

# **Evaluation of focus + context techniques applied to network data visualizations**

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# Evaluation of focus + context techniques applied to network data visualizations

by

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# Abstract

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Visualizing network data at different spatial scales is a vital need in today's applications such as transport planning or traffic management. Sometimes, it is difficult for map readers to explore network data visualizations with large amount of data. Generalization can be used to abstract a network data representation by different activities such as aggregation, but it leads to reduction of some necessary information. Zooming methods like conventional zooming try to provide different zoom levels for map users in order to explore network data visualization at different spatial scales, usually without any reduction or elimination in the network data representation. The problem with conventional zooming is that by zooming in, the context will be lost and overview is not visible anymore and by zooming out, users may get lost in the large amount of data. Focus + context techniques tackle this problem by providing both focus and context area at the same time and make navigation easier than conventional zooming for users. In this research, it is tried to evaluate three focus + context methods, applied on both static and animated network data visualizations. These methods are location map, magnifying glass and fisheye view. Besides providing focus and context at the same time, dynamic characteristics of these methods are other advantages which enable to move the focus area based on user's area of interest while maintaining the context. It is assumed that fisheye view is a proper method to apply on static network data visualization due to providing a smooth distortion from the focus to the context area, while it makes the focus area blurred in case of animated network data visualization, magnifying glass has constant magnification that leads to a clear representation of the focus area while it has problems in maintaining the connectivity of lines at the edge of the glass and location map is a proper method to apply on both static and animated network data visualization. These hypotheses are tested in usability test to see if they are correct or not. Enschede road network data is used as a case. Also, speed profiles of vehicles are included in an animated flow line map.

After applying focus + context methods on the static and animated network data visualizations, a usability test is held to evaluate the usability (efficiency, effectiveness and satisfaction) of the applied methods. 21 PhD students of ITC participated in the test and the results showed that some improvements need to be developed in the applied techniques, such as increasing the size of the enlarged area and providing different zoom levels for the magnifying glass and fisheye view methods. Most of the participants found location map as the most effective and fisheye view as the most efficient methods. 72% of participants found the location map technique more satisfying than the fisheye view and the magnifying glass techniques, because it provides different zoom levels for them. It is also concluded that the fisheye view technique is not such a useful method to apply on animated road network data visualization. Finally, some recommendations are mentioned for next researchers to consider as future work.

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# 1. Introduction

## 1.1. Background and problem statement

Nowadays, visualizing network data plays an essential role in making decisions for users such as traffic managers and transport planners. For example, transport planners at a regional and local level make transport policies by modelling, analyzing and visualizing road transport network data. Visualization is needed to make these policies based on a proper understanding of the network data and visualization may support the discovery of spatial, temporal and spatio-temporal patterns and relationships.

Network data consist of nodes and links with attributes that may change over time. So, besides space, time is another dimension that must be considered in transport network data (network dynamics).

It is useful to link network-related items like moving objects with their attributes to the nodes and links of a transport network to enable analysis of the relationships among them. As an example, understanding the travel time relationships of a transportation network can be vital for evaluating its performance (Ahmed & Miller, 2007), and using speed profiles of transport vehicles as linked data may reveal network congestion patterns.

There are different types of networks such as social network, computer network, road network etc. The irregular structure of nodes and links can already be complex, but change over time and multivariate network and other related data further add to the complexity (Robertson, et al., 2009). Decision makers often want to traverse an entire network (Shneiderman, 2003), but there is a growing mismatch between size and complexity of the data and decision maker's ability to understand the data (Robertson, et al., 2009). To reduce the amount of data for analysis, three methods are used traditionally; aggregation to reduce links or nodes, averaging to reduce time periods and thresholding for change detection (Becker, et al., 1995).

Above we have indicated that visualization of network data is important. Visualization of the nodes and links often take the form of graph visualization techniques (Patwari, et al., 2005) (see figure 1). Graphs can also be animated to indicate changing network structures and pattern variations over time (Wills, 2009) and visualizing the data associated with the network is as important as visualizing the structure of the network itself (Becker, et al., 1995). Graphs visualize the data in a non-geographic space; if geographic questions about patterns (in space and time), relations and trends need to be answered, geographic visualization (maps) should be applied.

Users of network data visualizations often prefer to visualize different areas of a network at varying levels of detail or at various scales due to the complexity of them (Schaffer, et al., 1993), or because they have to cope with network issues at different levels. For example, spatial overview might be mainly needed at national level. At lower levels, there might be more need for details, with regular references to the overview. But in large-scale visualization users may miss the context. On the other hand, uncertainty is reduced by providing more details and evidences, enabling users to construct more useful decisions, depending on their purposes (Robertson, et al., 2009). In small-scale visualization, there are lots of data that must be shown in a small space, which may lead to omitting or aggregation of some data, and details are hidden. Providing overview and making flexible transitions possible from overview to details and back is required for exploring network data. In the temporal dimension, level



Method	Advantages	Disadvantages
<b>Generalization</b>	Simplifies the representations by maintaining topology and overall characteristics/ eliminates the risk of overlapping of neighbouring objects	Problems such as deletion of some essential information, e.x.: due to aggregation of similar data or selections may occur
<b>Zooming</b>	Multiple levels of details are allowed/ Resulting in quick navigation / Flexibility	Can cause orientation and readability problem/ difficult to make a connection between a large scale and small scale map and to keep track of a specific location at different scales

Table 1: Main characteristics of generalization and zooming methods

## 1.2. Research identification

### 1.2.1. Research main objective

To evaluate alternatives to conventional zooming methods that support users of network visualizations in visual information seeking tasks at different spatial scales.

### 1.2.2. Research sub-objectives

- A) To design static and animated visual representations using different alternatives to conventional zooming methods on spatial network data visualizations
- B) To implement focus + context methods in prototype form as a facility for users to effectively change from overview to details and back
- C) To evaluate the effectiveness of the methods to judge if they can help users to deal with spatial network data
- D) To derive recommendations for the use of the evaluated methods for static and animated network visualizations

### 1.2.3. Research questions

- 1) What are the characteristics of spatial network data?
- 2) Is there a need for visualizations at different spatial scales?
- 3) What methods are available to create understandable transitions between visualizations at different scales?
- 4) What is/are the most potential method(s)?
- 5) Which network visualizations have to be designed (static and animated)?
- 6) How can focus + context methods be implemented in a prototype?
- 7) How can different methods be evaluated?
- 8) What is the usability of recommendations?
- 9) Which recommendations can be derived from the evaluation?

### **1.3. Methodology**

This research will be started by a literature study and related works done in network data visualization field and introduction of zooming techniques, case study and data that are going to be used.

The research questions 1, 2 and 3 will be answered based on literature review only.

A theoretical framework will be mentioned as a prototype for the design step. The research question 4 will be answered by this framework.

Applying selected zooming methods based on literature study and implementation of them will be the next step. The research questions 5 and 6 will be answered in this phase.

Next, evaluating the methods by a usability test will be executed. The research question 7 will be answered in this phase.

Then the results of the test will be analyzed. Research questions 8 and 9 will be answered.

Finally conclusions and recommendations will be mentioned for improvement of applied methods. The research question 10 will be answered in this step.

### **1.4. Thesis structure**

Second chapter of the research contains literature study in related fields such as basic visualization theories and tools, visualization methods, spatial network data and their characteristics, the Visual Information Seeking Mantra, map design, spatial scales, transitions, evaluation and usability and development of visualization recommendations. Each of these aspects needs to be discussed in various chapters in order to provide insight into visualizing transport network data at different spatial scales. Also related works done in mentioned fields will be discussed. Then, selected methods that are going to apply on network data visualizations will be introduced based on literature study.

Next, a theoretical framework will also be designed based on the results of literature study phase as a basic concept. This framework will be used as a model for the design step. The methods that are going to be applied to network data will be specified. Hypotheses of the usefulness of the methods will be mentioned. These hypotheses can be tested in next chapters to see if they are correct or not.

Designing maps using the most potential focus + context methods based on theoretical framework is the next step of the research and will be mentioned in chapter 3. A case study related to network and transport management issues, like Enschede, is needed for the design in this phase which involves network-related data (speed profiles).

Chapter 4 of the research refers to evaluation of the usability (effectiveness, efficiency and satisfaction) of the applied methods based on user tasks. Literature study in usability evaluation field will be done in this chapter. Then, a usability test will be held in which test participants perform the tasks. Also, test environment, test conditions and facilities that are going to be used will be introduced. Analyzing the results derived from the evaluation step is the next phase of chapter 4. Evaluating efficiency, effectiveness and satisfaction of applied methods on both static and animated network data will be done.

Developing recommendations for the use of methods that support decision makers in visual information seeking tasks at different spatial scales will be performed. Recommendations will be based on review of the last phase and on conclusions in chapter 5.

## 2. Zooming techniques and focus of this research

### 2.1. Introduction

As it is mentioned in the previous chapter, in road network data with moving objects attributes, for example, there are large amounts of spatial data that must be shown at different scales to cope with network issues at different levels (overview and detailed areas). But there are problems in visualizing and using the data. In small-scale visualization of these data, the problem may be complexity of massive data and users may be confused or may miss some information, such as different paths which are shown by various lines.

Traditional or conventional zooming enables users to change the scale of network data easily, but, it does not provide overview and details simultaneously and context will be lost while zooming in. Although panning can solve the problem, getting lost is still the main problem. Also, there is no detailed area while zooming out.

Shneiderman (2003) introduced Visual Information Seeking Mantra, that starts with getting overview, zooming and filtering, then switching to details. But, in massive data representation, the transition between overview and zooming leads to mentioned problems such as losing context.

There are some focus + context methods that provide overview and detail of the network data at the same time that will be introduced and implemented in this research. The focus area is the area of interest in which user wants to zoom in to explore that and context area is the remaining area of the representation. Providing the area of interest and remaining area simultaneously is the main goal of this research. The techniques will be applied on static and on animated maps. Applying these techniques on the animation is challenging since changes are happening in the focus and context area over time, so, it might be difficult for users to pay attention to both overview and detail in animated networks.

This chapter first discusses related literature about map types, generalization methods and zooming techniques (2.2). It gives an introduction to focus + context methods (2.3). A theoretical framework for the research based on the literature review is described (2.4) and the chapter ends with a conclusion (2.5).

### 2.2. Related literature

#### *Map types*

Networks are used as effective structures of data to represent relationships among links and attributes in different ways (Kershenbaum & Murray, 2005). Maps are graphical forms of representing networks to users. There are many kinds of maps for network data that have been introduced and improved during last decades.

Bertin (1983) and Dent (1999) designed some guidelines for producing traditional maps in the domain of cartography. For example, flow maps that represent linear movement between specific locations were achieved (Dent, 1999). These maps use varying line widths for quantitative data to show the movement and are very common. Flow maps enable users to spot spatial patterns (Phan, et al., 2005). Figure 2 is an example of a flow map that shows migration to California and New York. It can be seen that New York attracts mainly people from the East Coast while California attracts them from more regions in the United States. Schematic maps are a common form of graphic communication (Avelar & Hurni 2006), mostly used for public transport maps. Avelar & Hurni used the west side of Zurich as a test area which contains transport networks with different public transportation lines and stations. They also used vector data to schematize lines. They suggested cartographic considerations and symbolization rules to help the design of an effective schematic map, but, using schematic transport maps is decreasing in the world due to the lack of standardization and need for more guidelines for map designers. Schematic maps are also used as wayfinding aids. Casakin et al. (2000) used the Hamburg Volksparkstadion area as a case study to study wayfinding problems (see figure 3). A reason for selecting this area as a case was an inadequate existing schematic map in this area (see figure 4).

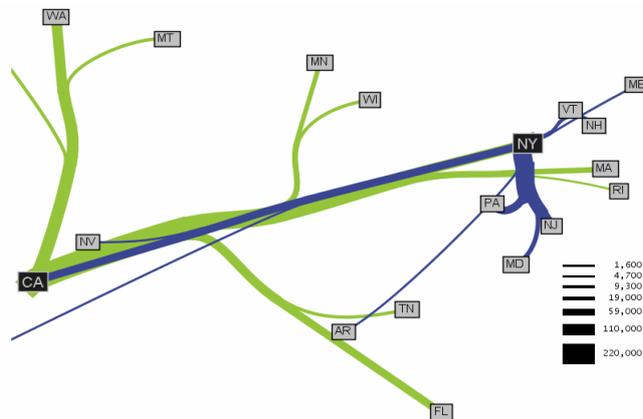


Figure 2: Migration to California and New York (Phan, et al., 2005)

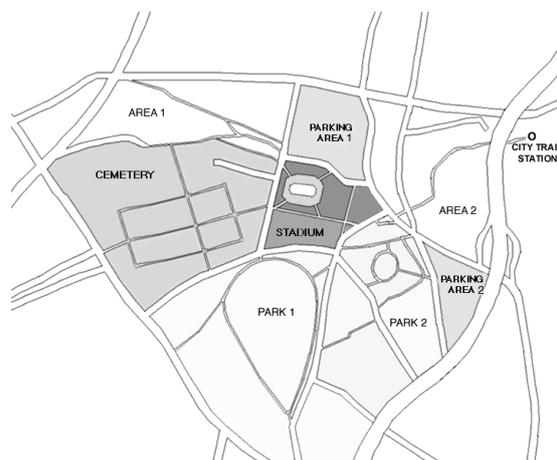


Figure 3: City map of the Hamburg Volksparkstadion (Casakin, et al., 2000)

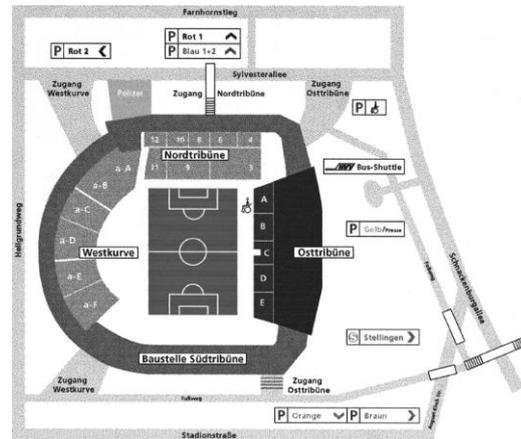


Figure 4: Inadequate schematic map for wayfinding tasks in Hamburg Volksparkstadion (Casakin, et al., 2000)

Tree maps are other types of representation of a network. They do not show the links of a network but a kind of hierarchical structure. These maps use size and color coding to show attributes of leaf nodes. Wood & Dykes (2008) introduced tree maps as a valuable representation method to represent attributes related to nodes by the size of nodes and a label for each node. Figure 5 illustrates an example of a tree and its corresponding treemap. The area sizes shown in the tree map are related to the sizes of nodes (Balzer, et al., 2005).

### *Generalization*

As it is mentioned before, network data representations contain lots of information which must be shown at different scales. The most obvious problem is that in case of a large network, it is difficult to represent it in a manner that can be seen especially in a case that details are important for the users (Kershenbaum & Murray, 2005).

Generalization is a method that aims to reduce the details and simplify the representation of an overview map by keeping the overall characteristics of a transport network (Fisher & Zhang, 2005). Fisher & Zhang described density differences in road network generalization that is known as the number of connections. Figure 6 presents an original road network and figure 7 is created using a connection criterion that is an abstraction of the original representation. Reduction of connections and generalization are obvious in figure 7. The results show that the differences between road density of center and road density of suburb are maintained after generalization. Generalization has some graphic and conceptual activities such as smoothing, filtering and aggregation (G. Andrienko & Andrienko, 2008). Aggregation is a way to put together data items that are similar. Drecki & Forer (2000) suggest a method for aggregated moves and generation of continuous flow maps that can reduce overlaps between movement symbols by involving the third spatial dimension in the representation of the movement of tourists in New Zealand.

Andrienko et al. (2009) generalized using a density-based clustering algorithm (DBCA) that can consider regions with low density as noise and those areas won't be shown in visualization in case of aggregation. Another benefit of this method is that the final clusters are not limited to a specific shape or size and can represent the natural distribution of the data, in contrast with a grid-based approach that

do not reflect the natural data distribution due to similar and regular size of cells (Andrienko, et al., 2009).

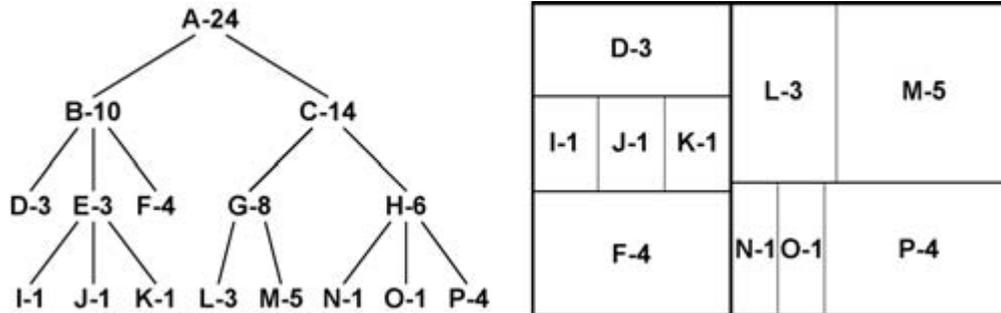


Figure 5: Tree and corresponding treemap (Balzer, et al., 2005)

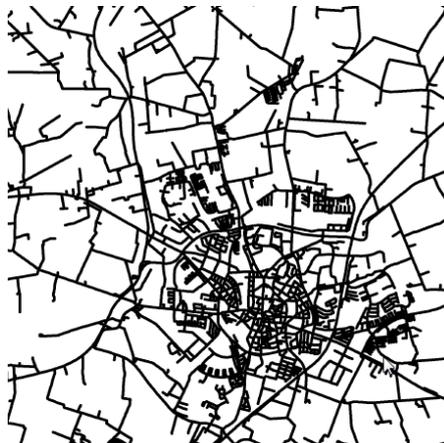


Figure 6: Original road network (Fisher & Zhang, 2005)



Figure 7: Generalized road network created by connection criterion (Fisher & Zhang, 2005)

### *Zooming techniques*

In some cases, users or map readers are more interested in one or more specific areas in a network representation and need to focus on those areas. So, visualizing network representations at different scales was needed to improve. Techniques to visualize data at different spatial scales that could even be combined with generalization are zooming or focus + context techniques (see below).

Spatio-temporal network representations need changing scales and different levels of details to make it easier for users to find answers to their task (Hornsby & Egenhofer, 1999). Switching between overview and details supports visual information extraction, particularly in large data sets. Hornsby and Egenhofer described temporal zooming and improved the transitions between different levels by explaining how shifts can occur between different temporal scales.

The focus of this research is on spatial zooming. Zooming techniques are proper methods to cope with overview and details in network visualizations. Conventional zooming enables users to zoom in to view more details and provide different spatial scales for them.

Frigioni & Tarantino (2003) presented a zooming model for visualizing an abstract of a representation in types of generalization, aggregation and filtering, by describing a set of basic zooming primitives as transitions between maps at different scales. They defined a zooming model to visualize gradually simplified representations. They presented a new multiple zooming primitive and introduced an implementation on maps based on a focus + context approach.

The main problem of conventional zooming is that by zooming in, the context will be lost (see figure 8), and by zooming out, details are not visible. Focus + Context techniques solve this problem by dynamic characteristics; enabling users to move the focus area over the network; and providing overview and detail for the users like fisheye view technique.

Sarkar & Brown (1992) applied the fisheye technique to graphs. They applied a threshold based on the Euclidean distance between the vertices in a graph. Nodes below that threshold will be removed from the network's view. Nodes above the threshold will be shown. Figure 9 shows a general graph and in figure 10, a fisheye view of this graph can be seen, focus is on node 48. Nodes closer to the focus are visible at larger size than others.



Figure 8: Conventional zooming. Details only (Cui, 2008)

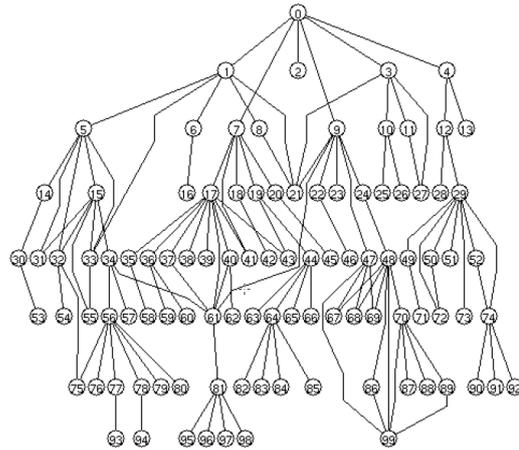


Figure 9: General view of a graph (Sarkar & Brown, 1992)

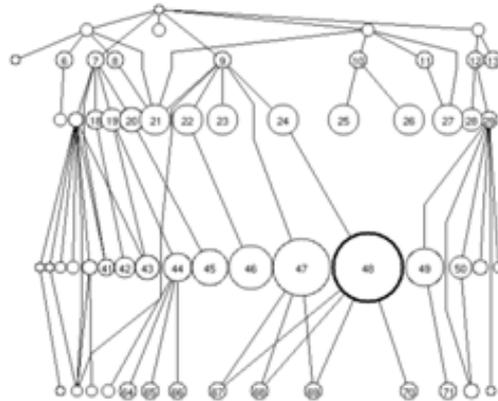


Figure 10: Fisheye view of a graph. Node 48 is the focus node (Sarkar & Brown, 1992)

Schaffer & Zuo (1998) compared two techniques for representing clustered networks, traditional full-zoom (conventional zooming) and fisheye views. They did not take into account animation. They concluded that results from fisheye views significantly improved the efficiency of users by reducing the number of navigational steps for them. They did not measure effectiveness. They also illustrated fisheye view zooming by an example that can be seen in figure 11 (before and after zooming node 'a'). It is obvious that by zooming node 'a', nodes 'b' and 'c' reduce to points and it shows fisheye view characteristic.

Lamping & Rao (1996) introduced a fisheye technique by using a hyperbolic browser that can be applied on a tree that can bring other areas into focus by smooth change. They believed that this is a solution to the large network data display problem and provides a focus + context. They have proposed a facility for changing the focus using pointer clicks or dragging to make the transitions across the network smoother.

Sarkar et al. (1993) proposed stretching of a rubber sheet for viewing large vector data in small display areas and based on this technique, different levels of details can be shown. They showed the overview on a rubber sheet that contained different areas and defined some tools called handles to hold and stretch areas of interest to see a greater level of detail. An overview representation of United States is

shown in figure 12. It can be seen that small circles indicate cities. Figure 13 illustrates stretched view of the overview and shows the city names and highway numbers in Colorado and Alabama.

Rauschenbach (1999) introduced the rectangular fisheye view for raster images like rubber sheets proposed by Sarkar et al. for vector graphics. This method has been developed to deal with size limitations of screen of mobile computing environments.

Storey et al. (1999) described a fisheye view algorithm that is proper for resizing nodes of a graph when more screen space is needed, by maintaining straightness of lines and the graph topology. They introduced a tree view and a nested graph view of hierarchies with composite nodes and this makes different levels of details visible.

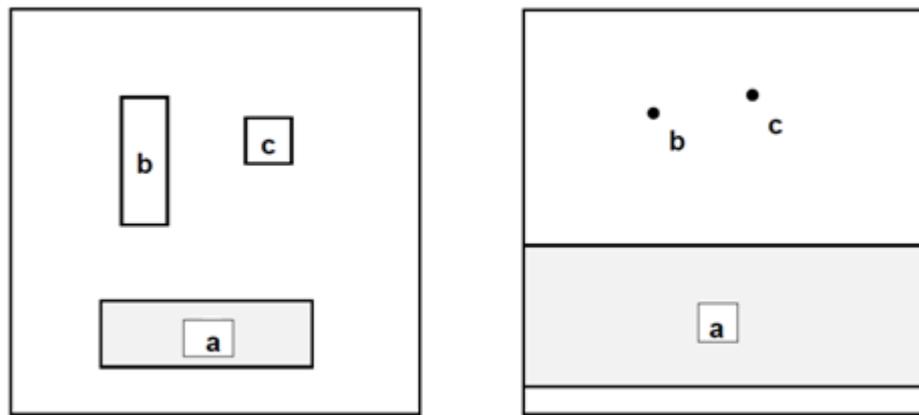


Figure 11: Fisheye view zooming example (Schaffer & Zuo, 1998)



Figure 12: An overview representation of United States (Sarkar, et al., 1993).

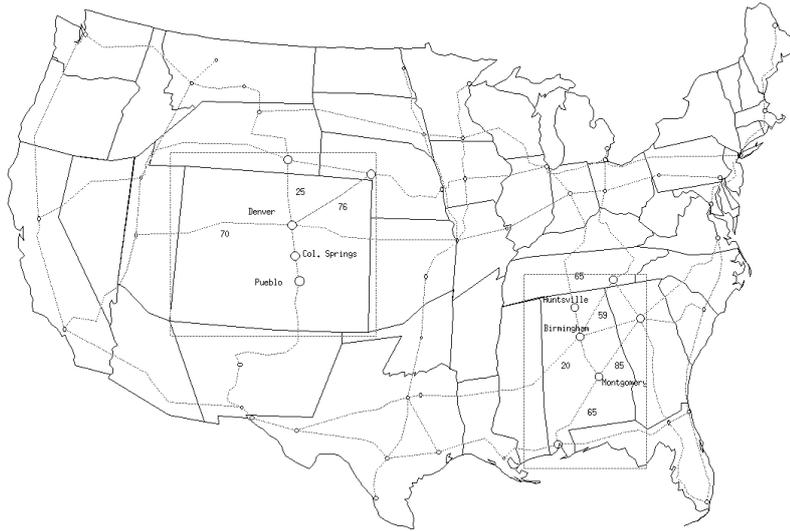


Figure 13: Stretched view of the overview of the United States. The city names and highway numbers of Colorado and Alabama are visible now (Sarkar, et al., 1993).

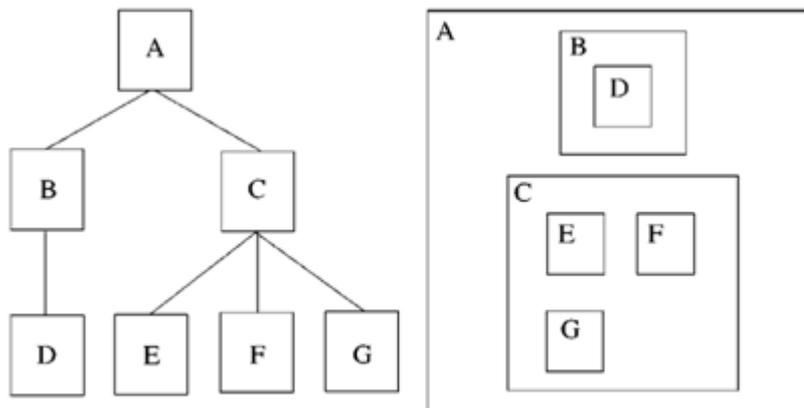


Figure 14: A tree view of a hierarchy and nested graph view of the same hierarchy (Storey, et al., 1999)

As it is shown in figures 14 a hierarchy with composite nodes A, B and C can be seen as a tree view or a nested graph view, in which context and details are visible at the same time.

Rauschenbach (2001) introduced the combined presentation of raster images, vector graphics and text using rectangular regions by describing three different context modes to provide scalability based on smoothness and computational requirements: uniform context scaling, belt-based context scaling and non-uniform context scaling. In case of uniform context scaling, there is only one context belt consisting of 8 grid rectangles that fit into the space left by the focus. In case of belt-based context scaling, several context belts are used. Computation of the main characteristic of the fisheye view which has priority importance is faster in this case. Increasing distance from the center of the focus area results in displaying less detail. These 8 grid rectangles make the resulting fisheye view smoother but there are still some deficiencies, needing more smoothness. In case of non-uniform context scaling, there is only one context belt like uniform context scaling. The difference is that in the latter case, with increasing distance from the focus, the context scaling factor decreases continually (see figure 15).

In all the above cases of application of the fisheye technique, magnification can lead to problems such as focus targeting, if a user wants to change the focus from one location to another.

Gutwin & Fedak (2004) introduced speed-coupled flattening (SCF) technique which reduces the distortion level based on pointer velocity and acceleration. When pointer velocity and acceleration are high, the magnification will be reduced to tackle the focus targeting problems. This improvement of focus targeting leads to both targeting time and targeting errors reduction.

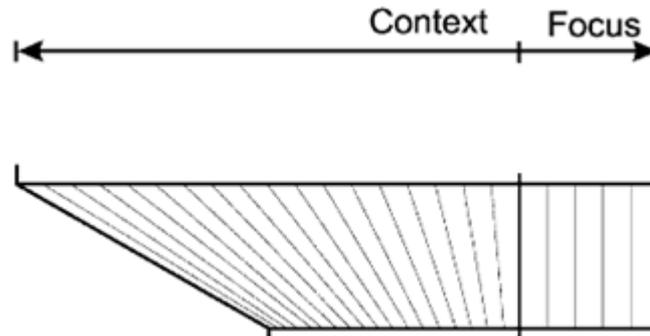


Figure 15: The idea of non-uniform context scaling. It can be seen that by increasing distance from the focus, context scale factor decreases (Rauschenbach, et al., 2001).

### 2.3. Conventional zooming

Conventional zooming is a well known way to visually explore the details in (network data) visualization, but it has some deficiencies, as explained before. By zooming in on the network visualization the context will be lost and by zooming out, no details are visible. Figure 16 shows the zoomed area (two levels of zooming) resulting from the conventional zooming method.



Figure 16: Zoomed area of the road network of Enschede

## 2.4. Selection of focus + context methods for network visualizations

As it is mentioned in the previous chapter, users prefer to visualize a specific part of the network at different levels of details due to the complexity of these networks (Schaffer, et al., 1993), and zooming in is one of the possibilities to enable this.

Although panning can solve the problem of conventional zooming for adjacent areas but it is easy to get lost and there is no possibility to see focus and context simultaneously.

As described in 2.2, there are methods that provide overview and details simultaneously for the users and it is even possible to represent overview and details on a small screen (Storey, et al., 1999), in different ways.

In order to represent both overview and details of network data at the same time, the visualization should show those large amounts of data without reduction or elimination of necessary information, but at the same time, there should be options to better see the details at selected locations. Focus + context techniques can be used, they save screen space, while representing the area of highest user interest in its context (Rauschenbach, et al., 2001). The focus area is a magnified area that provides detailed or enlarged views of the network and the context is provided by the not magnified, remaining parts of the network that are not present in the focus area.

Some of these techniques will be introduced, implemented and tested for road network visualizations in this research that are not yet done by comparing these methods on both static and animated visualizations of network data; they are magnifying glass and fisheye view by providing focus area over the context area and location map technique by providing overview and detail at separate windows.

### 2.4.1. Magnifying glass

The magnifying glass technique is one focus + context method that can be used to achieve the goal: presenting the detailed or enlarged area as 'focus' under the magnifying glass and providing an overview (context) outside the focus area. This method creates distortions at the edge of the glass (Schaffer & Zuo, 1998). It can be seen in figure 17 that in case of the river, distortion is created at the edge between glass and context area. The aim of this technique is showing the focus area with constant magnification in context, with the opportunity to move the glass and change the focus area dynamically. It is important to maintain the connectivity of lines, since they are necessary elements of a network.

### 2.4.2. Fisheye View

As described above, fisheye view techniques usually employ non-linear magnification of the focus zone, with distortions based on Euclidean distance from the centre of the focus area, while downscaling contexts (Schaffer & Zuo, 1998). Areas near the centre of the focus area are represented at the highest level of detail and at larger scale (Churcher, 1995). A non-linear magnification factor is needed for zooming in to nodes and links in the area of interest. The aim is to provide smoothness between overview and details and reduce abrupt distortions at the edge of focus and context areas. By defining some context belts around or inside the focus area, it is possible to make overview and detail fitting to each other at lower zoom levels (Rauschenbach, et al., 2001). Each belt represents a different zoom level and the maximum zoom level will be shown in belt 0 which is the core focus area. So by increasing the distance from the core focus area, the zoom level will decrease.

The importance of this technique is that areas near the focus, which are likely to be more interesting and more important for the users than further away areas, are magnified most, while context and connectivity are maintained (see figure 18).



Figure 17: Magnifying glass. Creating distortion at the edge between looking glass and context area is visible. Connectivity is not maintained (Cui, 2008).

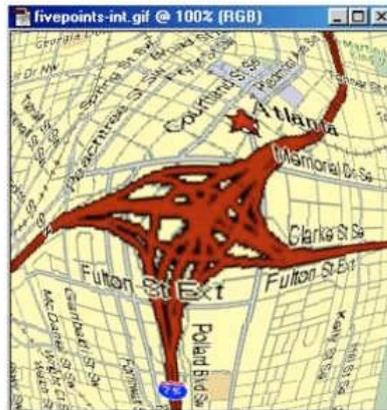


Figure 18: Fisheye view (Cui, 2008)

### 2.4.3. Location map

Another technique which can help the users to visualize the focus area at relatively large scale and simultaneously its context is using a location map. It contains two linked maps that represent overview and details separately and by panning on the overview map, the location of the focus zone will shift in the detailed map. It enables the users to focus on their area of interest in a relatively large window with constant magnification, and have an overview of the context.

The main problem of this technique is that these views need extra space for the overview and map users are forced to mentally integrate detail and context (Schaffer, et al., 1993). As it is shown in figure 19, there are two windows containing a small overview and a large detailed view and by changing the scale of the larger rectangle or panning on that, the area of interest will be shown as smaller rectangle or shift in the overview representation

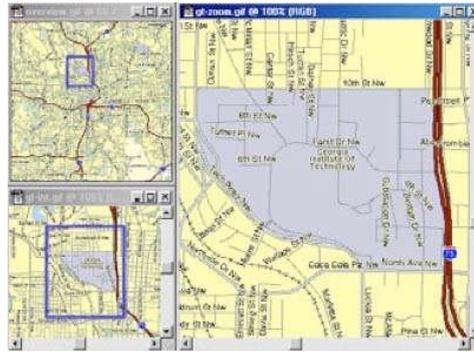


Figure 19: Visualizing overview and detail at the same time by location map. Pan and zoom. (Cui, 2008)

#### 2.4.4. Advantages and disadvantages

Each of the above mentioned focus + context methods has advantages and disadvantages. Based on their characteristics, these techniques are selected to be implemented in this research. A comparison between selected methods and their advantages and disadvantages is shown in table 2.

Focus + context methods	Advantages	Disadvantages
<b>Location map</b>	No distortion / familiar concept	Difficult to navigate in a large information space
<b>Magnifying glass</b>	No distortion in the focus area / Proper for raster and vector data / more clear representation of focus area than fisheye view technique	Less natural distortion than other techniques especially in a large magnification / does not maintain the connectivity of lines in the network at the edge of the glass
<b>Fisheye view</b>	Smooth distortion from the focus area to the context / provide priority importance concept	The whole focus area is distorted / areas close to the corner of the display has very high distortion

Table 2: Advantages and disadvantages of selected focus + context methods

## 2.5. Theoretical framework

The above mentioned focus + context methods will be applied and evaluated in this research using static and animated network visualizations. Based on their characteristics (table 3), hypotheses can be formulated that will be tested.

- a) Fisheye view is a proper method to apply on static network data visualization because it provides a smooth distortion from the focus to the context area.
- b) Fisheye view is not a proper method to apply on animation because it makes the focus area blurred.
- c) Magnifying glass has problems in maintaining connectivity of lines in network data visualizations
- d) Magnifying glass has constant magnification and it provides clear representation.
- e) Location map is a proper method to apply on both static and animated network data visualization.

Table 3 shows a comparison of the methods selected in 2.3 with conventional zooming based on some criteria such as size of the displayed focus zone, and magnification of the methods.

Bertin (1983) defined 3 reading levels for (static) maps; elementary level like one road, intermediate level like 3 or 4 roads and overall level like the whole network or map. These 3 levels are related to different zoom levels. By zooming in, intermediate level is visible and by more zooming, elementary level can be diagnosed well. This concept will be used in tests with users (chapter 4). Providing overall level and intermediate level or overall level and elementary level is another advantage of focus + context techniques that are in relation to user requirements.

Characteristic Methods	Size of the displayed focus zone	Magnification	Flexibility	Distortion at the edge of focus- context area
<b>Normal zooming</b>	Constant	Constant	Different zoom levels	Not applicable
<b>Magnifying glass</b>	Constant	Constant	Predefined zoom level	Abrupt changes at the edge of the glass
<b>Location map</b>	Constant	Constant	Different zoom levels	No distortion
<b>Fisheye view</b>	Constant	Non-linear magnification	Predefined zoom level	Distortion smooth changes

Table 3: Characteristics of different zooming and focus + context techniques

## 2.6. Conclusion

Focus + context techniques have useful characteristics that enable users to visualize network data at different spatial scales in an easy manner. They provide a possibility to change the focus area interactively and different zoom levels are possible in some of them. The methods further vary in size of the displaced focus area, magnification and distortion at the edge of focus and context areas.

These methods represent overview and detail at the same time which is the main goal to obtain in this research. In some cases such as with the fisheye view technique, visualizing details based on importance priority and smooth distortions are other advantages.

One advantage of focus + context techniques is their dynamic characteristic that enables the user to change the focus area interactively and multiple levels of focus and context area are possible, in contrast with conventional zooming technique that allows users to enlarge only one area of interest at one time (Storey, et al., 1999). So, these methods may provide more than one focus area in a map. Focus + context techniques are quicker for doing navigational tasks and need fewer unnecessary navigational steps than normal zooming method (Schaffer, et al., 1993). Also there is no need to remember the structure of the whole network in contrast with normal zoom (Schaffer, et al., 1993). Magnifying glass, fisheye view and location map are selected for evaluation on static and animated network visualizations. Some hypotheses and expectations are needed to mention to test in usability test, for example which methods are proper to apply on static or animated network data visualization. After usability test, the acceptance or the rejection of these assumptions will be resulted.

## 3. Design and implementation

### 3.1. Introduction

The literature presented in the last chapter showed that in exploring network data visualizations at different scales, it is an essential need to provide both overview and details for the users at the same time. As mentioned before, there are some focus + context techniques that tackle this problem.

These techniques are implementable on both static network visualizations and on animated ones. In case of static network visualization, besides scalability issues, an important issue that must be considered is maintaining the connectivity of lines which is a very important point in representing a network. In case of animation, differences and changes happening over in a network at different spatial scales can be considered, besides the connectivity issues.

The case study that is used in this research is the road network of Enschede. The TeleAtlas data is also used containing the percentage of free flow speed (FFS) of road traffic at 5 minutes intervals for a whole week. Exploring these data show that low percentage of FFS means high congestion.

The data selected for the case study of this research are the FFS percentages of 30 minutes time intervals for one day of a week (Tuesday), from 6.00 am to 20.00 pm. For example, if the FFS is 80% and the max speed allowed is 120 km/h, then the speed reached in the interval is 96 km/h, and if the max speed is 50 km/h, then the speed reached is 40 km/h, etc.

For the static map, the Enschede network, alone, is used. For the animated flow map, the classified FFS data are added to the network to create dynamic flow line map.

The first data which is used in this research is the road network of Enschede in a raster format and by applying speed profiles of vehicles at 30 minutes time intervals on that, the animation of this network is made.

In next step, the raster data is transformed to vector data and finally a movie clip of both a static network map and an animated flow line map of the vector data was made to apply the focus + context techniques on that.

Methods which are applied to these movie clips are conventional zooming, location map, magnifying glass and fisheye view based on characteristics, advantages and disadvantages mentioned in tables 2 and 3.

In the next section, some steps for preparing for design (3.2), applying different techniques (3.3), and development of the interface for testing (3.4) will be mentioned. Finally a summary of the chapter will also follow (3.5).

### 3.2. Preparing for design

#### 3.2.1. Raster data to vector data

The first data source was pre-generated images of network traffic flow of Enschede in a framework in a PhD project. Due to three main reasons, the original raster data was transformed into vector data in this research.

- a) Vector data is more realistic than raster data in network data visualization.
- b) Raster data has a lower resolution than vector data. Vector data provide a clearer representation than raster data (see figure 20 & 21).
- c) Raster data is a heavy file to run its animation in Flash software and a movie clip of the animation of this data does not give a clear result of the network data visualization. Adding different focus + context techniques to the network visualizations will make the data files even heavier to run in the software. By transforming that into vector format, it is implementable and running in the software.

### 3.2.2. Software

The software used in this research is Adobe Illustrator to change the raster data to vector data. Adobe Flash CS5 is also used for applying focus + context methods and creating animation. To define some operations and tools such as magnifying glass or fisheye, which are mentioned in section 3.3, scripting in Java Script language is used as code. Existing examples were used as code.

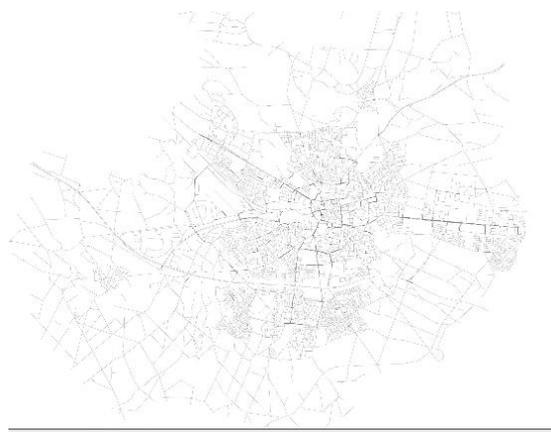
### 3.2.3. Creating the visualizations

As it is mentioned before, two types of network data visualizations are used in this research: static and animated network representations.

Figure 22 shows the road network of Enschede at one specific time interval which is static network visualization, without any speed information added to the lines. Figure 23 shows one frame of an animation of the same network plus congestions at time intervals of 30 minutes from 6:00 am to 8:00 pm of one day. It is running as animation in Flash software.

By assigning time intervals to each static layer on the time line of the Flash software, it is possible to make an animation and by running the movie, it is visible that over time intervals, the widths of the flow lines change.

The different widths of lines; show different congestion levels of roads, derived from the percentages of free flow speed at 30 minute intervals. Thicker lines show more congested roads (with lower percentages of FFS) than narrower ones. Speed levels are classified in two categories: light congestion and free flow.



---

Figure 20: The raster visualization of the road network of Enschede



Figure 21: The vector visualization of the road network of Enschede



Figure 22: A static visualization of the road network



Figure 23: Frame of the animated network visualization at one specific time interval

### 3.2.4. Making a movie clip

To apply focus + context techniques on both static and animation network visualizations, it is needed to make a movie clip from both visualizations and to add some Java Script language to the movie clips in the Flash environment. By making the static and animated network visualizations as a symbol and bringing them into the Flash library, movie clips are ready and focus + context methods can be applied on the network visualizations.

## 3.3. Applying focus + context techniques on static and animated network data visualizations

### 3.3.1. Location map

Two windows are presented in the location map method: one to represent overview and one for the details at the same time. By moving the slider in figure 24 up and down, different zoom levels are possible and by moving the small rectangle in the overview window, details will be shifted in the details window. This method is also implementable on the animation, which allows users to view changes in the congestion levels over time, at different spatial scales, while the animation is running (figure 25). It can be revealed from this method that no distortion will appear in both the static and animated network visualization, but always, more space is needed due to the overview window, and mental integration of both overview and detail is needed for users who explore the network visualization.



Figure 24: Applying location map on a static road network visualization of Enschede

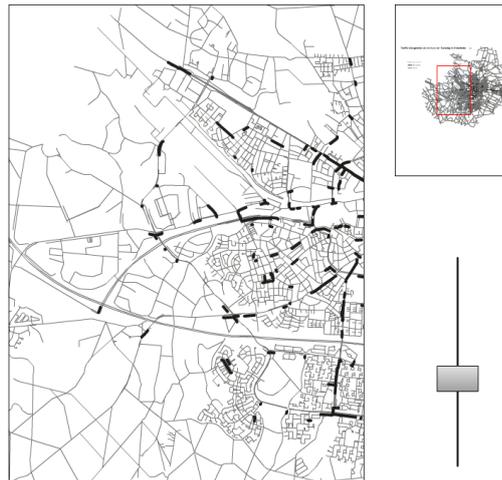


Figure 25: Applying location map method on an animated road network visualization of Enschede, here visible in one specific time interval

The Java script code used for designing this method contains 3 parts. The first part relates to some basic functions which are generic functions that can be used anywhere. Drawing boxes in movie clips and defining clamp are mentioned in this part of script (Appendix 1A).

```
MovieClip.prototype.drawBox = function (left, top, right, bottom, line, fill){
    this.clear ();
    this.lineStyle.apply (this, line);
    this.beginFill.apply (this, fill);
    this.moveTo (left, top);
    this.lineTo (left, bottom);
    this.lineTo (right, bottom);
    this.lineTo (right, top);
    this.lineTo (left, top);
    this.endFill ();
}
```

The clamp operation maintains the map inside the box. If the value is lower than low, low is returned and if the value is higher than high, high is returned. Otherwise, if the value is acceptably between those values, it is returned.

```
Function Clamp (low, value, high){
    return Math.min (Math.max (value, low), high);
}
```

The second part of the code relates to defining main map and mini map which show details and overview, and defining maximum zoom level. Also, aligning selection box in mini map that enables panning, using some general map interaction functions, such as aligning scale factor of the main map based on percentage between fully zoomed out (100%) and the specified maximum zoom (0%).

```
Function ScaleMapTo (percent){
    Percent = Clamp (0, percent, 1);
    Var scale = 100+ (maxZoom-100)*percent;
    Var inverseScale = 100*100/scale;
    mainMap.map._xscale = mainMap.map._yscale = scale;
    For (var i=0; i<noScaleClips.length; i++){
        NoScaleClips[i]._xscale = noScaleClips[i]._yscale = inverseScale;
    }
    RestrictMapPosition ();
    UpDateMiniMap ();
}
```

Applying scales to map, making sure that map doesn't go outside its boundaries by 'restrict map position' and updating the mini map to reflect changes are next steps. After these operations, defining thresholds of x and y directions for panning facility is needed. The point 0, 0 is in the center of the map.

```
Function PanMapCenterTo(x,y){
    mainMap.map.pan._x = -x;
    mainMap.map.pan._y = -y;
    RestrictMapPosition ();
    UpDateMiniMap ();
}
```

Because panning happens inside the map movie clip, all scaling is automatically applied and won't have to be derived in code. Then, a scale ratio based on the current scale of the map must be taken into account. As the main map scales larger, the view within the mini map gets proportionally smaller as does ratio value. When the ratio is small, the view in mini map is small and relates directly with the view in the main map. Defining the directions right, left, top and bottom as mouse variables to drag and for panning is the next step of second part of the code. Finally, a watch callback function is used to monitor the value within the slider bar: when that value changes, slider change takes the new value and uses it to scale the map with 'scale map to' (Appendix 1A).

```
Function Slider Change (prop, oldSliderValue, newSliderValue){
    ScaleMapTo (newSliderValue);
    Return newSliderValue;
}
slider.watch ("value", Slider Change);
```

The third part of the code relates to defining the slider characteristics. Defining the height of the slider and restricting that to a specific y axis limitation and keeping height above 0 are other steps (Appendix 1A).

```
grabber.Slide = function (){
    If (this._y > 0) this._y = 0; // keep _y 0 or above
```

```
Else if (this._y < -height) this._y = -height; // keep _y within height  
Value = -this._y/height; // derive value of value  
}
```

### 3.3.2. Magnifying glass

In case of the magnifying glass technique, there is a need to define a lens as a symbol at a predefined zoom level in Flash and a solid circle that shows the glass on the zoomed area. By moving the glass over both static and animation networks, different areas of interest are visible in details while maintaining the overview at the same time. Figure 26 shows magnifying glass on a static network and it can be seen that although focus and context are visible simultaneously, the connectivity of lines in the network is not maintained: there are distortions at the edge of the glass, the boundary of focus and context area. In case of an animated network (figure 27), by keeping the glass at one specific area, changes in congestions are visible. There is no non-linear magnification inside the magnifying glass area.



Figure 26: Applying magnifying glass method on a static road network visualization of Enschede



Figure 27: Applying magnifying glass method on an animated road network visualization of Enschede, here visible in one specific time interval

A simple Java script code is used to apply magnifying glass on the network visualization. First step is using a predefined glass and putting it onto the enlarged map. Then, by masking 200% enlarged map on the original one, it can be seen that by moving the glass over the original map, zoomed areas are visible under the glass (Appendix 1B).

```
setProperty ("largeobject", _x, (194 - _x) * 2);
```

```
setProperty ("largeobject", _y, (79 - _y) * 2);
```

By changing digit '2' in the code above, providing different zoom levels is possible. This code must be put into 2 frames: one for the original map and one for the enlarged map which is glass now.

### 3.3.3. Fisheye view

The fisheye view technique is coming from photography, so it is implemented on raster (image) data more than on vector data. There are less works of fisheye view technique done on vector data and on the animation than on raster data. In case on the fisheye view technique, it is needed to define a fisheye or a bulb that can be moved over the network visualization, and has a non-linear magnification. By moving the fisheye over the network, different areas of interest are visible at both overview and detail scales and by increasing Euclidean distance from the center of the focus area, the magnification factor will decrease (figure 28). It can be assumed that most of the times, areas close to the centre of the focus area are more important for users than areas further from the centre and this point shows the priority importance for the users. Figure 29 illustrates application of the fisheye view technique on the animation and it shows that by keeping the fisheye on one specific area, changes of line widths that indicate the congestion are visible like in the magnifying glass technique. But it is obvious that there are distortions inside the focus area, in contrast with magnifying glass technique, in which distortions appear at the edge of the glass, not inside the focus area.

Code mentioned below uses the displacement map filter to create a fisheye type of zoom. To get this kind of displacement, both components of the displacement filter (x and y) need to reference different color channels (Appendix 1C). These colors are used in the displacer symbol to distort each axis as needed. Red is used to displace along x axis and green is used to displace along y axis. Ignoring the colors and just showing the original map beneath the distorted one is the next step. Finally applying the displace filter when moving the mouse is the last phase. The main code used came from application on image data, but it is applied on the vector data in this research.

```
Var colorX = 1;
```

```
Var colorY = 2;
```

```
Var powerX = 75;
```

```
Var powerY = 75;
```

```
Var mode = "ignore";
```

```
Var offset = new flash.geom.Point (0, 0);
```



Figure 28: Applying fisheye view method on a static road network visualization of Enschede



Figure 29: Applying fisheye view method on an animated road network visualization of Enschede, here visible in one specific time interval

### 3.4. Developing the user interface

The focus + context methods mentioned above are ready to test on users but providing a user friendly environment is still needed. All 3 methods in case of both static and animated networks visualizations are put into one application and users can easily run each method by clicking on the name of the method.

A time line is also added below each animation with some buttons. This time line is divided based on hours from 6:00 till 20:00 and users can control the movie by means of buttons such as pause, play, forward and backward. Figure 30 illustrates the magnifying glass on animated network visualization as an example. Selecting method, time line and buttons are specified.

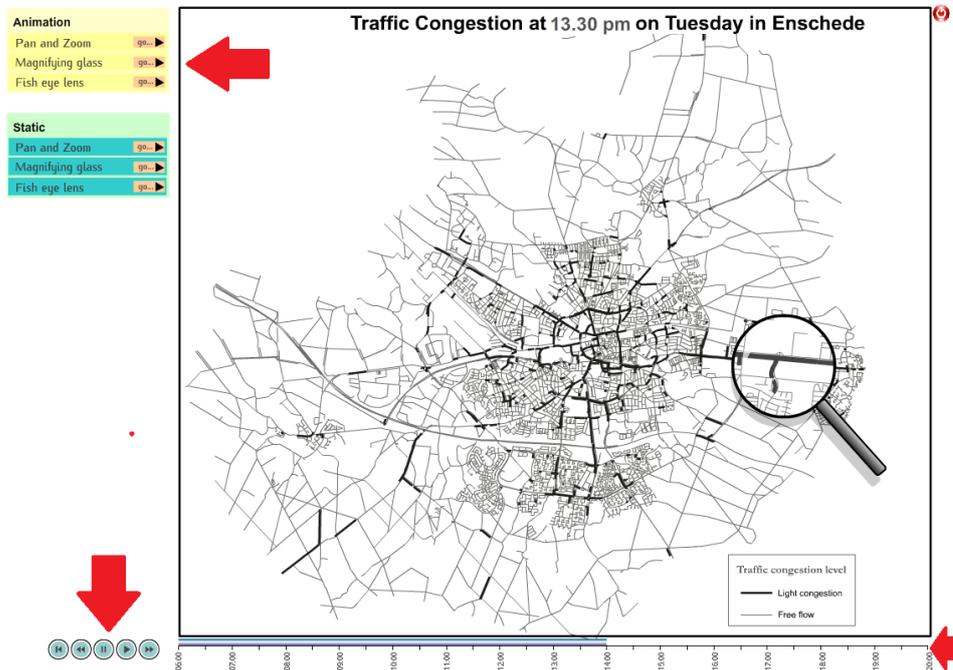


Figure 30: The interface for usability testing. The magnifying glass applied to the animated network visualization as an example. Methods, the time line and the buttons to control the animation are shown by red arrows here.

### 3.5. Conclusion

This chapter started with an introduction of network data visualization and steps of applying focus + context methods on both static and animation road network data visualizations of Enschede. The software used in this research is Adobe Illustrator and Adobe Flash CS5. Some Java Script programming was needed for applying methods in the Flash environment.

Changing the raster data to the vector data is the next section described. This operation makes the animation file implementable in software with a better resolution, more realistic and results in smaller data files than raster data.

Creating the static map and the animation based on 30 minutes time intervals that show changes in congestions on different roads of Enschede on one day is also described. Differences in line widths show different congestion levels that change over time.

Applying location map, magnifying glass and fisheye view on both static and animation road network visualizations of Enschede have been created to be able to test the methods (see chapter 4).

Finally, the user interface has been developed for usability testing by adding a time line for animation and buttons to control the movie.

## 4. Evaluation and results

### 4.1. Introduction

As described earlier (Chapter 3), to tackle conventional zooming problems such as losing context and providing overview and details of network data visualization at the same time, 3 focus + contexts methods are applied on both static and animated road network data of Enschede. These applied methods must be tested on users to evaluate three main components of their usability: efficiency, effectiveness and satisfaction (Elzakker & Wealands, 2007). Effectiveness is the accuracy and completeness by achieving predefined goals, Efficiency refers to minimum resource expenditure to reach a goal and satisfaction is the comfort of manipulating with applied methods (Wealands, 2006). A usability test shows success or lack in designed and applied methods (Butler, 1996).

Gathering problems that may arise during the use of methods can be gained by usability testing (Jeffries, et al., 1991). In each usability test, user profiling or gathering general information of participants, user task execution and evaluations of applied or designed methods must be considered in results. Evaluation is a valuable key in finding out and validating the concepts and problems of applied methods by using a feedback from users on how well the methods are working (Butler, 1996).

This chapter contains a section of the usability methods that have been applied (4.2), pilot test (4.3), about participants (4.4), tasks and materials of the test (4.5), test environment (4.6), test procedure (4.7), analysis of the results of the test (4.8) and finally a review on hypotheses proposed in chapter 2 to see if they are corrected or rejected (4.9) and discussion (4.10).

### 4.2. Usability methods

To collect data from users, 2 methods of data collection were used; questionnaires and observations. The advantage of questionnaire method is that it makes comparability of collected data easier (Kumar, 2005). It also helps to provide additional information about the tasks (Haklay & Zafiri, 2008). Observation method was used because users face reactions, voice and their operations on the screen can be recorded and used in the analysis of results (Elzakker & Wealands, 2007). During user testing, using special equipment to record the observation is more proper way than making notes and the results would be more verifiable also (Elzakker & Wealands, 2007). A disadvantage of observation method is that users may change their behaviour while knowing that they are being observed; this is known as the Hawthorne effect (Kumar, 2005). Other disadvantage of this method is that interpretation will be conducted by the experimenter, but these disadvantages do not overcome the advantages (Blok, 2005).

All the participants were asked to think aloud during the test and say everything in their mind and all the operations on the screen with loud voice. This helps to understand why they are doing things and what they are thinking (Elzakker & Wealands, 2007).

### 4.3. Pilot test

First, a pilot test is held. The goal of holding a pilot test is to find the deficiencies and ambiguities of the test and questionnaire and correcting them based on the observed problems. Testing software and camera to see if there is any problem or not are other goals of pilot test. This test executed 2 days before the start of the usability test.

After holding the pilot test, a note was written containing all steps of the main test. This note was used to provide all steps for all participants with the same conditions.

### 4.4. Participants

In total, 21 participants (12 male and 9 female persons) were used for the test, divided in 3 groups; TP1, TP2, TP3. Six days were considered for testing and each test took 15-20 minutes of each user (Appendix 2). Each group had 4 tasks, and each participant worked with all 3 focus + context methods.

Table 4 indicates the age of the participants. All participants were PhD students of Twente University, ITC faculty and had more than 3 years of working experience with computers. 66% of users were a bit familiar with the area represented (Enschede) and 34% of them mentioned that they are very familiar with the area, but none of them was familiar with the focus + context methods represented (Appendix 4A).

Test participants must reflect the characteristics of the end users of the methods and it must be likely that they will use it (Hinderer, 1998).

Age	Number of participants
20-30	9
30-40	10
40-50	2

Table 4: Participants' age

In the questionnaire, 15 participants indicated that they sometimes work with network data visualization, 5 of them mentioned very often and just one of them stated never. Furthermore, 10

participants indicated that they sometimes use zooming and panning techniques, 8 of them mentioned very often and 3 of them selected never.

#### 4.5. Tasks and materials

The test of this research contains 21 participants in 3 groups. All participants work with three applied focus + context techniques during the navigational tasks in both static and animation cases.

Navigation in a map representation such as panning and zooming requires the user to do standard things (Cartwright, et al., 2001).

The questionnaire given to users contained an introduction of the test, general questions that referred to user profiling, four tasks and finally some questions about 3 techniques users worked with.

Each participant work with static network data based on Bertins' 3 levels of reading; elementary, intermediate and overall levels, and one animation task (Appendix 3).

**Introduction:** At the beginning of each test, participant was introduced to the goal of the test and to 4 tasks. A brief explanation of the focus + context methods, the focus of the research and the (think aloud) method was also given. Other points described to users were explaining how to run the animation and how to control it via the timeline and buttons below the animation. Next, participants were reminded to think aloud and say everything in their mind aloud. The setting up of the camera and starting the software to record the observations were the last steps of introduction.

**Tasks:** As it is mentioned earlier (Chapter 2), Bertin (1983) defined 3 levels of reading; elementary, intermediate and overall levels. In case of applying focus + context methods on the static network visualization, 3 tasks were asked from users based on these three reading levels. The reason of selecting 3 levels of reading was to provide a condition for users to navigate and explore network data visualization by different zoom levels such as finding a sign, finding a road and diagnosing the area of Enschede with the least road density by using 3 focus + context methods. In case of finding the sign, participant must zoom in to the network and target the sign (elementary level). In case of finding the road, participant must decrease the zoom level compared to the previous task to target the road (intermediate level) and finally for the third task, the participant must look at the whole map as an overview to diagnose which part of network has the least density (overall level). Figures 31 and 32 illustrate the sign and the road that must be found in network by users.

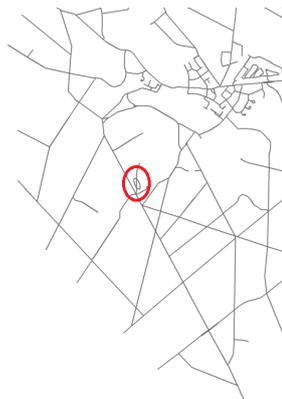


Figure 31: Specified sign in the network (elementary level)



Figure 32: Specified road in the network (intermediate level)

In case of animation, a 4<sup>th</sup> task was asked from users. They were requested to find an area in the center of Enschede (see figure 33) and count the number of roads inside the center which have light congestion in the time period between 13:00 to 15:00. This task forced participants to use zooming techniques (to find the center), animation (to see changes of traffic flow) and timeline (to control the movie in the period between 13:00 to 15:00).



Figure 33: Specified area (center of Enschede) for animation task. Users must find it and count the number of roads with light congestions in the period between 13:00 to 15:00

As it is mentioned before, 21 users participated in the test divided in 3 groups of 7 persons. The tasks of each group were the same but the method of each task differed. At the end, all 21 participants worked with all 3 focus + context method. Table 5 shows test set up for each group.

<b>Test Set up</b>	<b>Task 1(static)</b>	<b>Task 2(static)</b>	<b>Task 3(static)</b>	<b>Task 4(animation)</b>
<b>Group1</b>	Location map	Magnifying glass	Magnifying glass	Fisheye view
<b>Group2</b>	Magnifying glass	Fisheye view	Fisheye view	Location map
<b>Group3</b>	Fisheye view	Location map	Location map	Magnifying glass

Table 5: Test set up for each group

**Questionnaire:** After the tasks, participants had to answer questions about focus + context methods they worked with. A comparison between the sizes of enlarged area was asked from the users. After that their preference was asked: first for location map, or magnifying glass/ fisheye view; next preference choice had to be made between magnifying glass and fisheye view. Finally they were requested to write down their suggestions for improving the methods. Questionnaire takes a short time from participants to answer because it contains multiple choice questions and has a short length (Lewis, 1995).

## 4.6. Test environment

### 4.6.1. Test room

The room used for user test is located at the first floor of ITC faculty building. It is equipped with facilities to record participants' observations and provides same conditions for all users. Room's conditions and participant's seat can be seen in figure 34.



Figure 34: Test room's conditions. Laptop, user's seat and camera as backup can be seen.

#### 4.6.2. Facilities

All participants worked with a Sony laptop with 16.4 inch monitor. Laptop was equipped with Snagit 10 software that is used to record the users' operations on the screen and their voice. Face reactions of participants were recorded by webcam of the laptop to be able to analyze user's satisfaction with the methods or problems they faced during doing the tasks. A Sony digital camcorder DCR-SR 90E/100E was also used as backup and placed behind the users to record operations on the screen, their reactions and their voice (see figure 35). If something went wrong with recorded files on the laptop, backup files from the camera could be used for analyzing the collected data. Figure 34 also shows the location of backup camera behind the user.



Figure 35: Sony DCR-SR 90E/100E used as backup

#### 4.7. Test procedure

Test procedure went well as it was expected. Most of the participants presented at the test room at the mentioned time and they were satisfied with the test conditions. After each test, the data were transferred from the camera to the laptop and all recordings were saved into the specific folder for each participant. All conditions of the test and test room were maintained the same for all participants. The introduction given to all participants was the same. After the introduction, the tasks were given to them to start by thinking aloud. Finally, after doing the tasks, general questions about focus + context methods were asked in case of questionnaire (see 4.5).

#### 4.8. Results

The usability test is held to find out efficiency, effectiveness and satisfaction of applied focus + context methods. These 3 components were evaluated based on the data collected during the test (Appendix 4).

##### 4.8.1. Effectiveness

Effectiveness relates to correctness of answers and achieving predefined goals of each task. Table 6, shows the correctness of tasks done. Completed tasks are shown by (+) and not completed tasks are indicated by NC. Also, the names of methods are shown by word: location map (L), magnifying glass (M) and fisheye view (F). From the table, it can be concluded that participants found location map as the most effective method in all 4 tasks and found some problems in fisheye view method in case of animation task.

Task	Elementary level			Intermediate level			Overall level			Animation task		
	L	M	F	L	M	F	L	M	F	L	M	F
TP 1	NC				+			+				NC
TP 2	+				+			+				NC
TP 3	+				+			+				NC
TP 4	+				+			+				NC
TP 5	+				+			+				NC
TP 6	+				+			NC				+
TP 7	+				+			+				+
TP 8		+				+			NC	+		
TP 9		NC				+			+	+		
TP 10		+				+			+	+		
TP 11		+				+			+	+		
TP 12		NC				+			+	+		
TP 13		+				+			NC	+		
TP 14		+				+			+	+		
TP 15			+	+			+				+	
TP 16			+	+			+				+	
TP 17			+	+			+				+	
TP 18			+	+			+				NC	
TP 19			+	+			+				+	
TP 20			+	+			NC				NC	
TP 21			+	+			+				+	

Table 6: Effectiveness table. Completed tasks are shown by (+) and not completed tasks are shown by NC.

In case of elementary level of reading, 86% of participants of group 1 could do the task correctly using location map method. 71% of participants of group 2 did the task by correctly using magnifying glass method. The interesting point was that all participant of group 3 who used fisheye view method for this task could find the sign at last.

In case of intermediate reading level, all participants of the 3 groups could finish the task correctly, but, in case of overall level of reading, 86%, 71% and 86% of participants of groups 1, 2 and 3 could give a correct answer using magnifying glass and fisheye view and location map respectively.

Finally in case of animation, only 2 participants (28%) of all participants who used fisheye view method were successful to give right answer to the task, while 71% of participants of group 3 by using magnifying glass method and 100% of participants of group 2 by using location map method could give the correct answer. The reason is mentioned before. A fisheye provides a less clear focus area than two other techniques and while applying it on road network data visualization, it gets blurred.

#### 4.8.2. Efficiency

Efficiency relates to minimum resource expanded. Time is a proper factor to find out how fast the tasks can be done to conclude what the efficiency of methods is. In case of elementary level of reading, 71% of participants of group 1 and 71% of participants of group 2 did the task by location map and magnifying glass methods in less than 2 minutes. 86% of participants of group 3 did elementary task by fisheye view method in just less than 2 minutes. Figure 36 shows the efficiency of elementary task (static network). X axis indicates the time spent for task and Y axis indicates the number of participants. Also methods are specified by different colors. It can be revealed from the graph that fisheye view seems more efficient than magnifying glass and location map in this task.

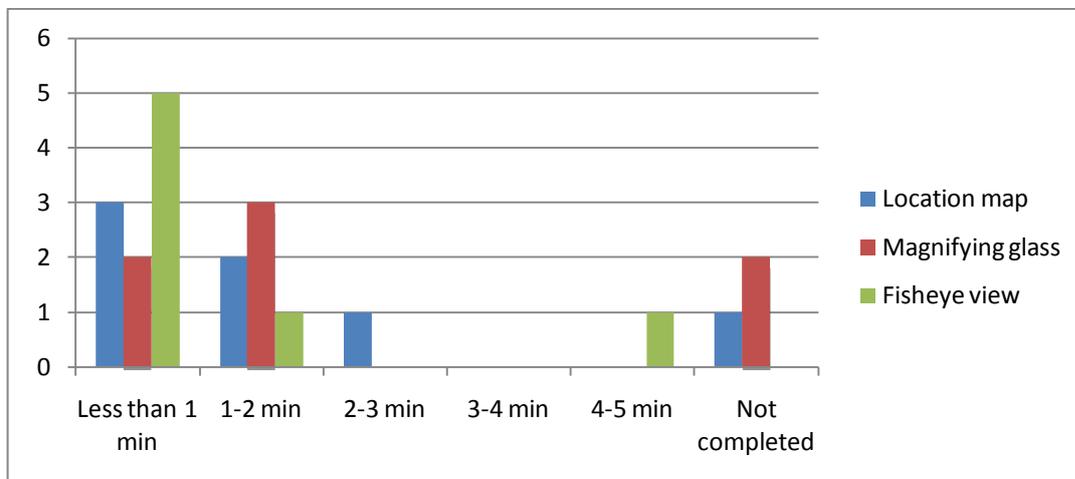


Figure 36: Efficiency graph for elementary task (static network). X axis indicates time and Y axis indicates the number of participants.

In case of intermediate reading level, all the participants of group 1 and group 2 did the task in less than 1 minute by magnifying glass and fisheye view methods while 86% of participants of group 3 who used location map for this level of reading could do the task at the same time (less than 1 minute). Figure 37 shows the efficiency of intermediate task (static network). X axis indicates the time spent for task and Y axis indicates the number of participants. Also methods are specified by different colors. Results show that magnifying glass and fisheye view seem more efficient than location map in intermediate level task (see figure 37).

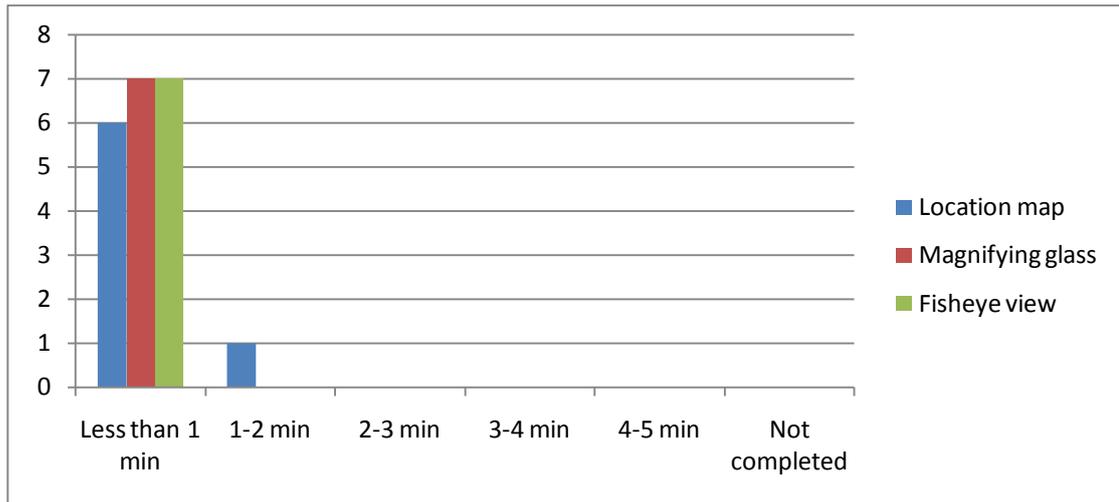


Figure 37: Efficiency graph for intermediate task (static network). X axis indicates time and Y axis indicates the number of participants.

In case of overall reading level, 86% of participants of group 1 did the task in less than 1 minute while just 57% of participants of group 2 and group 3 could do the task at the same time. It is clear that in this case, methods did not play an important role. To find out which part of Enschede has the least road density, there is a need to look at the whole map as an overview. Similarities of road density between north side and west side of Enschede may make the task difficult for some participants. Figure 38 shows the efficiency of overall task (static network). X axis indicates the time spent for task and Y axis indicates the number of participants. Also methods are specified by different colors.

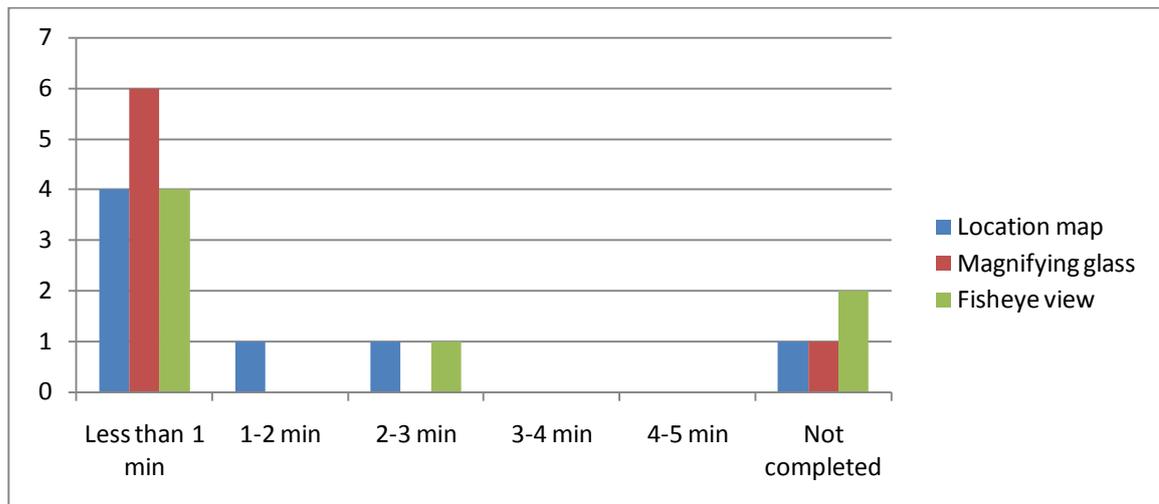


Figure 38: Efficiency graph for overall task (static network). X axis indicates time and Y axis indicates the number of participants.

Finally, in case of animation task, 57% of participants of group 2 and group 3 who used location map and magnifying glass methods could do the task in less than 3 minutes while only 28% of participants of group one could do the task using fisheye view method. It shows that fisheye view technique is not a proper method for doing animation task. Most of the participants mentioned that fisheye is blurred a

little bit when applied on a road network. Running the animation with changing widths of lines makes it difficult for users to diagnose and see the focus area under the fisheye. Figure 39 shows the efficiency of animation task. X axis indicates the time spent for task and Y axis indicates the number of participants. Also methods are specified by different colors.

It can be seen in figure 39 that location map and magnifying glass seem more efficient than fisheye view in animation task. This result was mentioned before as a hypothesis in theoretical framework (see 2.5).

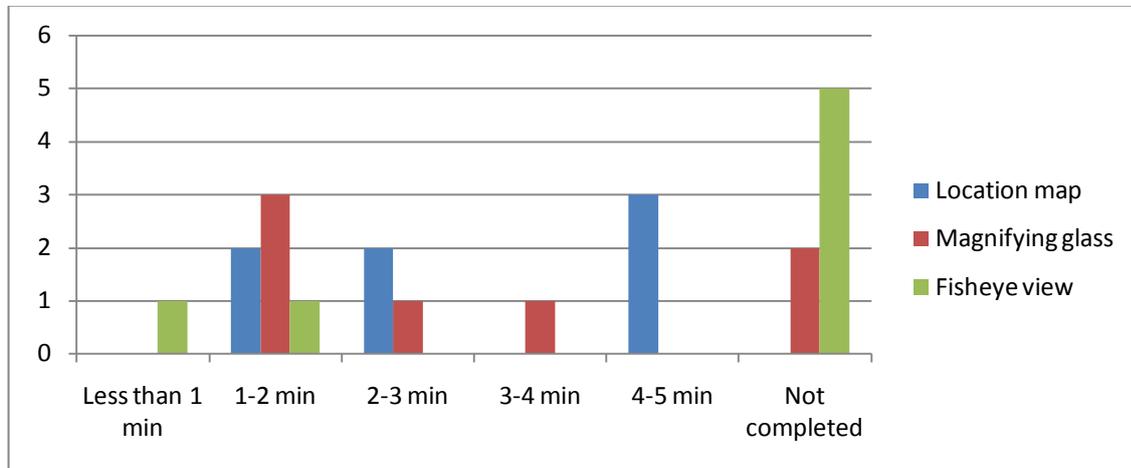


Figure 39: Efficiency graph for animation task. X axis indicates time and Y axis indicates the number of participants.

#### 4.8.3. Satisfaction

Satisfaction relates to freedom from discomfort. It can be revealed from participants face reactions and voices that most of them were satisfied about the applied focus + context methods and found them user friendly techniques. Others found some problems during doing the tasks (see 4.10). Participants' preference and priority of using methods were asked in two different questions of the questionnaire. The magnifying glass and fisheye view are first confronted with the location map due to having focus area on top of the context, in contrast to the location map, for which focus and context areas are located in two different windows and separate from each other. Second question asked participants preference between magnifying glass and fisheye view.

In total, 71% of all participants who worked with all 3 methods, preferred location map method while only 29% of them preferred magnifying glass and fisheye view category. They had their own reasons. It is concluded from thinking aloud method that most of those 71% of participants believed that providing different and flexible zoom levels as in the location map and having more clear representation of focus area affected on their mind. Others mentioned that being flexible to move around or easier to control and containing the whole object (focus and context) on top of each other were their reasons.

In case of second question, 71% of all participants preferred magnifying glass due to having more clear representation of focus area than fisheye view and providing enough zoom level. Only 29% of participants selected fisheye view more proper than magnifying glass and their reason was that there is no need to press mouse button to move the fisheye during focus targeting in contrast to magnifying glass. Figures 40 and 41 illustrate participants' preference of using applied focus + context methods.

So, it can be revealed that location map method is the most satisfying method in participants' preference.

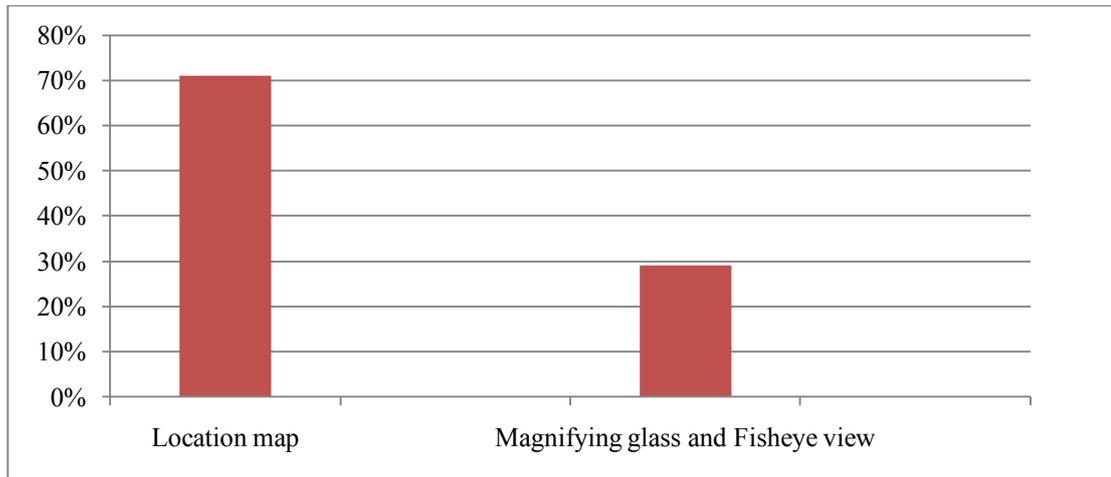


Figure 40: Users' preference between two categories; location map or magnifying glass and fisheye view

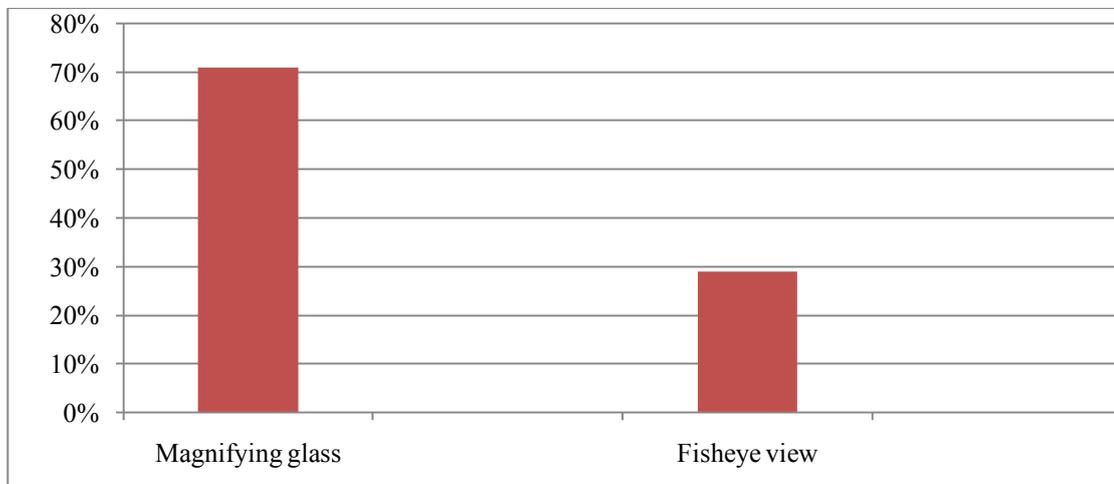


Figure 41: Users' preference between two categories; magnifying glass or fisheye view

#### 4.8.4. Size of the enlarged area

A comparison between sizes of the enlarged area of each method is done. Known as enlarged area are: in case of location map, the details window that is larger than overview window; in case of magnifying glass, the circle of the glass and in case of fisheye view, the bulb that represents focus area. Figures 42, 43 and 44 illustrate participants' ideas about sizes of these enlarged areas. Results indicate that in case of magnifying glass and fisheye view methods, there is a need to design a facility for users to enable them to change the size of the focus based on their interests. In case of location map method, 90% of participants were satisfied with the size of enlarged area.

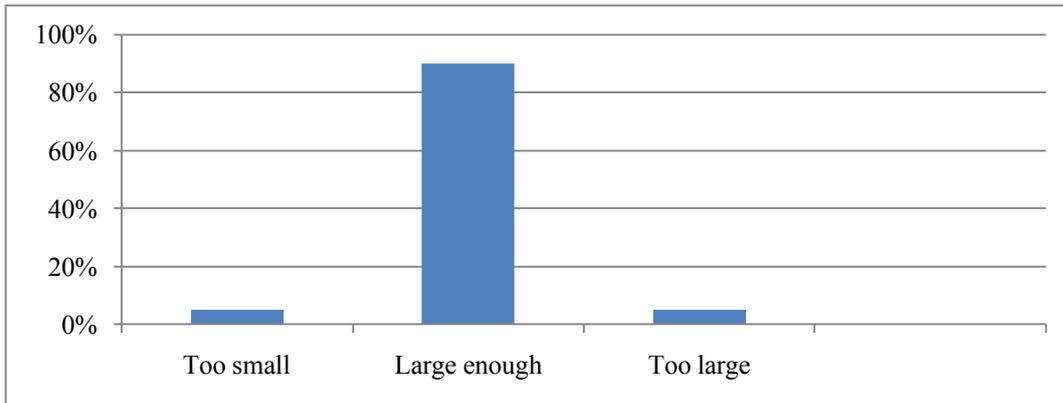


Figure 42: Participants' idea about the size of the enlarged area in location map method

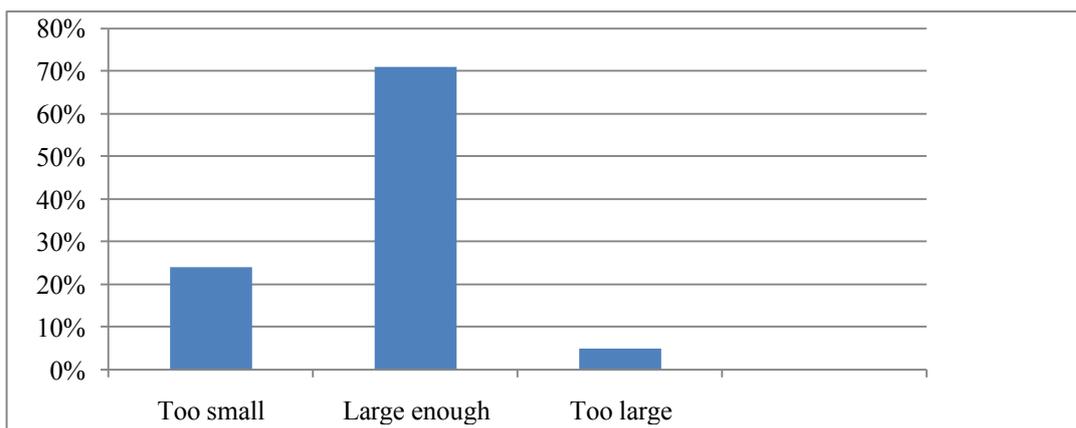


Figure 43: Participants' idea about the size of the enlarged area in magnifying glass method

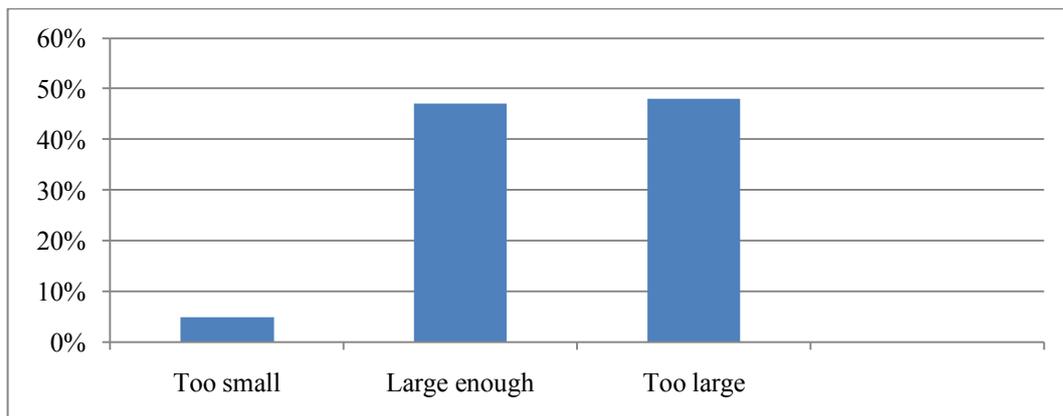


Figure 44: Participants' idea about the size of the enlarged area in fisheye view method

#### 4.9. Reviewing hypotheses

Referring to the hypotheses proposed in the theoretical framework (see 2.5), it can be concluded that defined hypotheses were correct as it was expected. The results of the test showed the weaknesses of applying fisheye view on animated network data visualization, especially in case of road network data visualization and effectiveness of applying this method on static network data visualization. Also, it can be revealed from the results that applying magnifying glass method on network data visualization

leads to distortions at the edge and handle of the glass and it does not maintain the connectivity of lines in road network data visualization, but its constant magnification leads to more clear representation of the focus area than fisheye view. Finally, participants found location map as the most satisfying method between 3 focus + context methods due to providing different zoom levels and easy control.

#### **4.10. Discussion**

During the test, a number of problems and design deficiencies were observed from users' reactions and thinking aloud. These observations show the usefulness of data collection methods used in this research. As mentioned before, laptop webcam recorded face reactions of participants and it led to observing users' face reactions and their satisfaction or discomfort of using applied focus + context methods. Also, by recording users' operations on the screen and their voices (thinking aloud method), the problems they had during doing the tasks could be observed. The participants' problems concluded from the observation methods and their suggestions written in the questionnaire are mentioned below:

- 1) As it is described before, the fisheye bulb seemed blurred on road network data visualization and made it difficult for participants to do their tasks, especially in case of animation task.
- 2) Zooming in and zooming out with a slider in case of location map was a little bit hard for participants and they preferred to have different zoom levels by scrolling the mouse.
- 3) Constant zoom level of magnifying glass and fisheye view was a big problem for most of the participants. They preferred to have more zoom levels and flexibility in these two methods.
- 4) Changing the size of the focus area of magnifying glass and fisheye view is really needed.
- 5) In case of magnifying glass, the handle and the edge of the glass disturbed some participants to explore the network data representation and covered some information.
- 6) Road network representation was without any reference or label and it made it difficult for participants to find the target, especially in case of elementary level tasks.
- 7) In case of location map, the size of overview window was diagnosed a little bit small.
- 8) In case of animation, some participants had problems to control the movie. They preferred to control the movie by dragging the timeline instead of using control buttons.

#### **4.11. Conclusion**

This chapter described the evaluation of the focus + context methods that were designed and applied on the network data visualization mentioned in chapter 3. It is described earlier that the goal of applying these methods was to provide overview and detail of network data visualizations at the same time to avoid conventional zooming problems. So, usability tasks were defined based on these criteria for both static and animated network data. Observations and questionnaire methods were used for usability testing. Users' face reactions and voices were recorded as observations and think aloud method was used to understand what is in users' minds. 21 Phd students participated in the test and test conditions such as room, laptop, software and camera as backup were the same for all of them.

The outcome from the usability tests revealed no main problem for efficiency and effectiveness of applied methods, but it can be concluded that fisheye view is not a proper choice to apply on animated visualization of road network data due to providing a blurred representation of focus area. Fisheye seems more efficient in task 1 which was elementary level task (static network) than the location map

and the magnifying glass. Also in task 2 which was intermediate level task (static network), fisheye seems more efficient than the location map.

Approximately, 71% of participants preferred location map for exploring network data visualization because of providing flexible and different zoom levels. Also, 71% of participants preferred magnifying glass over fisheye view because of providing more clear focus area.

A comparison between the sizes of enlarged areas of methods was done and 90% of participants had no problem with the size of the focus area of location map method. In case of magnifying glass and fisheye view, the ideas were different and revealed that there is a need to enable users to change the size of enlarged area of these two methods.

The last results that can be concluded from the test were participant observations recorded as face reactions and thinking aloud. During doing the tasks, some problems disturbed participants and that appeared in the recorded files. It can be revealed from these observations that providing different zoom levels and a facility to change the size of the enlarged area for the magnifying glass and fisheye view methods, providing clear focus area for the fisheye view method and increasing the size of overview map in the location map method were the most important problems.

## 5. Conclusions and recommendations

### 5.1. Conclusions

Focus + context techniques provide overview and detail of network data representations at the same time for users of these network visualizations such as transport planners and managers. The main goal of these methods is to avoid the problems of conventional zooming technique, such as losing context while zooming in and getting lost in large amount of data while zooming out.

Applying these techniques on both static and animated road network data of Enschede (as a case) revealed that users can explore network data visualization at different spatial scales. Dynamic characteristics of these methods enable users to change the focus area based on their interests while maintaining context area simultaneously. This research is an effort to gain a proper understanding in characteristics of focus + context techniques (zooming techniques) and evaluate them by answering research questions mentioned in chapter 1.

#### **What are the characteristics of spatial network data?**

Results from literature study show that network contains nodes and links with their attributes that may change over time and related data like speed profiles. Maps are graphical forms of network representations and often make network data more understandable in different types; flow maps, schematic maps or tree maps. Connections are important in network representations and they should be maintained as much as possible in network data visualization.

#### **Is there a need for visualizations at different spatial scales?**

Sometimes, there are large amount of spatial data that must be shown in a network data visualization. Exploring these data may confuse map readers especially in case of tasks where screen navigation is needed. Users may need to focus on a specific area of the network by zooming in to see more details or may need to visualize an overview of representation. These transitions between overview and details and back may lead to losing some context while using conventional zooming for zooming in and zooming out.

#### **What methods are available to create understandable transitions between visualizations at different scales?**

Generalization is used to make data representation understandable by different activities such as smoothing, filtering or aggregation leading to reduction of details and maintaining overall characteristics of network data representation. To avoid elimination of necessary information, zooming with flexible transitions can be used.

#### **What is/are the most potential method(s)?**

In order to provide both overview and details at the same time, 3 methods are used to apply in this research based on their characteristics; location map, magnifying glass and fisheye view. Dynamic characteristics (changing the place of focus) and easier navigational steps than conventional zooming were the main reasons of choosing these methods.

#### **Which network visualizations have to be designed (static and animated)?**

The case study that is used in this research was the raster format of road network of Enschede as static network data visualization. The TeleAtlas data is also used; it provides percentage of free flow speed (FFS) at 5 minutes intervals for a whole week. These FFS percentages of 30 minutes time intervals from 6:00 am to 8:00 pm for one day of a week is used to apply on road network data to produce animation.

#### **How can focus + context methods be implemented in a prototype?**

The format of the road network is transformed from raster to vector due to some reasons; being more realistic than raster format, higher resolution than raster format and being able to run in Flash software. Adobe Illustrator software is used for this transformation. Applying speed profiles on static layers of network data and adding a time line in Flash environment produces the animation. The animation enables a user to see width changes of lines based on speed changes at different time intervals.

To apply location map technique, two separate windows were defined by JavaScript code to represent overview and detail. A slider and a small rectangle are also added to provide zooming and panning facility. In case of magnifying glass, a predefined lens in Flash environment is used. The magnification factor is also added by JavaScript code to the application. To apply fisheye view, a bulb (fisheye) is defined to move over the network by moving the mouse cursor. In this case, it can be seen that by increasing the distance from the center of the focus, magnification will decrease. This advantage shows the priority importance (areas close to the focus are often more important than areas further from the focus for users). So, it reduces distortions at the edge compared to the magnifying glass.

#### **How can different methods be evaluated?**

Three main components of usability of applied methods (efficiency, effectiveness and satisfaction) are evaluated by 21 participating PhD students (3 groups of 7 persons) in usability test. Observations and questionnaire methods are used to collect data from participants. Participants were asked to do some navigational and focus targeting tasks. Results showed success in case of location map and magnifying glass methods, while fisheye view did not result in participants' preference due to providing unclear representation of focus area. Most of the participants believed that fisheye gets blurred on road network data visualization, especially in case of animation.

#### **What is the usability of recommendations?**

From participant's observations, it was obvious that applied focus + context methods have still deficiencies that must be improved. After analyzing the results, it is concluded that an improvement of methods is really needed to gain better insight and provide flexible facility for transitions between scales. Due to this, recommendations will be mentioned as future work for next researchers to take into account.

#### **Which recommendations can be derived from the evaluation?**

Observation methods used for collecting data including observing participants' face reactions, thinking aloud and operations on the screen. From these observations, problems of applied methods appeared as discomfort of using methods. Also, participants wrote down their suggestions for improvement of the methods as the last question of the questionnaire. These problems and suggestions lead to recommendations as future work such as providing different zoom levels for the magnifying glass and the fisheye view technique and changing the size of the enlarged area in these two methods.

## 5.2. Recommendations for future work

Applying focus + context techniques on both static and animated road network data visualization is only a small step towards providing flexible transitions between different spatial scales and providing overview and detail at the same time for network data representation. Future researchers can consider and take into account the following recommendations:

- Provide a clear focus representation in case of fisheye view technique
- Provide a facility for users to enable them to change the size of the focus area in case of magnifying glass and fisheye view techniques
- Provide different zoom levels for magnifying glass and fisheye view techniques
- Provide transitions by mouse scrolling instead of using slider in case of location map technique
- Try to mix focus + context methods with generalization techniques

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# Appendices

## Appendix 1: Java Script codes

### A. Location map

The Java script code used for designing this method contains 3 parts. First part relates to some basic functions which are generic functions that can be used anywhere. Drawing boxes in movie clip and defining clamp are mentioned in this part of code. Clamp operation maintains the map inside the box. If the value is lower than low, low is returned and if the value is higher than high, high is returned. Otherwise if the value is acceptably between those values, it is returned.

```
MovieClip.prototype.drawBox = function (left, top, right, bottom, line, fill) {  
    this.clear ();  
    this.lineStyle.apply (this, line);  
    this.beginFill.apply (this, fill);  
    this.moveTo (left, top);  
    this.lineTo (left, bottom);  
    this.lineTo (right, bottom);  
    this.lineTo (right, top);  
    this.lineTo (left, top);  
  
    this.endFill ();  
}  
Function Clamp (low, value, high){  
    Return Math.min (Math.max (value, low), high);  
}
```

The second part of the code relates to defining main map and mini map which show overview and detail and defining maximum zoom level. Also, aligning selection box in main map that enables panning, using some general map interaction functions are mentioned here, such as aligning scale factor of the main map based on percentage between zoomed out percentage of 100% and the specified maximum zoomed 0%. A scale of 100 and 1 (100%) is a scale of maximum zoom. Applying scales to map, making sure that map doesn't go outside its boundaries by 'restrict map position' and updating the mini map to reflect changes are next steps. After these operations, defining thresholds of x and y directions for panning facility is needed. The point 0, 0 is where the center of the map is represented. Because panning happens inside the map movie clip, all scaling is automatically applied and won't have to be derived in code. Then, a scale ratio based on the current scale of the map must be taken into account. As the main map scales larger, the view within this map gets proportionally smaller as does ratio value. When the ratio is smaller, the view in mini map is smaller and relates directly with

the view in the main map. Defining the directions right, left, top and bottom as mouse variables of drag and press for panning is the next step of second part of the code. Finally, a watch callback function is used to monitor the value within the slider bar changing. When that value changes, slider change takes the new value and uses it to scale the map with 'scale map to'.

```
MaxZoom = 700;
BaseSize = {width: 175, height: 250};
Miniscale = .33;
NoScaleClips = [
    mainMap.map.pan.visCenter_mc,
    mainMap.map.pan.sciences_mc,
    mainMap.map.pan.commonscs_mc,
    mainMap.map.pan.research_mc
];
mainMap.createEmptyMovieClip ("selection_mc", 1);
miniMap.createEmptyMovieClip ("selection_mc", 1);
Function ScaleMapTo (percent) {
    Percent = Clamp (0, percent, 1);
    Var scale = 100+ (maxZoom-100)*percent;
    Var inverseScale = 100*100/scale;
    mainMap.map._xscale = mainMap.map._yscale = scale;
    For (var i=0; i<noScaleClips.length; i++) {
        NoScaleClips[i]._xscale = noScaleClips[i]._yscale = inverseScale;
    }
}
RestrictMapPosition ();
    UpDateMiniMap ();
}
Function getMapScalePercent (scale) {
    Scale = Clamp (100, scale, maxZoom);
    Var percent = (scale-100)/ (maxZoom-100);
    Return percent;
}
Function PanMapCenterTo(x,y){
    mainMap.map.pan._x = -x;
    mainMap.map.pan._y = -y;
    RestrictMapPosition ();
    UpDateMiniMap ();
}
Function RestrictMapPosition () {
    Var ratio = 100/mainMap.map._xscale;
    Var padding_x = (baseSize.width – baseSize.width*ratio)/2;
    Var padding_y = (baseSize.height – baseSize.height*ratio)/2;
    mainMap.map.pan._x = Clamp (-padding_x, mainMap.map.pan._x, padding_x);
    mainMap.map.pan._y = Clamp (-padding_y, mainMap.map.pan._y, padding_y);
}
Border of the map.
}
```

```

Function UpDateMiniMap () {
    Var ratio = 100/mainMap.map._xscale;
    miniMap.view._xscale = miniMap.view._yscale = 100 * ratio;
    miniMap.view._x = (baseSize.width*miniscale)/2 -mainMap.map.pan._x*miniscale;
    miniMap.view._y = (baseSize.height*miniscale)/2 -mainMap.map.pan._y*miniscale;
}
mainMap.map.pan.click.useHandCursor = false;
mainMap.map.pan.click.onPress = function () {
    mainMap.selection_mc.press_x = mainMap._xmouse;
    mainMap.selection_mc.press_y = mainMap._ymouse;
    mainMap.selection_mc.drag_x = mainMap._xmouse;
    mainMap.selection_mc.drag_y = mainMap._ymouse
    mainMap.selection_mc.onMouseMove = function () {
    this.drag_x = Clamp (0, this._parent._xmouse, baseSize.width);
    this.drag_y = Clamp (0, this._parent._ymouse, baseSize.height);

this.drawBox (this.press_x,
                this.press_y,
                this.drag_x,
                this.drag_y,
                [0, 0xff, 100], [0x8888ff,5]);
        Var ratio = 100/mainMap.map._xscale
        Var scaledWidth = baseSize.width*miniscale
        Var scaledHeight = baseSize.height*miniscale;
        Var scaledown = miniscale*ratio;
        Var offset_x = miniMap.view._x - scaledWidth*ratio/2;
        Var offset_y = miniMap.view._y - scaledHeight*ratio/2;
this.selection_mc.drawBox (offset_x+this.press_x*scale down
offset_y+this.press_y*scaledown,
offset_x+this.drag_x*scaledown,
offset_y+this.drag_y*scaledown,
[0, 0xff, 100], [0x8888ff, 5]);
    }
}
mainMap.map.pan.click.onMouseUp = function (){
    if (mainMap.selection_mc.onMouseMove) {
        mainMap.selection_mc.clear ();
        miniMap.selection_mc.clear ();
        Delete mainMap.selection_mc.onMouseMove;

If (mainMap.selection_mc.drag_x < mainMap.selection_mc.press_x){
    Var left = mainMap.selection_mc.drag_x;
    Var right = mainMap.selection_mc.press_x;
    } else {
        Var right = mainMap.selection_mc.drag_x;

```

```

        Var left = mainMap.selection_mc.press_x;
    }
    If (mainMap.selection_mc.drag_y < mainMap.selection_mc.press_y){
        Var bottom = mainMap.selection_mc.drag_y;
        Var top = mainMap.selection_mc.press_y;
    } else {
        Var top = mainMap.selection_mc.drag_y;
        Var bottom = mainMap.selection_mc.press_y;
    }
    Var selectwidth = right-left;
    Var selectheight = top-bottom;
    Var scaleTo = (baseSize.width/baseSize.height > selectwidth/selectheight)
BaseSize.height/selectheight: baseSize.width/selectwidth;
    ScaleTo *= mainMap.map._xscale;
    Var ratio = 100/mainMap.map._xscale;
    Var center_x = ratio*(right - (selectwidth + baseSize.width)/2) -
mainMap.map.pan._x
    Var center_y = ratio*(top - (selectheight + baseSize.height)/2) -
mainMap.map.pan._y;
    if (selectwidth > 10 && selectheight > 10) {
slider.setValue (getMapScalePercent (scaleTo));
    }

    PanMapCenterTo (center_x, center_y);

}
}
miniMap.useHandCursor = false;
miniMap.onPress = function () {
PanMapCenterTo (this.map._xmouse, this.map._ymouse);
This. OnMouseMove = function () {
    PanMapCenterTo (this.map._xmouse, this.map._ymouse);
}
}
miniMap.onMouseUp = function (){
    If (this. OnMouseMove) {
Delete this. OnMouseMove;
    }
}
Function SliderChange (prop, oldSliderValue, newSliderValue){
    ScaleMapTo (newSliderValue);
    Return newSliderValue;
}
slider.watch ("value", SliderChange);

```

The third part of the code relates to defining the slider characteristics. Defining the height of the slider and restricting that to a specific y axis limitation and keeping height above 0 are other steps.

```
Height = 100;
LineStyle (1, 0,100);
LineTo (0,-height);
Value = 0;
grabber.onPress = function () {
This. OnMouseMove = function () {
    this._y = this._parent._ymouse;
    this.Slide ();
}
grabber.onRelease = grabber.onReleaseOutside = function () {
    delete this. OnMouseMove;
}
grabber.Slide = function (){
    If (this._y > 0) this._y = 0;
    Else if (this._y < -height) this._y = -height;
    Value = -this._y/height;
}
SetValue = function (percent){
    grabber._y = -percent*height; // set _y to position based on height
    grabber.Slide (); // use Slide to restrict position and set value
}
```

## B. Magnifying glass

A simple Java script code is used to apply magnifying glass on the network data. First step is using a predefined glass and putting it on the enlarged map. Then, by masking 200% enlarged map on the original one, it can be seen that by moving the glass over the original map, zoomed areas are visible under the glass.

```
SetProperty ("largeobject", _x, (194 - _x) * 2);
SetProperty ("largeobject", _y, (79 - _y) * 2);
```

By changing digit '2' in the code above, providing different zoom levels are possible. This code must be put in 2 frames; one for the original map and one for the enlarged map which is glass now.

## C. Fisheye view

This code uses the displacement map filter to create a fisheye type of zoom. To get this kind of displacement, both components of the displacement filter (x and y) need to reference different color channels. These colors are used in the displacer symbol to distort each axis as needed. Red is used to displace along x axis and green is used to displace along y axis. Ignoring the colors and just showing

the original map beneath the distorted one is the next step. Finally applying displace filter when moving the mouse is the last phase. The main code used was for the image data, but it is applied on the vector data in this research.

```
Stage.scaleMode = 'noScale';
Var colorX = 1;
Var colorY = 2;
Var powerX = 75;
Var powerY = 75;
Var mode = "ignore";
Var offset = new flash.geom.Point (0, 0);
Var bmp = new flash.display.BitmapData (image_mc._width, image_mc._height);
Var displaceFilter = new flash.filters.DisplacementMapFilter (bmp, offset, colorX, colorY, powerX,
powerY, mode);
OnMouseMove = function () {
    displace_mc.displacer._x = displace_mc._xmouse;
    displace_mc.displacer._y = displace_mc._ymouse;
bmp.draw (displace_mc);
image_mc.filters = [displaceFilter];
}
OnMouseDown = function (){
    displace_mc._visible = true;
    image_mc._visible = false;
}
OnMouseUp = function (){
    displace_mc._visible = false;
    image_mc._visible = true;
}
OnMouseUp ();
OnMouseMove ();
```

## Appendix 2: Invitation letter for usability test

Dear Sir/Madame,

My name is Shahab Shadaram and I am MSC. Student of Twente University, ITC faculty. I am studying in the GFM course. My research focuses on zooming techniques applied to visualizations of network data. You are kindly requested to participate in usability testing of this research. The aim is not evaluating your performance (e.g. speed or correctness of answers) but to learn more about usability of different methods for zooming. The test duration is about 20 minutes and contains 2 parts. The test will be started from 27<sup>th</sup> of September in the usability laboratory (room 1-066) of the GIP department. The names of participants and the results of test will be kept private. Please notify your interest date code from the attached time table, if you are eager to help me.

Best regards  
Shahab Shadaram

Day \ Time	9:30-10:00	10:30-11:00	11:30-12:00	14:00-14:30	15:00-15:30	16:00-16:30
Mon 27 sep	<b>M1</b>	<b>M2</b>	<b>M3</b>	<b>M4</b>	<b>M5</b>	<b>M6</b>
Tue 28 sep	<b>Tu1</b>	<b>Tu2</b>	<b>Tu3</b>	<b>Tu4</b>	<b>Tu5</b>	<b>Tu6</b>
Wed 29 sep	<b>W1</b>	<b>W2</b>	<b>W3</b>	<b>W4</b>	<b>W5</b>	<b>W6</b>
Thu 30 sep	<b>Th1</b>	<b>Th2</b>	<b>Th3</b>	<b>Th4</b>	<b>Th5</b>	<b>Th6</b>
Fri 1 Oct	<b>F1</b>	<b>F2</b>	<b>F3</b>	<b>F4</b>	<b>F5</b>	<b>F6</b>

## Appendix 3: User questionnaire

### A. Personal details

**Background education:** (ex.M.sc.)

**Current position:**

- Student
- PhD

**Age:**

- 20-30 years
- 30-40 years
- 40-50 years
- Older than 50 years

**Experience of working with computer:**

- Less than one year
- 1-3 years
- More than 3 years

**How often do you use network data visualization?**

- Very often
- Sometimes
- Never

**How often do you work with zooming and panning techniques on network data visualizations?**

Very often                      Sometimes                      Never

**Are you familiar with the area represented (Enschede)?**

Very familiar                      A bit familiar                      Not familiar

### B. Group 1 (Test participant 1-7)

**Task 1. Location map (static network)**

1. Move the slider up and down to see different zoom levels
2. Move the small rectangle in the smaller window to see the panning facility
3. Find the sign below in the network visualization

**Task 2. Magnifying glass (static network)**

1. Move the glass over the network with the mouse
2. Find the road below in the network visualization

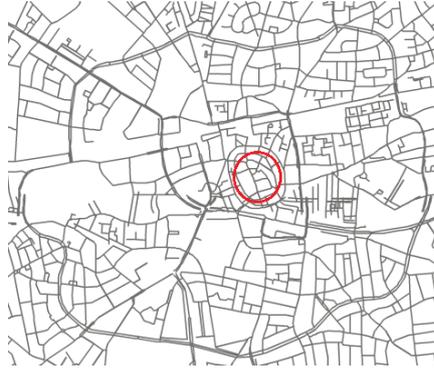
**Task 3****Q1. which part of Enschede has the least road density?**

- North side
- West side
- East side
- South side
- Center

**Task 4. Fisheye view (animation)**

1. Move the fisheye over the network by moving the mouse
2. Find the center area of Enschede (see picture below)

3. Find the number of roads in the center with a traffic congestion in the period between 13:00 and 15:00

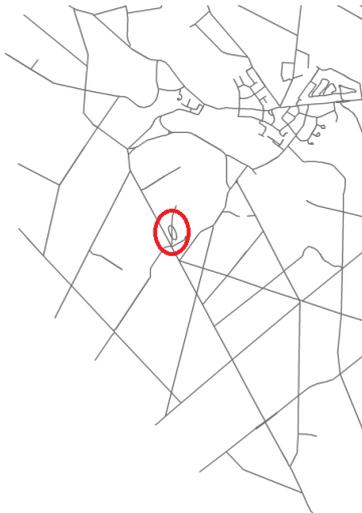


**Q1. How many roads with traffic congestion have you found?**

### **C. Group 2 (Test participant 8-14)**

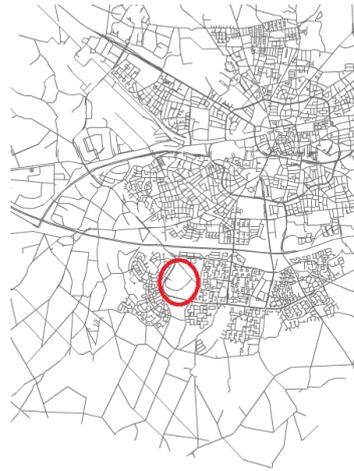
#### **Task 1. Magnifying glass (static network)**

1. Move the glass over the network with the mouse
2. Find the sign below in the network visualization
- 3.



#### **Task 2. Fisheye view (static network)**

1. Move the fisheye over the network by moving the mouse
2. Find the road below in the network visualization

**Task 3****Q1. which part of Enschede has the least road density?**

- North side
- West side
- East side
- South side
- Center

**Task 4. Location map (animation)**

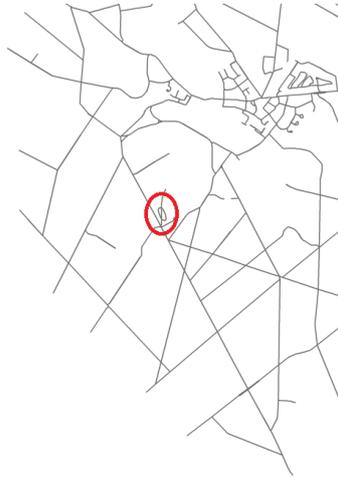
1. Move the slider up and down to see different zoom levels
2. Move the small rectangle in the smaller window to see the panning facility
3. Find the center area of Enschede (see picture below)
4. Find the number of roads in the center with a traffic congestion in the period between 13:00 and 15:00

**Q1. How many roads with traffic congestion have you found?**

## D. Group 3 (Test participant 15-21)

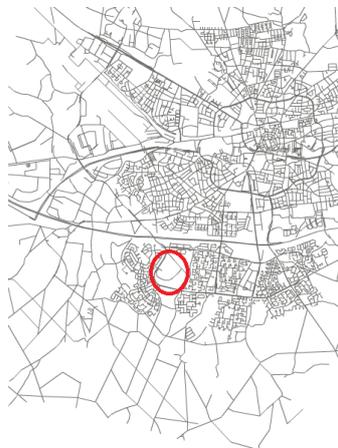
### Task 1. Fisheye view (static network)

1. Move the fisheye over the network by moving the mouse
2. Find the road below in the network visualization



### Task 2. Location map (static network)

1. Move the slider up and down to see different zoom levels
2. Move the small rectangle in the smaller window to see the panning facility
3. Find the sign below in the network visualization



### Task 3

#### Q1. which part of Enschede has the least road density?

- North side
- West side
- East side

- South side
- Center

**Task 4. Magnifying glass (animation)**

1. Move the glass over the network with the mouse
2. Find the center area of Enschede (see picture below)
3. Find the number of roads in the center with a traffic congestion in the period between 13:00 and 15:00



**Q1. How many roads with traffic congestion have you found?**

**E. General questions**

**Q1. What do you think of the size of the enlarged area of each method?**

Size of enlarged area Method	Too small	Large enough	Too large
Location map			
Magnifying glass			
Fisheye view			

**Which one do you prefer for zooming in and zooming out? Why?**

- Location map
- Fisheye view and magnifying glass

**Which one do you prefer for zooming in and zooming out? Why?**

- Fisheye view
- Magnifying glass

**Suggestions:**

**If you have any suggestions for improving methods you worked with, do not hesitate to mention it.**

Location map:

Magnifying glass:

Fisheye view:

**Thanks for your time!**

## Appendix 4: Results tables

### A. User profiling

<b>Profile</b>	Position	Age	Working with computer	Using network data visualization	Using zooming and panning techniques	Familiarity with Enschede
User 1	Phd	30-40	More than 3 years	Sometimes	Sometimes	A bit
User 2	Phd	30-40	More than 3 years	Sometimes	Very often	A bit
User 3	Phd	30-40	More than 3 years	Sometimes	Sometimes	A bit
User 4	Phd	20-30	More than 3 years	Sometimes	Never	A bit
User 5	Phd	30-40	More than 3 years	Very often	Very often	A bit
User 6	Phd	30-40	More than 3 years	Very often	Very often	Very familiar
User 7	Phd	40-50	More than 3 years	Sometimes	Never	A bit
User 8	Phd	20-30	More than 3 years	Very often	Very often	A bit
User 9	Phd	30-40	More than 3 years	Sometimes	Sometimes	A bit
User 10	Phd	20-30	More than 3 years	Sometimes	Sometimes	A bit
User 11	Phd	30-40	More than 3 years	Sometimes	Sometimes	Very familiar
User 12	Phd	30-40	More than 3 years	Very often	Very often	Very familiar
User 13	Phd	40-50	More than 3 years	Sometimes	Sometimes	A bit
User 14	Phd	20-30	More than 3 years	Sometimes	Sometimes	A bit
User 15	Phd	20-30	More than 3 years	Sometimes	Sometimes	Very familiar
User 16	Phd	20-30	More than 3 years	Sometimes	Very often	A bit
User 17	Phd	20-30	More than 3 years	Sometimes	Very often	Very familiar

User 18	Phd	30-40	More than 3 years	Sometimes	Sometimes	Very familiar
User 19	Phd	20-30	More than 3 years	Never	Never	A bit
User 20	Phd	20-30	More than 3 years	Very often	Very often	Very familiar
User 21	Phd	30-40	More than 3 years	Sometimes	Sometimes	A bit

## B. Time and correctness of tasks

Group 1	Task 1	Task 2	Task 3	Task 4
User 1	Not completed	15 sec	32 sec	Wrong
User 2	1 min	15 sec	35 sec	wrong
User 3	2.25 min	50 sec	30 sec	Wrong
User 4	1.10 min	30 sec	30 sec	Wrong
User 5	15 sec	5 sec	12 sec	Wrong
User 6	25 sec	5 sec	wrong	1 min
User 7	1.50 min	8 sec	32 sec	1.15 min

Group 2	Task 1	Task 2	Task 3	Task 4
User 8	1.20 min	10 sec	Wrong	4.10 min
User 9	Not completed	9 sec	34 sec	4.30 min
User 10	57 sec	46 sec	23 sec	2.37 min
User 11	35 sec	10 sec	27 sec	1.40 min

<b>User 12</b>	Not completed	15 sec	15 sec	2.30 min
<b>User 13</b>	1.13 min	37 sec	Wrong	4.07 min
<b>User 14</b>	1.04 min	6 sec	2.40 min	1.50 min

<b>Group 3</b>	<b>Task 1</b>	<b>Task 2</b>	<b>Task 3</b>	<b>Task 4</b>
<b>User 15</b>	25 sec	1.35 min	30 sec	2.18 min
<b>User 16</b>	1 min	40 sec	2.30 min	3.55 min
<b>User 17</b>	30 sec	33 sec	23 sec	1.02 min
<b>User 18</b>	12 sec	36 sec	15 sec	Wrong
<b>User 19</b>	1.35 min	30 sec	1.24 min	1.01 min
<b>User 20</b>	48 sec	12 sec	Wrong	Wrong
<b>User 21</b>	4.01 min	15 sec	11 sec	1.34 in

### C. Participant's idea about size of the enlarged areas of each method

<b>Size of enlarged area</b>	Location map	Magnifying glass	Fisheye view
User 1	Large enough	Large enough	Too small
User 2	Too large	Large enough	Too small
User 3	Large enough	Large enough	Large enough
User 4	Large enough	Too small	Large enough
User 5	Large enough	Large enough	Too small
User 6	Large enough	Large enough	Too small

User 7	Large enough	Large enough	Large enough
User 8	Large enough	Too small	Large enough
User 9	Large enough	Too small	Large enough
User 10	Large enough	Too small	Too small
User 11	Too small	Large enough	Large enough
User 12	Large enough	Too large	Large enough
User 13	Large enough	Large enough	Large enough
User 14	Large enough	Large enough	Large enough
User 15	Large enough	Too small	Too small
User 16	Large enough	Large enough	Too small
User 17	Large enough	Large enough	Too small
User 18	Large enough	Large enough	Too small
User 19	Large enough	Large enough	Too small
User 20	Large enough	Large enough	Too large
User 21	Large enough	Large enough	Large enough

#### D. Participant's preference for the use of methods and their reasons

Preference	Location map or magnifying glass & fisheye	Why?	Magnifying glass or fisheye	Why?
User 1	Mag & Fish	More clear	Magnifying glass	More clear
User 2	Location map	Different zoom levels	Magnifying glass	Nice results

User 3	Location map	No reason	Magnifying glass	No reason
User 4	Mag & Fish	Flexible to move around	Fisheye view	No need to press the button while panning
User 5	Location map	No reason	Magnifying glass	No reason
User 6	Location map	Different zoom levels	Magnifying glass	No reason
User 7	Mag & Fish	Easier to control	Magnifying glass	More clear
User 8	Location map	Flexible	Fisheye view	Easier to locate
User 9	Mag & Fish	More clear	Magnifying glass	More clear
User 10	Location map	Wide enough and clear enough	Magnifying glass	More clear
User 11	Mag & Fish	Flexible to move around	Magnifying glass	Enough magnification
User 12	Location map	More clear	Fisheye view	Smooth roads
User 13	Location map	Different zoom level	Magnifying glass	More clear
User 14	Location map	Different zoom level	Fisheye view	No need to press the button while panning
User 15	Location map	Easier to control	Fisheye view	Easier to locate
User 16	Location map	Wide enough and clear enough	Magnifying glass	More clear
User 17	Location map	Easier to control	Magnifying glass	More clear and larger
User 18	Location map	Different zoom levels	Magnifying glass	Sufficient zoom level/ No distorted view
User 19	Location map	Different zoom levels	Magnifying glass	More comfortable
User 20	Location map	Different zoom levels	Fisheye view	Easier to locate
User 21	Mag & Fish	The whole object on screen	Magnifying glass	More clear

### E. Participant's suggestions for improving methods

Suggestions	Location map	Magnifying glass	Fisheye view
User 1	No suggestion	No suggestion	No suggestion
User 2	No suggestion	No suggestion	Focus seems blurred
User 3	No suggestion	Provide different zoom levels	Provide different zoom levels
User 4	Use the mid wheel of the mouse to zoom in and out	Pan without pressing the button/provide different zoom levels	No suggestion
User 5	No suggestion	No suggestion	Increase the size of the fisheye
User 6	Use mouse scroll instead of click and drag	Make it without handle	No suggestion
User 7	Map is without reference	Provide different zoom levels	No suggestion
User 8	No suggestion	No suggestion	No suggestion
User 9	No suggestion	No suggestion	No suggestion
User 10	No suggestion	The edge of the glass covers information	Make it more clear
User 11	No suggestion	No suggestion	No suggestion
User 12	No suggestion	The zoom level is high	No suggestion
User 13	Scale factor would need to incorporate ex:1:100	Change the size of the glass	Change the size of the fisheye
User 14	No suggestion	Change the size of the glass	Make it more clear
User 15	Overview map is too small	Provide different zoom levels	Provide different zoom levels
User 16	Provide panning inside the detailed map	Provide different zoom levels	Change the size of the fisheye
User 17	No suggestion	Provide different zoom levels	Make it more clear
User 18	No suggestion	Provide different zoom levels	Provide different zoom levels

User 19	No suggestion	No suggestion	Increase the size of fisheye/ Provide different zoom levels
User 20	Scale factor would need to incorporate ex:1:100	Scale factor would need to incorporate ex:1:100	Scale factor would need to incorporate ex:1:100
User 21	Put the whole area in one frame	No suggestion	No suggestion