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SPEED AND EFFICIENCY IN USE

A user centered study of GUI:s for information visualization

Master thesis in Interaction Design
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ABSTRACT

The purpose of this thesis was to find ways to improve usability for an information visualization tool as TIBCO Spotfire with particular focus on speed and efficiency in use.

The work was carried out with two users as targets and followed a user centered approach. Target users were encoded as personas and they were provided by TIBCO Software Spotfire Division. The target users' tasks were first analyzed and then scenarios for the two targets were tested across four different commercial applications in a comparative walkthrough. The results from the analysis were then encoded in design goals and recommendations. With regard to these goals and recommendations seven conceptual designs were created. After a synergy evaluation and a goals and recommendation evaluation of these seven concepts two concepts were chosen for more in depth design. The in depth designs provide a more detailed view on these two concepts, evaluating benefits and important design parameters for speed and efficiency.

The report is written in English.

Keywords: Information visualization, TIBCO Spotfire, Analytics, Evaluation, Personas, Interaction Design.

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Göteborg, February 2009

Benjamin Mårtensson, Olle Rundgren and Johan Berg

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CHAPTER 1 –INTRODUCTION

This chapter gives a short introduction to the study which leads to the research question, delimitation and target users of the study.

Many human enterprises today rely heavily on the use of data and they collect this data in many different forms and from many different parts of their organizations. The need to relate this data and make it useful throughout the organization becomes a big task since collecting data on its own have little or no value. At one end of this equation is the computer and at the other end is the human. How do computers best represent and present information to support the knowledge needs of human beings? One area of research that tries to solve problems related to this equation is information visualization.

Visual analytics software grew out of this need to look at data to find details, patterns, trends and to relate different data to each other. In short visual analytics software allows the user to ask questions about the data in an accessible and interactive manner thus making the data sensible and aid for making decisions.

There are many different aspects that are important for a tool used to base knowledge on or to gather knowledge with. These aspects include among others the need for reliability, consistency, speed and efficiency.

1.1 RESEARCH QUESTION, PURPOSE AND DELIMITATION

This thesis was suggested by TIBCO Software Spotfire Division and the assignment was to evaluate their visual analytics product with speed and efficiency in mind and to find concrete designs to enhance the products interface on these points. The question was formulated as follows:

> *How can the design of a GUI be improved for speed and efficiency in use in an information visualization tool as TIBCO Spotfire?*

To keep the study within reasonable boundaries the scope was narrowed by some further delimitation. Focus was set to improve speed and efficiency for two specific user types and their tasks and goals. TIBCO Spotfire is an enterprise product and the platform includes a server, a web player and a desktop application. It was decided that the prioritized target of the study would be the desktop application. The main reason for this was that the desktop version includes the functionality of both target users. Speed in this thesis refers to time spent by users on any given task detached from speed of computation or time complexity of algorithms.

Efficiency refers to the ratio of user input to system output, that is, the property of doing things in the most economical way. Both speed and efficiency should therefore be seen first as relating to the tasks of users and second to the system in which the users carries out these tasks.

1.2 DISPOSITION

This report is structured into seven main chapters and for a complete understanding of the study it is suggested that all parts be read in order to get the full picture. For readers only interested in the results of the study emphasis should be put on the latter part of the report, chapter six through seven, with the addition of the background chapter. A short description of each chapter is provided below to let the reader herself decide what chapters to read and put emphasis on.

Chapter one provides an introduction to the study and the research question that the study is trying to answer.

The first part of the second chapter gives a description of the domain and context where the study took place and a brief overview of interaction with TIBCO Spotfire. The last section explains the target users of the study.

The third chapter explains some important concepts from the two main fields that this study gathered information from; information visualization and interaction design.

The fourth chapter explains the methodology used in the study.

In chapter five the work order and process of the study is explained.

Chapter six presents the results of the different phases of the study and summarizes and explains the results to give the reader concrete points for evaluation and criticism. The first part of results describes some possible points to improve speed and efficiency whereas the second part describes some concepts that could solve problems related to these improvement points. The third and last part of the results chapter describes in more depth two designs based on the results from the analysis and conceptualization phases.

In the seventh chapter the study is discussed from two different perspectives. First the work is discussed from a methodology perspective, trying to resolve how choice of method and process has had an impact on the study and the results. The work is then discussed from a result perspective to give insight where and how choices and selection has been done, and also to deepen the understanding of how the study connects to related work. We round up the last chapter with conclusions.

CHAPTER 2 - BACKGROUND

This chapter will give a brief introduction to the context in which the study was carried out. A short description of visual analytics and business intelligence is first provided. An introduction to the company TIBCO Software Spotfire Division and their analytics platform will then be given. The last parts of the chapter describe the most important aspects of the user interface and the target users of the study.

2.1 VISUAL ANALYTICS AND BUSINESS INTELLIGENCE

Visual analytics is a part of the information visualization field where users seek insight from data sets through computer aided interactive visualizations (Wilkinson et al, 2006). The merger between analytic statistical algorithms and interactive visualizations is referred to as visual analytics. Analyzing data and trying to get insight from interactive visualizations is called visual exploration.

The term Business Intelligence (BI) is an umbrella term that refers to methods, processes and systems that collect and make information or data more useful and understandable to support a business. Business in this context is meant in a broad sense and can be read as any business enterprise within science, technology, commerce, industry, law or government. The term business intelligence is relevant since it describes the domain where TIBCO Software Spotfire Division is active.

2.2 TIBCO SOFTWARE SPOTFIRE DIVISION

The company Spotfire was founded in Gothenburg in 1996. TIBCO (The Information Bus Company) is based in USA and provides business integration software and business process management. Spotfire was acquired by TIBCO in 2007 and is now referred to as TIBCO Software Spotfire Division. We will refer to the analytics software as TIBCO Spotfire.

Today not only expert users like analysts need to get fast access to data. Managers and sales people among others need to use data on a regular basis to support their actions and decisions. This puts strict requirements on software since several different levels of usage has to be considered. The goal of TIBCO Spotfire is to help users gain insights from their data, aiding them in making better and faster decisions. This can mean finding trends, patterns and relationships in the visually displayed data.

TIBCO Spotfire is an enterprise analytics tool for visualizing and exploring data in real time. Data can for instance be represented in scatter plots, bar charts, map charts or summary tables. TIBCO Spotfire can import data from a range of sources e.g. databases, data warehouses, Microsoft Excel- and text files.

2.2.1 TIBCO Spotfire interaction

This is a general description of the interaction with TIBCO Spotfire. Some of the most important parts of the interface that are involved in the interaction are described in brief to give the reader an overview.

TIBCO Spotfire documents/reports are structured into pages that can be showed either in tabs or in step-by-step mode. Pages consist of panes with visualized data or text areas. Text areas can contain descriptive text, images and links. In a standard view the other elements visible per page are the filter panel and the details-on-demand panel. The filter panel contains different dynamic queries and the details-on-demand panel contains a table of the data currently marked in visualizations.

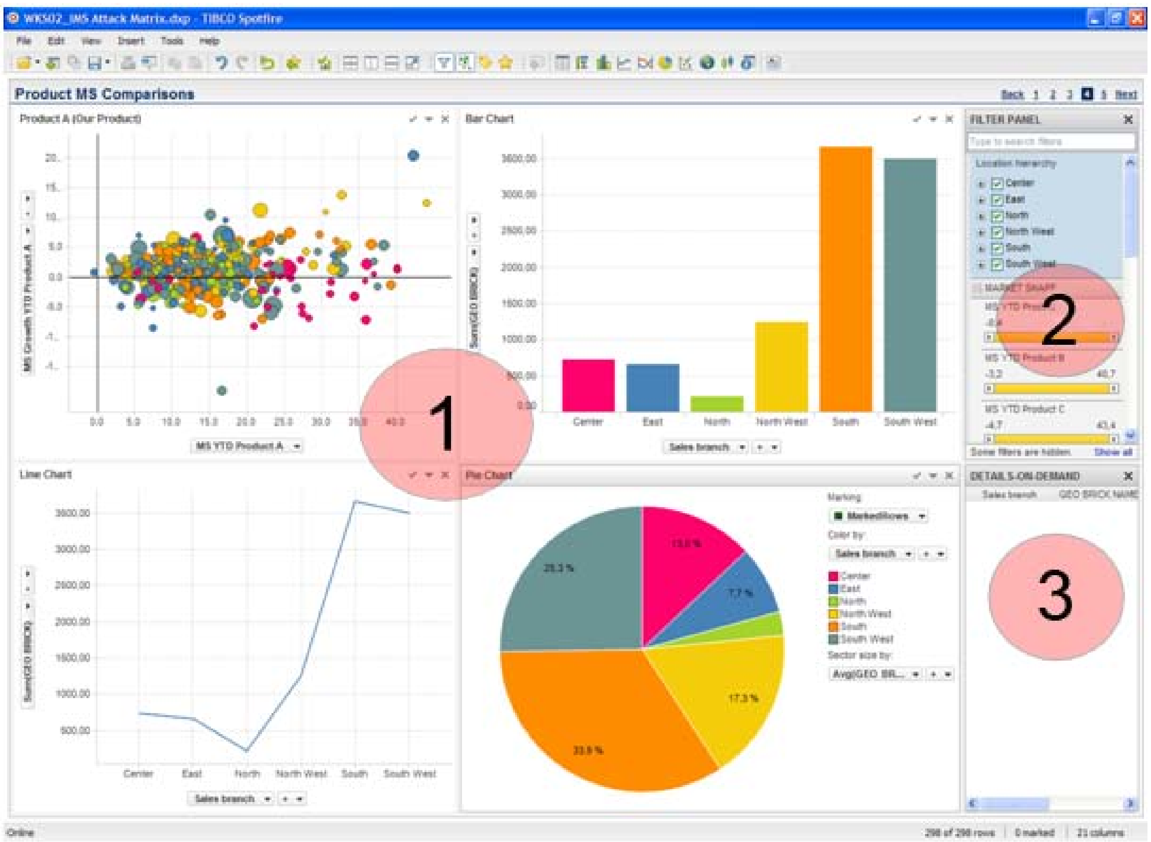


Figure 1.Part 1 shows a page containing four different visualizations. Part 2 shows the details-on-demand panel and part 3 shows the filter panel with different filters

Visualizations can be of different type and each type can be configured in a variety of ways. Configuration of visualizations decides what and how data is showed. Configuration can be done through three different interaction patterns; through a properties dialog, by using selectors in the legend and the axes or by drag-and-drop from the filter panel. Interaction with data in visualizations can be done directly in visualizations by clicking specific values or by lassoing groups of values. This interaction marks values by highlighting them in a different color. Interaction with data in visualizations can also be done by filtering values via the filter panel. Filtered values are hidden dynamically from visualizations. These two types of seemingly simple interactions with the data together with the many configuration options give rise to almost endless combinations. This is one of the main powers with TIBCO Spotfire.

The filter panel can contain several different types of filters. Filters are created automatically when importing data into TIBCO Spotfire. The data types that need to be filtered dictate what type of filter suits best. For example range sliders can be used to filter continuous ranges, radio button filters can be used to allow mutually exclusive filtering of categories and hierarchy filters can be used to enable filtering of hierarchical data.

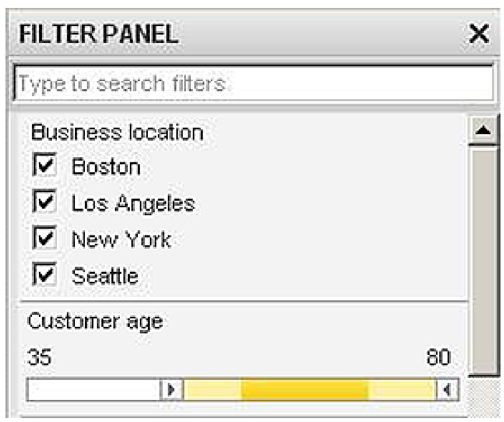


Figure 2.Image showing a detailed view of the filter panel containing a check box filter and a range slider filter.

Filtering gives the user power to pose multiple queries in conjunction and directly see the effect of queries in the visualizations. As an example filtering can be performed by adjusting both a hierarchy and range in conjunction which in real time prunes the visualized data. This makes it easy to find patterns, trends and relationships in subsets of data or simply put focus on the data that are of interest for the moment.

Marked data is highlighted across visualizations and additional details on currently marked data are given in the details-on-demand panel. Markings can be both filtered to and filtered out which gives the user the ability to first make arbitrary selections and filtering based on visual properties and then filter based on the selection. For example values with a certain placement, shape, size or color can be marked and then filtered.

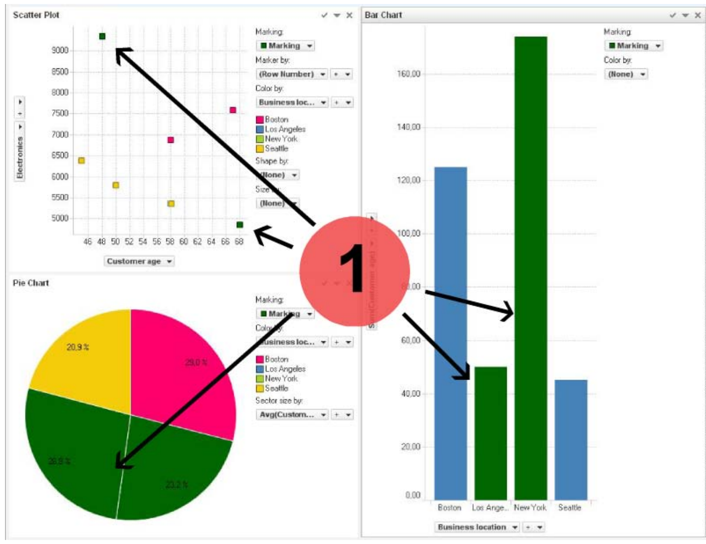


Figure 3.Image showing markings across visualizations

Text areas can be used to make explanatory text for the reports. These areas are commonly used to guide analysis by explaining steps with formatted text, images and links. Links provide a direct coupling to states in analysis and functionality. They can contain bookmarks, actions, navigation to specific parts in reports and links to web pages. Links are very powerful since they allow complex behavior to be embedded in the natural language output that is inherent in the link concept. By embedding for instance a bookmark in a link both a predefined filtering and a marking can be combined into a descriptive state of analysis, given in natural language.

This is like mentioned earlier a very brief overview of a small portion of the interactions available in TIBCO Spotfire. Each of the concepts explained above have a lot more to be said about them but some important aspects of them has been chosen to give readers not familiar with the application or similar applications a chance to follow the rest of this thesis report better.

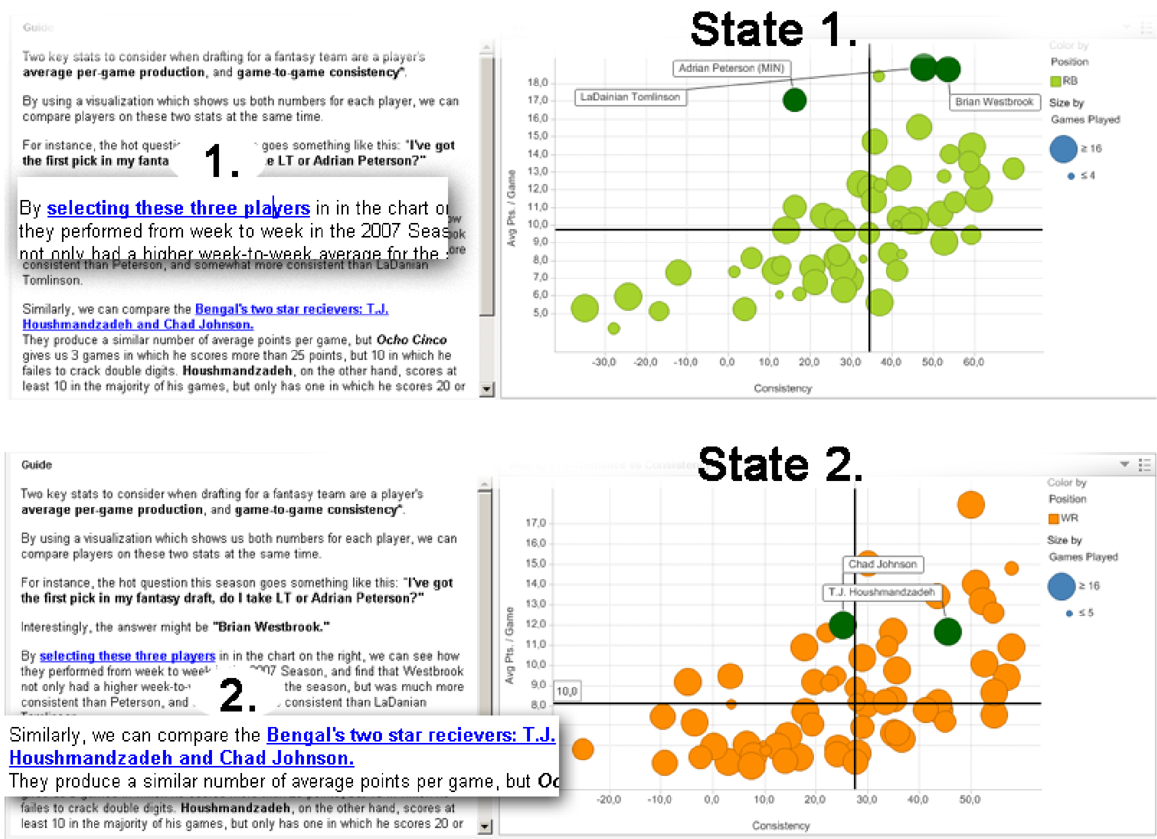


Figure 4.Image showing a detailed view of the same page in two different states. Link 1 leads to state 1 and link 2 leads to state 2. Text areas have been zoomed in on to show the descriptive aspect of links.

2.3 USERS AND TARGET USERS

When evaluating software and designing software interfaces it is important to keep the intended users of the software and their needs, goals and tasks in mind. There are many different perspectives and aspects that need to be considered with just one single user group. When the software in question has a diverse set of intended users a big part of the challenge becomes how to combine and provide functionality and constructs to support all different types of users without disturbing needs, tasks or goals of particular users.

The background material to the study contained material on the two types of users that the study aimed at. User data was encoded in personas and was provided by TIBCO Software Spotfire Division. Data that the two personas were based upon came from interviews with users from different application domains, supplemented with sales and marketing data. The personas were completely new when the study started and were distributed throughout the whole company.

The two different user groups that the thesis proposal aimed at had very different sets of goals and tasks so a bigger part of the functionality would be covered. The two different sets had dependencies and connections between them that were considered from the beginning of the study. Other user groups also encoded in archetypal users in the form of personas were only considered secondary. Full access to the secondary personas data was given at the beginning of the study. The secondary personas were studied in order to understand the boundaries between all users but also to avoid disturbing any needs, goals and tasks.

2.3.1 Target users

The first target user author reports and set up analysis for others to view and consume. The end goal of this user is to create reports that facilitate good analysis and usage for consumers of reports. The tasks of an author can be summarized under the following general goals:

1. Importing data – Making the data sufficient and correct.
2. Setting up visualizations – Represent the data to allow the right questions.
3. Create guides for analysis – Make reports easy to use.
4. Making the data secure - Letting the right people see the right set of data.
5. Deploy reports – Make reports available.

The first three general goals were the ones that were considered during the study and each group contained a large set of tasks that were considered important. This target user will be referred to as ***the author*** from here on.

The second user is a consumer of reports and need to make decisions based upon the data and findings in the data. The end goals of this user are to make well informed decisions and convincing communication throughout the organization. Consumers have little coherent time to spend on reading reports. The tasks of the consumer type can be summarized under the following goals:

1. Understand the data.
2. Get answers to questions on the data fast.
3. Make decisions based on findings in the data.
4. Communicate findings in the data to others.

These groupings were all considered important for the study and contained a diverse set of tasks with connections to the author type of user's goals and tasks. The second type of user will from here on be referred to as ***the consumer.***

CHAPTER 3 – THEORY

3.1 INFORMATION VISUALIZATION

Information visualization is the use of graphical techniques and methods to illustrate data with images. The purpose is to create better understanding of data that has been gathered by humans or created by information systems. Graphical representations are more suitable for us humans than numbers and that is the reason why information visualization exists today. It can help humans to better understand datasets because graphics reveals data in a better way than if you were to look at data as pure numbers (Tufte, 2001). Different visualizations can reveal different patterns and trends in the data but knowledge of information visualization is often needed in order to choose the proper visualization.

Tufte (2001) explains that a good graphical representation of data first of all should show the data it is trying to communicate. The visualization should also be made in a way that the reader thinks more about the substance and meaning of visualization rather than the technology or the graphical design, and it is therefore important to remove all unnecessary details and additions that distract the reader. It should also be able to represent many numbers in a small space and make large data sets coherent. The visualization needs to encourage the reader to compare different pieces of data to get an understanding of the data it is trying to visualize.

It is necessary to have all these things in mind when creating a visualization if it is going to have any value for the reader. There is a large difference in creating a visualization and reading one. The person that creates a visualization either by hand or with the help of computers understands the data and how the visualization should be read. But it is almost and art to create a self explanatory visualization that the reader immediately understands and to be of any use.

"*A chart says more than a thousand table cells*" (Wallgren A et al. 1996,p. 6).

A set of data can either be visualized in a table or in a chart (charts may also be referred as diagrams). Charts do not give a detailed view of a data set but show rather immediate differences and patterns. The reader can see the differences and patterns in seconds instead of scanning trough thousands of lines of data. The eye can take in all this information quickly because a chart itself is very simple, and the eye is trained to recognize patterns by nature. It is thanks to this that the eye can quickly register differences in lengths of bars, color gradients, size differences etc. (Wallgren A & B., et al. 1996).

3.1.1 Visual perception

Visual perception is the study of how one can recognize familiar objects in the world. The acts of attention can be described as visual queries (Ware, 2008). When we interact with a computer application, a map or a graph we are usually trying to solve a cognitive problem. Ware states that visual thinking rests in pattern finding.

3.1.1.1 Attentive and pre-attentive processing

Human beings process information attentive and pre-attentive. Attentive processing is a sequential and slower process than pre-attentive (Few, 2006). Attentive processing can for example be to determine a specific number that exists several times in a long series of varying numbers, it takes a lot of effort go through this sequentially trying to find each number. Pre-attentive processing is when the specific numbers you are looking for are distinguished with larger size or being bold from the other numbers and therefore much easier for the eye to recognize. Stephen Few have categorized pre-attentive attributes in dashboard design into four categories: color, form, position and motion. The color category includes hue such as green, red or yellow and saturation for different levels of intensity of hue. Form category includes size, enclosure, orientation and shape to make data stand out in a visualization. Position suggests that data that is shown with difference in 2-D position is easier to perceive. The last category is motion which involves flicker that often should be avoided because of annoyance but is useful in some situations for example when information need direct attention.

3.1.1.2 Pop-out effects

Pop-out effects refers to objects that catch eye focus in a single fixation, they are easy to find, objects that do not pop-out requires more attention to catch eye focus. By using different color, shape or size you can make objects different from the surrounding. There are many ways in which you can make objects easier to find.

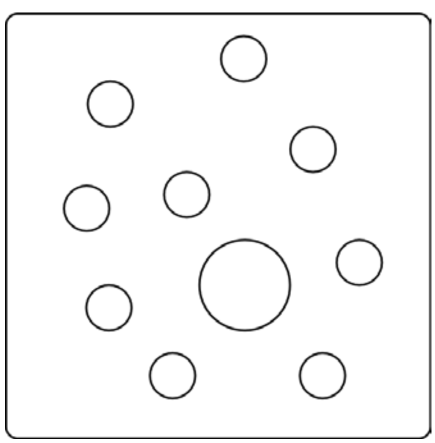


Figure 5. Size by pop-out effect.

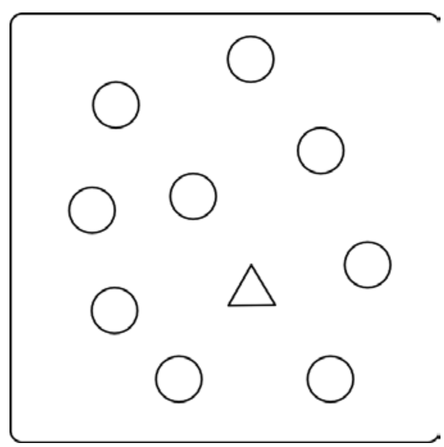


Figure 6. Shape by pop-out effect.

Practice in trying to find things does not help much, it is more about the direct finding of patterns out of the corner of the eye (Ware, 2008). When designing to make several objects easy to find you have to use channels. Channels rely on showing objects in a different shape and color. When channels are used in a scatter plot you could use shape coding for one variable and color coding for another to make them stand out more. In most information visualization applications you can use shape coding or color coding in visualizations.

3.1.1.3 Gestalt principles

Gestalt psychology includes a collection of principles for perception, gestalt means pattern in English. These principles can offer useful insights that can be applied to dashboard design, to for example separate or tie data together. Gestalt principles that are important for information visualization is: proximity, similarity, enclosure, closure, continuity and connection (Few, 2006).

The first, the principle of proximity says that objects that are located near to one another are perceived as belonging together. The similarity principle says that objects of same shape, color, orientation or size are grouped together. Similarity works well for linking specific data that exists in several graphs as belonging together by using the same color throughout the report. The principle of enclosure says that object can be enclosed by a visual border such as a line or color around them and can then be seen as enclosed. Closure principle claims that we perceive open structures as closed or complete. This can be applied to whole structures in dashboards, especially with graphs. Principle of continuity declares objects that belong together are part of a single whole. The last principle connection refers to objects that are connected and thus can be seen as a group.

Few states that one of the greatest challenges in dashboard design are to make the most important data stand out from the rest. A good understanding of pre-attentive processing of information, visual perception and gestalt principles forms a good ground to understand and design better dashboards and visualizations.

3.1.2 Tasks of information visualization

It is not sufficient to have data or to have statistics in order to arrive at a decision. Items of data do not add the necessary information by themselves to aid decision making. There are a few different stages in decision making that must be followed to make simple items of data into something useful and answer the questions a user have (Bertin, 1981). These stages should also be seen as different tasks the user has to accomplish to visualize information from raw data, and these relate to the same tasks that our two target users follow in the process of creating and presenting a report with TIBCO Spotfire. Jacques Bertin was early to document these tasks or stages in the 60s-70s and many later principles within the field of information visualization derive from or share common ground with these.

Define the problem is the first stage where a question has to be made, what decision must be made? What choice has to be made? The problem is to define simple questions which permit a composition of potentially useful data. There must be data that can support and answer the questions in mind or there is no point in processing the data into graphical representations.

Defining the data table is the second stage, to use an existing data table or create a new one with the necessary columns and items in rows. The data should share something in common, to be able to find the relationships and patterns inside the data. The use of a single data table indicates that the problem is well defined, the table has to be homogenous and we should not be mixing two completely unrelated problems. This could relate to data import phase in TIBCO Spotfire, where the set of data needs to be in form of a single table and the structure of the data may have to be modified for the application to support it.

Adopting a processing language is the third stage that means graphic transcription of the data table so that the similarities inside the data become visible. What type of visual representation is going to be used? It is important to strive for maximal visual efficacy and this is something difficult to achieve. The visualization will have to be created and later reconstructed or manipulated several times until all relationships that hide inside are visible. This is the part in TIBCO Spotfire where the user has to choose the type of visualization, its underlying properties and visual appearance.

Processing the data, simplifying without destroying is the fourth stage where the visualization has to be rearranged and simplified. We cannot have a visualization showing every item inside the data table, for example a pie chart with 500 slices, one for every row inside the data table. This would make the graphic transcription absolutely useless, it is therefore important that the data is rearranged and if necessary filtered. This is in TIBCO Spotfire filtering of data, and what might be called as visual analysis.

Interpreting and deciding or communicating is the fifth and last stage in the process of decision making. We have now after the fourth stage useful visualizations representing the initial data set. These visualizations can now answer our question(s) and help us solve the problem we had had in the first stage. It is possible that the visualization does not answer all questions or the right question at first, in that case it is necessary to go back and redo earlier stages, so it becomes an iterative process of going back and forth between the stages. It is up to the user in this stage to interpret the visualizations for decision making or to communicate it to other users. This is what is called guided analysis in TIBCO Spotfire, where the user who authors the report needs to explain its content with explanatory text fields, titles and images.

3.1.3 Information levels

Bertin (1981) divides information relationship into three levels for graphical representation of data. Data in graphics can be viewed at all these levels.

The elementary level refers to specific values such as the value between element x and y. For example the categorical x axis refers to months in the calendar and y values to days in the month.15th May is an elementary level value. There is no further level below the elementary level since it points to a specific value in the data table.

The intermediate level is a broader question, for example "When does summer occur in Sweden?" The answer to this question would be May, June, July and August. The relationship exists within these months. While the elementary points to specific values, intermediate values refers to groups of data in graphics.

The overall information level is the whole graphical representation. A user will look at all x and y values and draw conclusions of the data that is presented. This level is the most important for decision-making and it is the main purpose of graphics (Bertin, 1981).

3.1.4Chart types

A chart can have almost any type of appearance, it can be two or three dimensional, it can use any type of symbols, sizes, colors or shapes. It all depends on what we want to show with the chart, what type of data and to what type of reader. It is something of an art to find the appropriate chart for a data set and to show the right information. It depends on the structure of the data and the type of variables, if it's qualitative or quantitative data, or if it's discrete or continuous data we want to show. We are going to give some brief examples of some ways to show data and what type of charts that correspond to them.

Development over time or time series is commonly shown using line charts. Since time is continuous it's easy to join the different values with lines to create a larger time line. They are good to answer questions like "In what periods were the changes large?" or "When were the turning points?". Parallel coordinate charts are also commonly used to show time series and comparing several variables with each other.

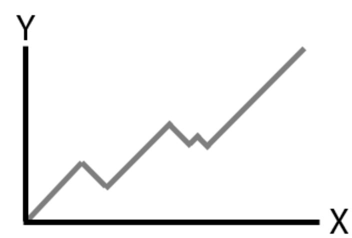


Figure 7.A line graph.

Percentage distributions of a data set are well shown with a pie chart. Pie charts are used to illustrate percentage distributions of qualitative variables. The downside with pie charts is the difficulty to make precise measurements with the eye. It is also important to not have too many sectors in a pie chart for it to be readable and easy to get an overview. It is recommended to not have more than five or six sectors (Wallgren A & B., et al. 1996). If you want to show more sectors and want the reader to be able to make a more precise measurement with the eye, it is better to choose a bar chart. It is both easy to draw and to read. It is also easier to make precise measurements with the eye compared to a pie chart. Bar charts are used to illustrate values that are distinct like qualitative or discrete variables. They are also a good choice in situations when we want to show frequencies, sums and averages.

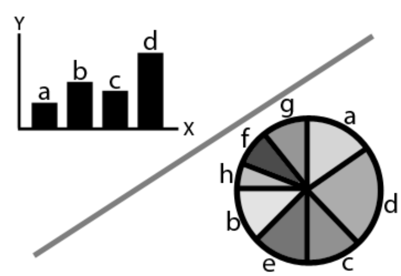


Figure 8.A bar graph and pie chart.

Variable relationships between two quantitative variables are often shown with scatter plots. The charts consist of dots or symbols (for example circles, stars, squares or triangles) that are pairs of data variables distributed in coordinates (x and y). Scatter plots often uses a large amount of data and the closer two dots are the higher the correlation between two variables, and vice versa. Scatter plots are also used to show three dimensional data with a third dimension. These are shown with three dimensional scatter plots adding a z-axis.

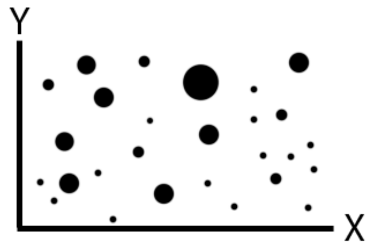


Figure 9.A scatter plot.

Showing frequencies in continuous variables are well shown in both bar charts and histograms. Histograms show a continuous variable and cover the whole range of its values. Histograms can show both absolute and relative frequencies. There are also variations of histograms like population pyramids that are used to show the population of a country or an area divided according to gender or age.

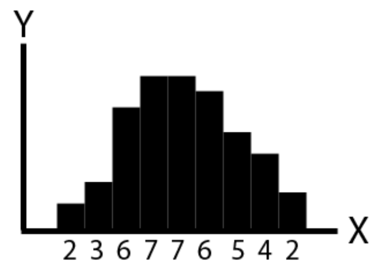


Figure 10.A bar graph.

Geographical variations are often shown with statistical maps that use images of areas or countries that has the statistical information put on the real locations. The statistical information can be shown with different gradients, patterns, symbols etc. There are several types of charts to show geographical variations like square maps, density maps, cartograms and several more.

Figure 11.A map chart.

These are only some of the different types of structures there is to show data. It depends entirely on the data and what we want to illustrate with the chart if we choose one type of chart or another. There may even be occasions when we prefer to use a simple table to show our data. That is why it's also important to have a good knowledge of the data and its structure before a chart type is chosen.

3.1.5 Interactive visualizations

When William Playfair (Tufte, 2001) invented the most common type of charts in the late 18th century they were all created with paper and pen. And they have since then until the late 20th century been created this way until the modern aid of computers. There is also a great difference between the old visualizations created by hand and today's created by computers. The difference is that it's possible today to create interactive and dynamic visualizations, which allows direct manipulation. Two of the pioneers in interactive visualizations and direct manipulation are Christopher Ahlberg and Ben Shneiderman (1994) who invented new ways to create interactive interfaces in visualizations for information seeking and data exploration. The user interface of TIBCO Spotfire is based on some of these early inventions and concepts like tight coupling of dynamic queries and visualizations are still the foundation of the interface.

The desire to manipulate objects on a computer screen has been the driving force behind many popular user interface design paradigms. This had led to an increase of layers in the user interface between the user and the computer, with more tools, options, possibilities, etc. Yet the interface between the two is becoming more transparent, more natural, and more intuitive thanks to better HCI methods and increasing usability, as for example the "what-you-see-is-what-you-get" (WYSIWYG) user interfaces, and "point-and-click and drag-and-drop" direct manipulation user interfaces (Chen, 2006).

With direct manipulation it is also possible for the user to manipulate the visualization itself and not the data by changing chart types, colors, styles, size, shapes etc. Here are some of the advantages with interactive visualizations compared to static ones:

Dynamic Queries: This allows the user to ask questions and let the visualizations reply the answer. An example could be that a user wants to see a specific range of data, or wants to see some specific values. Some example questions could be, "Who are the top ten sellers", "What do girls between age 15-25 buy the most", "How did this product sell during years 2005-2008". Dynamic queries take help of the ability to filter data, and only sort out the essential to answer the question in mind (Shneiderman, 1994).

Dynamic visualizations: Updates themselves when the data is changed. Visualizations can also be linked together, which means that changes made to the data in one visualization updates all visualizations. This is also called tight coupling when user operations (querying, zooming, etc) is done on one visualization but reflected on all other linked visualizations. With dynamic visualizations it is also possible to create a detailed visualization that shows the marked data in another representation. This makes it possible for the user to ask quick questions and to zoom in on data by selecting data in one visualization and then view the selection both in related to the rest of the data and in the detailed visualization.

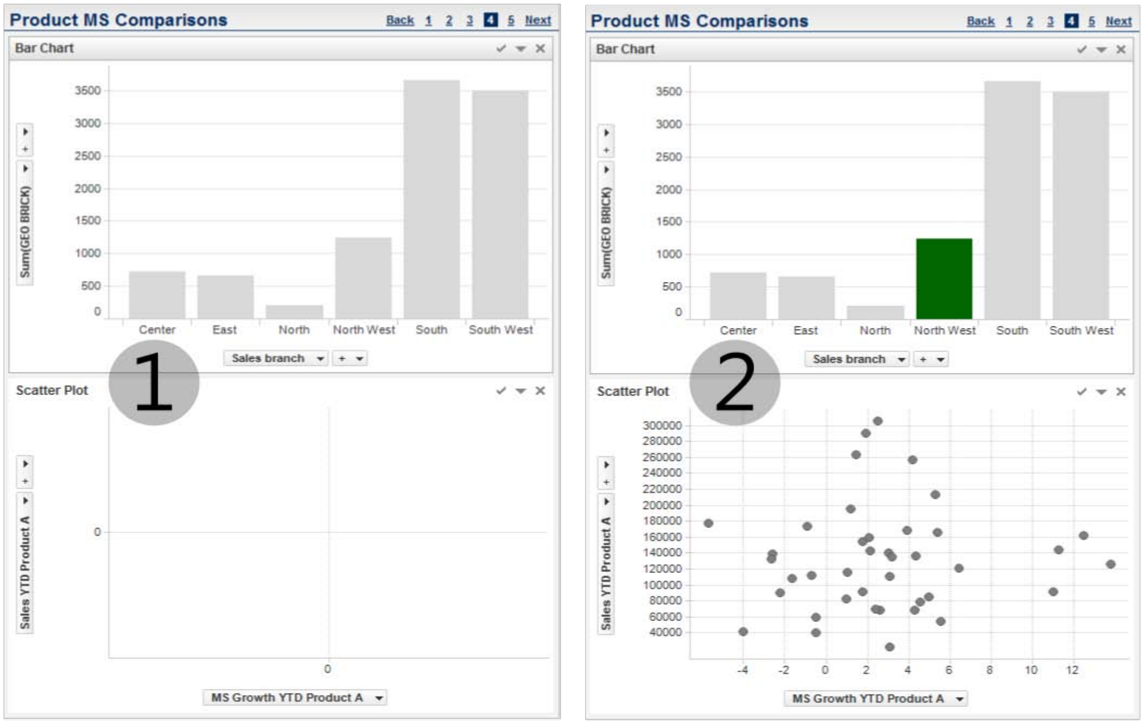


Figure 12. Image showing the concept of detailed visualization. Part 1 shows the empty detailed visualization when no data is marked. Part2 two shows the marked data and a populated detailed visualization.

View support: Makes it easier for the user to read specific areas inside visualizations. This can be done by changing the color or shape of some values inside a visualization, or marking out a whole area inside a visualization. View support is often volatile for example highlighting values when hovering with the mouse over them, or highlighting a whole range of values when clicking on ranges in the x or y axis in a scatter plot. View support makes it easier to read and to communicate a visualization.

Direct manipulation of data: Allows drill-down, zooming, filtering, cropping and dynamic queries of data. This makes data exploration much easier and powerful together with direct manipulation of visualizations. There are also tools such as brushing and linking with which multiple different visualizations of a dataset are viewed simultaneously by brushing selected markers in a visualization and selected markers are shown in linked visualizations.

Visualize large quantity of data: Is possible to create a chart of thousands of rows of data in just a matter of seconds with the help of computers.

Speed and efficiency in use: It is both faster and more efficient to create charts interactively, it gives faster results and errors cost little. It is easy and quick to add a visualization or make changes to it; you can for example change the type of visualization with a mouse-click. Filter data and finding answers to specific questions are also some of the benefits of interactive visualizations.

These are some of the advantages that interactive visualizations add and that TIBCO Spotfire also incorporates. This helps the user to easily query and comprehend complex or large amounts of data, something that would have been almost impossible doing with paper and pen.

3.1.6 Information Dashboard

The increased amount of information or data that people need today has created new problems for the information industry. The problem is that we today have a sea of information and there is a constant need to be up-to-date with all this information. It is because of this that a tool has emerged to solve this problem recent years and that tool is called information dashboards. An information dashboard is put simply a single-screen display of the most important information people need to do a job, presented in a way that allows them to see what is going on in an instant (Few, 2006).

A dashboard can contain almost any type of information, but they are usually presented visually with both text and graphics but with an emphasis on graphics. That’s because graphical presentations often communicate information with greater efficiency than text alone. That is also the reason why BI dashboards often contain statistical charts for example. The required information is often a set of KPIs but is not necessarily so depending on the information needed to do ones job. It is also important that dashboards fit on a single computer screen, so the viewer can see it all in one glance with small effort. Dashboards should also be customizable so they can be modified to meet the requirements given by a person, otherwise it won’t serve its purpose.

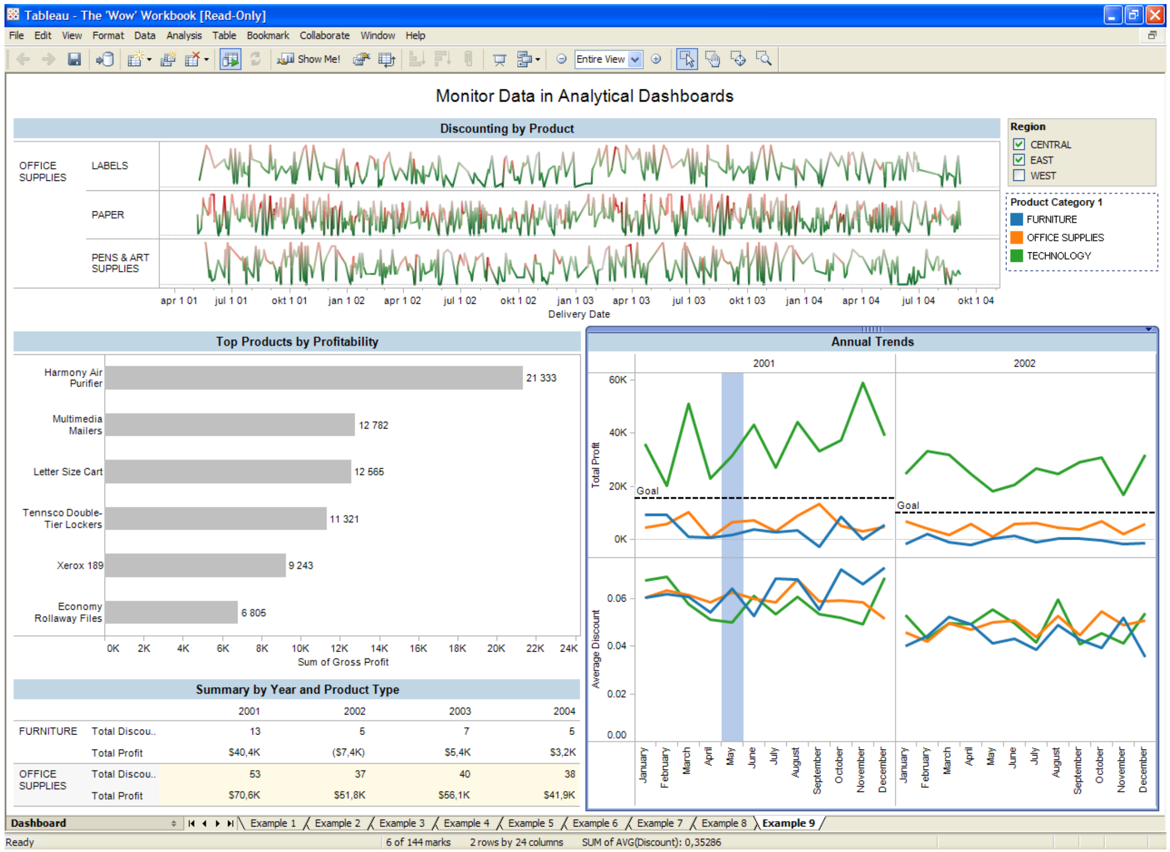


Figure 13.A dashboard composed in Tableau.

3.2 INTERACTION DESIGN

Human computer interaction (HCI) sometimes referred to as computer human interaction (CHI) is the field of study concerned with the interaction between humans and computers. The field grew out of a need to understand and improve human performance when working with computers. HCI is an interdisciplinary discipline and as such there are many different fields that contribute to HCI. These contributing fields can generally be seen to deal with either the computer side of interaction or with the human side of interaction. Different systems need information and theory from different fields and definitions therefore tend to differ slightly. The definition of HCI provided by ACM special interest group (SIGCHI) is sufficient in the case of this study and reads as follows:

> *Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with and with the study of major phenomena surrounding them (ACM SIGCHI, 1992, p. 6)*

Interaction design in turn can be seen to have grown out of HCI to address the needs that arises when computer and computer systems no longer are delivered in just the traditional package of a personal computer. It also adds dimensions to understand non work related computer systems where “mere” usability constraints might not be the only dimensions on which to model requirements and to design systems. A shift from evaluation and requirements gathering towards more focus on the practical work of designing interactive system can also be traced. Interaction design can therefore be seen more as a design discipline that rests on psychological principles and theory from the HCI field. Inspiration and methods is added to the field of interaction design from several other design related fields. Interaction design thus extends the scope of HCI to include products that might not be viewed as computers and also adds to the scope a range of design parameters and methods to solve problems related to this wider scope of practice (Preece et al, 2007). Within the scope of this study the distinction can be seen as superfluous since concepts and methods are gathered freely from both fields and thus the distinction isn´t made clear. Below follows short descriptions of concepts common to HCI and Interaction Design that are especially important for this study. These concepts are also important for the readers understanding of results, discussion and conclusion.

3.2.1 Usability

Nielsen (1993) states that usability applies to all kinds of interaction with which a human is involved and that it is very hard to find a feature that doesn’t have any user interaction. The term usability refers to goals that interactive products should have. It also refers to methods for improving ease-of-use in the design process. Usability consists of several measurable components and Preece et al (2002, p. 20) states that an interactive product should be:

- Easy to use (learnability)
- Easy to remember how to use (memorability)
- Safe to use (safety)
- Effective to use (effectiveness)
- Efficient to use (efficiency)

These goals should be seen as questions that designers should ask themselves in order to find flaws and faults early in the design process. Ease of use refers to how efficient and effective the user interface is, how fast a user can accomplish a task. A poorly designed interface can be very frustrating and time consuming to interact with. The more efficient a user interface the faster a user can accomplish a task. Efficiency is measured by tests on experienced users and how well they perform a test task. Nielsen mentions that there is a trade-off of designing a system that is easy to learn for novice users and efficient for experts, this can increase complexity of the user interface. It is important to design an interface that novice users won’t need to confront with expert functions that increases chance of doing mistakes and confusion. This approach implies a dual interaction style but Nielsen says that good default values when designing an interface can help avoid this problem.

3.2.1.1 Information visualization and usability evaluation

When evaluating information visualization tools for usability and utility there are mainly four different strategies or practices being used (Plaisant, 2004).

- Controlled experiments comparing design elements.
- Usability evaluation of a tool.
- Controlled experiments comparing two or more tools.
- Case studies of tools in realistic settings.

The evaluation approach used in this study can be seen as a hybrid of the two latter strategies. Our study wasn't a case study since we didn't observe the users directly but the target users were directly derived from interviews with real world users from real world usage settings. Our approach also used comparison of different tools as an evaluation technique. Usually this is done by comparing one novel technique with another proven or state of the art technique. Our approach instead compared the tasks of our target users across four different commercially successful applications with the specific goal of finding issues related to speed and efficiency.

A number of challenges with specific implications for usability evaluation of information visualization tools have also been identified where the two most relevant to this study are:

- Matching tools with users, tasks and real problems
- Addressing universal usability

The first challenge is relevant to this study since we have two target users directly derived from interviews with real users and their tasks and problems. The second challenge of addressing universal usability is also relevant to some extent since the two target users of the study are not the only users of the system that our study is evaluating and designing for. There is a wide range of users that are equally important and universal usability therefore becomes a challenge in order to make the application maintain usability at least for all target users if not for all possible users.

3.2.2 Affordances

The theory of affordances was first introduced by psychologist J. J. Gibson in 1977 and later adopted by Donald Norman to support the practical problem solving task of designing things (Norman, 1988).

An affordance according to Norman is a relationship between an agent and an object. More specifically the kind of signal that the object sends to the agent about what operations can be done upon the object. For this relationship to be efficient it has to be visible and clear, thus leaving no room for misinterpretation. An extension to the concept of affordances put forward by Clarisse De Souza is to view an affordance as the communication between the designer of an object and the user agent of an object. A well designed object then communicates the operations that can be done with it in a tacit way without the user of the object even knowing that the communication has taken place (Norman, 2007).

In the case of computer software most affordances are conveyed through the channel of visual perception and most often in 2-dimensional graphics with the addition of events in time showing progress and effect. This means that principles of graphic design and visual communication are important sources of knowledge when designing affordable screen elements.

3.2.3 Idiomatic interfaces

Idiomatic interfaces are a natural way of learning how to accomplish things (Cooper, 2003). It is a non-technical approach to how we learn and accomplish tasks.

"All idioms must be learned; good idioms need to be learned only once."(Cooper, 2003, p. 251).

In our daily life we encounter a myriad of different interfaces or systems without understanding how they work yet we can use without any problem. Many user interfaces today are visual idioms, desktop windows, the mouse, menu bar, drop downs or a title bar, we all learn how to use these idiomatically. When we first use a mouse we learn to use it very fast and we never forget it, we do not have to understand how the mice work in order to use it. Another idiomatic interface is for example an ATM machine, you learn very fast how to use it and when you go to another ATM machine you know exactly how to operate it without having any knowledge about how it actually works. Idioms that are popular on the desktop today are drag-and-drop operations and direct manipulation of data. When we want to move a file to the trash bin we can simply click-hold and drag it to the trash bin. This is very similar to how we do it in the real world. Direct manipulation strengthens the feeling of fast feedback and a mastery of the interface because they are the initiators of the action (Shneiderman, 1997).

3.2.4 Context sensitivity

The concept of context is important but also ambiguous since there are many different levels of context that are important for different reasons. When talking about context in interaction design it is therefore important to specify which type of context that one refers to. Context within this study refers to the concept of context sensitivity and context within an application. This should be distinguished to context of use which deals with environmental constraints, what environment the application will be used in.

Many interfaces today implement at least some kind of context-sensitivity without having the users ever knowing it. When well implemented context-sensitivity can bring big gains for the user since seemingly meaningless parameters can be made meaningful. For example when editing a grayscale image in an image editor a user have little or no use for color correction adjustments and this context of “grayscale” could be used by the image editor to hide all tools that have to do with color corrections from the screen display and put emphasis on tools that have to do with grayscale image editing. But what if the user wants to paint colors into the grayscale image? All of a sudden the intelligent feature of inferring context is a big pain instead of a big gain, since the application has hidden the tools that the user wants. This situation could probably be avoided but in this simple case of grayscale images and image editors perhaps it’s better not to infer context after all. When inferring context and when using context-sensitivity we have to be careful. If careful we can help the users in many different ways.

A what-where-when-who categorization of context can be useful in order to understand what can be used to infer context (Dix et al. 2006):

What data or text that is in the users focus, e.g. marked or selected.

Where means immediate environment of the user – for example the grayscale image editing scenario mentioned earlier.

When would mean inferring context from the action history of the user, e.g. if two actions follow each other they make up a new action.

Who in turn means using profile/preferences of the user to infer context, e.g. using the history of long-term use to give the right input, for instance automatic input of passwords in web browser.

Another concept that is useful in order to understand context is the concept of *incidental interaction*. Alan Dix defines incidental interaction as:

> *“Where actions performed for some other purpose, or unconscious signs, is interpreted in order to influence/improve/facilitate the actors' future interaction or day-to-day life” (Dix, 2002, p. 2)*

This way of making the application interpret the user’s actions is different from intentional and expected interaction in the sense that the interpretation is something that the user might not be aware of but still have use for. Of course if the interpretation done by the application is wrong the whole incidental interaction looses all meaning and can even confuse the user. Great care should be taken to avoid this type of scenario.

3.2.5 Flow

A person in a state of flow can be very productive, especially when engaged in constructive activities such as engineering, design, development or writing. It is therefore important to design interactive products to promote and enhance flow, if the application consistently disrupts a user it will also disrupt the users flow and productive state. An interface must therefore be designed to disrupt the user as little as possible, and the ultimate user interface for most purposes is no interface at all (Cooper et al. 2007). The interface must be transparent for the user in the sense that the interaction mechanism in the interface disappears and the user can focus on the objectives instead of the interface elements.

There are different strategies or concepts that are important when it comes to improve flow with speed and efficiency in mind. The following strategies are only a few and there are several more strategies to improve flow, but these are the most important ones for this study.

Follow users' mental models are an important strategy because every user has its own mental model and sees the way the application perform its tasks differently. It should be easy for the user to recognize patterns in the interface related to the type of work they are doing and the way they think.

Enable users to direct, don't force them to discuss is important because the users want direct interaction with the interface. The common user does not want to the interface to interrogate him with dialog boxes before or after every interaction. It should be like using a real world tool, take a hammer for example, you just use it and it will not ask you if you want to or how you should use it.

Keep tools close at hand means that the most used tools should be easy to find inside the interface. It is common to keep the most used or important tools in toolbars or palettes for beginners to find them easy, and the more advanced tools accessible by keyboard shortcuts for the expert users. The user should never have to divert his attention from the application to search out a tool, because it breaks the work flow.

Provide direct manipulation and graphical input. Software fails often in presenting ways for the user to manipulate numerical information trough graphical input instead of on command. A good example is to let the user set the indent in Microsoft Word by dragging a marker on a slider to where he likes the paragraph to start, instead of forcing the user to enter "1.456" in some text field to get the same result.

3.2.6 Feedback

Visual feedback is an important aspect to have in mind when designing an interface. One of the reasons why software is so hard to learn is that it so rarely gives positive feedback. Users needs to know when they do something right and get feedback about the application's state. For example if a user has to make a CPU demanding calculation with an application that could take a minute or two it is wise to add a loading bar that shows the progress of the calculation. That way the user will know the application is still working instead of thinking that the program may have crashed and stopped working. People learn better from positive feedback than they do from negative feedback. People want to use their software correctly and effectively, and they are motivated to learn how to make the software work for them. (Cooper et al. 2007)

3.2.7 Navigation

Poorly designed navigation presents one of the largest and most common problems in the usability of interactive products. Users are often forced to do a lot of work just to navigate through the interface and that work has seldom something to do with their actual needs or goals. Poorly designed navigation will also affect the work flow and by consequence the productivity of the users.

A general rule is that less navigation is often better. The user should not have to go through unnecessary steps to accomplish tasks. But there are exceptions where well designed navigation can help the user to understand what is available to him and find the right tools. It has to be easy to navigate through an interface and find the tools or answers the user is looking for. A method that is often used to aid navigation is the use of keyboard shortcuts; they can often aid the user to immediately access a specific tool or answer and reduce the cost of navigating through multiple menus and dialogs. Minimizing the need to navigate an interface and the time spent to find specific tools or interface elements will lead to increased speed and efficiency in use.

CHAPTER 4 - METHOD

This chapter describes the overall methodology used when conducting the study and the specific methods used in each phase of the process. Further it explains why these methods were selected and how they were used in this particular study.

4.1 DESIGN PROCESS AND METHODS

This study gathered methods mainly from the fields of human computer interaction and interaction design. Some of these methods are not unique to any of these fields but rather they have been proven useful within these fields as well as other fields and customized for purposes unique to human computer interaction and interaction design.

The methods used in this study were in all aspects of qualitative nature and this choice was made due to the exploratory nature of the study. In order to gain a deeper understanding and to be able to dig into the problems that were encountered a flexible structure of the study was also preferred to a completely fixed plan.

The overall design process can informally be seen as following Jones model for a disintegrated design process with divergent elements, transforming elements and converging elements (Jones, 1992). These elements were spread out through the process and they are best viewed as shifts in focus throughout the process from early divergent methods and later towards more transforming and convergent methods. The divergent elements are the ones forming the design space, defining the boundaries of the design space. Transforming elements are the ones finding patterns and paths to form concepts and groupings in the design space. The converging elements in turn are the elements eliminating excess and uncertainties from the concepts to form designs. In the case of this study the convergence meant the design of communicating objects consisting of drawings and prototypes.

This model of the design process explains well how methods were chosen as means to a lesser goal on a need basis. Instead of choosing methods in advance and fit the data into them the methods were chosen to fit the data and the needs that the data brought to the surface. Jones' view on the design process also takes into account the fact that effects from some methods were not singular, i.e. some methods had both divergent effect and transforming effect but also converging effect. Below follows descriptions of the specific methods that were used in the study.

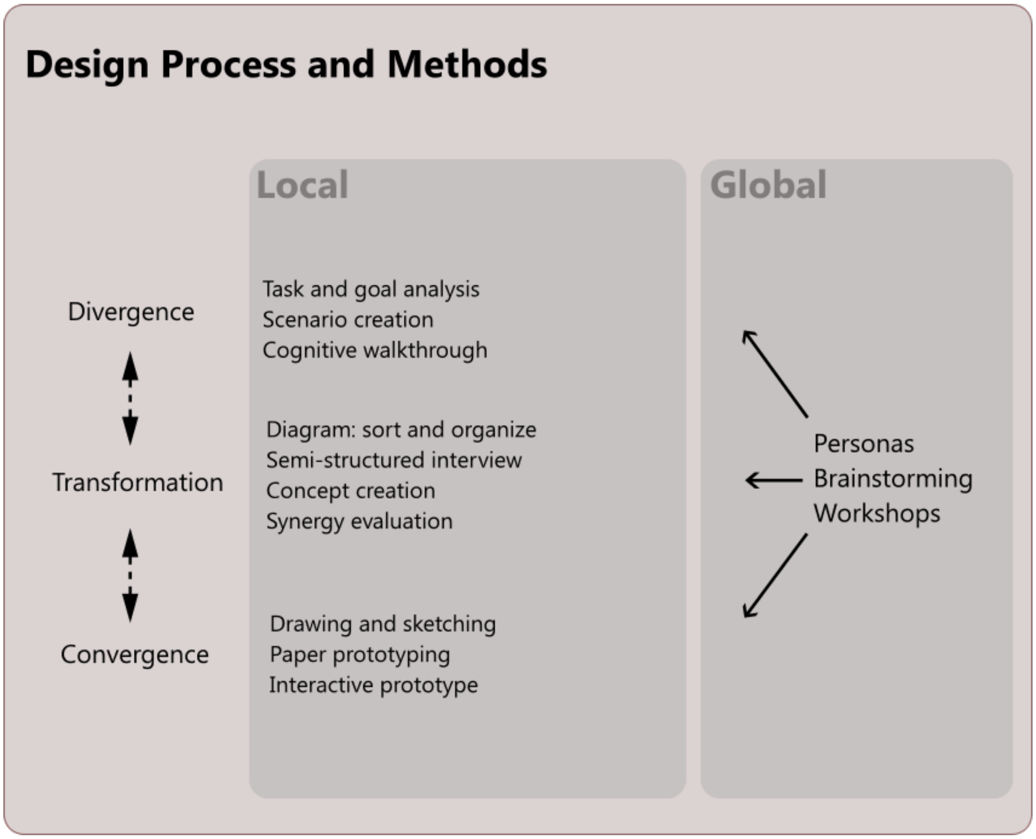


Figure 14. An overview of local and global methods used.

4.2 GLOBAL METHODS

Some of the methods were used throughout the whole study in different ways and these methods can be seen as being global methods. Below follows descriptions of these global methods.

4.2.1 Personas

The persona method was created by Alan Cooper in the late 1990´s as a means to conduct user centered design (Cooper, 1999). Personas are composite archetypal user models ideally clearly driven by real user data. Personas encode the goals, tasks and contexts of users and as such a model it is important to synthesize the model from research done on real users. Each persona collects and encodes data from many different users and each persona can therefore be seen as a focal point of a user group. The reason and rationale of having personas modeled as personifications (specific, individual beings) is to engage the empathy of the design and development towards the human target of the design (Cooper et al, 2007).

4.2.2 Brainstorming

Brainstorming is a group technique that consists of a large number of spontaneous ideas that are generated and gathered without evaluating them, usually in groups consisting of 4 to 10 people. The goal of brainstorming is to find new ideas, with focus on quantity, to solve a problem. Brainstorming is a very common technique used to generate or externalize ideas and make them tangible (Löwgren et al. 2004). There are many benefits with brainstorming but the main advantages seen from the perspective of this study was the flexibility, rapid procedure and the utilization of the group.

4.2.3 Workshops

Workshops were held both internally within the group and externally with programmers, interaction designers and usability engineers at TIBCO Software Spotfire Division. Workshops were held throughout the process and always had a clear goal. They were used externally mainly as a controlling instance, checking information and findings brought forward during the study, but also internally more as a creative instance, where ideas could be brought forward, criticized and developed.

4.3 LOCAL METHODS

Most of the methods were used mainly in a local manner at a certain point in the study. Results of these methods were used throughout the whole study but the main work of each of these methods can be localized to a certain point in the study. Some methods were iterated on when need arisen.

4.3.1 Task and goal analysis

Task analysis is used to investigate how users act in existing situations. It is used to investigate the procedures people go through and answer questions like: what are they trying to achieve? Why are they trying to achieve it? And how are they going about it (Preece et al. 2007)? Task analysis is done to model the way users reach their goals through mapping the steps needed to carry out tasks that are required to reach a goal. The delimitation of the task analysis was decided to the two target users of the study.

Two different methods were used during the task analysis. First flowcharts for both target users were created for their tasks to map the steps that both users need to carry out to reach their goals. Then these maps were reviewed and analyzed with speed and efficiency in mind allowing a wider perspective for tasks than the existing interface. This later activity was done in order to understand the tasks not only connected to the interface but also in the wider perspective of the target users goals. Dependencies and connections between the different users were considered as well as steps external to the interface.

4.3.2 Scenarios

Scenarios can be used in many different phases of the design process and with different purpose. They encode context, goals and tasks of the users in a narrative. Scenarios also encode information that involves planning and evaluating an action and therefore can be said to not only explain tasks that users carry out in an interface but also the wishes and expectations of users (Rosson et al. 2002). Persona-based scenarios put emphasis on the goals even more and also emphasize the people part even more than traditional scenarios (Cooper et al. 2007). The distinction between different scenarios are made explicit by Cooper and he suggests context scenarios as high level scenarios that describes ideal user experiences on a general goal level while key path scenarios are meant to deal with more detailed interactions.

Scenarios were mainly used in this study to test similar functionality across different applications. The scenarios were based on users goals to allow this type of testing but also allowing going in more depth when more advanced functionality were present for tasks that were considered prioritized with speed and efficiency in mind. Two general scenarios were created to allow testing of the different personas tasks in several different interfaces. These scenarios were in type similar to Cooper's context scenarios.

Later in the process scenarios were used to show what kind of tasks and workflows that the designs were meant to solve. These later scenarios were more detailed and specific in nature and their aim was to show real world use cases that the designs could solve. This communicative way of using scenarios was also used during the design process to communicate the effect or idea of different concepts between team members. These scenarios were more in line with the key path scenario proposed by Cooper.

4.3.3 Cognitive walkthrough

Cognitive walkthrough is a usability inspection method used to find usability problems in interfaces. The cognitive walkthrough method has been around for almost 20 years and many different variants of the method exist (Hollingsed et al. 2007). The method grew out of a need to make cognitive theory in Human-Machine Interaction more applicable and specifically to allow early evaluation of usability aspects on design time level (Lewis et al. 1990). The comparative cognitive walkthrough that was carried out in this study was done to understand the tasks of users better and also to understand what different solutions meant for the speed and efficiency for the two different target users.

Additional positive aspects are that it can be carried out in many different parts of the development process, i.e. it can be used on both low fidelity mockups as well as production interfaces. In a standard cognitive walkthrough one or more people step through the tasks of the intended users and ask questions at each step that the user need to take in order to carry out a task. Questions can be of different form depending on the system that is being inspected but in general they focus the inspector´s attention to the goals, tasks and actions of the end user. Problems that are found can be ranked on a scale to indicate how big percentage of users that are expected to fall victim to the specific type of problem. Since the cognitive walkthrough catches also problems that have to do with ease of learning it´s important not confuse this with ease of use. Three competing software were evaluated and they were chosen based on availability and relevance to the domain. These interfaces were stepped through on several different tasks and steps were noted and compared with the other interfaces.

4.3.4 Diagram: Sort and Organize

In order to make the information from the analysis phase more useful and tangible the information was reviewed, sorted and regrouped in affinity diagrams and mind maps. This sorting and organizing was done as a group activity and the resulting discussions had the effect of both sorting out misconceptions and give the group a common image of the problem space.

4.3.4.1 Affinity diagram

The affinity diagram is an easy method to see all the issues across several users. It must take into consideration all users as a whole and the structure of their work. With the help of affinity notes it is possible to see the issues for all users and not just the individual. The affinity diagram is built from bottom up, grouping individual notes that reveal key themes inside the data. The labels should not be picked by forehand but instead be suggested naturally from the notes. That means that a group of notes should be labeled after the common issue, distinction, work pattern, needs etc. The notes used are usually Post-its written by hand and put on a whiteboard, wall or table. The first step is to get all the affinity notes up on the wall in loose groupings with no labels. Then take one note at the time and start making columns or groups of notes that share similar keywords. Lastly put labels on the groupings or if necessary create hierarchies of groups with different levels if some groups are connected (Holtzblatt et al. 2004).

4.3.4.2 Mind mapping

Mind mapping is a way to structure thinking and creating associations between words of images. A mind map is a type of diagram with a central word or image that expands to all directions where new words or images that are connected. Minds maps work in hierarchies and categories where all thoughts have to be structured, from the inside and radiating outwards. Minds maps uses the term Basic Ordering Ideas (BOIs) that are key concepts within which a host of other concepts can be organized. An example is the term “People”, which can contain subcategories like “Family”, which later can contain other categories like “Father” or “Mother” and so on. Seen from this perspective we see that the word “People” is more powerful than “Family” and the word “Family” is more powerful than “Father” or “Sister” (Buzan, 1994).

4.3.5 Semi structured interview

Interviews are used to gather information qualitative or quantitative. Interviews can be very useful in the requirements gathering phase. There are many different types of interviews and the type should be chosen to fit the background of the interviewee and the kind of information that is needed from the interviewee. There are two main types of interview, structured and unstructured. Structured interviews have a predefined set of questions and allow little flexibility. Unstructured interviews are more flexible and have a couple of set topics but no predefined structure (Preece et al. 2002). A semi structured interview is a more flexible interview type, no general sequence is chosen but there are questions to direct the interview if the interviewee abscond from the topic (Preece et al. 2002). The interviewee is allowed to speak openly and new questions are allowed to come up throughout the interview as long as they are within the domain of the interview. The interview in this study was seen as a controlling instance with the purpose of calibrating and correcting both subsequent efforts and earlier information gathering.

4.3.6 Concept Creation

Concept creation is a common method to communicate ideas and to share a common vision between people or team members and external stakeholders (Laurel, 2003). A conceptual design is meant to communicate the main features of a design, justifications and shortcomings alike. It can also include early tests and simpler prototypes also known as mockups. A plan for extensions to the design and a plan for the design process is elements that could be included as well.

The concepts created in this study were created to make sure a clear common vision between the team members was in place and also to be able to communicate ideas of designs to people external to the study. The idea was to develop a bigger set of ideas to a point where possible benefits could be evaluated and then decide which ideas to go further with.

4.3.7 Synergy Evaluation

An evaluation of synergy effects between the existing interface and the created concepts were undertaken to find mutually beneficiary concepts. This was done in order to make sure that the concepts that were brought into the design phase had the possibility to integrate well in the existing interface, in this way making sure the strengthening of the interface. This synergy evaluation in conjunction with principles from the analysis phase was the selection criteria on which concepts for design were chosen.

4.3.8 Sketching and drawing

Sketching plays an important role in the design process of software, it is through sketching that the first rudimentary interaction can be designed, it is very cheap and the investment is much lower than a prototype (Buxton, 2007). Sketches and drawings should be used early in the ideation stage to propose different solutions. Buxton states that sketching is central to design thinking and learning. A sketch and prototype are two different things, they are both included in the design concept. Sketches and prototypes serve different purposes and are therefore needed at different stages of the design process (Buxton, 2007). A sketch or drawing compared to a prototype wants to propose, raise questions and is more of an exploratory nature.

"Fail early and fail often. And learn." (Buxton, 2007, p. 141)

4.3.9 Paper prototyping

A paper prototype is a very lightweight prototype that can be used to try out task flows and steps in an interface before time is invested in a high-fidelity prototype. Paper prototypes are created to design, test and refine user interfaces early in the ideation stage (Snyder, 2003). Users testing a paper prototype can perform simple workflows to get a look-and-feel of what the user interface will look like. It shows simple interactions through paper sketches that can be stepped through. Testing workflows as well as finding interaction flaws early in the process are the main advantages and a paper prototype can also give insight into what parts of the interaction that is important to try out in the high-fidelity prototype. Together with other sketches and information a paper prototype can be seen as kind of a blueprint for the high-fidelity prototype.

Prototypes are often a much larger investment than a sketch. Paper prototypes are a low-fidelity prototype that brings the best from both worlds, rapid as sketching and with the possibility to enlighten the designer about problems and important parameters of design very early on.

4.3.12 Interactive prototyping

An interactive prototype is often done to communicate and try out interactions that can't be communicated efficiently in sketches or paper prototypes. Interactive prototypes can also be built to allow early testing with users. Interactive prototypes where used in this study to show how the designs could be incorporated into the existing interface and also to show what kind of tasks that could be supported with these concepts. Since it was not feasible to allow user testing of prototypes the prototypes were more seen as means for communication rather than testable programs. This made it possible to keep the prototypes simpler in some aspects, allowing the main goal to be the communication of the underlying concepts.

CHAPTER 5 – REALIZATION

This chapter explains the work process throughout the thesis work. It explains the practical steps of the study and how and why methods were used.

5.1 TIBCO SPOTFIRE AND LITERATURE STUDY

In order to get a better understanding of the application we were given training manuals to deepen our knowledge of both the tasks that were supported by the interface and the different constructs that the interface builds upon. To get an overview of information visualization and the usability aspects speed and efficiency a literature study was conducted in parallel. Books and articles about information visualization, dashboards and human computer interaction were studied. The literature study concentrated on aspects that were considered important for speed and efficiency in use and this meant studies mainly within three different task areas:

- Visualization setup
- Visual Analysis
- Visual Communication

Visualization setup was important since at some point all visualizations has to be set up by some person which give a lot of room for human factor type of errors. It was important to understand what tasks that these users have to deal with? What kind of tasks is especially cumbersome? And what do the users need help with to make set up as fast and efficient as possible?

Visual analysis was important since this is the main goal with information visualization, to analyze data and find answers to questions in the data. This meant studying different ways of querying the data and also different ways of connecting data and different visualizations. What visualizations can answer what questions? And how can interactions with visualizations answer questions?

Visual communication was important to understand the medium that would carry all interactions and also the communication between users. What makes two elements appear to stick together? How can different relations be communicated? What need to be shown at the same time? And where should elements of importance is laid out?

After the initial training and literature study we had an overview of the field and a broad understanding of the concepts present in TIBCO Spotfire. This made it easier to see where efforts should be put and the work that needed to be done.

5.2 PROJECT PLAN

A general plan was set up for the whole study with time scheduled on three different phases. Some iteration on the different phases was expected but with clear shift of focus at the end of each phase.

The three phases were planned in chronologic order as follows:

- Analysis phase
- Conceptualization phase
- Design phase

In the *analysis phase* the plan was to dig deeper into the tasks of the users and different ways of supporting these tasks. The planned activities for this phase was to analyze the structure of the existing TIBCO Spotfire interface and then carry out a task analysis for both target users. A comparative walkthrough of some competing software were also planned to find out in what respects software from the same domain differed and what could be important aspects for speed and efficiency. In order to carry out the comparative walkthrough with consistency scenarios for both personas needed to be created as well.

The conceptualization phase was not as tightly defined since we didn’t know the exact nature of the output from the analysis phase. The plan was to sort and organize the information from the analysis phase and then create at least five concepts based on this information that could improve the interface with speed and efficiency in mind. At the end of the conceptualization phase two or more concepts were to be chosen for design.

In the *design phase* the planned activities was to develop some of the concepts further and find the most important aspects of these designs. Prototyped versions of these designs were to be delivered in order to communicate the possible benefits and important aspects of the designs.

In the end methods in the two later phases were chosen to handle the information and needs brought forward during the analysis phase. This way of selecting methods throughout the process were chosen since we didn’t know from the beginning exactly what kind of output we would get from each of the different phases.

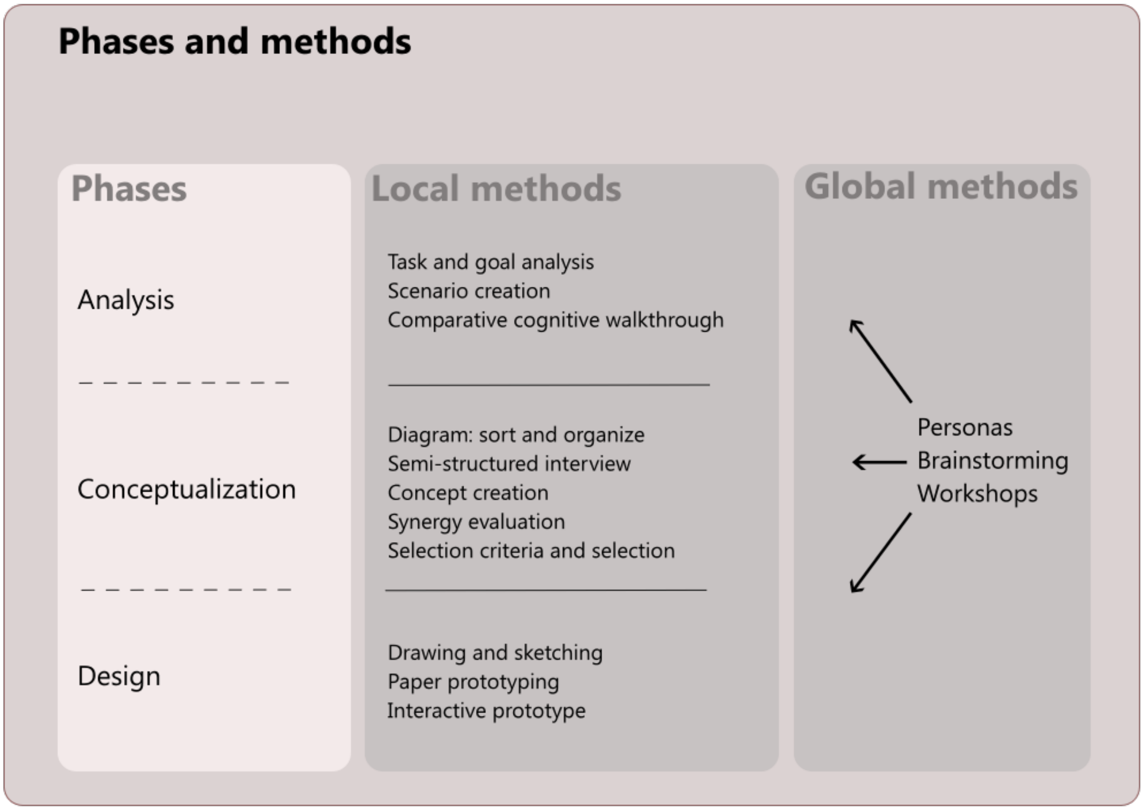


Figure 15. Overview of the phases, local and global methods.

5.3ANALYSIS PHASE

In the analysis phase the activities were in nature explorative and defining activities. The main goal of this phase was to define the design space and to find aspects of the software that could be improved with speed and efficiency in mind. This meant dealing both with existing concepts of the software and the tasks and goals of the target users. The methods that were used in the analysis phase were chosen on their merit to provide deeper understanding of the target users goals and tasks and also their ability to explore the different design parameters involved when providing support for the end users.

5.3.1 Task and goal analysis

To get an overview of the interface and tasks that the interface of TIBCO Spotfire supports a structural analysis was carried out. The interface was mapped to hierarchical maps that showed interface elements and navigation paths of tasks which clarified both the navigation and elements of the interface, thereby creating a kind of meta model of the interface elements and navigation paths. The maps encoded both breadth and depth of the interface and in this way gave a good overview of the software. No specific meta model language like Unified Modeling

Language (UML) or Entity Relationship Modeling (ERM) was used, but the flowcharts that were created could be seen as a simplified version of any of these. This lightweight approach was chosen since results from this method were only to be shared within the group (as opposed to sharing with external people), and also because the relations and entities that we wanted to map didn't need the expressiveness nor the complexity that these languages allow.

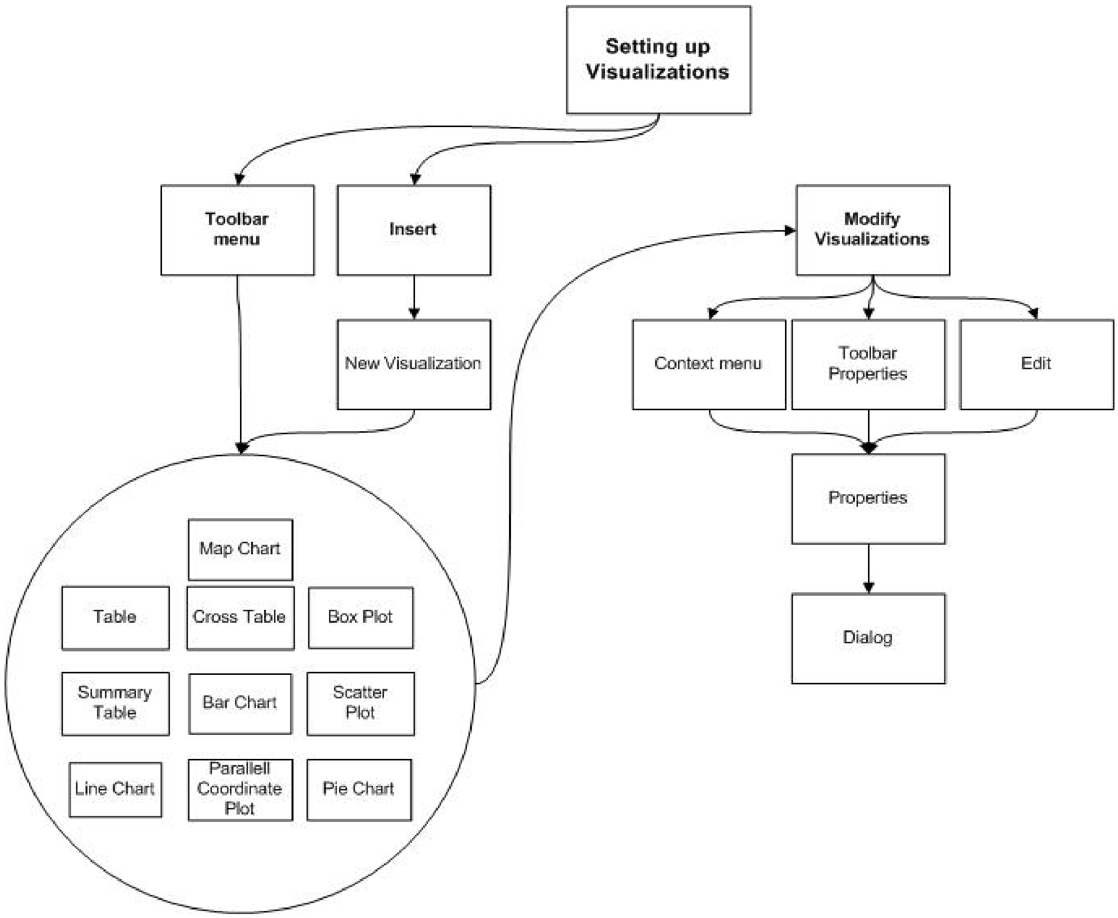


Figure 16.Image showing the steps of adding and modifying a visualization in TIBCO Spotfire.

The task analysis was carried out to gain a deeper understanding of the procedures that the users need to go through to reach their goals in the software. It was also done to better understand the relationships and dependencies between tasks and goals of the two different target users. Since the tasks were already encoded in the personas that were given the general tasks were already defined. The main questions that we wanted answers to were: How were tasks carried out? Were the goals met and how well were goals met? What factors were important to carry out tasks and reach goals?

The task analysis was done first in the existing interface but tasks were then analyzed on aspects that could improve speed and efficiency had they been present in the user interface. This meant investigating the flowcharts and finding points were additional functionality could improve the how well goals were met. This way of relating the tasks to the goals of target users gave insight into where speed and efficiency could be improved if new concepts would be introduced to the interface.

5.3.3 Scenarios

When the tasks had been broken down, analyzed and grouped scenarios were created for both personas (See Appendix 2). The scenarios were a step-by-step process that was very general in order to fit with the different software that was to be evaluated. This was done to be able to evaluate the software from the two different persona perspectives and these scenarios were to be a foundation for the comparative walkthrough that was going to be carried out next. The scenarios were created to reflect everyday usage of the software and to contain a broad range of tasks for each persona. Connection points between the two different scenarios were explicitly accounted for to make testing of the two scenarios in conjunction possible. The scenarios modeled the tasks on a high level and they were also made to be quite general in nature in order to make testing in different software possible.

5.3.4 Comparative walkthrough

The comparative walkthrough was based on the scenarios created for the personas. We chose three competitive applications to evaluate that were similar to TIBCO Spotfire. The three other applications were Tableau v3.6, QlikView v8.5 and Xcelsius v4.5. The evaluation of the applications was carried out by each evaluator on their own and followed the scenarios for each of the target users' point of view. Each evaluator documented their findings and then we discussed findings in our internal workshops. All applications were evaluated with speed and efficiency in mind for both target users. This meant probing, comparing and exploring the interfaces on different tasks. This made the walkthrough slow and an iterative process in comparison to a traditional cognitive walkthrough but gave insights regarding advantages and disadvantages with different solutions. Applications that we found to be of greater importance were evaluated more than others on some tasks to really understand some hard to grasp aspects. The walkthrough was a good way of understanding the consequences of different solutions and gave a wider perspective on all tasks that were evaluated.

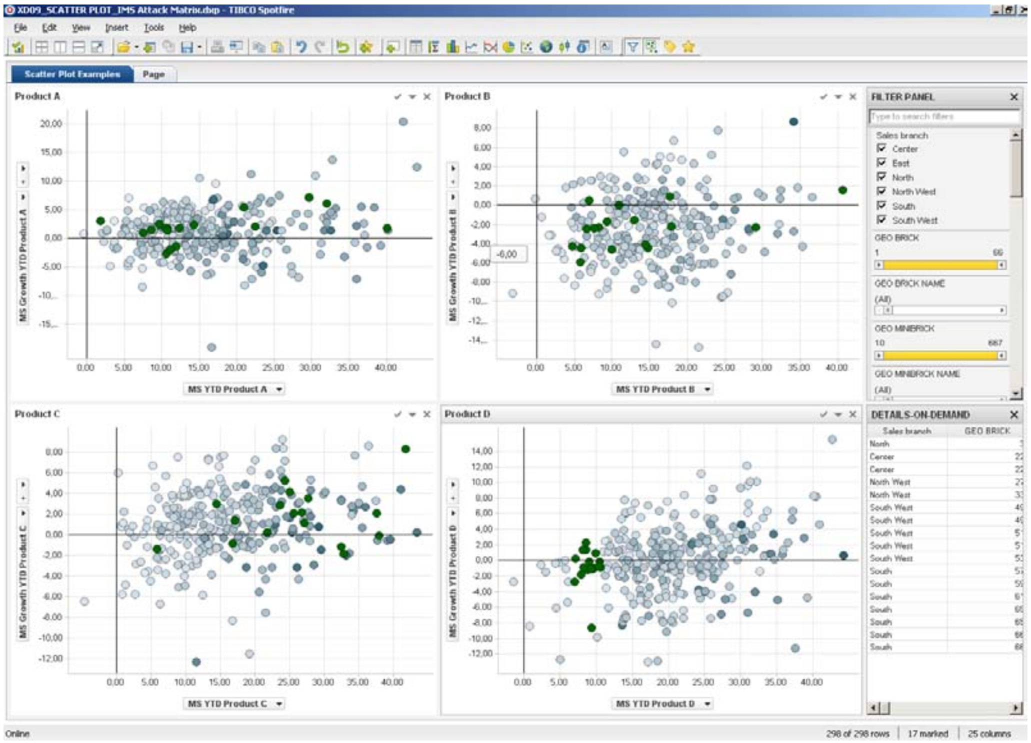


Figure 17.Dashboard/report created in TIBCO Spotfire.

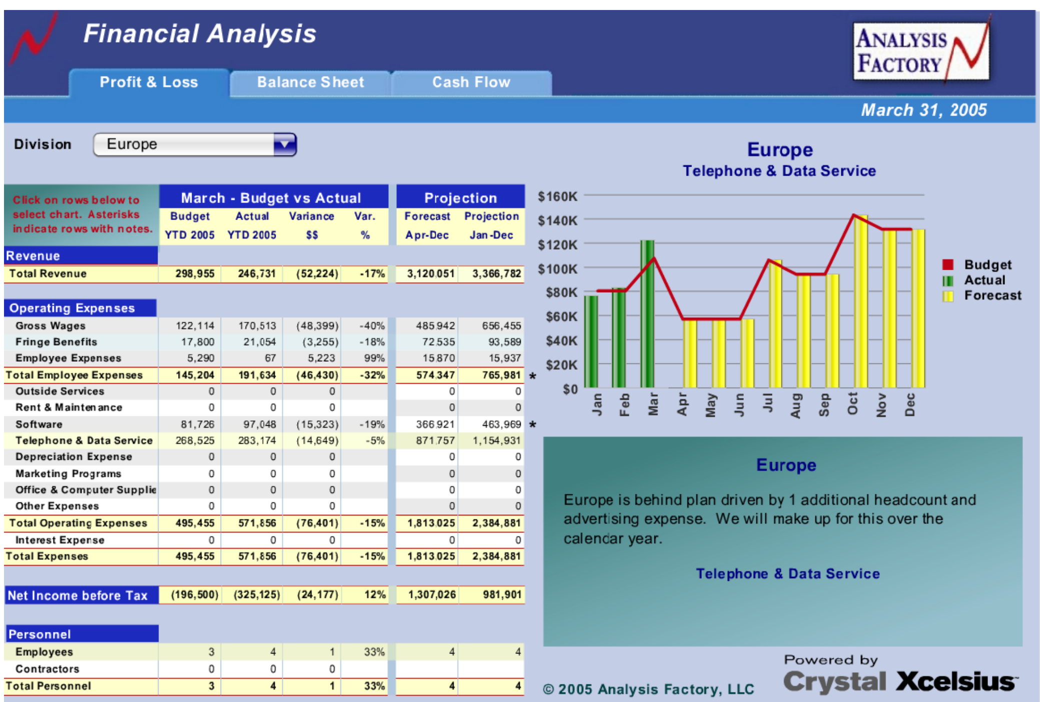


Figure 18.Dashboard/Report created with Business Objects Crystal Xcelcius.

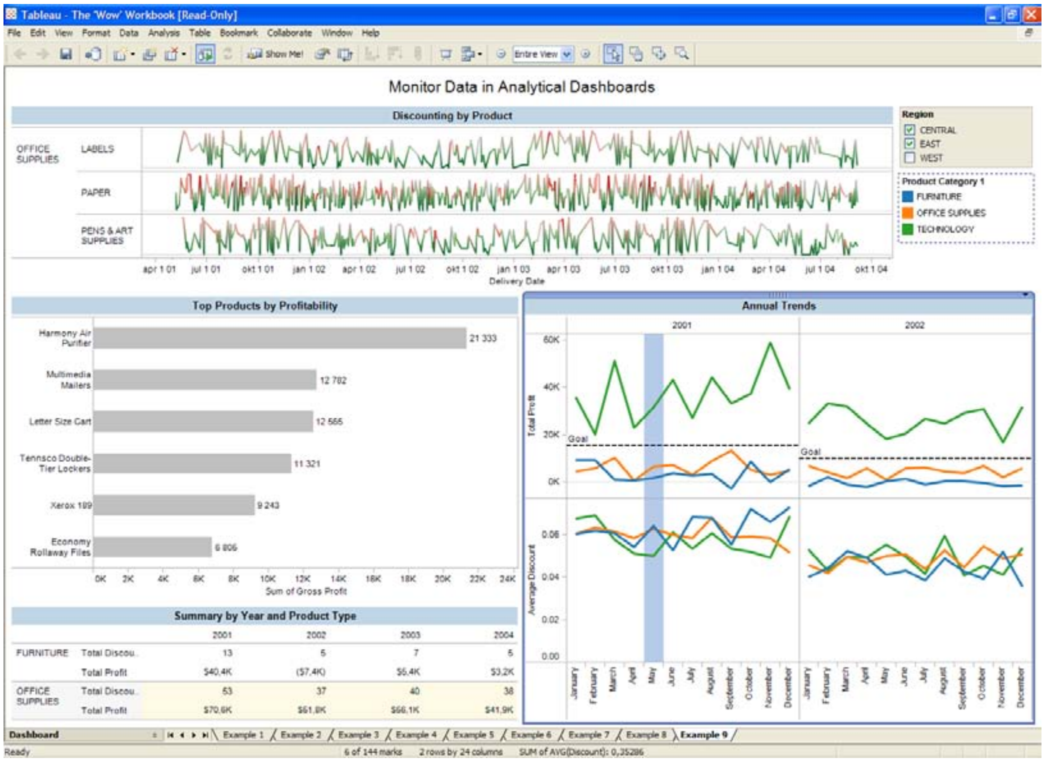


Figure 19.Dashboard/Report created with Tableau.

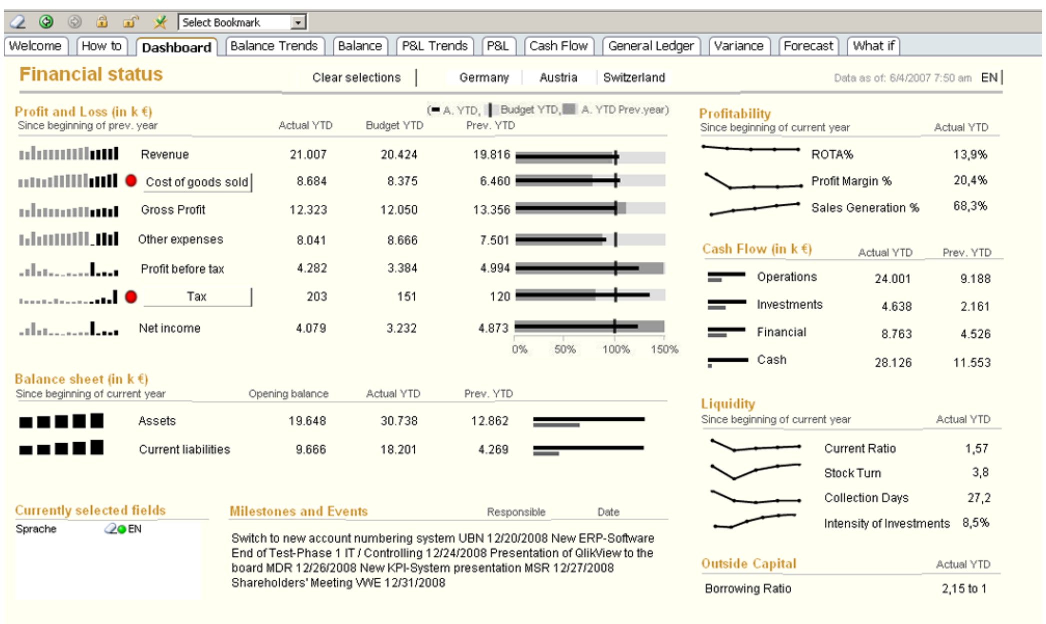


Figure 20.Dashboard/report created in QlikView.

Since the field of interest of this study wasn't ease of learning but speed and efficiency in use which are more related to ease of use than ease of learning some modifications were made to the walkthrough in order to make the method suit the needs of this study better. The first and biggest modification was that instead of evaluating just one interface and how the tasks were carried out in this interface a comparative walkthrough was carried out. In total four different interfaces were evaluated. Since the personas that modeled the target users were created to support the development of the TIBCO Spotfire product the scenarios had been created to be more general in some aspects in order to make testing over the different applications possible. This generality was a necessity since features differed quite a lot between applications and would have been hard to test if tasks had been too specific.

All advantages, disadvantages, problems and strengths were documented and grouped in different groups of goals rather than on the task level and where problems included both target users the relationship were made explicit in the documentation. The fact that the personas were created specifically for TIBCO Spotfire and also that knowledge of the TIBCO Spotfire product was a lot deeper had to be considered all the way through. Time had been spent on both structural analysis and task analysis with TIBCO Spotfire in mind and additionally all team members had gone through training for TIBCO Spotfire. The walkthroughs of the other three interfaces were therefore given considerable more time and a lot of effort was taken to make comparisons as unbiased as possible. It was of course impossible to avoid bias all together and this had to be taken into account when compiling the results.

When the comparative walkthrough had been carried out we had a lot of different types of results from the evaluation. Different principles, requirements and guidelines could be discerned and also a lot of different problematic constructs as well as particularly strong constructs were made clear.

5.4 CONCEPTUALIZATION PHASE

In the conceptualization phase the activities were in nature organizing, sorting and transforming activities. Methods in this phase were chosen to handle, merge, correct and make useful the information collected in the analysis phase. They were made to fit the information that had been collected and were chosen on their merit to fit these needs.

We collected a lot of principles during the analysis phase, and together with ideas of possible improvements of TIBCO Spotfire we started to spawn basic blue prints of new concepts. The conceptualization phase consisted mostly in internal workshops of two types, sessions of unrestricted brainstorming and sessions of discussion of ideas we had. The unrestricted brainstorm sessions consisted in getting together in a meetings room and just express all the ideas we could think of and write them down on paper or Post-its without limits or restrictions. Every idea was valid and written down during the unrestricted brainstorming. The internal discussions we had of the ideas we found consisted in trying to develop these ideas and to make sure they follow the principles we found earlier during the analysis phase. We discarded the ideas and concepts that didn't follow our principles and did not have their focus on improving speed and efficiency in use. It was also important that both personas were involved and that their tasks were in mind during the whole conceptualization phase. Both target users had to be the basis of every idea and concept, and every idea was always valued into both user groups tasks to see what benefits they added or if they had any negative effects. We used a large map during our brainstorm sessions where we put all our ideas with post-its, using the affinity diagram method. This became a systematic and iterative work of adding more Post-its to our affinity map during every session, and if necessary remove some ideas that we found had little or no value with our thesis in mind. We followed this iterative process during a short period of time until we were satisfied with the ideas we found and little or nothing more was added to the map. At this point we started to sort and organize our map into something useful by regrouping all our ideas into smaller groups were similar ideas came together. We digitalized our map of Post-its as well by creating mind maps with Mindjet Mind Manager Pro 7, and we shared these with the user experience team on TIBCO Software Spotfire Division trough external workshops. These external workshops helped us reorganize our mind maps and removing ideas that were already tested or evaluated. Mind mapping was also a way to easier structure our ideas and concepts and finding associations between these and a tool to aid our affinity map.

Figure 21.Image showing organized ideas and relations.

We had at this stage an interview with an expert of TIBCO Spotfire that helps customers setting up reports of their data and training customers to use the software. The interview was semi-structured with open questions were the interviewee could express real world problems from his own point of view, and also discuss some of our own ideas and concepts. The input we got from the interview helped us reorganize our mind map even more, and to focus on the most important concepts. The interview helped us also to remove some concepts that the interviewee thought would add little value to TIBCO Spotfire. We continued with our internal workshops trying to piece together the different ideas to larger concepts rather than simple idea or small improvements (See Appendix 1).

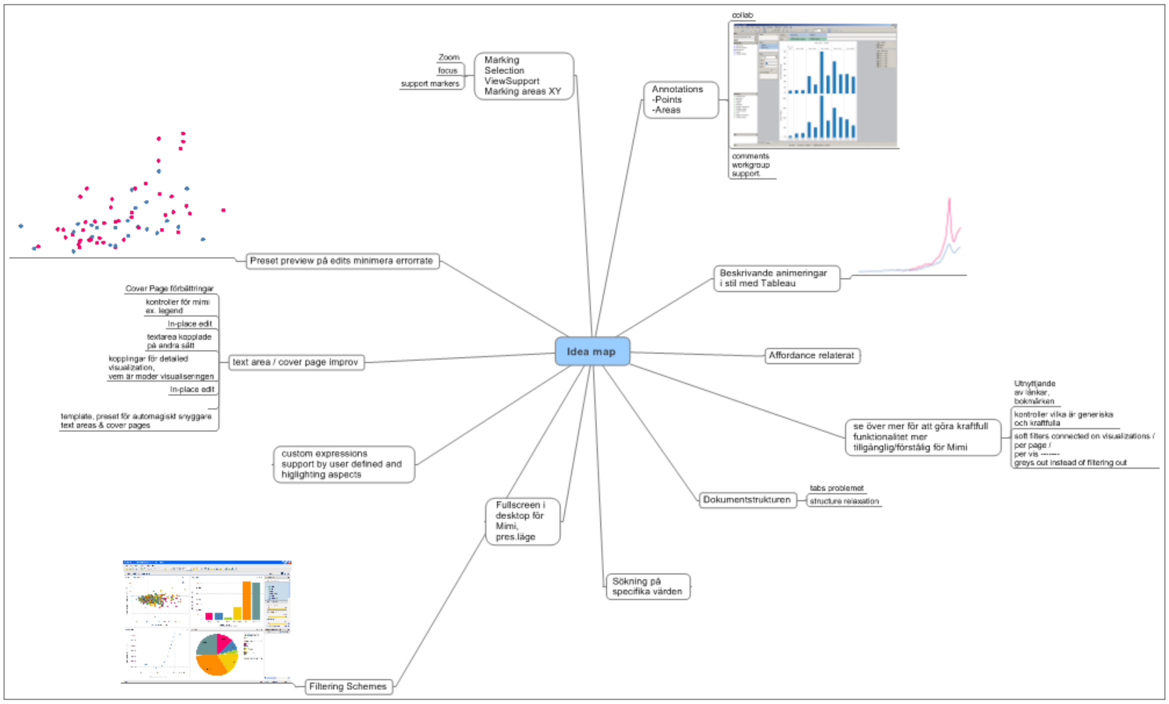


Figure 22.A mind map.

Synergy analysis was used during later part of the conceptualization phase by looking for ways to take advantage of the already strong concepts implemented inside TIBCO Spotfire. It was important from one of our principles to try and take advantage of the existing concepts, and we searched because of this for synergies. The concepts had to fit inside TIBCO Spotfire without breaking its current interface and concepts but rather the contrary, to enhance the current concepts. The persona info, scenarios, idea maps and existing concepts were involved in this search of synergy effects. The concepts had to fit in with both personas by adding speed and efficiency in use and support the tasks of both user groups.

The final refinements and evaluation were done in external workshops with the user experience team at TIBCO Software Spotfire division where discussion of the final concepts where made. We made sure the concepts had clear goals to meet and that they describe what constructs to improve before we started the design phase.

5.5 DESIGN

We chose to go further with the area marking and search integration concept. Several paper sketches were made to try out and construct a feeling of the interaction before we chose to design it. The sketching and drawing was something that followed throughout the whole prototyping process because it was cheap and much easier. The global methods used were something that runs parallel throughout the whole design process, the target user consideration, brainstorming and workshops. To get a better overview of the interface and the hierarchies in TIBCO Spotfire we sketched several maps to try to break down it to smaller parts. When we found faults or wanted to redesign the high-fidelity prototype, instead of redesigning through high-fidelity design we made paper sketches to save time. Sketching was a very iterative task, sometimes several redesigns on one day. We also sketched tasks and goals and structures that a user performs. Throughout the sketching phase we formed a common ground of understanding of what parts that was important and not. Concepts that were sketched went further to become a more interactive paper prototype that we could test within our workshops and evaluate.

The low-fidelity prototypes were created with a pen, paper and a scissor. Paper prototypes were prototypes that one could interact with testing different workflows and to get a better feeling of what the earlier synergies of sketches would feel like. It was much cheaper with time in mind and easier to create than a high-fidelity prototype. The paper prototype was tested in our internal workshops and discussed to point out problems or if something felt good or bad. These prototypes were not made on a daily basis but more when we had a feeling that sketches or drawings had to be tested early in the ideation stage. The two concepts that we chose to investigate further was area marking and search integration and we continued to develop a more interactive prototype to show how the interaction with them would look like and they can connect with other tasks in the interface.

We knew early in the analysis process that the high-fidelity prototype was not going to be tested on users but instead be of a more demonstrative prototype showing workflows and communicate the concepts. This approach caused us to focus entirely on the interface design and not on the underlying architecture, implementing a fully functional search concept or a fully working prototype of TIBCO Spotfire would take too much effort and time. The prototype can then not be seen as a full scale prototype but instead of a light weight demonstrator of the concepts. We started doing research for a tool that was more design specific than programmatic that we could implement our concepts in. The prototype was created with Microsoft Expression Blend 2 and some parts in Microsoft Expression Design 2.

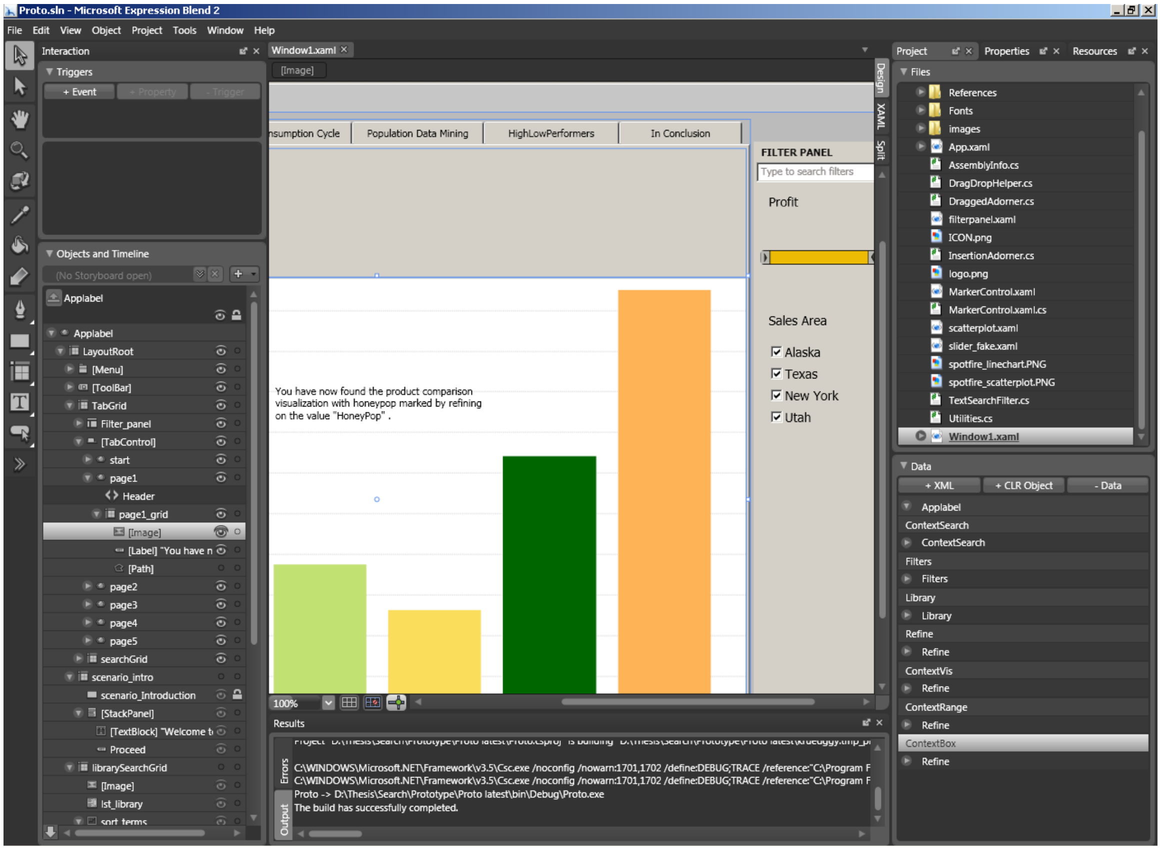


Figure 23.Microsoft Expression Blend 2 in action.

The design suite was new to all of us so a lot of time was spent on training, instruction videos and tutorials to get a better understanding. In this stage we still made parallel paper sketches to test but also to communicate ideas that came up while designing the prototypes. Daily internal workshops were held to discuss and to delegate tasks. The purpose of the interactive prototype was to create a deeper understanding of the interaction and to support our sketches and paper prototypes. This is also to support design ideas and evaluate them in a more realistic environment. The high-fidelity prototypes were designed to support and show how a typical workflow can be performed.

To demonstrate our concepts we created a demonstration video in Adobe Captivate. We recorded workflows of the two prototypes with annotations explaining the interface and how tasks can be performed and how you can connect these to other tasks in TIBCO Spotfire. The whole design process was of a very iterative nature and we had to go back to paper sketching several times and then implement the changes to the demonstrative prototype. The daily internal workshops helped us calibrate and save time.

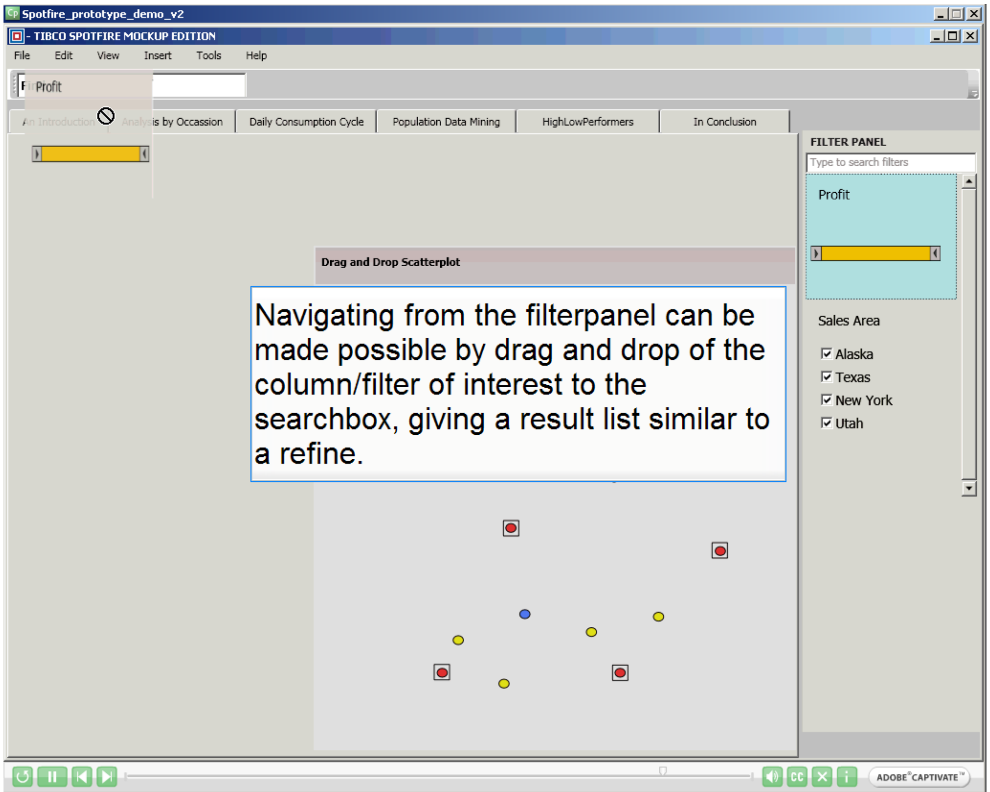


Figure 24.Demonstration video showing the search integration concept.

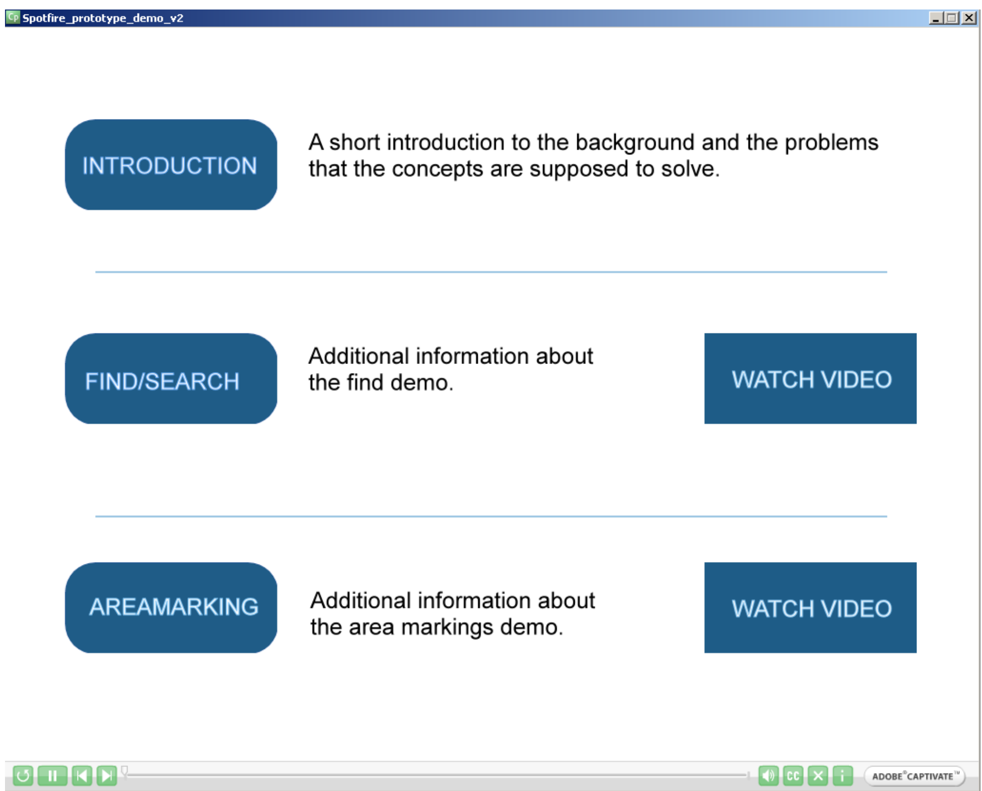


Figure 25.The demonstration video showing the overview of the concepts.

CHAPTER 6 - RESULT

In this chapter the result of the work is described. The analysis results are summarized as design goals and recommendations. Concepts and designs that build upon these goals and recommendations are then described in more detail.

6.1 INTRODUCTION

The results from this study are of several different forms. They depend upon the research question of speed and efficiency in use, the interface of TIBCO Spotfire and the target users of the study. Results are split up on the three different phases that the study was centered around and the connection between different results is explained below. Results move from more general types of results in the analysis phase to more specific types in conceptualization and design phase.

Results from the analysis phase are general and are meant to provide clear goals and recommendations for design of concepts to improve speed and efficiency in use. These principles reflect both theory and findings from the investigation of applications, goals and tasks. The form of goals and recommendations was chosen to encode requirements to provide tangible design parameters without crippling the design space. Parts of the analysis result was revisited, iterated on and extended when more detail was needed.

The concepts that are brought forward in the conceptualization phase are more specific but build directly upon the results from the analysis phase. Concepts are more specific since they all aim directly at improving the user interface of TIBCO Spotfire on certain aspects and therefore reflect and consider this particular interface more than others. Some parts of these concepts are still very general and the concepts can therefore be viewed as possible solutions to common problems that were found in the analysis phase.

The results in the design phase section are a lot more specific and deal more directly with concepts that are specific for the TIBCO Spotfire interface. The proposed designs have a firm foundation in the analysis and conceptualization phase and they were chosen on their merit to solve problems found in the analysis phase, follow the more general principles and their possibility for integration in TIBCO Spotfire. Results from the design phase consist of a couple of designs to improve speed and efficiency and are meant to communicate important parameters of design and are also meant to make possible an evaluation of benefits with these two concepts.

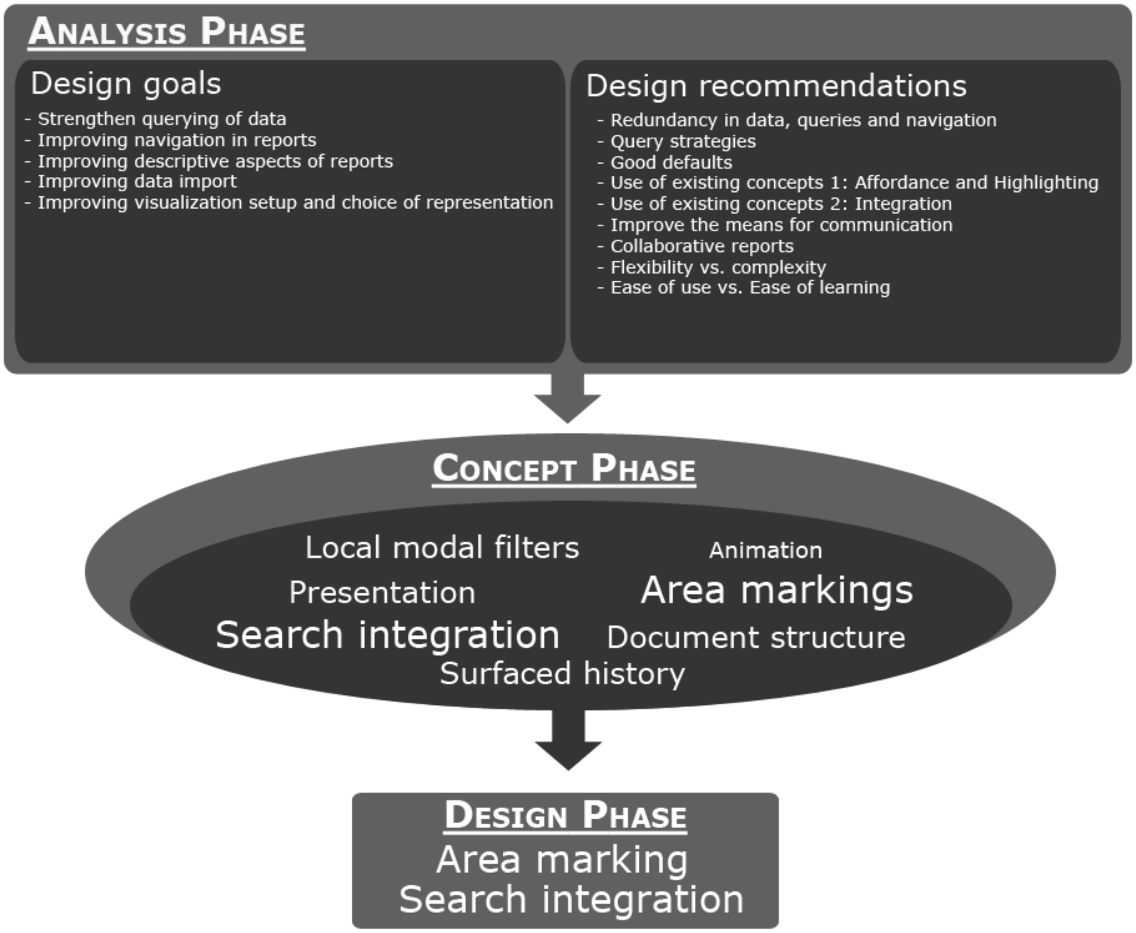


Figure 26.Block diagram of results.

6.2 ANALYSIS PHASE

6.2.1 Design goals

When all aspects and problems from the design space were grouped and organized a thematic ordering could be revealed under five different design goals.

- Strengthen querying of data
- Improving navigation in reports
- Improving descriptive aspects of reports
- Improving the data import
- Improving visualization setup and choice of representation

These were the five areas we found to be most relevant considering speed and efficiency in use for both target users.

6.2.1.1 Strengthen querying of data

This is one of the goals that we found important during the analysis phase. This goal is especially considered to benefit the consumer but it can help the author as well. Easy and quick queries are a way for the user to ask simple volatile questions on a report. Questions or queries that might be easy to pose for someone knowing the dataset might not be as easy when knowledge of the underlying dataset is shallower. There is a big difference between the author and the consumer. What might be an obvious and simple task for an author or an analyst might be more complicated to more lightweight types of users like consumers. It is important to provide consumers with rapid ways of posing relevant queries where they are most needed. Consumers have little time to spend on analysis which makes more complicated flows of querying doubtful. Consumers speed and efficiency can benefit from lightweight ways of querying and this can lead to both better usage and understanding of reports. This will benefit the author as well because the report becomes more self explanatory and less guided analysis is needed.

6.2.1.2 Improving navigation in reports

Improvements to navigational aspects of reports will also greatly improve speed and efficiency in use. These improvements are not restricted to one or two types of users and thus this aspect can in a sense be seen to surpass the scope of this study since it makes possible improvements for many types of users. For the consumer type navigation is very important because they don't setup the analysis themselves and therefore need more help to find relevant data and questions on the data. They might not be aware of subtle aspects like partitioning of data and might not even look at what they are doing as analysis. Consumers need answers and they need them fast, exploration can be seen as secondary. Two general strategies for improving navigation can be discerned. The first strategy makes navigational steps meaningful in the sense that they exploit the state that the user is currently in to add something to the analysis of the data. An example of this type of meaningful navigation is the ability to zoom in on data markers that have been selected. This makes use of the state that the user is in to perform an easy query that is relevant in the context. The second general strategy is to minimize superfluous navigation by making things available when and where they are needed or by hiding complexity. An example of the former could be to provide queries in the context where they are needed and an example of the latter can be to make sure that logical groupings are done when possible.

6.2.1.3 Improving descriptive aspects of reports

Setting up reports to be descriptive and easy to understand can be hard to do since there is a lot of options and choices for the person doing the setup. Automating small tasks where automation is possible improves for the one doing the setup and enforcing good principles by providing good defaults means a higher quality of reports. Providing tools that make descriptions easy to do while maintaining some type of standard for descriptions could mean a lot for making reports easier to read. It is important that the author can make the data into something useful for the consumer through simple explanations and guided analysis. Solutions to this type of problem can be seen to use either out of three strategies.

The first way of solving problems of this type is to make available efficient tools for the author, allowing her or him to make efficient explanations of important aspects of the reports.

The second type of solution is also one involving communication, but between report consumers. If consumers can collaborate and make available for others the findings and insights they have while analyzing reports less time consuming setup work might be needed for the author. This strategy could also have the important aspect of enforcing communication within workgroups and enterprise usage situations.

The third and most important type of solution to this problem could be seen as the holy grail of information visualization. This is to make information visualizations and supporting concepts self explaining, thus enforcing the meaning of the data and giving the reader direct means of exploring and understanding the data on their own in the best possible way.

6.2.1.4 Improving data import

Improving the data import could mean a lot for speed and efficiency since this is a big task in every scenario of analysis setup. The most important aspect of data import should be seen as correctness, security and making sure that the data can be shown in all possible ways that can be good for the understanding of the data (analysis). Providing the author that imports data with tools that ensure this while letting them work in a fast and efficient way could mean a lot for consumers as well since more time can be spent on setting up analysis, visualizations and descriptions to ensure the best possible guided analysis for consumers.

6.2.1.5 Improving visualization setup and choice of representation

Improvements to visualization setup and the choice of representation of data affect both authors and consumers of reports. For authors both speed and efficiency is important whereas for consumers only efficiency applies since they don't usually setup visualizations or choose representation but consumers are directly affected if the most efficient representation is chosen. There are several other types of users that are directly affected from changes to this aspect and tradeoffs must be done with extreme care to all users or not at all.

6.2.2 Design recommendations

The recommendations below were all found important to consider when designing for speed and efficiency. Some of the recommendations overlap more than one of the design goals. Together goals and recommendations are meant to provide guidance for understanding important aspects and principles that are relevant for both speed and efficiency.

6.2.2.1 Redundancy in data, queries and navigation

When authoring reports for others to view and consume it is likely that the data and analysis needs of several people have to be considered in the same report and therefore a certain amount of redundancy is needed in reports. There are efficient means of partitioning the analysis into pages and also ways of grouping filters in different ways in different applications that help the author handle redundancy issues. Redundancy may sometimes be required but any redundancy that can be eliminated without reducing the number of answers a report can give can increase speed and efficiency. If redundancies can be kept low the navigation of reports will be both faster and more efficient. If queries can be reached easily in the context where they are needed both navigation and understanding of the data will be more efficient.

6.2.2.2 Query strategies

The querying of data in different applications is done somewhat differently. This difference in strategy has deep implications for speed and efficiency and should be considered thoroughly. If querying is understood to mean all questions that can be put on the data one has to consider the different means that both queries are put in and also the means that answers to queries are given in and what effect this has upon analysis, and also what effect it has on analysis by different types of users. Which queries are needed locally? Which queries are best with global effect? What does a rich visual feedback have for effect and what effect does a rich set of queries have on speed and efficiency? These are all parameters for design when it comes to speed and efficiency in use and ways of combining globally given queries with locally given in a manner that facilitates as many tasks as possible can aid speed and efficiency.

6.2.2.3 Good defaults

The use of good defaults is a strong point in TIBCO Spotfire that should be kept in order to maintain speed and efficiency. When introducing new concepts great care should be taken to make them enforce good principles. Good defaults can be seen as especially important for the context with the relationship of authors setting up analysis for consumers since they may not have the ability to see if something is wrong or might not be able to correct it. This in turn can mean that they will make the wrong judgments and decisions. The principle of good defaults thus relates to both target users and the connection between the two and should therefore always be considered important.

6.2.2.4 Use of existing concepts1: Affordance and Highlighting

Enhancing already existing concepts, features and interface elements in TIBCO Spotfire to make them stick out more or to be easier to use can have positive effects on speed and efficiency. This could mean for example enhancing the filter panel, bookmarks, tags or even visualizations. All of these concepts are already powerful but some of their power can be hard to realize because of affordance issues or because they are not made to stick out enough in the interface. One such concept is bookmarks that can host complex queries and help consumers a lot in both guided analysis and by allowing them to save interesting states on their own. By making bookmarks stick out more in the interface its power could be exposed to become even better. Another example could be to allow the legend in visualizations to act as a control letting the users click and use the description that the legend provides to select or mark out the data in visualizations. These types of small improvements can together mean a lot for speed and efficiency.

6.2.2.5 Use of existing concepts 2: Integration

Finding ways of using old concepts in conjunction with new concepts can be a good way of improving speed and efficiency. By searching for concepts that can integrate well with the existing concepts allowing usage in conjunction with each other to allow even another meaning, speed and efficiency can be improved without introducing ad hoc solutions or unnecessary complexity. Many of the existing concepts can be seen to use this principle and the existing interface can in this way be seen as a recommendation in its own. Two good existing examples are the concept of dynamic queries that are the founding innovation of the interface that hides more complex queries behind easy to use widgets and integrates this with visual representation. Another powerful example is the links that can hide complex behavior behind an easy to use text string in the form of natural language output. This way of integration should be sought for with new concepts as well to allow the strengthening of what is already there at the same time as creating new possibilities for speed and efficiency.

6.2.2.6Improve the means for communication

Improving the means for communication between the author and consumer can have big effects on speed and efficiency in use. Improving communication between these two users will make it easier and faster for the author to create good reports with guided analysis thus making it easier for the consumer to understand the report. Making it easier for the author to communicate the report will automatically result in improved speed and efficiency during set up and better quality of reports for the consumer. An example of this is the authors' current need of external applications to create explanatory images for guided analysis; it can require unnecessary work to communicate a simple thing. Communication can be split up in two different types. The first being communication within reports and the second being the communication of results and findings in reports. By providing for both of these types of communication speed and efficiency can be improved not only on the individual level but also on an organizational level.

6.2.2.7 Collaborative reports

Presenting and communicating results and findings and share through different channels can help consumers of reports since their knowledge of the entire dataset could be improved and new ways of gaining insights into the data could be acquired. This would ideally take advantage of work that is done anyway, preserving this work and make it become beneficial for the group and not just the individual carrying out the work. This will mean both speed and efficiency improvements. An example could be collaborative reports where users can exchange their findings and knowledge between each other, through comments or annotations inside the report.

6.2.2.8 Flexibility vs. complexity

The connection between flexibility and complexity was one issue that was very apparent after the evaluation. The more customization and different setup options that are available in an application the more complex it becomes to set up the reports and visualizations to show the data in the best possible way. Flexibility should be put on concepts and integration between different concepts instead of introducing to many different concepts to choose from. Rather than having twenty different options to choose from that do the same thing it is better to design to allow for combinations of different smaller parts into different bigger constructs. A describing metaphor could be to compare it to LEGO where the old fashioned LEGO pieces could be seen as the favored way to go. Some small different building blocks can be used to build basically anything because they are easy to combine to new structures whereas more specialized pieces always build the same type of thing and are harder to combine with others. When flexibility of the wrong kind is introduced the result is the overly complex product or software that might seem advanced and flexible but actually adds little or no new insight to the data which is the main goal of the application. There are also several aspects of flexibility. It is for example flexible to be able to create very customizable reports with advanced layout schemes but later it can be difficult to make changes to them. Opposed to this flexibility can also mean the ability to create simpler reports that is easy to modify and make changes to. With speed and efficiency in mind it is important to automate with care where possible and always make sure that errors are very hard or impossible to make.

6.2.2.9 Ease of use vs. Ease of learning

The distinction of ease of use and ease of learning is important for speed and efficiency. Some concepts that seem faster and more efficient compared to others when first encountered can be shown to be both slower and sometimes less efficient when practice is given. This has to do with the fact that some concepts might have a threshold for the first time of use but once they are learned they are a lot easier to use. A typical example of this is the use of shortcuts, they take some time to learn but once you learn them they will improve the speed efficiency in use considerably. This raises the question when to sacrifice ease of learning for ease of use and vice versa. Of course if both ease of use and ease of learning can be accomplished this will be the best for both speed and efficiency.

6.2.3 Summary of analysis phase

Design goals and recommendations collected the findings from the analysis phase. This form was chosen both to aid our own further efforts but also to communicate the most important findings from the analysis phase to others.

The most surprising insight from the analysis phase was the fact that a lot of the possible improvements were found on the consumer type of user and the dependency on the author type of user. When we began the study the author type was considered to be the primary target of the study. After the analysis phase the relationships and dependencies between the two target users became more of the focal point for further work and later phases turned the consumer to the primary target.

The design goals and recommendations that were put forward in the analysis phase were used throughout the rest of the study. This made sure that both concepts and designs followed the findings in the analysis phase and also provided guidance on where to look for more details when needed.

6.3 CONCEPTUALIZATION PHASE

Results from the conceptualization phase were of two different kinds. The first type of result was a search of the design space that we had built up in the analysis phase and the second type of result was concepts that are meant to directly deal with these types of problems, trying to solve them while reflecting both goals and recommendations brought forward during the analysis phase. At the end of the conceptualization phase two concepts were selected for design using selection criteria based in part on the principles from the analysis and in part on merit of the concepts synergy effect with the existing TIBCO Spotfire interface.

6.3.1 Search of design space

When searching the design space we noticed that most of the possible improvements that we could find grouped themselves under the three first design goals. The data import goal was hard to find anything at all that had to do with the interface and this goal were therefore after consulting with our supervisor at the company dropped in favor for the other goals. Some early ideas on improvements on the visualization setup and choice of representation were disregarded after interviewing an expert user but also because most of the ideas were found to interfere with other user groups in ways that couldn't be allowed. Therefore the decision was made to narrow our further efforts to include the three first design goals:

- Strengthen querying of data
- Improving navigation in reports
- Improving descriptive aspects of reports

Subsequent efforts of concept creation and design tried to solve problems regarding these three design goals while leaving the other two goals behind.

6.3.2 Concept creation

The concepts that were considered for design follows below with short descriptions of what kind of problem they are meant to solve and the general idea of how they are supposed to work. They all build upon the principles put forward in the analysis result part and are supposed to solve problems of the types explained above.

6.3.2.1 Concept 1 - Surfaced History

The concept of a surfaced history is meant to solve problems that relates to the themes of navigating and querying the data. It would help navigation by enabling jumping back faster to an old point in analysis and browsing the history of analysis. It could also help the user querying and marking the data or rather help the user re-querying or re-marking the data if steps of history could be surfaced to show which steps that involved queries or markings.

The conceptual design is to make the history available as a list of distinguishable items showing what kind of step it is. Navigational steps, filtering and markings are the obvious ones but other types of items should also be considered. These items should be clickable and actionable by clicking with mouse or by keyboard navigating to the item of interest. As the name history implies the history list should be chronologic but it would be interesting to have a sort enabled list to allow groupings of the same type of steps making it easier to find related items. The groupings should hold the chronological ordering to allow the concept of history to hold even if a grouping has been done. Alternatively one could hide all history items except the group of items that the user interested in for the moment. This could be especially efficient to toggle different filtering points and marking points creating a kind of user controlled animation of the history for analysis steps.

6.3.2.2 Concept 2 - Local Modal Filters

The idea behind the local modal filters concept is to make tasks other than filtering available through the filter panel. This concept would solve issues related to both navigation and querying the data since it would lessen the navigational steps needed to pose queries that involve marking out a subset of data in the superset. The main advantage with this concept would be to allow further navigation from the already strong navigation point of the filter panel, thus allowing more different queries to be posed in almost the same manner as already available queries.

This new way of posing queries could be done by allowing users to drag and drop a filter from the filter panel and localize it to a specific visualization. When this action is being done the filter could change mode to mark values instead of filtering and in this way give the possibility to relate the values to the whole instead of filtering out values. This way of marking would take advantage of the strong concept of dynamic filters that are already incorporated by allowing users to carry out other tasks in the locality of specific visualizations. The markings would still work globally or alternatively the unused pop out effect of graying out values could be used for an interaction like this, allowing another level of making values stick out. The main advantage of using graying out filtered values instead of marking values with this type of functionality is that graying out would feel more like a lightweight filtering but still give the possibility to answer questions about relating subsets to the whole. It would also mean a new way of communicating this type of finding. If a small history of dropped filters could be kept for the visualizations this could mean the possibility for users to setup their own query contexts for visualizations. These "new mode" controls should probably look somewhat different and should be hidden either until the context is entered or until the user explicitly asks them to be shown. This hidden until needed approach is important since the display would become very cluttered if they were shown all the time and cluttered with elements that is really not needed until the user enters the specific context.

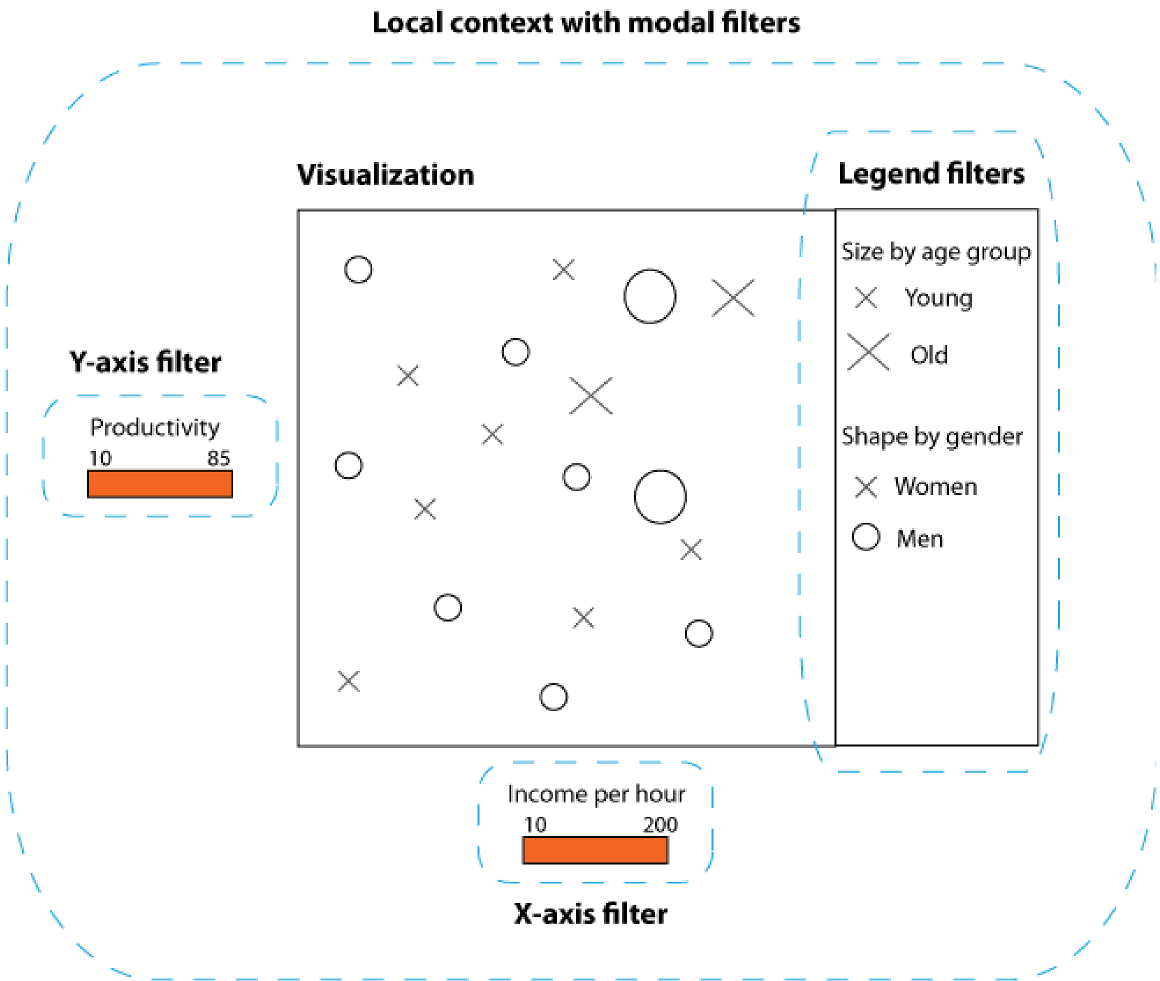


figure 27 Image showing local context of modal filters.

Local Modal Filters

Strengthening the querying of data	Improving navigation in reports	Improving descriptive aspects of reports
-Local filters in Visualizations		*-Easier to find related filters to specific Visualizations*

6.3.2.3 Concept 3 - Area Markings

The concept of area markings build upon direct manipulation of visualizations and more specifically on direct manipulation of the axes of visualizations and the plane that the axes describe. Area markings have the ability to solve issues related to all three themes of problems. Some navigational issues and query related issues are solved by letting the user put queries directly on the axes of specific visualizations while reading the visualizations, therefore eliminating navigation to secondary constructs to put queries on the main dimensions of the visualizations that are encoded on the axes. In this way both navigational and query related issues can be solved. Descriptive aspects could also benefit from the concept of area markings in three distinct ways. The first beneficial effect would be that reading values and querying could be done at the same time with the view support that area markings would mean. The second beneficial descriptive effect would be that if exporting images with area markings present another level of communicating findings and evidence would be made possible giving exported material greater communication power. The third descriptive effect that really could benefit is if area markings are well integrated with existing functionality it could be a very good way for the report author to explain entry points for analysis and areas of interest directly in the visualizations. This would be done with a concept that the report consumer probably would be familiar with and directly could use to take additional analysis steps.

Area Markings

Strengthening the querying of data	Improving navigation in reports	Improving descriptive aspects of reports
-Volatile in-context queries	*-View support* *-Can be used to make explanations directly in visualization* *-Bookmarking of area markings*	*-Easier to mark with precision*

6.3.2.4 Concept 4 - Document Structure Improvements

Document structure changes could solve issues from all problem themes and the concept is very wide in scope. By enforcing the meaning of report parts descriptive aspects of reports could be improved and by allowing this to be done while maintaining the automated layout of reports it could save time both for the author and the consumer users. By allowing some constructs to be presented in the context where they are meant to be used navigational and querying issues could be resolved at the same time as descriptive aspects would be improved.

The strategy suggested is to make the text areas more advanced. Allowing text areas to exist like child items on visualizations would mean new descriptive features and if the text areas could contain simpler controls like drop down lists containing bookmarks this could have the effect to make strong functionality even more useful. Some kind of snap to visualization functionality would be preferred for this new type of text area since the rapid set up of reports in part is enabled by this automation. Making text areas more advanced could also mean benefits for the cover pages that could be made into a control panel for the reports. This would be analog to a home of reports always giving the user the ability to go back there to find the right parts of reports. This would only be truly beneficial in larger reports but wouldn't on the other hand be required to set up in smaller reports. The main problem with this concept is to decide what controls to allow in localized form.

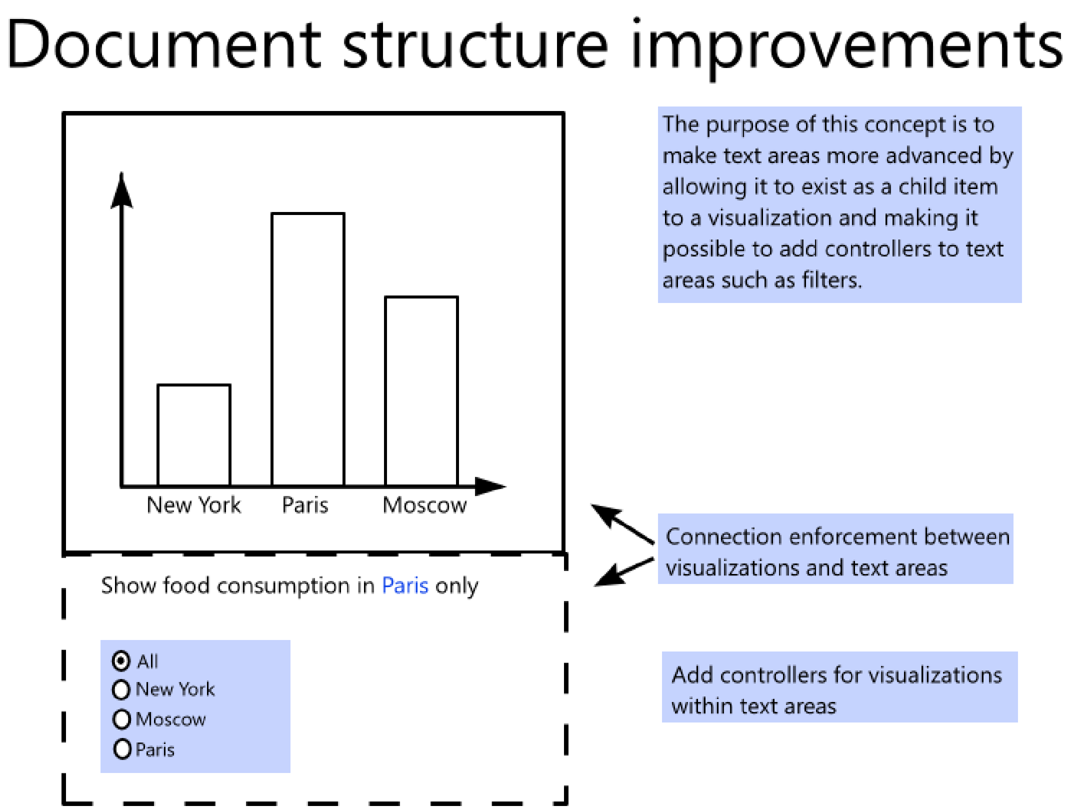
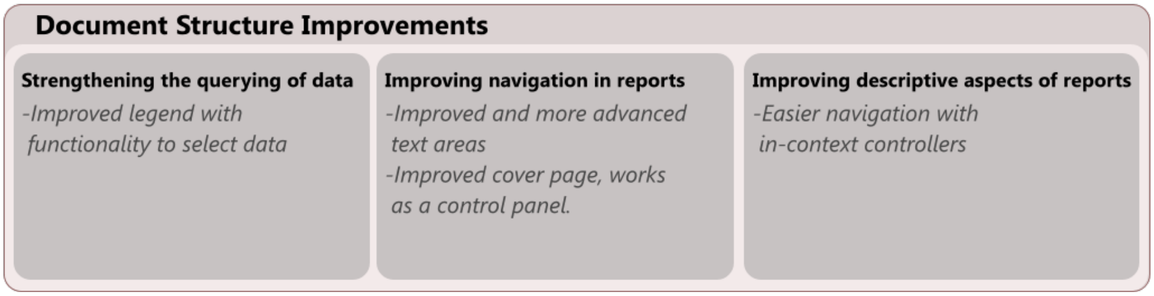


Figure 28. Overview of the document structure improvement concept.



6.3.2.5 Concept 5 – Presentation capabilities

In an enterprise use context advanced presentation capabilities could mean a lot for speed and efficiency since communication of findings and questions on data could be a very important task within organizations. The ability to give interactive presentations within TIBCO Spotfire could be very powerful, fast and efficient since the step of exporting findings would be eliminated from the scenarios where interactive presentation is a possibility. Other presentation or communication situations could include sending parts of reports containing findings in the data to people that might not have access to the TIBCO Spotfire product and export functionality could be extended first and foremost with explaining aspects in the visualizations and if some interactivity could be maintained when exporting speed and efficiency in communication could also benefit.

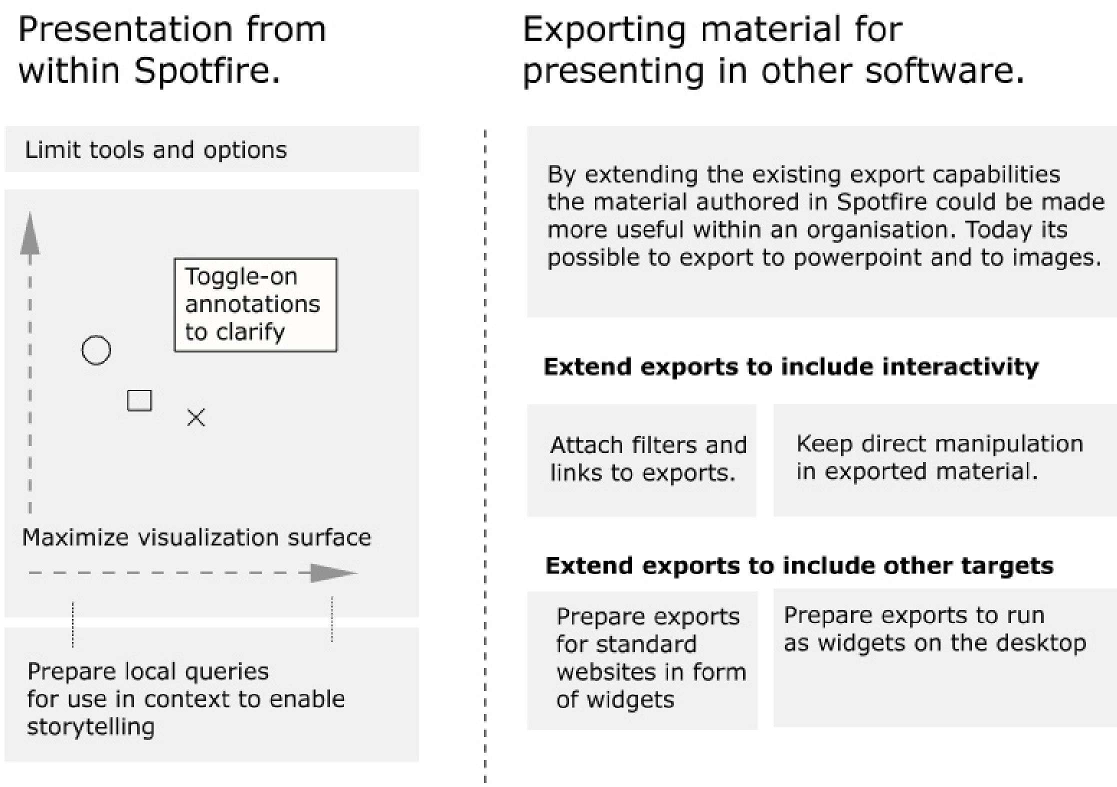


Figure 29. Image showing different aspects of presenting findings from Spotfire.

6.3.2.6 Concept 6 – Search Integration

Search functionality can increase speed and efficiency in a software product. The concept of search integration were suggested in order to find ways of integrating search functionality into TIBCO Spotfire and find ways of using existing concepts and structures to improve speed and efficiency. Search functionality has the ability to improve on all themes: navigation, querying and descriptive aspects of reports.

The concept was set out to deal with ways to make use of the existing concepts and elements in the user interface and the connection between search and existing interface rather than more technical aspects of search like indexing mechanisms and search algorithms. The whole idea was to gain insight into what tasks that could be beneficial to support and in what way to support these tasks to allow improvements in speed and efficiency.

6.3.2.7 Concept 7 – Descriptive animation

The concept of descriptive animation is meant to solve problems relating to descriptive aspects of reports. By allowing the author to setup animated sequences in the visualizations that can be played and stepped through additional descriptions and automated analysis steps could be done. It would be beneficial if this concept could support both automated animation over dimensions in the data as well as recorded step by step analysis to explain workflows through the data since more different scenarios could be explained if this was allowed.

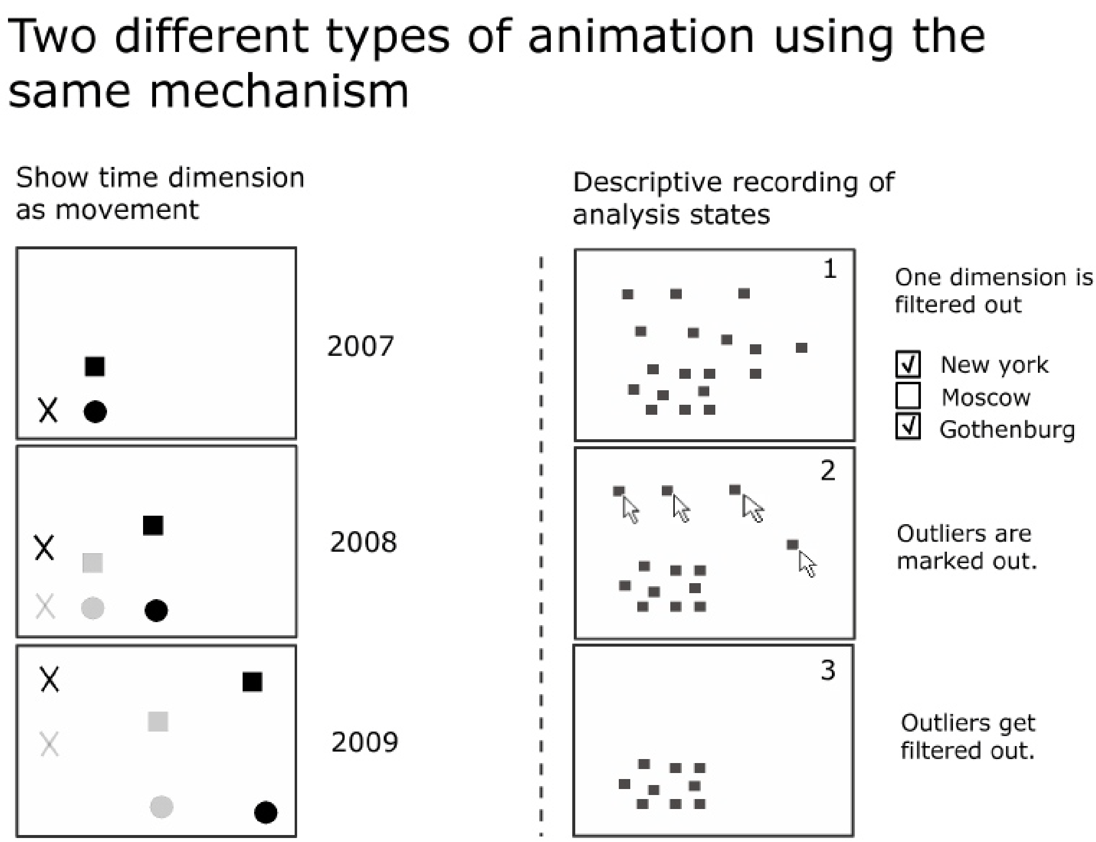


Figure 30. Diagram showing the concept of animation.

Descriptive animation

Strengthening the querying of data

Improving navigation in reports

-Descriptive animations ease the understanding of data for the consumer and descriptive aspects for the author

-Show analysis flows

-Use animations to express time changes

Improving descriptive aspects of reports

6.3.3 Selection criteria and selection

In order to decide which concepts that would be most interesting to create designs forthree selection criteria were set up. The selection criteria that concepts were to be chosen upon were:

- Ability to meet design goals
- Ability to follow and make use of recommendations
- Degree of synergy effect with the existing interface

All the concepts were evaluated with these three criteria in mind and most concepts could be seen to at least fulfill the criteria of meeting design goals and recommendations. The criterion of synergy effect with the existing interface therefore became paramount for the final selection of concepts for design. The two concepts that we found had the greatest possibility for seamless integration and synergy effect was area marking and search integration.

Area marking have the possibility to reach into all three design goals while at the same time make use of several of our recommendations. Further, area marking has capacity to strengthen existing concepts while at the same time add new support for common tasks.

Search integration can also fulfill parts of all three goals and follow many of the recommendations. We also found a lot of possibilities early on to make use of existing concepts and combine it with search capabilities. The challenge to find good ways of integrating search was both interesting and seen to have a lot of potential. The combination of potential and uncertainties made search integration ideal for further investigation and design.

6.4 DESIGN PHASE

The designs presented here consist of two prototype designs that both are meant as proof of concepts. Fidelity of prototypes was of varying degree and the prototypes primary object was to deepen the knowledge of important aspects of the concepts. The secondary object was to create and communicate a feeling for the benefits with each concept.

6.4.1 Area markings

The area markings prototype was created to explore how speed and efficiency in TIBCO Spotfire for both authors and consumers can be improved. The idea is to let authors use area markings to setup explanations directly in visualizations which aid consumers with analytical steps and areas of special interest. For consumers area markings introduce a new way of posing some common queries in direct context and connection to the visualization that are currently in focus. This will mean less navigation and a good starting point for analysis of data within visualizations by enabling view support. Area markings are meant to enable:

- Stronger descriptions by tightening coupling between visualizations and text fields.
- Local lightweight queries and view support in visualizations.
- Strengthen already existing functionality in TIBCO Spotfire.

Since TIBCO Spotfire has many levels of interaction with visualizations it is important not to disturb the existing interaction forms. Area markings are meant as a volatile type of query that is posed through click enabled axes. By allowing this type of queries on axes both descriptive, navigational and a new type of query can be enabled.

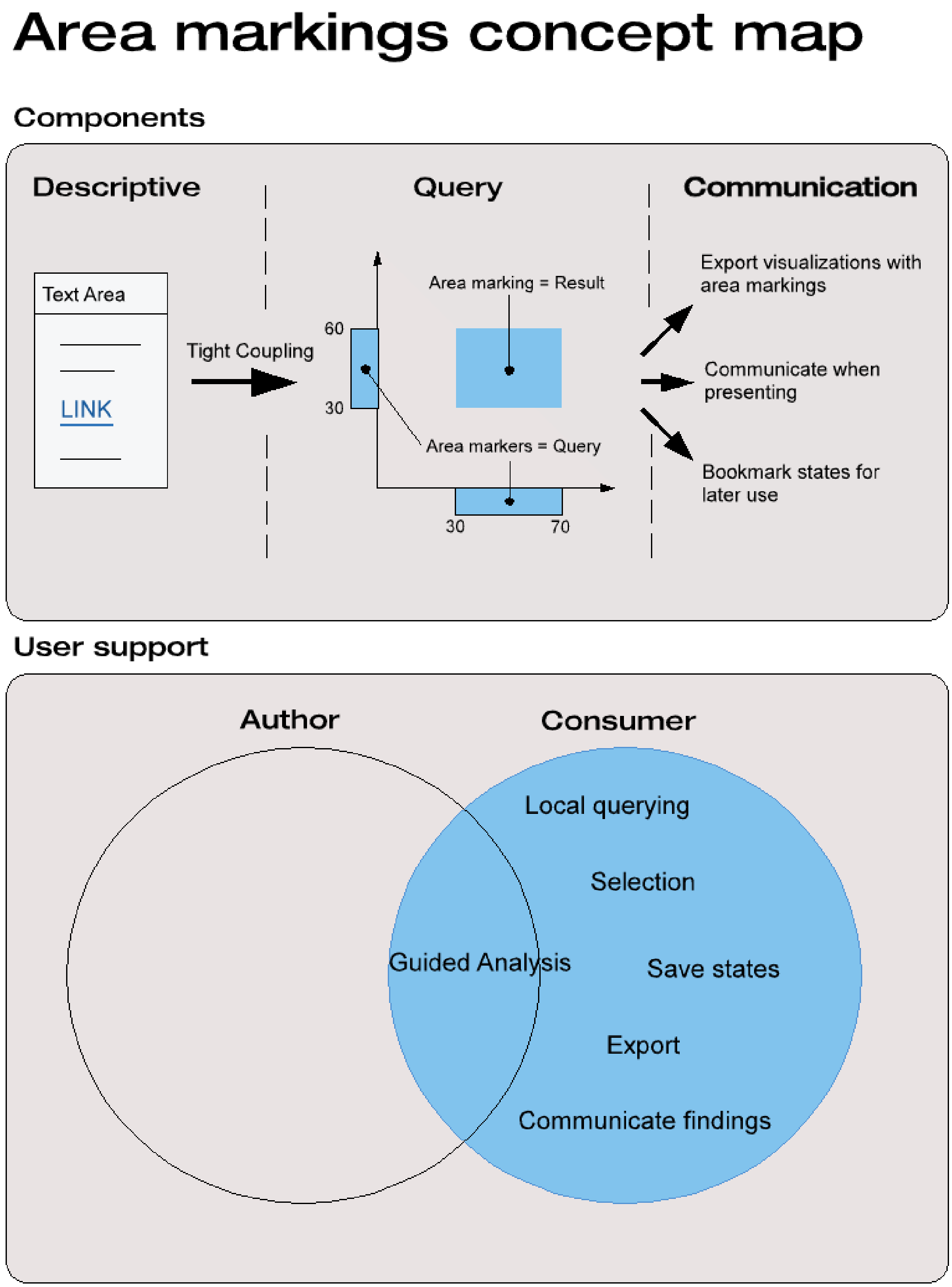


Figure 31.Area marking concept map.

6.4.1.1 Scope

The scope of area markings can be described as a subset of a bigger task. This bigger task is the exploration of axis queries and what type of queries and answers to queries that can be given in different visualizations. As earlier explained our work explores how area markings can be used with existing concepts in TIBCO Spotfire to improve aspects of speed and efficiency. The existing concepts that are involved include interaction patterns, descriptive aspects in reports and visualizations. Some visualizations are not suited for area markings since they don't have information encoded on axes, for instance pie charts and map charts. Other visualizations that do have information encoded on axes but where the concept of area markings is doubtful were also excluded, e.g. 3D scatter plots. Visualizations where the particular concept of area markings is doubtful could still have interesting ways of using axis queries but this was considered to be outside the scope of this study. The visualizations that we found most interesting to explore for the aspects in this study were scatter plots, bar graphs and line graphs.

Consideration of multi platform usage of the concept has been explored to some degree. The core functionality of the prototype is meant to work in both web player and on mobile platforms but the main target is the desktop version of TIBCO Spotfire.

6.4.1.2 Integration

In order to realize the full potential of area markings integration with several existing concepts in TIBCO Spotfire is necessary.

The biggest change is that area markings would mean a necessary change to the visualizations themselves. This change includes both the axes and the plane of visualizations since area markings make use of the axes to pose queries and the plane to answer queries.

Another integration point is needed to allow for the descriptive aspect of the concept. This includes the existing concepts of bookmarks, tags and links. By integrating area markings with these concepts guided analysis can be improved and interesting findings can also be saved in a new way.

Area marking introduces a new type of lightweight query posed in context of a visualization and will affect the existing concept of marking. Marking is used to mark out or select groups of values and specific values which mean that this concept is closely related to area markings. Careful consideration and integration between the two can make them work together and allow for a richer language for posing and answering questions within visualizations.

6.4.1.3 Tasks

For the author type of user area markings provides a new tool to make descriptive explanations directly in the visualizations. This can be done by integrating area markings with links in text areas allowing authors to use a well known toolbox for guided analysis but still allowing for richer expressions. Area markings have the ability to eliminate some possible need for external image editors to make explanations of important areas of interest in analysis. This would be beneficial to the author of reports since they don't have to leave the program to create additional material as often. The coupling between the information in text areas and the visualization of concern can also be improved which makes the authors work more efficient. The natural language output that links provide is perfect to hide unnecessary complexity for the user and can bookmarks of both marked values and marked areas be combined into links even more types of explanations are possible. Not only can interesting factors be shown where they are of concern but links give the possibility to put the user in a state that can be used for further analysis as well. This way of allowing consumers to "piggyback" into analysis on the author's knowledge and work is perfect for guided analysis and area markings can strengthen this type of interaction. The main benefits with area markings for authors should be seen as an improvement to their toolbox without limiting their creativity or adding much complexity to their work.

Consumers of reports can benefit from area markings not only if authors make use of the concept in their setup of guided analysis but also by using area markings directly. Area markings are local to a visualization and give help to answer questions directly in the visualization. This means that area markings and other possible axis queries are perfect for introducing more localized queries in TIBCO Spotfire. This will benefit the consumer since some navigation to find queries in the filter panel can be avoided and view support will be given directly in the visualization. Especially helpful are area markings to help relate subgroups within the visualizations to the entire set and to each other. In trellised visualizations area markings have ability to be a great aid in reading the visualizations and compare across the multiples. Comparisons across visualizations and even over datasets can also be made easy, fast and efficient to do. If exporting visualizations with area markings can be done this could mean significant improvements for the consumer when presenting or communicating parts of their results. The combined benefits that area markings can mean for consumers are bigger than for any other type of user. Descriptive parts are beneficial in guided analysis but also for communication and presentation of results. The localized query part is beneficial for both comparisons within and across visualizations but also as view support when reading visualizations.

6.4.1.4 Visual properties

For area markings to be successful as a concept consideration to visual principles in TIBCO Spotfire has to be followed and some additional constraints are also needed. Since area markings add visual information in the visualizations themselves it is important to make them very volatile to avoid adding chart junk in the visualizations. A full scheme for when area markings are canceled out has not been suggested since it has to do a lot with choices for how they shall interact with value markings and also across visualizations (linked views) but volatility shall be considered as a primary parameter for design. Since area markings are meant as a type of local query that doesn't act globally until turned into a selection/marking they should be more volatile than standard markings in order to avoid having to cancel out a value marking to cancel out an area marking that isn't supposed to be there. This volatility can be reached by allowing some navigational tasks (e.g. page navigation) and filtering to cancel out area markings but there are some good aspects of not making area markings too volatile as well. For instance if they are supposed allow being used as temporary markers to make arbitrary comparisons across visualizations and pages it is not possible to have them too volatile. An area marking can always be turned off by clicking any of the area markers.

To avoid disturbing the primary visual elements in the visualizations, the data markers, it is not only important that area markings are volatile. The hue and saturation are also very important aspects of area markings and only well calibrated values for hue and saturation shall be allowed. With well calibrated it is meant that the area marking shall be clear enough against the background of the visualization but considerably weaker in saturation than data markers to not disturb reading the data. One way could be to use a light shade of grey which would produce a clear distinction between the white background and still allowing them to be clearly separated from the color of data markers. For the descriptive and communicative component this should be viewed as a true disadvantage since color can carry descriptive and communicative power. A grey shade may also simply look dull and should perhaps be avoided just because of this reason. If different colors for area markings shall be provided to allow more descriptive and communicative power a good palette of default colors should be provided and no customizations possible since it is hard to find these good color values and customization is therefore bound to be misused. A positive effect of area markings in comparison to value markings is that area markings can mark out values without destroying the information carrier of color on data markers. This has to do with the fact that value markings mark out values by changing the color whereas area markings reside in the background marking out by the principle of enclosure. This has some subtle but distinct positive effects when comparing subsets of data in visualizations.

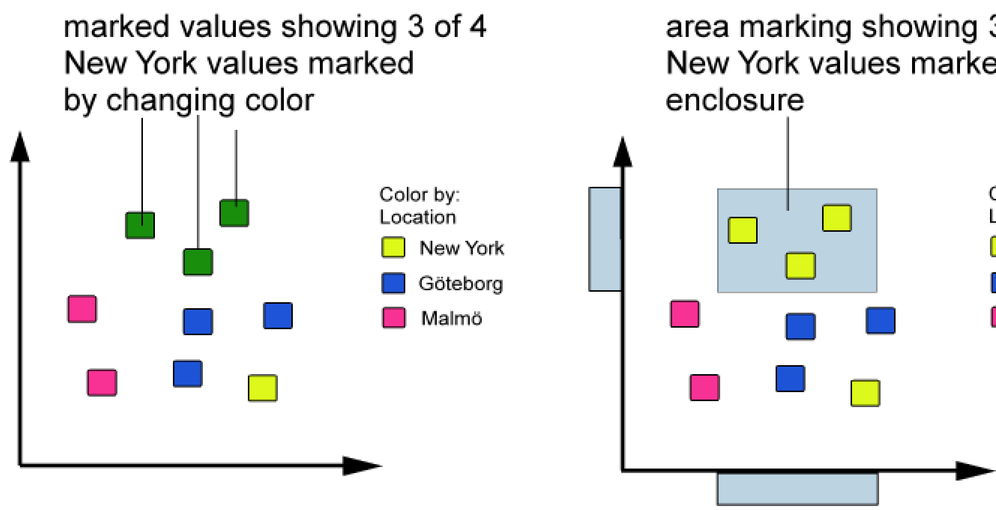


Figure 32.Same visualization showing the difference of marking out by color (left) and marking out by enclosure (right).

The area markers on the axes are also an important part of the visual design of area markings. In order to make an area marking affordable a possible area marker should be marked out visually by highlighting the area marker when it's hovered. This puts visual constraints on the hover behavior not to disturb the axes values and labels and some modification of the axes would be needed for this to work properly. When an area marking has been performed it is important that the area marker show the values or label that the area relates to in a clear manner and also that other labels and value tick marks are disturbed as little as possible. Additional constraints involves configuration of visualizations. For instance if a bar graph shall allow area markings a constraint on the width of bars is needed since the area marking need space between the bars in order to be visible.

One of the main benefits with the visual properties of area markings and area markers is that they provide a good mapping between representation, the axes and the area being marked out, that is between the visualization itself, the query and the result. This positive effect is related to gestalt principles. The axes and area markers become a unit because they are connected while visual similarity provides mapping between query (area marker) and result (area marking). Explained in plain language you see the measure, you pose the query in direct connection to the measure and are given the result in a visually similar manner. Some intricacies of these aspects will be explained in more detail in section 6.4.1.6 (Axes and plane – Queries and results) and section 6.4.1.7 (Visualizations).

6.4.1.5 Interaction

To perform an area marking users will click a category scale axis or a continuous scale axis to area mark a category or a range respectively. When clicking on a category or a range the area of the plane that corresponds to that part of the axis will be marked out**.** When the user hover the clickable areas in the axes the area in the axis is highlighted to hint the user that it is clickable and also to hint what area will be marked out if a click is performed.

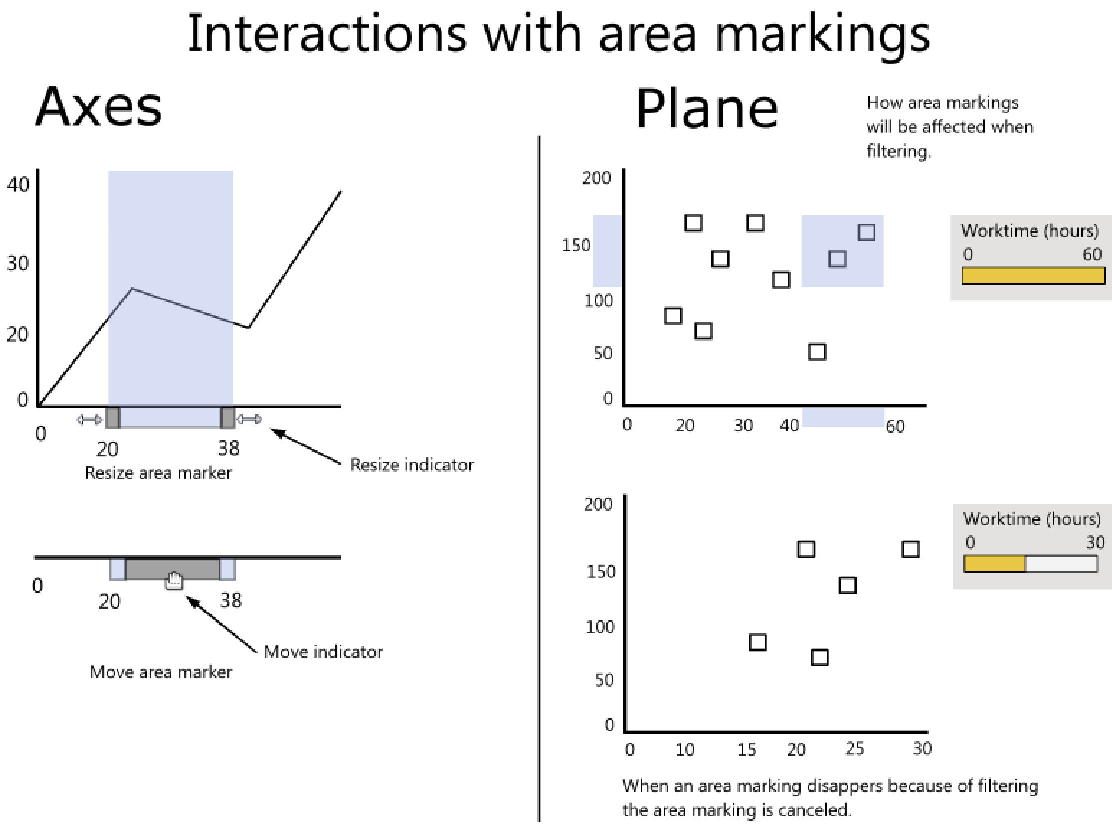


figure 33 Diagram showing problematic aspects of area marking interaction.

Multiple categories and ranges can be clicked to refine the area marking by using the control key as a modifier. With these combinations most areas in a visualization can be highlighted. Area marked ranges can also be refined by grabbing the edge of the area markers in the axes and expand or shrink the area by click-and-drag its edges. In this case the values should be shown on the area markers at least while dragging is done to allow the user to get exact measures of the area. This way of refining is really just useful for ranges but can be allowed for categories as well with the difference that categories would give discrete steps over categories instead of continuous refinements. If an area marker has been refined in this way the values on the new range would preferably be shown. This could be done either by adding a temporary tick mark with label as long as the area marking is in effect or by superimposing the values of boundaries on the area marker when hovering on it.

With the help of area markings users will be able to make quick and efficient comparisons between both categories and ranges and see if value markers or lines are located within certain boundaries. Keeping the area markings local to visualizations allow for arbitrary comparisons across visualizations while still allowing exactness for each marked area. By enabling area markings to be upgraded to mark the values within the area the global state of each area marked group can be reached. This type of upgrade to value marking (marker selection) can be done through a context menu for each area marking and all values within the area is then marked. When performing value marking by upgrading area markings the operation follow the same logic as multiple value markings. Upgrades to value markings can in some scenarios be incomprehensible and the option to upgrade area markings is not available then (grayed out in common manner). Combinations of value marking and area marking can be allowed when the control modifier key is in effect but this can possibly confuse users because of the difference of global (value markers) and local (area markers) effect. The advantage of allowing combinations can be viewed as big enough to consider it since more different states can be reached this way.

Area markings are supposed to be a very lightweight type of query and are cancelled out both by just clicking in the visualization, marking a value or lassoing a group of values. An area marking is also canceled out by marking another category or range unless the control modifier key is in effect. The volatility of area markings is important to avoid cluttering of the visualizations.

When creating bookmarks and links the interaction should be unified with existing bookmarking and link functionality. In this way little or no new training will be needed to be able to use the functionality area markings bring in this aspect. Ability to choose the color of area markings could be interesting to enable more advanced explanations in the scenario where it is used under links and bookmarks. This ability to change color could be grouped in the context menu for area markings and would also be useful when exporting visualizations with areas marked out.

6.4.1.6 Axes and plane – Queries and results

The two most important parts of area markings as a concept are the axes and the plane of a visualization. The axes are used for posing queries and the plane of the visualization is used to give the result of posed queries in a graphical representation. The benefits with this are the direct mapping between posing a query and the information that a visualization encodes and the local context that both queries and the results are given in. It also provides a unified way of posing queries for visualizations that use axes. A problematic aspect is the use of areas for showing results of the queries. Many visualizations don't encode continuous information in both dimensions of the plane and this means that the use of areas as an encoder of results becomes somewhat flawed since one dimension of the area lose meaning. This fact means that other graphical representations than area markings can be considered for showing results of some axis queries.

When filtering data the axes are transformed and this means that area markings will be affected. Our suggestion is that when an area is filtered out partially or completely this will mean that an area marking will be canceled out since this will avoid some hard to understand states for users. In the same manner an area marking will be canceled out if zoom sliders are used and a zoom result in a partial or complete concealing of a marked area. The labels on axes also need to be adjusted to work with area markings.

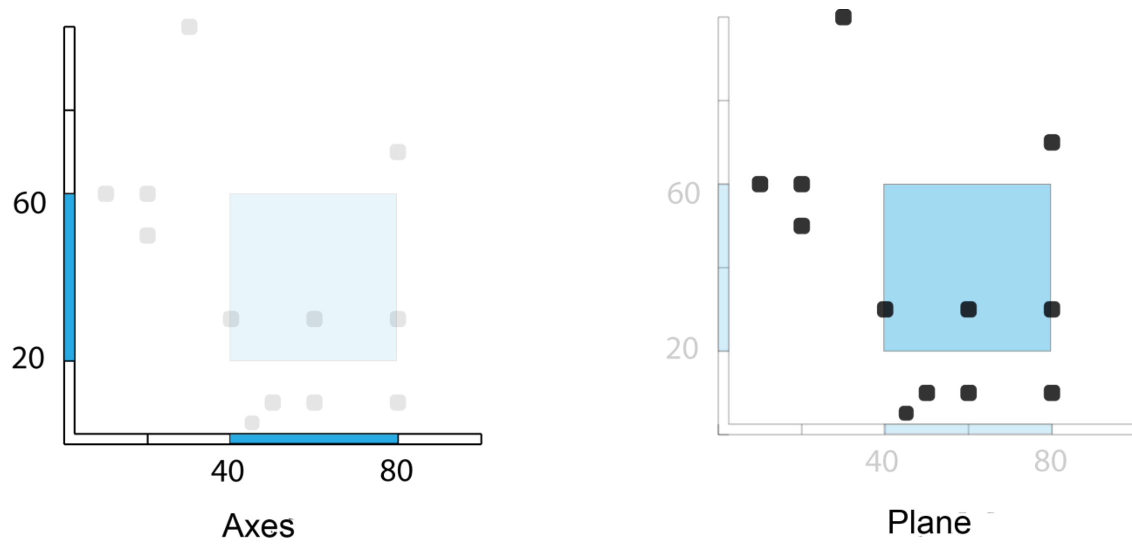


Figure 34. Left part shows the highlighted axes, and the right part shows the highlighted plane

6.4.1.7 Visualizations

Area markings are best suited in visualizations that encode continuous information in both dimensions of the plane (e.g. scatter plots and line charts). This doesn't mean that area markings are useless for visualizations of other type. Both the descriptive property used for guided analysis and the property to serve as view support when comparing subsets in or across visualizations are maintained. For instance in a normal bar graph one of the dimensions does not encode any information but is still used in the graphical representation to clarify the bars.

Selecting bars by area markings are still useful since it gives view support without changing the information encoding of the bar. This is opposed to direct marking which shows selection by changing color. This makes selection and comparison between different bars more efficient when using area markings since the color of bars and thereby all their information will remain intact.

In visualizations that have two continuous axes area markings have additional benefits. Area markings can in these cases be used to make well specified areas into reference points in visualizations. This can be used to check if values are within boundaries or to make selection queries based on the axes. This is useful to make descriptions in guided analysis more expressive and efficient. The ability to select data areas that might not contain values means that goals, warnings and items of importance can be showed directly in visualizations. This can also be used by the consumer to set up bookmarks of areas that need to be checked over the course of time.

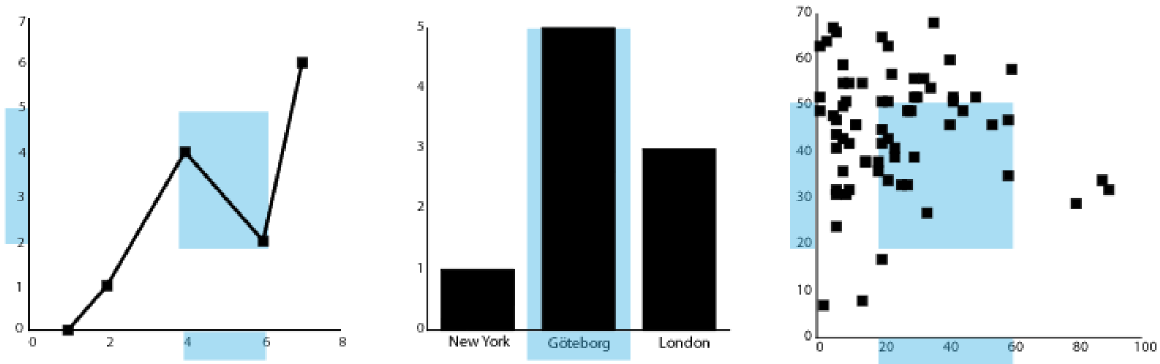


Figure 35. Showing area markings in the best suited visualizations: line graph, bar graph and scatter plots.

6.4.1.8 Multiple markings within visualizations – Refining and logic operations

Area markings uses logical AND and OR operations to perform refinement in areas of a visualization. By using logical AND in combination with OR operations area markings can cover a large number of areas within a visualization, even areas not containing any markers in certain visualization types like scatter plots and line graphs.

Area markings can perform queries on a single axis or across axes. On a single axis, logical OR operations are used and there is a simple reason behind this, you cannot perform an AND operation on a single axis. Several axis queries can be combined to compare on a single axis by using the control modifier key.

If OR operations would have been used when performing queries across axes users cannot refine areas of interest in the same way as AND operations would. OR operations would cover all markers within the chosen area.

As discussed earlier AND operations can only perform across axes, our implementation of AND uses logical conjunction to perform refinements on area markings. By using logical conjunction across axes refinements can be done with a better precision than if logical disjunction had been chosen. Conjunction makes possible more refined area markings than disjunction. This was considered more useful both for the descriptive- and the selective-comparative component of area markings.

AND operations perform best in scatter plots and line graphs. The reason behind this is that they use continuous information on both dimensions of the planes which makes the mapping between query and result sensible. On bar graphs that uses one continuous and one categorical axis only OR operations on the categorical scales are preferred because performing queries across axes with area markings doesn't provide a good mapping between query and result.

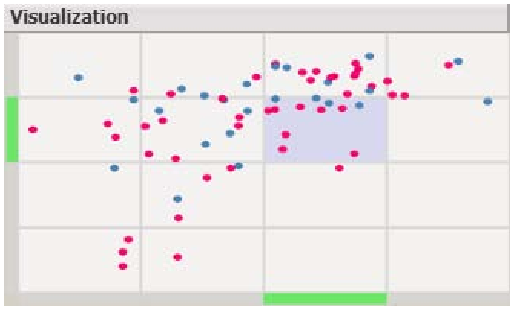


Figure 36.Performing a logical AND operation across axes in a scatter plot.

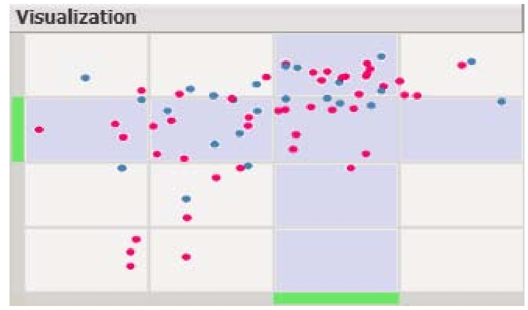


Figure 37.Performing a logical OR operation across axes in a scatter plot.

In trellised visualizations AND operations across axes will function the same way as a single visualization, the only difference is that the same area within each visualization in a trellised visualization will be area marked. OR operations on single axes will have the same behavior across trellised visualizations.

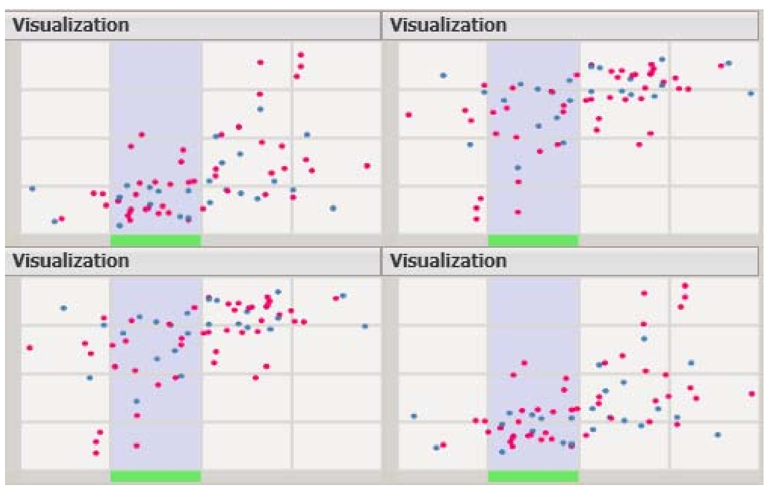


Figure 38.Showing a logical OR operation on a single axis in a trellised scatter plot.

6.4.1.9 Area Markings Summary

Area markings have clear possibilities to improve the descriptive and communicative aspects of reports in TIBCO Spotfire. The reference points they provide directly within visualizations can be used to strengthen the coupling between text areas and visualizations. These reference points can be set up by authors and then used directly by a consumer to get started with analysis. Area markings can complement existing concepts that are used for guided analysis in a natural way.

Consumers can use area markings in the same manner as authors for making more expressive communication when exporting visualizations for use in external material. This could be beneficial in some situations to make use of analysis results in a more fast and efficient way.

The other major benefit with area markings is the possibility to provide local selection queries that can be used to select areas of interest in visualizations. These local queries are posed in a unified way in all visualizations (given that they contain axes) and can also be used to compare subsets of the data both within visualizations and more arbitrarily across visualizations. This unified way of providing some common queries together with the local aspect are both very important aspects for evaluation. If the more general case of axis queries is considered even more descriptive aspects and different types of queries could be made possible local to the visualizations. The possibility to hide complexity by letting users pose local queries in a unified way in different visualizations and still be able to give the most valuable result for each visualization by different graphical representations have a greater potential than area markings alone. Questions that have to be explored in this case are what results would be best to support? How is the result best showed graphically? This need to be done per visualization with regards to the descriptive component, the querying/view support component (both selective and comparative) and the component dealing with integration with existing concepts.

Area markings alone can complement the existing selection queries and the filtering used in TIBCO Spotfire today and would improve both navigation and descriptive aspects of reports. Extending area markings to axes queries can improve on all benefits that area markings have on their own if done carefully. The impact for speed and efficiency for authors and consumers can if all things considered be significant.

The problematic aspect to consider in order to make area markings successful is the integration with existing concepts and quite a lot of changes would be necessary. Most of these changes have to do with constraining existing concepts to give room for area markings. The rest have to do with consideration of what queries that are most useful locally and how are results best represented graphically in visualizations.

6.4.2 Search Integration

Since a search feature in software like TIBCO Spotfire is a big feature with technical restrictions further delimitation of the designs that were reasonable to complete within the time limit of the design phase was expected to take place when exploring the “search” design space. In parallel with the investigation and design of the search features that were developed within this study an experimental but fully functional search feature for TIBCO Spotfire was implemented. This experimental design also informed and calibrated the efforts taken within this study. The previous efforts and results from the analysis phase and conceptualization phase and the initial question of the study were also to be respected and guided the way that search was treated.

Search introduces a new modality in TIBCO Spotfire, a type of dialogue with the application and the issues that were especially interesting from the perspective of this study was how to integrate search with the existing interface to support speed and efficiency in use. What could be mutually beneficial connection points and what kind of tasks could be supported with search functionality?

Search is supposed to help users find answers questions like “Where can I find the visualization showing shoe sales in 2005?” or “How well is Nick performing compared to other sales people?” Other tasks could be finding a visualization, page or navigate to a specific filter.

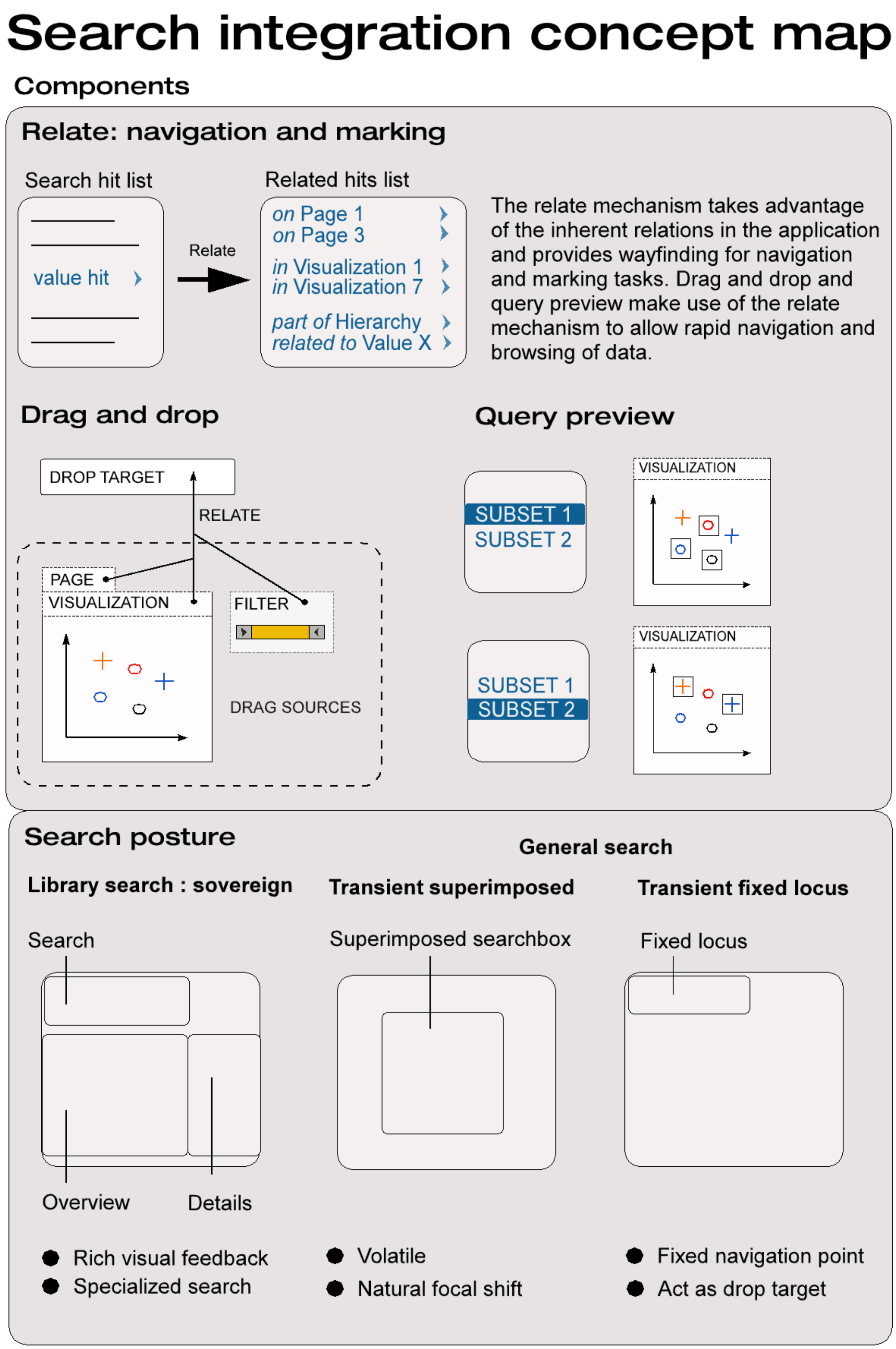


Figure 39. Search integration concept map.

6.4.2.1 Scope

There were three main scopes of where search could be useful, on enterprise, library and report level. On the library level the focus was on finding ways to speed up the process of finding reports and get a better overview of the report library. The report level included a much bigger array of different tasks. The study focused mainly on finding where search could be improved on report and library level. Enterprise level search was excluded mainly because it would need a bigger and more complex study of how to infer context and data from an intranet or remote sites. Considerations of multi platform usage on mobile, desktop and web were discussed but the main focus was put on the desktop application. The foundational concepts of search should be built to work on all platforms and for all users.

6.4.2.2 Tasks

There were two different task group scenarios that were chosen for further investigation because of their direct relation to earlier results and speed and efficiency in use generally. Navigational tasks are tasks that take the user to a certain point in the software. Eliminating required steps for navigational tasks means direct gains in speed and efficiency in use since more time can be spent on the real tasks that users have. The second task scenario were marking scenarios where the user mark out data points or groups of data in order to show these values in relation to a superset of data. These two types of task scenarios were considered to have most potential for improvement, considering speed and efficiency in use.

6.4.2.3 Navigation

Navigation of reports in TIBCO Spotfire was sorted into three different types of navigations.

1. Navigate to document part (visualization, page, text area)
2. Navigate to filter/query (filter panel navigation)
3. Navigate to functionality (menu, context menu, toolbar navigation)

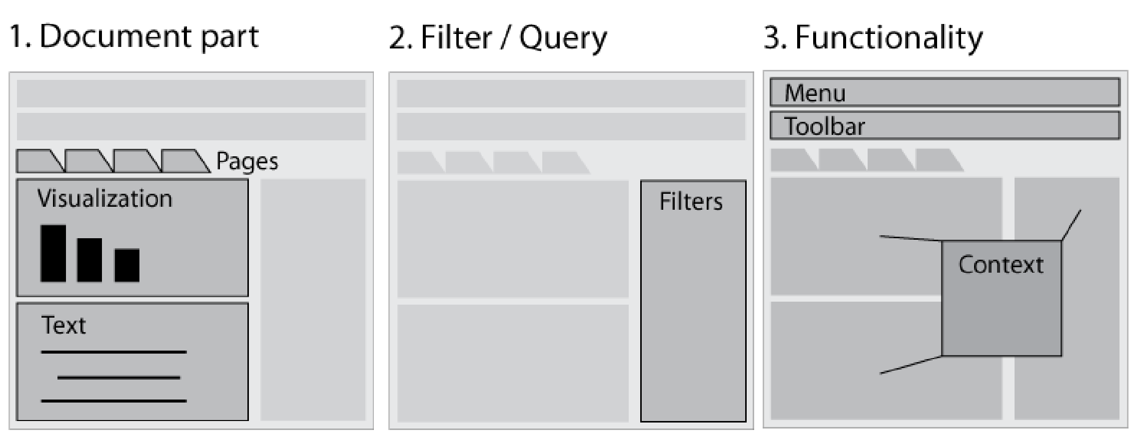


Figure 40 Simplified map of the different types of navigation and the parts of the interface that they relate to.

The most important navigational tasks for speed and efficiency in use were considered to be the two first types with the addition of navigation to some key functionality.

The problem with navigation to something that you already know the name of is solved very straightforward with search functionality. The interesting problem with navigation was found to have less to do with finding your way when you know the name of something and more to do with that you often want to navigate to items that contains, is affected by or is related to an item that you have knowledge of. This relation between starting point and end point that a navigation task contains is an important design parameter for navigation. What do the users know, what do they want to know and what can the application help with?

6.4.2.4 Marking

Marking of values in TIBCO Spotfire has several different responsibilities. Marking specific data points can be used as view support and groups of values can be marked either by additive marking using the control modifier key or by lassoing groups of values. Marked values are marked globally and can be added by selecting from different visualizations and the marked values are also used for controlling what is showed in detailed visualizations. Markings can also be tagged, bookmarked and it is also markings that give details on demand. The concept of marked values is very well integrated in the interface and supports many other concepts. These facts together with the fact that markings don't change the visualizations to the same high degree as filtering means that it is ideal for posing fast queries and relating smaller sets of data to the larger set.

6.4.2.5 Visual properties

For search to integrate well in the interface it is important to keep a well calibrated visual feedback to allow the direct search hits to be easily browsed and discerned. Visual feedback should be kept to a minimum and only contain the most important affordances needed to navigate the search functionality.

Since there are many relations between items in TIBCO Spotfire search should be seen as a possible modality for making use of these relations. One such mechanism is proposed in section 6.4.2.6 (Relate). This "relate" mechanism tries to make use of relations without introducing too complex visual feedback. The good thing about keeping visual complexity low is that it doesn't disturb the pure search functionality of search, which means that direct search hits will be more easily discerned. One of the advantages of allowing more complex visual feedback in search functionality is that it can strengthen the relations between items making the structure of data and also the document structure useful for the user. This advantage has more to do with browsing behavior and a good balance between browse and search means a good balance between visual complexity and simplicity.

A mechanism like relate need some kind of hint/affordance that express its existence in order to be useful and the suggested design uses a caret in form of a small arrow to afford horizontal navigation that this relate browsing mechanism uses. Since a search hit list often contains a lot of hits this use of a visual element for each hit can be seen as problematic since it is repeated for each hit. When introducing such visual elements it should be made sure the mechanism that it represents hides more complexity than it introduce.

In some cases it could be a good idea to enforce the connection between search and the interface visually. That is, the meaning of acting on a search hit. This type of connection ideally makes use of pop-out effects since these are more easily processed by the human brain. One such enforcement is suggested with query preview (section 6.4.2.8) that makes use of the added surround box already present in the interface and used when hovering single data markers in TIBCO Spotfire. This also enforces the meaning of hover since it would mean hover of a subset of data both in the natural language representation in search and visually in the visualizations, making the connection between them clear.

One way of keeping visual complexity of search functionality at an appropriate level can be to allow different posture (section 6.4.2.9) of search in different parts of the program to allow more specialized search behavior. This can make the modality of search and its connection to items that it's meant to find tighter, more meaningful and thus more useful.

6.4.2.6 Relate operation

Finding by name is a very strong feature and should be seen as the primary way of finding items of interest in TIBCO Spotfire. For some scenarios finding by name isn't enough though, e.g. when the user doesn't know exactly what kind of item he/she is looking for or when the user simply don't remember the name for the item of interest. In order to support these other scenarios we investigated a browsing mechanism that we chose to call relate.

The basic idea behind relate is to use structures of and relations between different elements that are present in TIBCO Spotfire and by doing so enabling new ways for users to find their way rapidly in the interface and finding values for marking. The main strengths with using the inherent structures for relate is that it both reinforces the existing interface while still adding important functionality that can speed up navigation and finding the way in reports. This would mean that search could be used as a kind of actionable metadata that the user can search, browse and act upon to accomplish tasks.

A relate on a search hit in a result list is meant to give a new result list that contains hits that directly relates to the item on which relate operation was done. For example if a relate operation is done upon a filter in the filter category "Products" the new result list will show items that relates to this dimension. This would include pages that have the products discernable, visualizations where the dimension is discernable and the values that the "Products" dimension contains. In addition the new result list could contain actions or custom queries that act on the dimension.

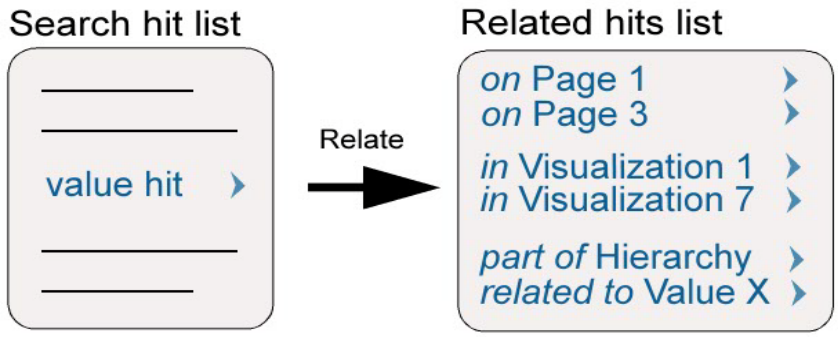


figure 41 The related list and the type of items it contain.

This way of letting the application interpret the action of relate to show search items that directly relates to the original value requires well defined metadata for items and an indexing mechanism that supports this metadata. The relate operation can be used in more ways to add additional value to the design and make an implementation more worthwhile.

The second part of the relate operation of browsing result lists has to do with inferring context. If a user finds a search item of interest but relates to reach the true search item that she/he is after the interpretation done by the relate mechanism can be used to make an action upon the latter item more valuable. For example if first a filter is found but the user chooses to refine to find a visualization that contains the dimension that the filter covers, acting upon the visualization could be interpreted to mean something more than navigation to the visualization. Instead the action could be allowed to mean navigate to the visualization *and* navigate to the filter in the filter panel that was related upon. This way of letting the application interpret the relate mechanism to connect small tasks would make possible support of a couple of new scenarios that would mean very direct gains of speed and efficiency.

The two task groups that have been considered are markings and navigation. A marking task can be connected with a navigation task if a value and a page, visualization or filter is combined through relate. For example if a value is related upon and then a visualization that contains the value is acted upon this would mean the combination of marking-navigation, resulting in navigation to the visualization showing marked values in the visualization. In a similar manner different navigation tasks could be combined to mean something more. As an example if a filter is related upon and then a visualization is acted upon it would make sense to combine the task of navigation in the document with the task of navigation in the filter panel, resulting in a selected filter *and* navigation to the right visualization.

Basic tasks supported by relate:
Navigation to page
Navigation to visualization
Marking values

Combined tasks supported by relate:
Navigation – Navigation
Marking – Navigation

All relate actions don´t need to make this second interpretation of task connection and it wouldn't harm the concept if non sensible connections were removed. For instance it makes little sense to connect page navigation and visualization navigation so if a page is related upon and then a visualization is acted upon the result would be just visualization navigation.

6.4.2.7 Drag-and-drop search

Drag-and-drop is a direct-manipulation idiom on the desktop today and it is very much like how we interact with things in the real world. A drag-and-drop search is a relate operation on dropped items and make possible to navigate or mark on the result. By performing relate operations on a drag-and-drop search a visualization, filter or page can reveal relationships between data and visualization, data and filter and data and page. Questions posed by drag-and-drop can be seen as a more general type and a way to relate findings to pages, filters or visualizations.

Drag-and-drop is an interaction pattern that already exists in TIBCO Spotfire. Drag-able objects will indicate drag pliancy when clicking on them and the search bar that acts as the target drop zone indicates drop candidacy. The same affordance that exists in TIBCO Spotfire will be used by showing a thumbnail of a filter, page or visualization thus making it easier to see and understand what object that is being dragged. Drag-and-drop search will include the following three interface elements in TIBCO Spotfire.

- Pages
- Visualizations
- Filters

Pages can contain lots of information about visualizations, data, text areas and filters. When dropping a page on the search bar all information that relates to the page will show up in the query making a huge variety of options visible to continue explore. Visualizations show pages, data and filters that apply to the specific data used in the visualization.

To further explain how drag-and-drop search is done an example is given of each type. When a user is interested in a particular visualization and wants to find other visualizations showing the same data he/she can by dragging the visualization to a drop target reveal several other pages showing the data. When a filter is dragged to the search bar the filters context is exposed showing what data, pages or visualizations that are connected to it. Conducting a drag-and-drop search on a page is done by click and hold the page tab and dragging it onto the search bar.

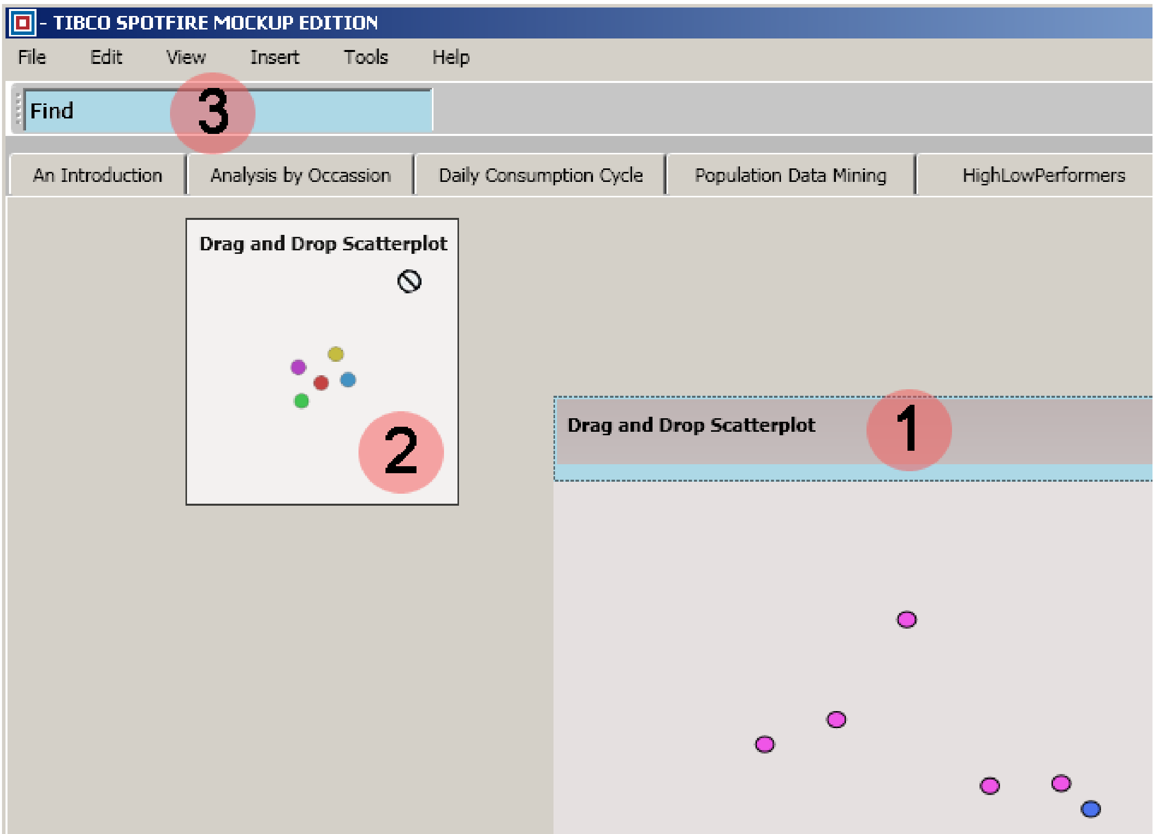


Figure 42.Part 1 shows the drag source, in this case the title bar of a visualization. Part 2 shows the dragged item as a thumbnail to indicate which item is being dragged. Part 3 shows the drop target for a drag-and-drop search.

6.4.2.8 Query preview

Query preview is performed on categorical values in a search result. Query preview is a way to automatically help users in the task process of a selection and get a preview of where a selection of data will be done in a visualization by hovering the values included. Hovering will have the same visual appearance as done with the mouse in TIBCO Spotfire. Hovering will have a global effect which means that all visualizations that include the value will be hovered as well. When a user wants to perform an operation on data in the search bar he/she gets an automatic preview of the data that will be affected by the action and can draw decisions of performing an action or not and thus preventing faults of marking the wrong category. The benefits with query preview are the minimization of faults, automatic feedback and view support. Query preview doesn't come with any restrictions in certain visualization types and will function across all types of visualizations in TIBCO Spotfire.

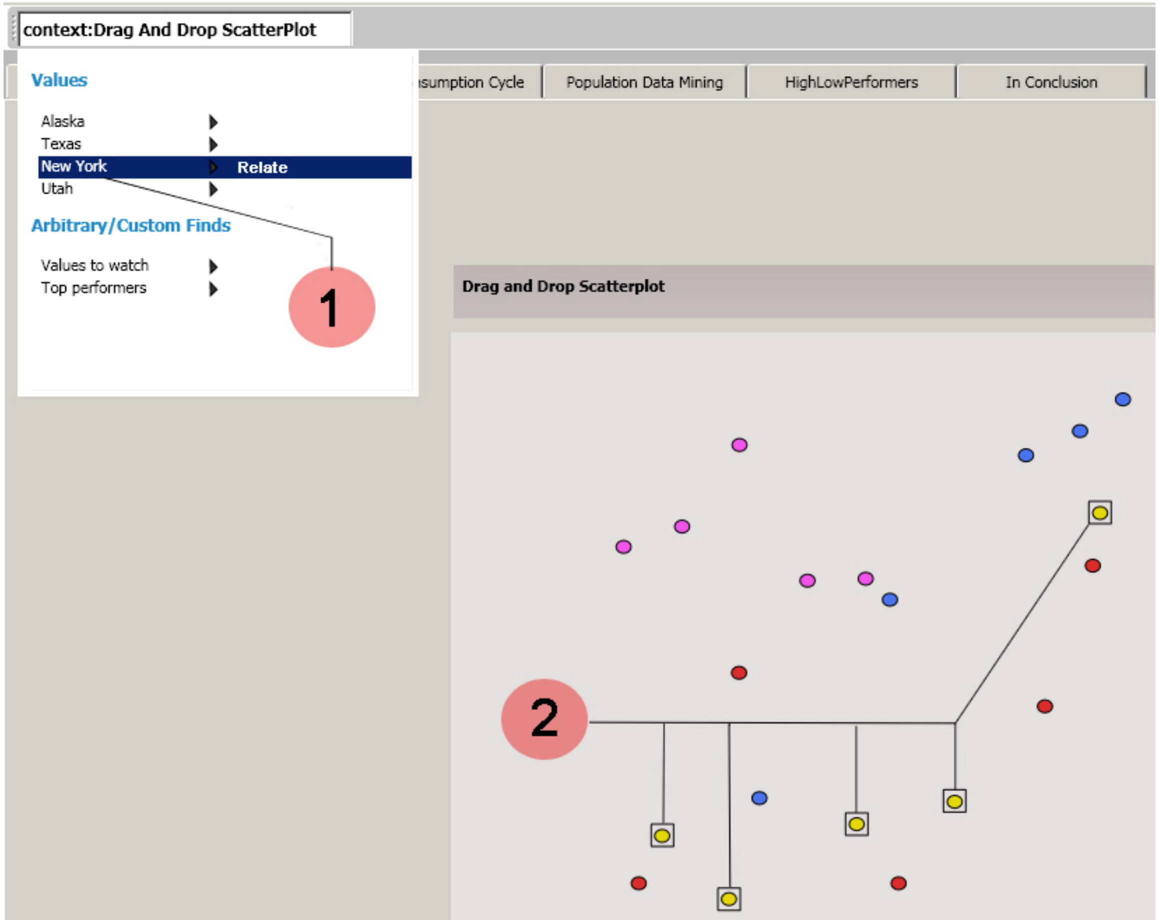


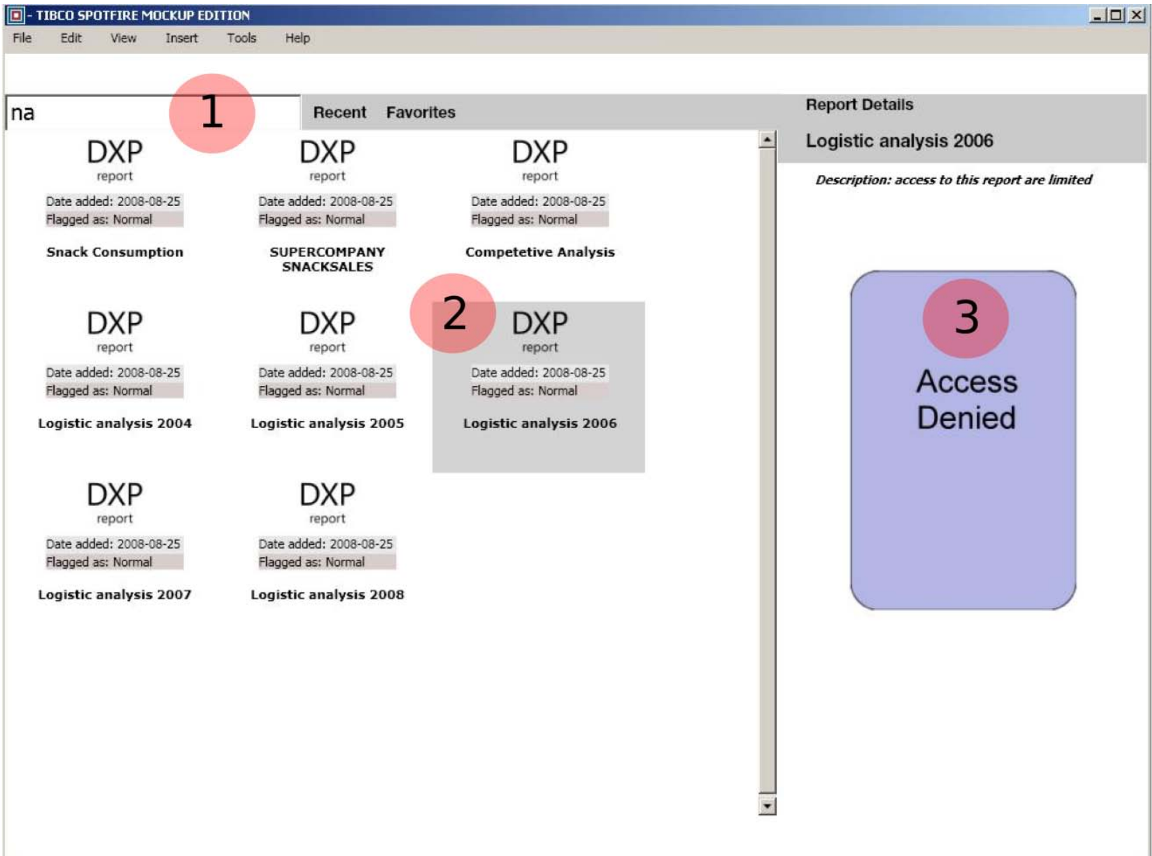
Figure 43.In part 1 New York is shown as being selected in the search window. In part 2 all markers that belong to New York are marked out by the same pop-out effect as hover on a single value.

6.4.2.9 Posture

A lot of discussion and investigation was done to understand where the search bar suited best for all the different types of interaction. There are two types of behavior of how to interact with search, sovereign and transient. Investigation of where a transient or sovereign approach suited best was done and in some areas, for example in the library search a more fixed approach to the search bar suited best. A transient functionality would work like a popup where a user has to press a keyboard combination to reach the search bar. The search bar can be closed when pressing escape or clicking somewhere outside the search area.

6.4.2.10 Library Search

The library search concept was created to support finding of reports and get a better overview of reports. Today users have to navigate the file explorer to find the right report to open. Library search was created to eliminate the task of exploring folders to find a report; instead users can conduct a search of the report title. We chose to use a sovereign posture for this concept which means that library search is taking up the whole interface. Library search consist of four interface parts, the search bar, report library overview, the detailed report description and sorting criteria options. When launching TIBCO Spotfire the library search window is the first view a user gets. The goal is to increase speed when finding and opening the right report for both the author and consumer. As the user types a search word the result narrows down immediately giving direct feedback of the query. When clicking on a report a preview of the report is showed and the user can see a brief description of what is included in the report. Some reports can be locked for security reasons and this is shown by a marking saying that the report has restricted access. Recently opened reports or reports that have been marked as favorites can be opened by clicking on the “Recent” or “Favorite” labels in the sorting bar. The concept of library search will improve speed efficiency for both target users since they get a better overview and can find their reports faster with less effort.



Figur 37. Image showing the main parts of library search. Part 1 shows the search bar with the search input field. Part 2 shows the result list of the search query. Part 3 shows a detailed view of the selected report.

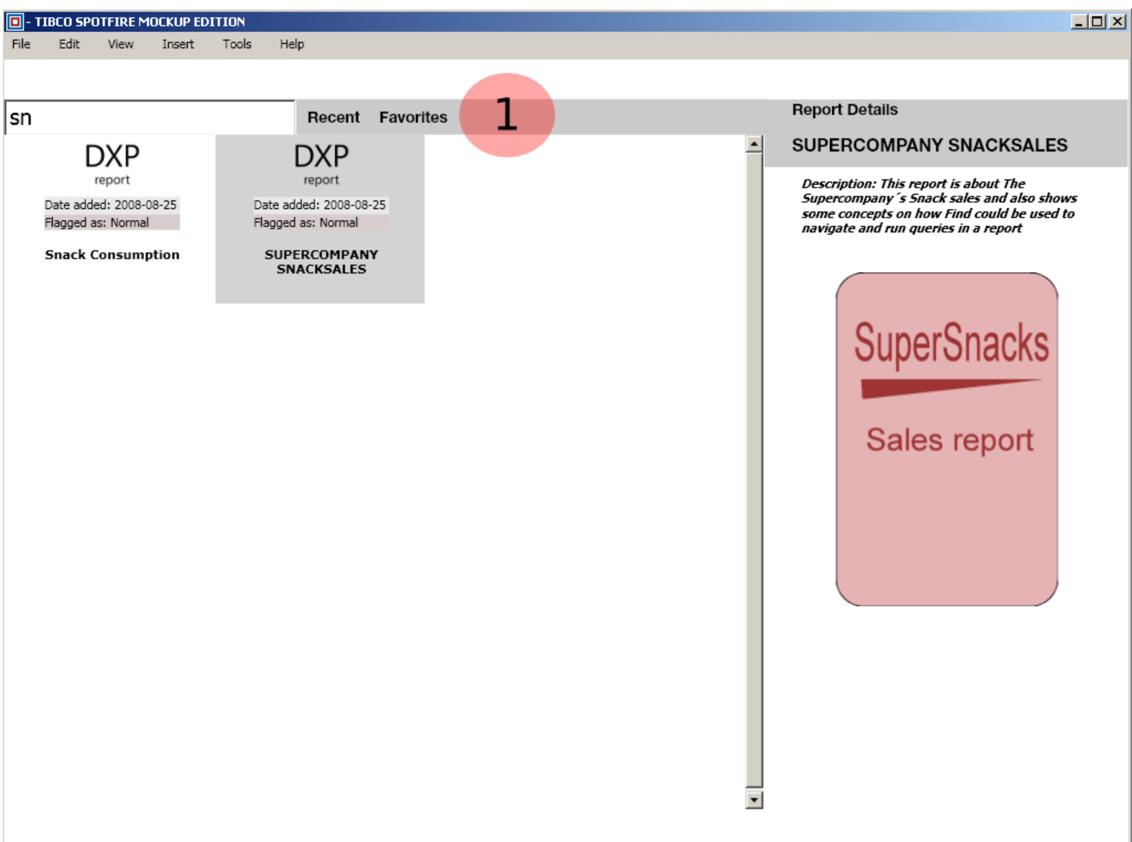


Figure 44.This screenshot shows the library search when clicking on the favorite button (part 1) in the sorting criteria bar, only reports marked as favorites are shown.

6.4.2.11 Custom queries

Usually managers want to know what is selling best and where this is happening, by creating customized queries users can find answers to these types of questions. Customized queries are supposed to answer questions to otherwise complex queries that can be very time consuming for a consumer to perform. An author can create a customized query that can easily be found as an alias in a search result. Next the consumer can type in these searches in the search bar, they would look something like “Top 10 sales in Europe 2004”. The consumer could later customize this expression by her own, modify simpler parameters in the query and show “Top 30 of shoe sales of 2008”. To go further with a found customized query the user can hit enter or double click on the text in the search bar, next a selection or marking is done. This behavior is similar to how a bookmark or tag works in TIBCO Spotfire.

6.4.2.12 Search Integration Summary

By integrating search functionality in TIBCO Spotfire there are good possibilities to improve both navigational and marking tasks not only for the target users of this study but for all users. New paths of way finding and support for new tasks can be added with little or no disturbance of existing functionality.

Taking advantage of already existing structures, concepts and idioms can also aid understandability in reports and provide ways of making the users’ state of interaction into something more valuable. In this way already strong interaction patterns can be strengthened, still providing new task support. Relating search hits to other items not only reinforce structures that are already in the interface but also give the user the ability to browse the contents in reports from an initial search hit. This can be used both as a means to find the right initial search item but also to follow up on findings by exploring related information. By extending relate search functionality to work through the drag-and-drop functionality the interface elements themselves can be made into useful way finding points. This also provides a form of localized selection query since the drag-and-drop relate give all values that are discernable in a visualization and thus can be used to select/mark these values. Query previews are useful to avoid faulty selections and can also be used to preview subsets of data. This type of preview could be extended to include navigational tasks within search to avoid faulty navigation as well. Previews should be seen as especially useful in conjunction with drag-and-drop searches since it gives the user ability to browse locally given selection queries.

Posture of search functionality is important. In different parts of the interface search should be able to exist in different manners to allow the information to be presented in the best possible way. Library search illustrates a completely different search layout than in report search. Search in reports should keep a transient posture to allow rapid invocation but equally rapid disappearing to not disturb any other interactions. Specializing search for different areas of the interface can be a powerful way of improving on some functionality. General search shouldbe done in different levels allowing more advanced functionality like command language operators (AND OR + -) to be added on top of a base functionality like the one proposed above. Letting the base functionality be useful to all users but in particular consumer type of users is a good idea since it will mean several benefits for these users.

Search integration can improve speed and efficiency in TIBCO Spotfire for many different tasks and also add new benefits for a wide array of users. If integrated well with the existing interface, search can be made into a natural part of the interface; strengthening already strong interaction patterns still adding new functionality.

CHAPTER 7 – DISCUSSION AND CONCLUSION

In this chapter we discuss the research question, methodology and result. Results are discussed first in general and then from a theoretical standpoint. Further discussion deals with limitations of our result. The chapter ends with a conclusion of the study.

7.1 PREREQUISITES AND METHODOLOGY

7.1.1 Research question

The research question *"How can the design of an information visualization tool as TIBCO Spotfire be improved for speed and efficiency in use?"* is a wide question. The main advantage with this type of wide question from the point of view of this study was that the whole user experience of the target users could be considered in the study and not just specific concepts that contribute to the user experience. The main disadvantage was that the necessary overview of the problem was very time consuming to acquire and sometimes important details had been left out or not fully understood making a lot of backtracking necessary. This took a lot of time and the analysis part of the study needed more time than was planned from the beginning.

7.1.2 Methodology

The choice to use flexible and fast paced methods without overly strict documentation requirements worked well but could probably have been a problem in a larger team and if more detailed documentation had been needed for each step in the process. Since we were only three team members it was easy to keep everyone up to date with the documentation. The main advantage with this flexibility was that more time could be spent on exploring different ideas and resolving issues as they came along instead of putting them on a stack of to do things and resolve them later. Especially useful was the fast paced idea generating activities that utilized the group almost on a daily basis. Had the research question been narrower it would have been a good idea to keep a stricter plan but with consideration to the question and the work that we carried out the flexibility was necessary if not completely without complications.

7.2 RESULT

In this section the three types of results and their connection to theory are discussed. At the end of the chapter problematic aspects of the results are discussed and further work suggested.

7.2.1 General

In the analysis phase the foundation for all other results in the study was laid. This means that these results in a sense should be seen as the most important results coming out of this study. After the analysis phase some important choices were made that had a big influence on the direction and results of the study in the later phases. The most influential choice of these was to concentrate on improving speed and efficiency for both target users at the same time rather than finding ways to improve for one of the two different users at a time. Practically this meant trying to improve explanatory aspects of reports which had to do with navigation, readability and querying, without laying a heavier burden on the author of reports. The reasoning behind this was that if speed and efficiency for the report viewer is improved without putting extra burden on the report author this will automatically mean an increase of efficiency for both target users since efficiency for the author of reports depend in part on how well reports meet the needs of the report viewer. This choice was based on findings in the analysis phase that indicated that the setup of reports was very fast in TIBCO Spotfire compared to other applications and also that several differences in descriptive aspects were found between all applications. Many of the parameters for design were found in the dependency area between the two target users. This point of communication between the target users and the different ways of supporting communication in different applications was a very important part in many decisions. It was also important to understand the consequence of different choices. The type of sought for improvement can be seen as extending the software to be more expressive in order to facilitate navigational, descriptive and query aspects of reports. The goal then became to automate as much as possible of new concepts without crippling their expressive power.

The second type of results from the study was the concepts that were created and they are meant to provide clear points for improvement in TIBCO Spotfire and an initial idea on how improvements can be done. They deal with issues related to the design goals from the analysis phase while considering the design recommendations. These concepts are not considered exhaustively and some parts of them can therefore be discussed with regard to their feasibility in the product in their current form. This is not to say that the concepts are completely unrealistic but rather that they are expected to need refinements to reach the goals they aim for. Some of the concepts overlap in certain aspects and try to solve similar problems using different strategies. A selected set of these concepts can definitely be integrated successfully together without overlap. Synergies between suggested concepts themselves can already be found in their current state.

The third and last type of result, suggested designs, aims directly to improve the interface of TIBCO Spotfire on aspects stated in the design goals. These results depend heavily upon the existing interface; existing features, concepts and the coordination of them. The designs stand as proof of concepts and as such we feel confident that they bring something to the table. The most important general finding derived from all three phases was how globally and locally given queries and results affect the target users of this study. This global-local aspect of queries and results together with coordination and coupling of different items give rise to very different user experiences and complexity for both target users. Refinement and calibration of automatically generated local queries and well thought through representation of results have big potential for positive impact in TIBCO Spotfire. This would aid not only querying but also navigation and communicative aspects both between the target users and in an organizational setting. If considering an enterprise perspective of the interface consideration to these aspects can mean a lot for different platforms and future more modular usage contexts. To speculate beyond tomorrow local queries, other types of coordination and ways of giving results can mean benefits and be very powerful if considering mobile units, mash-ups or exporting of dynamic material like widgets. In these extended cases benefits would be added on many levels. These benefits would not be specific to certain user types like most benefits that have been considered in this thesis. For instance in the case of mobile units where screen space is even scarcer and navigation more constrained local queries and results could be an efficient way to avoid problems related to the local-global aspect. In the case of mash-up scenarios local queries would help since coupling between query, result and visualization becomes very natural and avoids some complexity inherent to the coupling of items of different items. If exported material should host dynamic behavior local queries would also make possible naturally-scoped units for exportation, since a visualization would already contain the most urgent of queries.

7.2.2 Theoretical connection

Previous research has influenced the results of this study in two different ways. Directly by means of literature that explains important ideas and principles but also in a more indirect way since at least two of the applications that were evaluated grew directly out of the research community and as such can be seen as commercialized variants of principles developed in the research community. This connection is very clear and deserves mentioning since some of the results from this study depend directly on the different strategies used when connecting concepts into applications. There are deep implications for the user experience when connecting different concepts that are well researched on their own and sometimes in limited conjunction with others into a product to solve usage situations. When connected with other ideas and real usage situations the idea in a way becomes something else. The whole is bigger than the sum of the parts. The interface of TIBCO Spotfire itself grew out of the invention of tight coupling of dynamic queries with star field displays (Ahlberg, Shneiderman, 1994).

The concepts of tight coupling, linked views, filtering and brushing are used differently in different applications and have several subtle but important implications for speed and efficiency. How these concepts are connected within the different applications has direct effect on the way the data is explained, queried and understood. Previous work on classification of these and other concepts and ways of connecting them includes work on coordination of multiple windows (North, Shneiderman, 1997) and classification of coordination patterns (Weaver, 2007). These sources provide useful guidance on different possible solutions and also give clear indication on how and which parts can be connected. For user-centered approaches these sources provide guidance for possible solutions, options and what works best for different situations. It seems interesting to add the dimension of different users to this equation and explore how different users and communication between them can be supported by different coordination and how to make coupling between elements easier to understand.

In addition to exploring the way components are connected it is important to understand the visualizations themselves and the tasks that each of them supports on their own and how overall representational complexity affects the different types of users and their tasks. Overall complexity within reports are best kept low when considering guided analysis since it is hard to make advanced patterns self explanatory. This self explanatory aspect can be seen as preferred modus operandi for guided analysis since it leaves less room for human error in setup. A lot of work has been done for understanding visualizations and the tasks that they support. A general and pragmatic perspective on tasks is provided by Jacques Bertin (1981, 1983). More specific perspectives can be found in Stuart Card's and Jock Mackinlays' (1997) structuring of the information visualization design space and in Ben Shneidermans task by data type taxonomy (1996). All this work is very important in order to understand the complexity that is introduced by choosing different visualizations and configurations of visualizations both on a per page and document level when considering extended concepts like reports and dashboards. These perspectives provide a good foundation for design on the task level and are directly related to speed and efficiency in use.

In addition the theoretic track of collaborative aspects in information visualization could also provide significant gains for speed and efficiency especially viewed from an organizational perspective and both past and future work on collaboration models can be worthwhile to look at (Heer et al, 2007).Collaboration and communication between users become increasingly important both as data needs and understanding of this data become greater but also when information visualization shall support both organizational needs and more different types of users.

7.2.3 Limitations

There are some limitations of the study that are important to explain in order to make the results fully understandable. The first and perhaps most obvious limitation was that the study was concentrated on the core functionality of the interface and some advanced features were completely left out of the study. This had to do with the fact that some features don't affect both target users of the study and therefore they were not within the scope of this study. Some of these features might have been interesting to look at with speed and efficiency in mind but not with the added restrictions put on the study with the target users.

A couple of choices that were made throughout the study further limited the study and these also need to be explained. The choice to leave some design goals behind were made in order to be able to focus efforts on the parts where we found most possible improvements involving both target users. For instance the data import phase could have been interesting to look into deeper but wasn't considered to be of prime interest of the study since it was considered more a question of architectural than interface improvements. The other design goal that was dropped was visualization setup or representation of data. This goal was dropped because speed in this phase had been proven in the comparative walkthrough to be faster than in other evaluated applications. We had some early ideas regarding improvements for the visualization setup goal. After interviewing an expert user with lots of experience authoring reports it was realized that little or no problems would be solved with these ideas. The decision to concentrate on the three other design goals was therefore made since more potential for improvements had been found there. There are definitely ways to improve these areas with regard to specific users but with consideration to the full spectra of target users of TIBCO Spotfire we didn't find any significant improvements.

One possible objection to the study is the fact that no user testing of designs was done. If designs are chosen for implementation more high fidelity prototyping would be recommended allowing user testing. The design work that has been carried out should therefore not be seen as complete but rather as early designs communicating ideas, recommendations and the possible impact of these. The weakness of the approach used in the study is that some uncertainties still are present in designs because some depth was traded for breadth. This tradeoff was considered to be a requirement to cover as much as possible of both target users' tasks.

The persona approach for understanding the user's needs, goals and tasks worked well and felt fully adequate to carry out the design work that was the main goal of the study. More direct contact with users would have been interesting at some point of the study but rather at the end then in the beginning of the study since the full understanding of subtleties and important aspects of the existing design simply weren't acquired in the beginning of the study. It would have been interesting to try out some of the ideas we developed further on real users and interview users with this in mind but for reliable evaluation with target users an almost full implementation of the designs would have been necessary.

Suggestions for further practical work includes a recommendation to look closely to the users' needs and what type of querying, navigation and coupling of components that are best suited for the particular data and user context. The distinction between having analysis set up by others compared to setting up analysis for oneself is extremely important.

7.3 CONCLUSION

By investigating the needs, tasks and goals of the two target users and compare these across several different applications a wide range of problems regarding speed and efficiency for these targets was found. Through the two target user approach used in this study a lot of problematic aspects were found in the intersection point between the author and the consumer. Looking at intersection points between users in this way was found to be a powerful way of identifying problematic aspects and important parameters for the usage context.

The analytic part of the study defined the problem space and consists of design goals and recommendations. These stand as the definition of the problem. The experimental part of the study consists of concepts and designs proposing solutions to and testing the problem definition. The concepts provide breadth and the two designs provide more depth on possible solutions. Together the problem definition and solution provide answers to questions regarding speed and efficiency in use and give guidance on how to attack other aspects. By going first on breadth and then in depth for solutions the definition could be both refined and tested on many of its aspects. Some of the findings from the analysis had deeper implications for the target users than we first thought. These implications wouldn't have been fully understood unless both breadth and depth had been covered in the way we did.

The user centered approach used in the study showed that the differences and dependencies between users give very important parameters for design in TIBCO Spotfire. By designing for a certain target user while still showing strong consideration to other target users, extensions to the interface can be made that benefit certain target users without disturbing any of the other targets' tasks. Even if concepts and designs aim to improve for certain users they might show benefits also for other users. Navigational, descriptive and query aspects should be seen as the most important for the consumer. To support the author it's good if improvements can be done with automated concepts or by allowing already strong set up tasks to be more expressive. If these aspects are improved TIBCO Spotfire can be made to support more dashboard-like interaction still showing significant benefits over pure dashboards through its rapid and powerful visual analytics capabilities.

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APPENDIX 1. TIBCO SPOTFIRE INTERVIEW GUIDE

GENERAL QUESTIONS	
1.	How do you get an assignment?
2.	What people are the typical contacts in a business?
3.	What information or specification do you get?
4.	How much discussion do you have?
a.	➢ With end user (Consumer)?
b.	➢ With other actors?
5.	How does the work process look for a typical assignment?
a.	➢ Which steps?
b.	➢ Which step is the most time consuming?
c.	➢ Is there any step that repeats itself more than others and require more iteration?
6.	What are the time requirements for an assignment?
a.	How many reports at the time?
b.	Reuse of old work?

SETUP OF REPORTS	
DATA IMPORT	
1.	Which are the steps during data import?
2.	How many adjustments are needed before the visualization work can begin?
3.	Dependencies on external software?

4.	Are there any functions or tools that are extra helpful? (internal or external to TIBCO Spotfire)
5.	How often do you need to go back to the raw data?
6.	How many raw data sources are used at the time and how does it look in that case?
7.	Do you get the data import completely done first and later visualize, or is it an iterative process?
VISUALIZATION SET UP	
1.	Are there any external requirements, does the consumer know what she wants?
2.	How does the workflow look like when doing an analysis report?
3.	How much analysis and experimentation is done with the data inside the application?
4.	Does one know more or less which visualizations that are needed from the beginning?
5.	How much choice is up to you?
6.	Are several versions of a report ever done, is there any dialog with the end user, do they give any input?
7.	Which functions are most used except filters?
8.	How much are bookmarks and tags used?
9.	Could they be used more as an advantage with the end user in mind?
GUIDED ANALYSIS	
1.	How is the work process?
2.	How much information do one have about the end user, and which detail level does the descriptive factors have?

3.	Is there anything that is missing when it comes to descriptive elements?

APPENDIX 2. TIBCO SPOTFIRE PERSONA SCENARIOS

SCENARIO – AUTHOR	
1.	The author gets a new assignment from her external customer. She reads the assignment and requirement list for the analysis. The author will also at this stage discuss with her customer on how to access the required data and also how the data is structured and formatted. The author and her contact discuss who the end user(s) is and how the report should be presented. She makes time estimation and schedules the assignment.
2.	The author will later analyze the data, both its structure and meaning. Found problems and questions will be discussed with her client and resolved.
3.	The author creates a detailed strategy for how to solve the problem. At this point she might look for possible ways to reuse earlier work.
4.	The author reformats and imports the raw data into the system. After importing she makes sure that the imported data matches the raw data without errors.
5.	At this point the author chooses the best visualizations to answer the needs in the requirements list. She also starts thinking of the overall structure of the report, both content and layout.
6.	Together with the creation of the visualizations additional views of the data is considered, for example filtering of data and calculated columns etc.
7.	After finishing the visualizations the author starts describing the analysis with the end-user in mind. Refinements of the Visualizations and layout, explanatory texts and images are added.
8.	Once finished the report the author distributes it to her client with considerations of user administration and security. Additional refinements and support may be required after end-user review.

SCENARIO – CONSUMER	
1.	The consumer is at work preparing a presentation she has to give to her superior within the hour. She needs additional support for her strategy decision and therefore opens the report she got earlier from the BI division. She has 10 minutes to look through all the KPI’s of interest. She decides to export some of the visualizations in order to be able to communicate her decision in a convincing way.
2.	The consumer meets her superior and communicates her thoughts. The superior agrees with the consumer and wants her to communicate customized reports for each of the consumer’s subordinates within a week.
3.	The consumer is busy during the rest of the week with meetings and other tasks until late in the evening.
4.	The week after the consumer opens the report in the morning and creates the customized reports for each of her subordinates and e-mails them. The consumer is satisfied with the results and makes notes for further usage of the same BI-tool.