to do what they want to achieve without unnecessary (Tidwell, 2005). If designing something with an original appearance this is even more important, as users will base their understanding on things they are already familiar with (Tidwell, 2005). In order to know what the users might consider familiar it is necessary to understand them (Tidwell, 2005). This understanding may be achieved by involving the users in the design process (Sharp, Rogers and Preece, 2007; Tidwell, 2005; NRC, 2009; Sein, et al., 2011). Tidwell (2005) presents 12 behavioural patterns of users, such as *instant gratification* and *deferred choices*, based on observations made by interface designers and researchers that highlight important considerations when designing visualisation interfaces to support a good user experience.

Case Study Domain

The case study domain used in this thesis is the domain of crisis management. This field has provided context for our work as well as provided the organisational feedback needed to conduct Action Design Research. The case study and organisational involvement have provided invaluable data and feedback during the process.

The research of Christian Uhr (2009) has been an inspiration to this thesis. While his research is primarily focused on understanding multi-organisational emergency response management, and as such has been a valuable resource and theoretical backdrop for our domain specific research,

he also offer many points more closely related to our tool-building (ibid). Amongst other things Uhr (2009) developed and tested a method for collecting data and analysing emergency response management networks. Based on these two areas Uhr (2009) has been a great source of both inspiration and theoretical reference for both our case study domain and the tool-building.

Researchers and practitioners see great potential in the use of SNA to facilitate understanding and development of emergency management but call for more efficient tools to be developed for the use of practitioners (Uhr, 2009; NRC, 2009). Emergency response networks often include agents from many different organisations as well as private actors. These, many times, ad hoc networks does not follow prescribed plans or easily discernible patterns (Uhr, 2009). By using SNA tools the networks can be better understood and in turn help to strengthen the emergency resilience and preparedness of both communities and emergency response networks (Uhr, 2009; NRC, 2009).

While much research have been done in the field of SNA and the development of aiding tools, these efforts primarily focus on the needs of researchers and not the everyday need of emergency response practitioners (NRC, 2009). By allowing quick visualisations specifically made for practitioners SNA tools would be useful and gain acceptance as means of maintaining a healthy network and information environment (NRC, 2009). As such, tools based on SNA, would generate immediate use during all phases of an emergency to promote situational awareness and facilitate coordination (NRC, 2009) as well as aid in analysis of the response management (Uhr, 2009).

To gather the amount of data needed to generate useful visualisations is usually a time-consuming undertaking (Uhr, 2009; Francis and Fuller, 1996) and the availability of relevant data is often a problem (NRC, 2009). To gain a full understanding of a network it is necessary to include many, if not all, of its participants as the single perspective of centralised management poorly reflects the actual response network (Uhr, 2009). Understanding how people interact and communicate within a network is considered important as this helps to build flexibility into the network to avoid or deal with communication breakdowns if they occur and to identify how to most efficiently communicate with the right people (NRC, 2009). While organisational charts do account for some answers they do not aid understanding of an emergency network as containing both formal and informal parts (Uhr, 2009; NRC, 2009). Obtaining data from informal sources is considered important but difficult (NRC, 2009).

While the potential of using SNA tools in emergency response operations is believed to be equally revolutionising as the adoption of geographical information systems (GIS) have been, its use cannot be left only to researchers (NRC, 2009). Researchers alone cannot gather data to reflect intra- and inter-organisational in the timely fashion needed to visualise the changes in a network to be used for decision support. This points to a need of developing techniques and tools that allow members of networks to produce and report data themselves, in order to aid researchers and analysts (ibid).

Research Method

As research method for our thesis work we have used Action Design Research (ADR). ADR aims to address the dual mission of IS-research of both contributing to the furthering of theoretical understanding and the solving of current or anticipated problems (Sein, et al, 2011). ADR is a Design Research (DR) method. DR is mainly focused on technical aspects and generalised design knowledge of building IT-artefacts leaving the organisational context as a secondary consideration. DR has been criticised for the lack of connection to the problems of every-day practices in organisations and for being too theoretical. ADR address this by drawing on principles of Action Research (AR). AR focuses on solving problems in everyday practice and keeps the organisational intervention as a primary concern. By incorporating aspects of action research into its design research foundation, ADR bridges the technical and the organisational domain. It aims to contribute both to the theoretical understanding and to solve situated organisational problems. This is achieved by building an artifact to solve a situated problem that has been identified as an instance of a general class of problems. The lessons learned are continuously abstracted to add to the understanding of the problem class and its solution. This is then used to derive design principles as solutions to the class of problem (Sein, et al., 2011). The integrative approach of ADR addresses Encarnação's (2011) call for closer ties between academia and practitioners, encouraging the use of visualisation technology, to fuel understanding and innovation.

While research with similar approaches have been undertaken (Sein, et al., 2011) ADR is a new method. Satisfying evaluation has yet to be conducted on whether it reaches its intended goal of answering the critique of DR by incorporating AR aspects. Frisk (2011) regards ADR as an interesting option for future research and states that its dual focus on both the artifact and the organisational environment could possibly help to heighten the relevance of IS-research. The reader should however keep in mind the lack of a substantial body of research proving or disproving the effectiveness of ADR.

ADR consists of four stages: problem formulation; building, intervention and evaluation; reflection and learning; formalisation of learning. The three first stages are conducted iteratively and in parallel. The stages adhere to a number of principles to guide the work.

Problem Formulation

In the first stage the research question is formulated. This can be based on input from researchers, users, practitioners, existing technologies or prior research. The research problem is cast as an instance of a class of problems for which the research aim to generate knowledge about. Guiding principles in this stage are to keep the research inspired by practice and to maintain a theoretically sound base for the artefact.

Building, Intervention and Evaluation (BIE)

During this stage the artefact is built, put into the organisational situation and evaluated continuously. The initial design of the artefact is based on the findings of stage one. As the artefact is used in the organisational context it is evaluated and refined to meet the needs of the users. Depending on what kind of artefact that is considered this stage can take different forms. In the case where the aim is innovative technological design this stage starts with limited organisational exposure of the artefact. The artefact is then gradually put into larger organisational context. Guiding principles in this stage is to let the artefact and organisation

shape one another as well as letting researchers and practitioners influence each other. Another important principle is to allow evaluation to be continuous and organisational situated.

Reflecting and Learning

This stage deals with the experiences and insights from the BIE stage in respect to the class of problems defined in the problem formulation stage. While the BIE stage deals with the situated problems this stage puts them in broader perspective to address the general research issues. This stage considers the *guided emergence* of the artefact as a guiding principle, referring to the emergence of the artefact through the repeated cycles of BIE.

Formalisation of Learning

In this final stage the lessons learned in the organisational situation are developed into general solutions. The solutions are formalised as design principles to address the class of problems. In this stage the guiding principle is to generalise the outcome of the organisationally situated intervention and artefact building.

The Design Process

The design process in our work could be outlined as follows: we followed the ADR method of repeating the three phases: building, intervention, evaluation (Sein et al, 2011). We repeated the process two times; the first iteration of building was based on the problem formulation and the second followed up on the feedback received from the evaluation of the first.

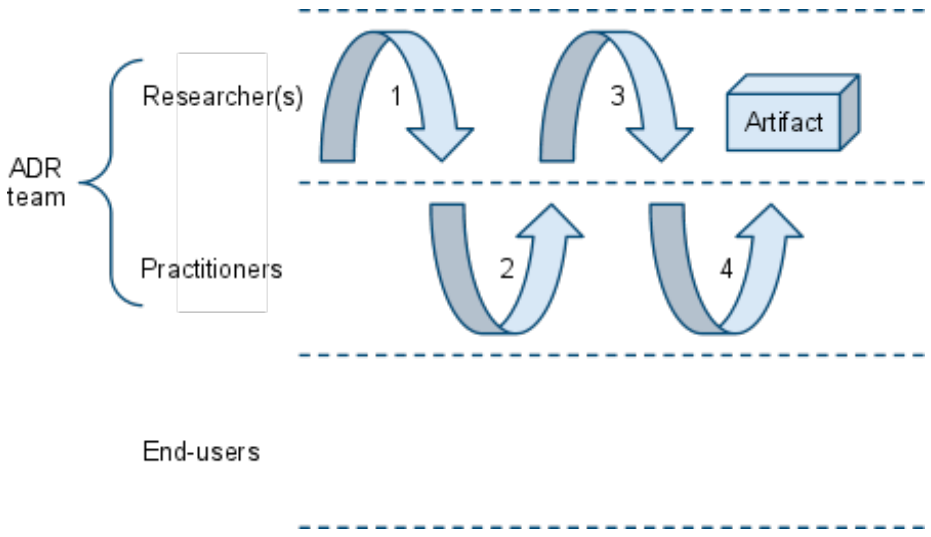

*Figure **4**. Our BIE workflow.*

Figure ***4*** visualises our work process based on the ADR's Generic Schema for IT-dominant BIE (Sein et al, 2011). The numbered phases represent: 1) the building of the first prototype, 2) the evaluation there of, 3) the building of the second prototype and 4) the last intervention and evaluation sessions. Following the ADR process the next step would be to involve the end users, given that the development process has reached a stage where it is relevant to include them. The aim of this thesis is to examine the design space of network visualisation tools by building a

prototype, and reaching a stage where end users should included was not within the scope of this thesis.

Formulating the problem

We started out on a mission to find and formulate the research problem, beginning with a thorough discussion together with Crisis Response researchers. The next stage consisted of researching and testing different tools to get a better understanding for the environment of SNA supporting technologies and tools that existed. We tried several tools for storing network data (with nodes and edges in graph databases) and tools for visualising different kinds of social networks (both stand-alone desktop applications and, mainly, web browser applications).

Constructing and Evaluating the first prototype

Based on the findings from the first stage (formulating the problem) we worked in design sessions with discussions about the domain (with input from the researchers) and whiteboard wire framing. In accordance with the ADR method, we based this process on our conceptual framework, an integrated theoretical framework drawing on the field of SNA, and where it intersects with the fields of data gathering and visualisation. This led to the implementation of a first web based prototype for entering details about the relations between the people involved in an event. Early on, after creating our first prototype, we met with an SNA researcher conducting research about the usage of an online web forum during the 2010 Haiti earthquake disaster recovery. We demonstrated our functional prototype and received feedback on how to improve it further, with more advanced weighting algorithms and leads into existing SNA research that we could look further into.

Creating the second prototype

Based on the attained feedback from the meeting with the researcher we continued the development with sketching, designing and implementing additional features. The feedback concerned the graphical user interface, in what ways and situations to use the tool as well as requested additional features, such as the inclusion of more information dimensions into the visualisation.

The first single-user prototype was improved and split into two parts: a server side and a client side application. The server side application was implemented in Javascript and the framework Node.JS (www.nodejs.org) which was used to create an HTTP server that is also able to handle HTML5 WebSocket connections with Socket.IO (http://socket.io/). The latter was used for handling real-time communication to and from all connected clients. The client side application part was developed using basic HTML5 as well as HTML5 WebSockets (with Socket.IO) for real-time communication with the server (and thereby on to all other clients), jQuery (www.jquery.com) for dynamic forms and handling of events, Arbor.js (www.arborjs.org/introduction) for graph calculations with nodes and edges and HTML5 Canvas for the dynamic graphics visualising the social graph. It was all hosted on a virtual Linux server.

Intervention and evaluation with practitioners

Following the ADR method we conducted continuous intervention and evaluation sessions during the design process. After creating the second stage prototype we did four rounds of intervention and evaluation. The three first sessions were each together with different rescue service professional - or practitioners as they would be referred to in ADR terminology. These

practitioners all had several years of experience of managing rescue service operations. Besides these roles, one of them was a manager for investigation and analysis of rescue operations and another had IT responsibility within the rescue organisation. The fourth intervention and evaluation session was performed as a part of a meeting between researchers, practitioners, and domain experts of crisis response management from different organisational backgrounds. Representatives of the Rescue Services, the Police Force, and the Swedish Security Services where involved in using, discussing and providing feedback on the prototype and its application in inter-organisational contexts.

At each intervention and evaluation session we started out with presenting wide description of the topic of our work and the functions and intended use of our prototyped tool. It was presented verbally and based on a manuscript we prepared before the intervention and evaluation sessions:

> *We are designing a tool for visualising connection and collaboration networks which can be used for effective analysis of these networks. Our starting point is that the tool can be used before, during or after an event to map how the mobilised network looks (or looked). The mapping is generated through the process of involved persons entering what relations they had during the event. The people indicated in these relations, then get to answer which relations they had. The gathering is conducted through a simple web interface to which the respondents are invited through email. The visualisation is done in real-time and shows how all relations are connected. The tool will also be able to show additional aspects of these relations, such as the time of contact and the users comments.*

We continued by asking a few questions (as semi-structured interviews) about the user´s view of the phenomenon of collaboration networks in crisis situations and whether new contacts and channels of communication were created, and if so, how they were created. They also responded to the question of what need they saw for visualising and understanding collaboration networks, as well as if they currently were using any tools to do this.

This was followed by a very short explanation of how to use our prototype and almost immediately allowing the practitioner to interact with it and fill in relevant data based on their own experiences. During those sessions where only one practitioner was present, we also simulated multiple collaborators at the end of the practitioner´s test phase, to get some input on how this was perceived. This was done by connecting our own computers and manually inputting data, affecting the practitioner´s interface and showing the new network structure that appeared.

After the test was conducted, the prototype was left running and visible but we continued the evaluation with questions about the prototype and its usage. The practitioners were asked about which possibilities and gains as well as which problems and difficulties they perceived when using it. We queried them on what kind of information they thought would be interesting to gather with a tool like this (such as different dimensions as means of communication, organisation, geographical location, time, particularly important contacts). We also asked who they thought could be interested of this kind of tool and when they would be interested in doing these kinds of analyses (i.e. before, during or after an event).

In addition to doing audio recordings and taking notes of the sessions we also captured screenshots and a few screen recordings of the prototype in use during the evaluations, which

were used for recollecting what data and of what types were entered by the different practitioners.

Identifying design solutions and principles

Analysing the feedback from our sessions we continued by discussing and sketching suggested design solutions set to answer problems and requests extracted from the domain of emergency response management. We based this process on our conceptual framework as well as on the knowledge and experiences gathered through the previous stages of the design and evaluation sessions. This work paralleled to the ADR stage *reflecting and learning*, and the suggested design solutions that emerged came to be in accordance with the principle of *guided emergence*.

In order to answer to the next stage in the ADR process, *formalisation of learning*, we continued to merge our findings with the theoretical base of the conceptual framework in order to create design principles. We generalized the findings in the light of the conceptual framework which resulted in these principles, meant to provide guidance for further research and design work on network visualisation tools, outside the domain of emergency response management.

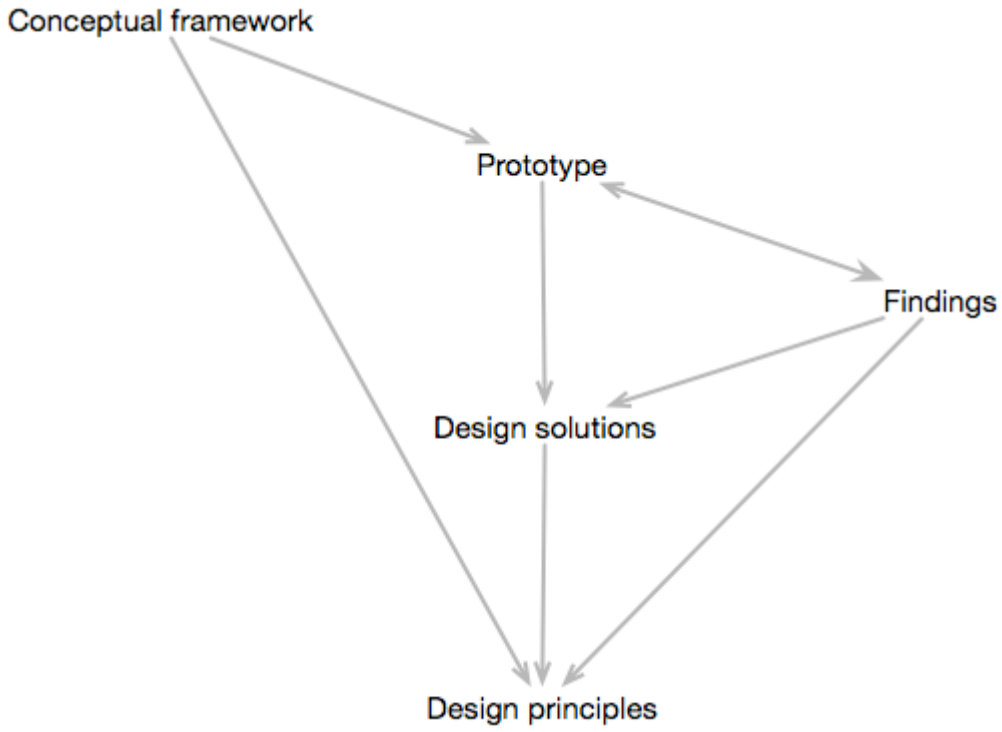

*Figure **5**. Illustration of how different aspects of the design process have influenced each other.*

Findings

In this chapter we present the findings from our design process. We present them in the order they relate to the ADR-methods two first stages, *problem formulation* and *building, intervention and evaluation*.

Findings from the problem formulation stage

The introduction to the field was given by researchers that in their research had noticed a growing interest and need for SNA for emergency response networks. They had also noted the growing use of visualisation tools to aid understanding of emergencies. Amongst the notable tools were Ushahidi (www.ushahidi.com) and the Japan Quake Map (www.japanquakemap.com). The general notion was that technology as these two examples represent have become both mature and widespread enough to gain traction in the field of emergency response.

Practitioner interest in SNA

Our early research into the use of SNA for emergency response networks supported this notion. The usefulness and need of SNA to understand emergency response networks was already well established (Uhr, 2009; NRC, 2009). Uhr (2009) applies SNA to research and understands multi-organisational emergency response management and concludes that it aids in the identification of key persons and illustrating the complexity of the networks. Practitioners also share the interest in SNA but notes that the tools and methods available does not support practitioners during an emergency (NRC, 2009). SNA research show that while there is a wide variety of fields where SNA can and have contributed to the understanding of them these are primarily research based (ibid). The participants of the NRC workshop (2009) highlighted the need for SNA-tools to be used by lay persons in their profession as support.

Lack of tools for lay analysts

During our introductory research we could not find any SNA tools for lay analysts that deal with real-time network visualisation. While there are many powerful tools, such as R (www.r-project.org), these all presuppose that extensive data gathering be done prior to visualisation and analysis commence. This is both time consuming and ill suited for real-time needs. Available tools for lay people, such as Netvizz on Facebook (apps.facebook.com/netvizz), draw on existing and static data. These available tools and conventional methods kept the network and analysis as well as the data gathering and visualisation temporarily disjunct from each other.

Unexplored design space - real time support

As called for by NRC (2009) SNA tools to be used by practitioners in emergency response situations need to offer more direct usefulness in order to gain acceptance. The noted disjunction between data gathering and visualisation would not meet those needs. This suggested to us that the design space for multi-user real-time SNA tools targeted for lay-analysts in their field of work was still much unexplored.

Findings from the BIE stage

In order to receive feedback and input from practitioners we started to build a prototype. The development of this prototype required us to consider new questions. Based on our research into SNA and visualisation the graph was quickly decided upon as our base due to its common role in network visualisation.

Based on these findings we also decided to make the prototype web-based as to easily allow future distribution and multi-user testing. On researching suitable technology for our prototype we considered several alternatives, such as Flash (www.adobe.com/flash) and Java applets (java.sun.com/applets), but finally decided on HTML5 technologies. While not fully supported by older browsers it is a widely supported standard (Gutwin, Lippold and Graham, 2011).

Our early research clearly indicated that multiple dimensions of a social network are generally of interest but we decided to keep our first prototype simple and focusing on relationships alone.

The first prototype

Upon starting the first prototype (visiting the URL for the web application) the user was faced with a form and an image of a network graph with him/herself in the middle (figure ***6***). The form asks for who you contacted in a specific event and in which way you contacted (called, emailed or met with) them.

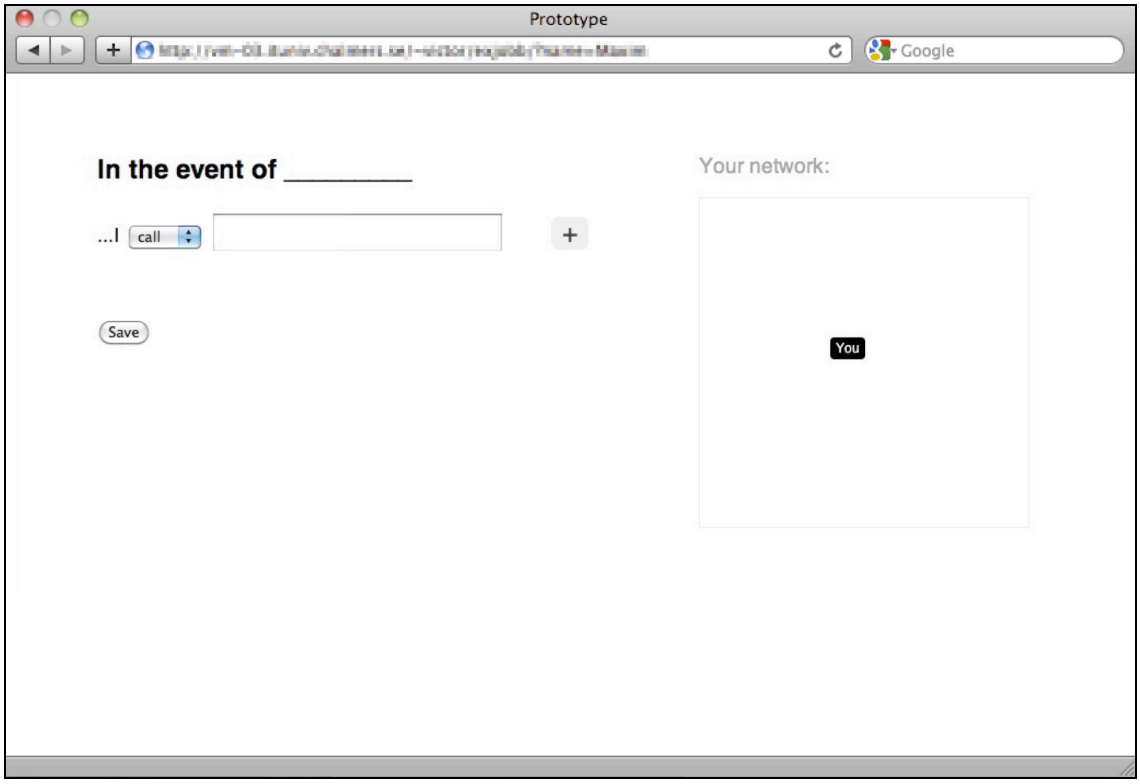

Figure **6**. The start interface of the first prototype.

Immediately when the user starts to fill in the form, the image graph is updated to show the users network with him or her in the middle and all his or hers contacts around (figure *7*). Each relation is represented in the form as a row of who the user contact and how. Pressing the plus button would instantly add another row for adding more relations.

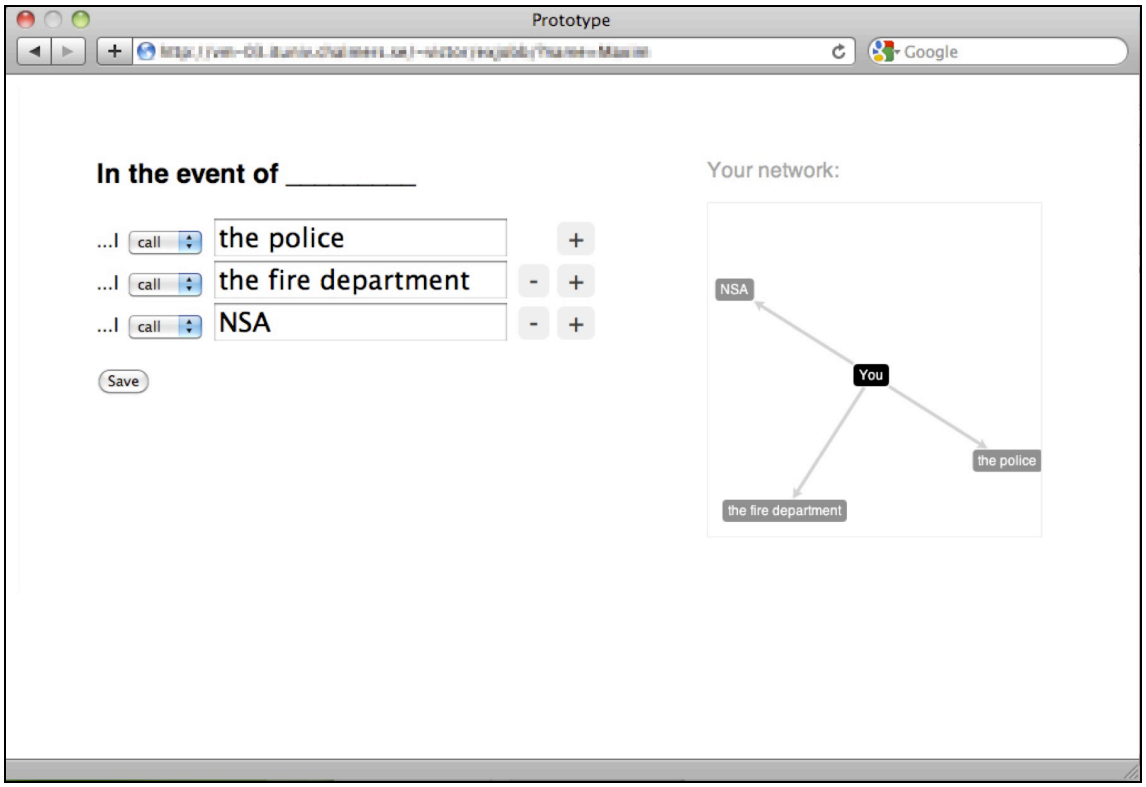

Figure 7. The first prototype, showing three relations filled in.

The second prototype

After the first prototype and the intervention and evaluation thereof (all *Intervention and Evaluation sessions* are explained in the next section) we continued with further development. The second prototype was an evolution with a series of new features.

Here is a usage scenario of this prototype:

- You receive a link, inviting you to collaborate on describing a network.
- You visit the prototype and instantly see the current network structure as filled in by previous respondents.
- You start by filling in who you contacted and your contribution to the network is immediately visualised.
- You can also, in real-time, see when other people are entering more connections and changing the network.

The second prototype supports multi-user collaboration which enables relations filled in on one computer to instantly show up on all other connected computers. The relations are not sent on a character-by-character entry basis but after each finished relation entry (upon adding a new relation, leaving an input field or pressing the save button) to make sure only completed relation entries are sent to the other clients.

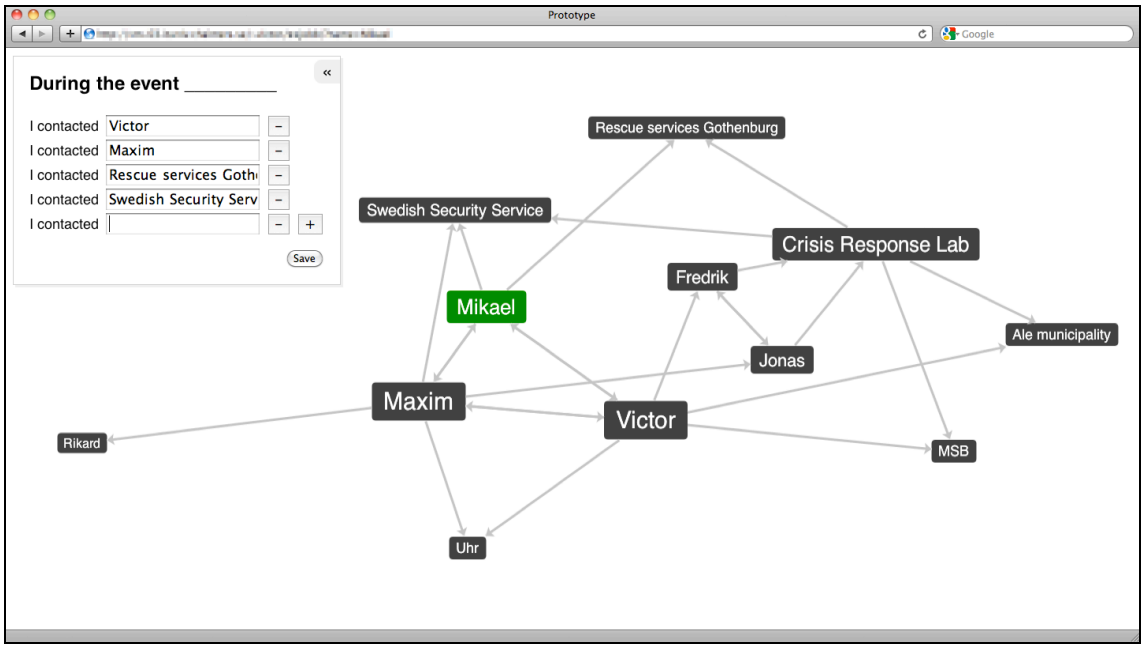

*Figure **8**. This is a screenshot of the second prototype. The user is highlighted in green.*

The full size of the browser window is used for showing the social graph (figure ***8***). The form for entering relations is shown over the graph but can easily be toggled to slide away to allow the entire graph to be shown. Nodes are automatically positioned so that the total network will use as much of the available space, and the size of the nodes are automatically determined by the amount of connections to and from other nodes.

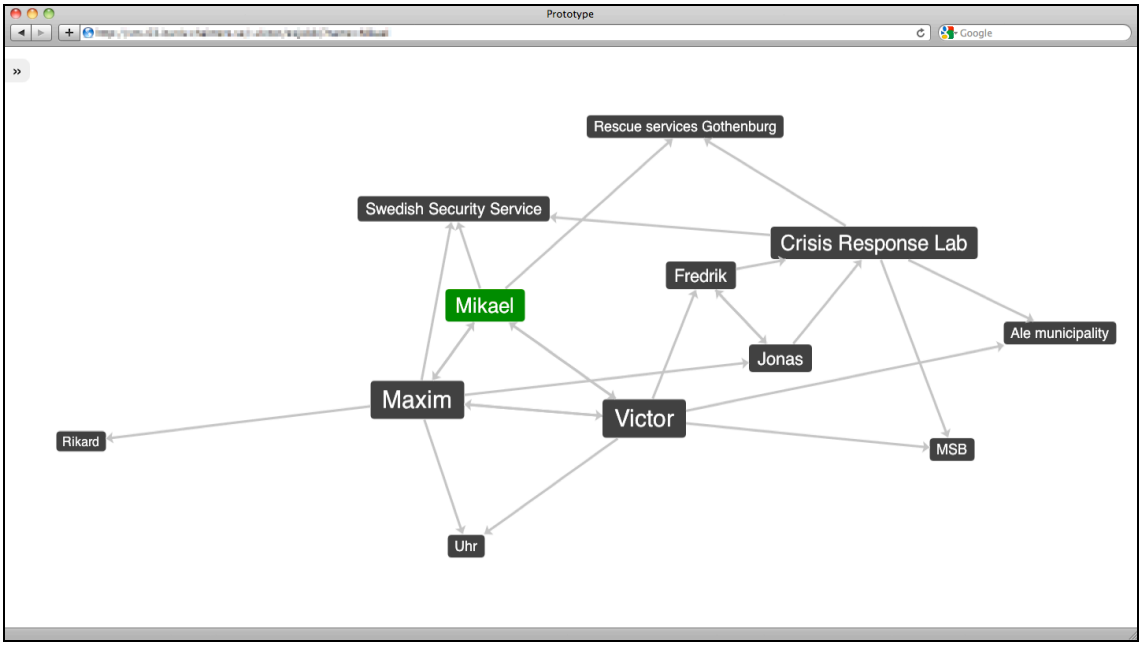

*Figure **9**. A full screen view of the prototype.*

As a response to feedback of keeping the entry as simple as possible the communication type (calling, emailing or meeting with a contact) was removed in favour of a less complex interface. This can also be re-added at a later stage as an additional optional field upon selection of a relation in the network graph. Also, to ease entry, new fields were automatically selected for input after adding a new relation.

If you leave the prototype and return at a later time (using the same personal link) the tool will recognize you, find your data and have all the input fields and your network filled in and ready, right where you left off.

Findings from Intervention and Evaluation sessions

During our Intervention and Evaluation sessions, the prototype tool was thoroughly tested by both researchers and practitioners of the crisis management domain. These sessions were designed to generate feedback on the usability, features and overall design of the prototype, to be incorporated in the design process. It is important to state that guidance and answers to any of their questions were given to the practitioners in order to aid their understanding of the intended use and features yet to be implemented. Feedback during the sessions touched several areas, ranging from abstract phenomena to very practical considerations. Through the course of the intervention and evaluation process, a number of areas appeared repeatedly, whereas some subjects where brought up only by one researcher or practitioner. Below we will present the results of these sessions, divided into categories by which area of the tool prototype they concern. The statements below are to be regarded as the opinion of the chosen population of responders/evaluators, and not as undisputed facts.

Following the ADR method, we continuously performed development and evaluation side by side during the design process. The work of incorporating the feedback given by practitioners and researchers was an effort that followed throughout that process. The practical results of this became a series of suggested design solutions, matched to answer problems and requests extracted from the domain of emergency response management. These possible extensions of the prototype have not been implemented, and exist only at the design stage as concepts and possible solutions. During the process, efforts were made to produce solutions that can also be of value for usage outside the chosen domain. These possible solutions are however exemplified based on the domain of emergency response management. The following paragraphs, which each presents one area of interests from the discussions, will be divided into the two sections *Usage of the tool* and *Dimensions of the visualisation.* Some subjects refer to both these sections, and will then be placed where they seem most appropriate.

Usage of the tool

The following paragraphs will describe the discussions and feedback given from the practitioners that dealt with the usage of the tool, divided into different areas.

Input methods must be simple and intuitive

A reoccurring theme concerned the entry of information by the user. The respondents almost unanimously stated that the process of manual input of information must be kept simple. A time costly input procedure, in the domain of crisis management, means that the application will not be used. If extra information is needed, it is important that this can be included at a later time. Incorrect information must also be editable. The similarities to an address book was noticed and a respondent said: “This could be used as I use my address book today, but with benefits”.

Suggested design solutions: The amount of information needed to complete an entry into the tool should be kept to a minimum. It must be possible to add additional information later. A solution for this is to make pop-up windows visible by hovering or clicking on any node or edge, where the user can see any information, edit it, and complete it if necessary. Different choices can be

illustrated with click-able glyphs. For example, a phone symbol for contact by phone or a letter symbolizing e-mail contact.

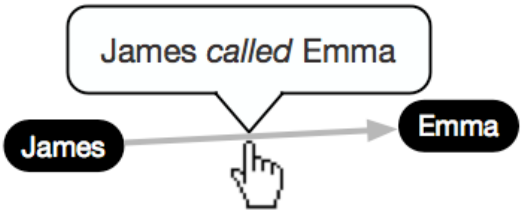

*Figure **10**. Example with edges that show more information when hovering/clicking on them.*

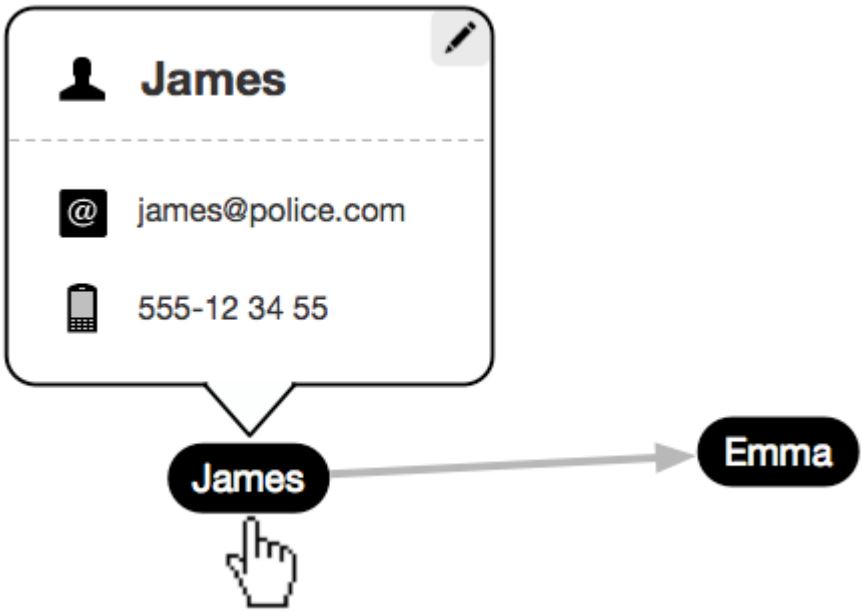

*Figure **11**. Example showing more information about a node when hovered/clicked on.*

Usage in crisis response situations - motivating use by instant rewards

A second theme to arise regarding input revolved around the user´s motivation for taking the time to use the tool in a stressful crisis situation, where time often is of essence. Several practitioners stated that the system must instantly give a reward that at least matches the time and work needed to fill in the information. The notion that the information would be valuable for analysis later would not be enough. Several examples was given to what this instant gratification could consist of, most of them revolved around the possibility to use the prototype as a memory aid, regarding the contacts made. Information for social network analysis (SNA) is usually attained through surveys, often in the form of questionnaires (Sharp, Rogers and Preece, 2007). The practitioners of crisis management did in several cases not view the tool mainly as a questionnaire or even as a tool for SNA. Instead, they reflected upon it from their context of crisis response work and judged its features based on this. The tool was in these cases regarded mainly as an aid for fieldwork during emergencies. One practitioner stated "It [the tool] has to be helpful for me at the time I do the input, if not I will simply not take the time to use it." On this topic, it was stated that direct practical results while on a call, was viewed as more important than the opportunity of evaluation later. Practitioners from the rescue service also stated that even though circa 8500 missions are conducted every year by their organization, only about twenty of them are

thoroughly examined and analysed. Several of them saw a potential in the tool to heighten this number, if implemented and widely used.

Suggested design solutions: To present the user with instant gratification and thereby motivate use, the tool can act as a replacement for other methods of aiding memory. The use as a written address list motivates input according to practitioners. Adding useful information about the contacts during a mission can be supported by allowing "free-text"-fields connected to edges and nodes. Information entered during emergency response missions can then be used for analysis later.

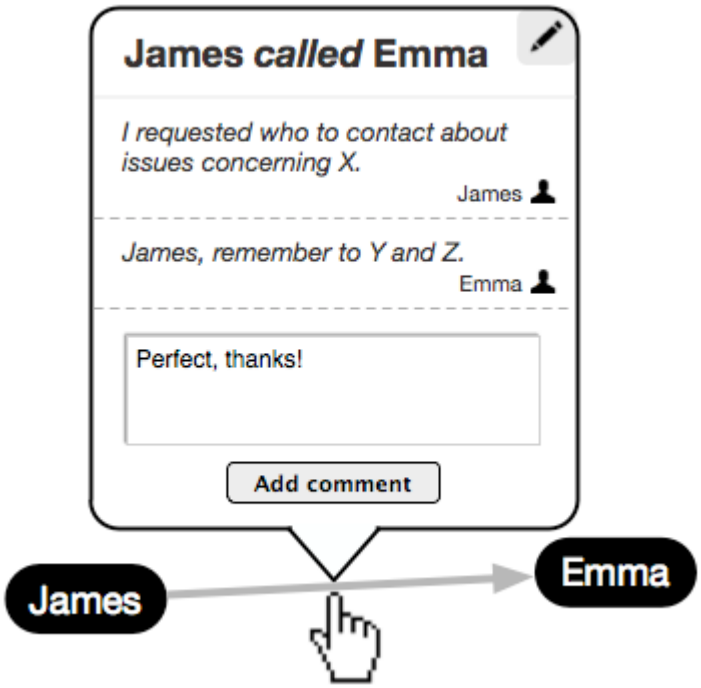

*Figure **12**. Example with free-text comment fields for adding more information about an edge.*

Cooperating with external actors - generativity and security

For usage in the field, it was stated that the first hand contacts made by oneself was of the greatest importance. The possibility to see other people's contacts had a secondary role, and was regarded more as a possible option than something to be presented with at all times. When asked, the responders who had this view, more precisely those involved in emergency response management, all saw the possibilities for seeing their contacts connections with each other for later analysis work. They did however not think that it would be possible to collect this information from everybody. Some concerns were brought up regarding the efficiency and security of the invitation system; one respondent said "Will people be interested in participating, and what do we want them to see?"

Suggested design solutions: In order to receive input from external contacts, they must be invited to the visualization. One example of invitation is via a personalized e-mail link, or alternatively via a link sent via telephone text messages, with or without a password. The invitation process could be as simple as an "invite"-button. Since information about emergency response operations may be sensitive, some filtration of what invited co-users gets to see and edit is needed. Different levels of trust might be used, ranging from the invited user only being able to see his or her own contacts, to full viewing and editing rights. The less work needed for the invited user, the lesser the motivation needs to be to enter the asked for contacts.

Automatic import of information where applicable

In conjunction with the discussions revolving the manual input of information, many of the practitioners brought up the possibilities of automatic input, via import of data from other systems. Examples where given of communication logs which contained information that could be usable. No system tracking was however available for calls made by the practitioners on their personal cell phones. No reliance could therefore be given to the completeness of imported data, and some degree of manual input was seen as a necessity. A combination of imported and of manually inputted data was requested.

Suggested design solutions: The tool should be integrated with surrounding information systems, in order to allow import and export of data. Examples is importing phone-lists and communication logs for visualization, as well as exporting data to databases for more complex data mining. Imported information should be made editable in the tool, in order to suit the users needs.

Templates for specific situations

One practitioner brought up the idea of having a list of suggested contacts to make, based on previous similar situations. A list like this could appear in the tool if that situation was specified. The system with lists, suggesting contacts to make in a given situation is used today, but not accessible from the field in an easy way. This discussion lead to the notion of the responder that the analysis made from the tool could help in creating and refining this type of lists.

Suggested design solutions: When starting a new visualization session in the tool, the user should be given the option of choosing among templates, based on the knowledge of previous situations. A template should contain suggestions of important contacts in that situation; for example, the weather report central and surrounding fire departments in the case of a big fire. These contacts would then be existent in the graph from the start as memory aid, visualized as nodes without any edges connecting them. Templates could also contain presets of what input information to ask from the user.

Dimensions of the visualisation

The following paragraphs will describe the discussions and feedback given from the practitioners that dealt with the different aspects and dimensions of the visualisation, divided into different areas.

Aspects of visualising communication

Several questions and suggestions came up regarding different aspects of showing information about the contacts made. All of the responders, to some degree, requested additional information about contacts. They did not view contacts as binary; either contact or no contact being the only two options, instead they saw several dimensions. One was the status of a contact, if initial contact is taken, is it ongoing, or is it finished? This view exemplifies how some practitioners viewed the tool as being a part of the fieldwork. Another aspect regarded the number of individual contacts taken with a certain connection; many practitioners wanted the edges to reveal how intense this connection was, by the edge becoming thicker or brighter. The intent of the communication was also important; was it taken to inform, to collect information or to make an order? Some possibility to save additional information about contacts was also requested, this information would be useful as a memory aid during long operations, spanning days or even weeks. The method of contact was an issue, responders wanted to know if it had been via mail, cellphone or face to face.

Suggested design solutions: In order to present the requested information about contacts without confusing the user, information must be able to hide and show on demand. There can be controls for hide/show of certain information for all edges, as well as the option of revealing all info about one edge by clicking on it. Some important information can be visualized and visible at all times. This includes the number of communications taken with a certain contact; visualized by the thickness of the edge, and the most prominent direction of contacts taken between two nodes; visualized by the size of the arrowhead. Examples of other information to include is, means of contact (mail, telephone, person to person, group meeting), the time of contact and the information presented.

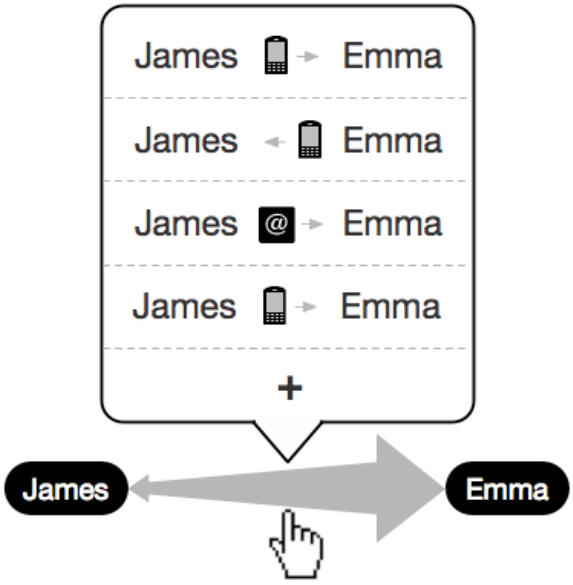

*Figure **13**. Example visualisation showing several communications between two contacts. Arrows are showing the directionality of each contact, glyphs are visualising the mean of communication and the thickness of the edge shows the proportion of the directionality between the nodes.*

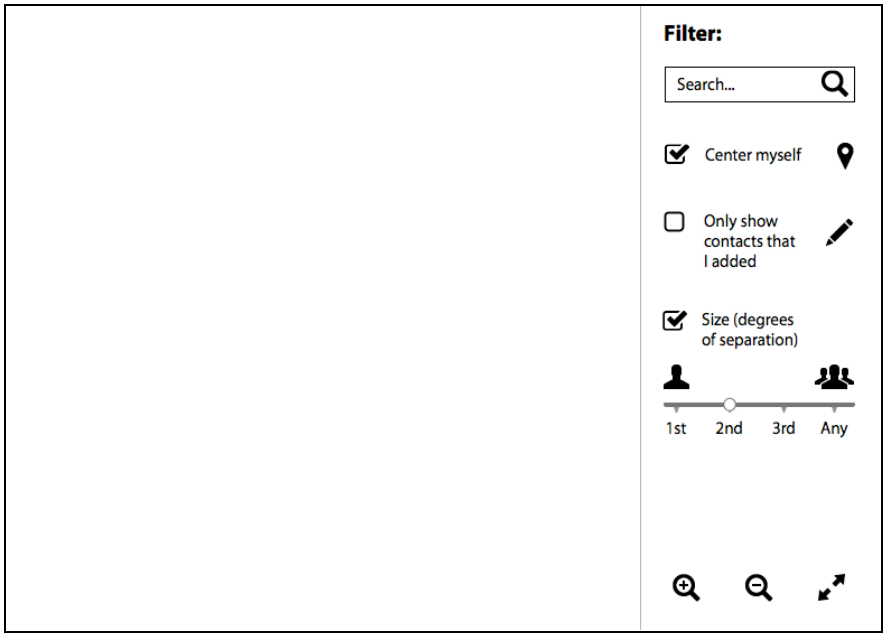

*Figure **14**. Example with settings for individually adjusting what information is shown.*

Contact management - roles, persons and organisations

A fact that became apparent early in the evaluation sessions was the multitude of variations of the input. Individual differences and interpretations of the tool resulted in nodes representing a multitude of things. Some responders put in the names of the persons they had contacted, others the roles these persons represented (i.e. commander in chief etc.) and a third option was to simply put in the name of the organisation. This option presented another issue, since important organisations within the domain, such as the police force, often was subjected to different communication attempts. Questions came up as to how specific one should be; "should this refer to the Gothenburg or Kungsbacka police, or to the emergency response line?" An aspect was internal and external contacts, over organisational borders, should they differ in how they are treated and presented? This also related to private persons and instances of the government. The possibility to sort the nodes based on these distinguished characteristics was asked for. The option of seeing only the contacts made within the own organisation, outside it, or with another specific organisation was named as important.

Suggested design solutions: With every new entry of a node, the user should be given the possibility to state if the node refers to a person, an organization or a role. This information is then visible in the graph by a symbol connected to that node. Editing and defining nodes can be done at any time. A node defined as a person or a role can still be associated with an organization. Connections with external actors or organizations are examples of aspects that can be highlighted by the user if that aspect is of interest. The user should be able to view the visualization with different granularity, ranging from seeing all individual nodes, to seeing nodes clustered by organizational belonging, to only seeing organizations.

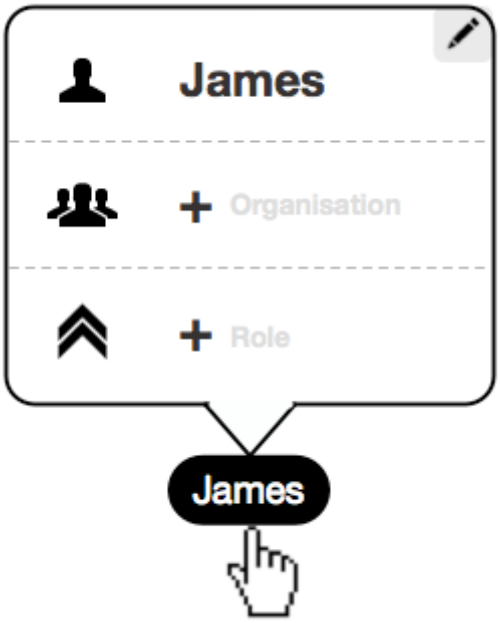

*Figure **15**. Example with option to enter both person, role and/or organisation on a node.*

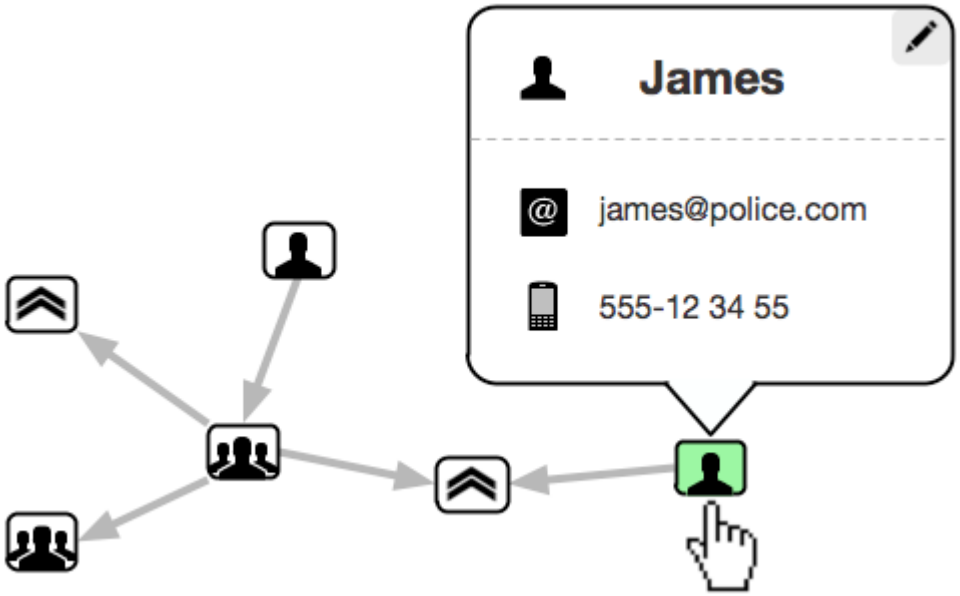

*Figure **16**. Example using glyphs in the graph for visualising different types of actors.*

Customised interfaces for field work and analysis

Differences in what was viewed as the relevant information occurred between the sessions. The common theme was that only information deemed as relevant should be presented. This was especially important during emergency response work, where no tolerance was given for time consuming activities without direct benefits. Customisation was brought up by as an answer to this issue. Another solution was to present different preset interfaces for different uses of the tool, one for the operative management in field, and one for the "system management", in this case referring to the in house management and analysis department. All responders supported the idea of showing extra information on demand, while hiding it when not asked for. Different methods discussed was to have pop-up windows appearing from any node and edge when clicked on, or to make all information viewable and hidden with a single button, this included controls for hiding and showing parts of the graph, according to its use at the moment. The use of colors, shapes and size was discussed to represent different information and aspects about nodes and edges. Different views where presented as to what the best use would be of these parameters. "Easy to understand", and "simple" where phrases used, that when further explained, seemed to have different meanings between the responders. The information relevant and necessary at the moment, graphically presented in a way easy to understand, and overview, without any irrelevant information; was the general consensus, even though the interpretation of this varied among the practitioners.

Suggested design solutions: Different interfaces should be supported, answering to the need of the user. One graphically clean interface for use during field emergency response work, where extra information is visible on demand, and one interface focused on the needs of the analysis situation, with controls for showing, hiding and highlighting aspects of interest. Color, shape, size and the use of glyphs can all be used to visualize different aspects of information.

Visualising the dimension of time

One of the most relevant aspects, asked for and discussed, was the dimension of time. Many of the practitioners saw great advantages and possibilities in the presentation of this dimension. The possibility to pinpoint a certain contact in time was seen as very important, both during emergency response and to the analysis work done afterwards. "We often work with milestones,

it is of great importance to see if communication took place before or after that time.” The degree of exactness wanted could vary greatly. There was also a request to be able to sort contacts and connections after the exact time the communication was made. Ideas came up as to if this information could be manually imported from cellular phones. Or if a ‘timestamp’ could be made at every entry, this assuming that communication was represented, in or close to real time, while it took place. The possibility of being able to ‘replay’ the chain of events, was mentioned by several practitioners. The idea was that during this replay, contacts would appear in the order they were taken, and then fade away. How to distinguish for how long a contact should remain as “active” was named as a potential problem.

Suggested design solutions: The dimension of time can be included by the user if deemed relevant. Two approaches to collecting information about the time of different contacts could be used, either manual input by the user, or the import of communication logs. The two can also be used in conjunction. When visualizing time, the tool should allow the user to scroll back and forth on a” time line”, where only the contacts actualized at the chosen particular time will be visible. Several variations of this concept can exist. One option is to include all communication made before the chosen point in time, another to let contacts remain visible in the view only for a certain amount of time. For example, an event of communication that took place at Friday will become visible as the user scrolls to Friday on the time scroll-bar, and if the chosen time-span is two days, the contact will fade back to not being as the user scrolls on to Sunday. The granularity of these controls should also be controllable; hours might be the appropriate measurement in one scenario, while another call for a scale based on days. A “play”-function can be used to playback the visualization of the scenario from start to finish. Important milestones could be marked on the timeline, in order to heighten visibility of in what order important events and contacts took place.

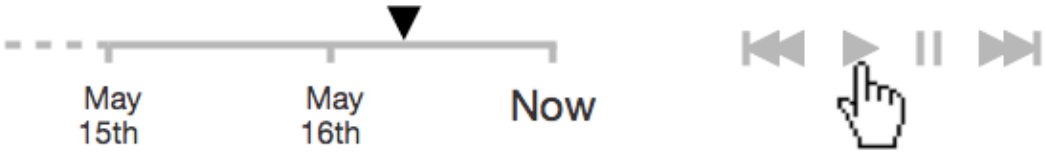

Figure 17. Example timeline and playback controls for navigating between times in a graph.

Discussion

In this chapter we discuss our findings and how they translate into generaliseable design principles. We discuss and reflect on our experiences of working with the ADR method and the domain of emergency response management and on the contribution of this thesis. Lastly we present a few examples of areas where the kind of tool explored might be further applied.

Design Principles

Presented below is a set of design principles that were derived from our findings to address the needs put forward in this thesis. The Design Principles are presented by title, description and the findings they relate to and were derived from. For each principle, we first present the principle (italicised), related to our experience accumulated from designing and evaluating this kind of tool. We then describe and discuss the principle from the standpoint of the conceptual framework used in this thesis. In describing the Design Principles we make use of two categories of users: "users" and "analysts". The user represents the respondents and lay-analysts, while the analyst represents the session-initiator and users interested in follow-up in-depth analysis of the session.

Allow Partial Data Entry

Allow users to enter partial data (e.g. only a name for a contact) and return at a later time to enter additional information. This creates a traceability that will allow both analysts and users to see and follow-up non-complete entries if necessary.

Common issues with questionnaire-based data gathering are that users might skip questions they do not feel like answering or choose not to participate at all (Follet and Holm, 2009; Sharp, Rogers and Preece, 2007). Practitioners in our study often returned to the need for simple data entry and not being forced to enter more data than they felt necessary. Allowing users to enter as much data they find affordable and relevant at the time of the event recorded will create a data-trace that could be followed up at a later time by the user or by analysts. This would also allow for recovery after interruptions and the deferral of choices (Tidwell, 2005).

Integration with other systems

Allowing for integration with other systems for both import and export of data will serve to balance users need for rich visualisations, the limited time for manual data entry, and need for in depth analysis. Integration with other data sources, such as HR-systems, social media platforms and log-files, will allow for automatic data entry to complete and lessen the burden of the manual entry. The ability to export allows for the data collected to be used in other situations, such as educational presentations.

Practitioners already create data traces in other systems (e.g. by emailing or writing reports). By integrating with such systems there is no need for entering same data at multiple points. Similarly many systems create data-logs (e.g. call-lists in mobile phones) that consists of rich data otherwise time-consuming to manually duplicate (Fry, 2003). Integrating with other systems (e.g. social network platforms and Geographical Information Systems), may also yield new possibilities of integrating and combining data to provide richer pictures than would be possible

by just using user-data (Segaran, 2009). Practitioners in our study considered it valuable as it would require less manual work for them while still contributing to the visualisation.

User Selected Data Granularity, Focus and Multiple Perspectives

Allowing the user to select the granularity and focus of the data visualised will keep it relevant and cognitively manageable. Presenting data on demand will allow for the user to select their level of engagement. The use of multiple perspectives (e.g. ego-centric, geographical, organisational, temporal) will serve as both visual presets and allow for alternative visualisation types (e.g. maps, time-lines).

There are limits to how much information a user can handle (Perer, 2010). Allowing for data to be visualised in different ways can greatly aid in its understanding (Fry, 2003; Viégas & Donath, 2004; Shapiro, 2010). Our case study showed that practitioners required different focus and information in different situations and did not want to be exposed to superfluous data. The ability to get data on demand and navigating the visualisation (i.e. panning and zooming, and temporal playback) were highly sought after to increase understanding and usefulness. Visualisations must be kept relevant to avoid taxation of the users cognitive faculties (Sharp, Rogers and Preece, 2009; Tidwell, 2005; Fry, 2003). Different data-types and data-scales allow different levels of analysis (Hanneman and Riddle, 2005) and require different visualisation types (Shapiro, 2010).

Generative and Distributed Multi-User Data Gathering

By allowing distributed multi-user entry (e.g. web-based questionnaires) the data gathering can be conducted at the source in, or near, real-time. Including notification and communication technology (e.g. e-mail or SMS services) allows for snowballing data gathering, as the system would be able to invite users to contribute as they are indicated by an entry. The invitations should also serve as simple authentication (e.g. by authenticating direct invitation link to the tool) to allow users to easily both start and return to the data entry. This should also allow users to subscribe to notifications and reminders.

The snowballing method allows multiple users to contribute to the data gathering activity facilitating in the generation of a rich data-set (Hanneman and Riddle, 2005). Web-based questionnaires allow for guided data entry (e.g. showing help on demand) and minimizing problems with misunderstandings. The e-mail-based invitational system helps in targeting relevant users and assuring that the population consists of individuals within the same networks. (Sharp, Rogers and Preece, 2007). Together these methods, i.e. snowballing, web-based questionnaires and e-mail-based invitations facilitates a data gathering that generates and informs new responders and therefore has the potential of reaching even ad hoc networks.

Domain Specific Session Design and Templates

Applying the design of questionnaires, data dimensions and visualisation perspectives to the domain is essential to make it relevant and easy to use. Using templates for specific sessions can both add a sense of familiarity and provide preliminary data entries for quick start-up.

Different sessions call for different data and visualisation. Designing sessions and using templates will allow the use of language and patterns familiar to the target audience (Fry, 2003; Tidwell, 2005; Iliinsky, 2010). This will also allow designing to enable different levels of analysis depending on needs (Steele and Iliinsky, 2010).

Direct Feedback and Usefulness

Allowing the visualisation to be real-time serves as direct feedback as well as encouragement to add more data and enables direct use of he data entered. The visualisation provides a real-time view of the session as it unfolds allowing the users to be updated and encourage additional data entry.

Keeping the user motivated to contribute to the data gathering is a key consideration where the reward for participating must be equalled or higher than the amount of work required (Sharp, Rogers and Preece, 2007). Designing for real-time visualisation would provide needed acceptance for the tool by users (NRC, 2009). In the case study practitioners regarded the tool as a possible memory aid, allowing them to use the tool to alleviate memory retention instead of using paper and pen, while at the same time serving more purposes, such as decision support and promoting collaborative situational awareness.

Concluding Discussion

The method used in this thesis has been Action Design Research, where design driven research is combined with the organisational involvement of action research. An important aspect is the interconnectedness of a theory ingrained design process and the feedback from the practitioners in the organisational context. This process is meant to ensure that the artefact produced answer to guidelines and theories found in literature as well as relates to problems and needs in the chosen domain, in our case emergency response management. We conducted our research through an artefact driven process, where the main focus was on exploring the design space for this kind of multi-user, real-time visualization tool.

The domain chosen to conduct our research in served its purpose very well, in that it presented us with specific problems and needs to take into consideration. We also received feedback on the design, intended use and the overall usefulness of our prototype tool. Emergency response management is a domain that deals with complicated operations, often spanning cross-organisational borders, demanding both informal and formal collaboration networks to be created. These networks are in most cases never analyzed, even though this could produce greater understanding of how to manage crisis response situations. Our tool presents one solution to how information about these networks could be gathered and visualized for analysis. Throughout the design process, we have incorporated knowledge and feedback of the practitioners on the possible usage of our visualisation tool for SNA in their domain. We also present suggestions for further development of tools for SNA in emergency crisis management. By conducting this research, we hope to have highlighted the possibilities presented by lay SNA, and to have enhanced practitioner awareness on the area of network visualisation tools to increase situational awareness.

In accordance with ADR's formalisation of learning, we have also translated our findings to generalized design principles, created to offer guidance and background for future attempts to create multi-user, real-time visualization tools for SNA. In the process of creating these principles we viewed the problems of our domain as instances of a class of problems, and adapted our findings to better address the class as a whole. Future research on other domains is suggested and can most likely bring up other points of interest to complement and further develop these principles.

Our contribution from the work and research in this thesis consists of three parts: *Suggested design solutions* answering to problems and needs related to designing a tool for SNA within the domain. *Design Principles* derived and generalised from the findings of our research to aid future developments within other domains with building tools for SNA. *The prototype,* that has been developed and evaluated during our research process and constitutes an example of a possible design solution for social network analysis tools.

Suggested areas and domains for application of the tool

During our discussions revolving the usage and design of the visualisation prototype created, we have discovered a number of possible alternative areas and domains where the tool could be applicable. As previously recommended, domain specific customisation would be appropriate, which could also open up for new opportunities and challenges. We believe the following areas could be further explored as examples of possible domains for application of similar tools: Visualising generative genealogy, visualising references between research papers, connecting to existing (social) network services and visualising that data, mining other systems, finding network data and visualising it, analysis of informal networks within companies for comparison with formal organisational plans. Which of these areas, if any, that would be suitable for the kind of tool presented in this thesis, could possibly present a good starting point for future research.

Conclusion

Concluding the work of this thesis we have seen several examples of the need for a real-time, multi-user social network visualisation and analysis tool within the domain of emergency response management. Emergency response operations often generate ad hoc networks, situations that could be better understood by the usage of a tool for SNA.

ADR has proven to be a suitable method for conducting examinations of the design space for this kind of tool. The use of the method has resulted in a set of design principles, for future research and development projects. These principles where generated through the process of designing and evaluating the prototype, followed by a generalisation of the problems encountered and possible solutions, based on the knowledge of the practitioners and domain experts, as well as the literature on the topic.

The prototype produced has possibilities for future continued exploration, as it constitutes an example of possible design solutions in an area that is largely unexplored and where similar attempts are scarce. The concept of real-time multi-user network visualisation tools brings up interesting issues, well suited for future research. Our firm belief is that research on the development and possible uses of similar tools in other domains could result in even more understanding of how to design for real time collaboration and social network analysis.

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