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Towards an Evaluation Methodology for the Aesthetic Factor in Information Visualization

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Kurzfassung

Informationsvisualisierung (IV) ist eine Schlüsseltechnologie des Informationszeitalters. Im Zuge der Etablierung von datenbasierten Systemen in allen Bereichen des modernen Lebens treten IV Techniken immer häufiger außerhalb des wissenschaftlichen Kontextes auf. Besonders Künstler und Designer machen von den neuen Methoden Gebrauch, was Ästhetik zu einem wichtigen Faktor in der Praxis macht. Theoretische Bezugssysteme und eine adäquate Taxonomie, die Ästhetik mit einbeziehen, sind derzeit im Entstehen. Der umfassendste Ansatz ist das Konzept Information Aesthetics (IA), das einen Kompromiss zwischen traditioneller IV und Visualization Art (VA) darstellt. Um Ästhetik als wertvolle Ergänzung für traditionelle IV zu etablieren und um den Ängsten vor einer Trivialisierung dieses Feldes entgegenzuwirken, sind wissenschaftliche Ergebnisse über die positiven Effekte der IA Technologie nötig. Um solche Ergebnisse zu liefern, wird in dieser Arbeit ein umfassendes Studienkonzept für eine nutzerbasierte Evaluierung vorgeschlagen.

Der Kern des Studienkonzepts besteht aus drei Visualisierungsprototypen, die darauf zugeschnitten sind, die Spezifika der Felder IV, IA und VA abzubilden. Somit werden kontrollierte Bedingungen geschaffen, die es ermöglichen, im Rahmen der Studie aussagekräftige Ergebnisse zu erzielen. Ein substantieller Teil dieser Arbeit ist der umfassende Designprozess für die drei Prototypen, der auf der Analyse verwandter Arbeiten sowie theoretischen Überlegungen fußt. User Engagement und Insight Generation wurden als Größen für die Studienmethodologie verwendet um den qualitativ unterschiedlichen Effekt von ästhetischen Einflüssen in den drei Domänen zu messen. Besonders die Messung von Insight Generation mit der Thinking-Aloud Methode ist geeignet um analytische und emotionale Ergebnisse gleichermaßen zu erfassen. Die Schaffung eines Verständnisses für die kognitiven Auswirkungen von IV, über das effektive und effiziente Lösen von vorgegebenen Aufgaben hinaus, ist für den systematischen Einsatz von IV Technologie in neuen Anwendungsgebieten essenziell. Das Ergebnis dieser Arbeit, drei Testapplikationen mit maßgeschneiderter Evaluierungsmethodologie, bildet ein exemplarisches Setup für das Messen einer großen Bandbreite von qualitativen kognitiven Benutzerreaktionen in der IV Domäne, mit besonderem Augenmerk auf den Faktor Ästhetik.

Keywords: Information, Visualisierung, Ästhetik, Kunst, Evaluierung, Insight, Engagement

Abstract

Information visualization (IV) is a key technology in the information age. Following the establishment of data-driven systems in all areas of modern live, IV techniques are increasingly common outside of a scientific context. Particularly artists and designers are applying the new techniques, making aesthetics an important factor in practice. Theoretical frameworks and an adequate taxonomy considering aesthetics are currently emerging. The most extensive approach is the concept of information aesthetics (IA) as compromise between traditional IV and visualization art (VA). To establish aesthetics as a valuable complement for traditional IV and to antagonize fears of a trivialization of the field, scientific results on positive effects of information aesthetic visualization techniques are required. To produce those results a comprehensive study design for a user evaluation is proposed in this thesis.

The core of the study design form three visualization prototypes that are especially implemented according to the respective specifics of IV, IA, and VA. Thus, controlled conditions are created and comparable results can be obtained in the scope of the suggested study. A substantial part of this work is the extensive design process for these three prototypes, which is based on the analysis of related work and theoretical considerations. For the study methodology, insight generation and user engagement are chosen as central measures to capture the qualitatively different effects of aesthetic influences in the three domains. Especially the measurement of insight with the thinking-aloud method can capture analytic and emotional results alike. Creating an understanding of the cognitive effects of IV, beyond effective and efficient task solving, is necessary for the systematic and reasonable application of IV techniques in new settings. The result of this work, a set of three test applications with tailored evaluation methodology, forms an exemplary setup for measuring a broad range of qualitative cognitive user reaction in the IV domain with especial emphasis on aesthetics.

Keywords: Information, Visualization, Aesthetics, Art, Evaluation, Insight, Engagement

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Content

1 Introduction

1.1 Background

Advanced computer technology and the Internet led western society in a new era: the information age. Our world is now linked and controlled by huge streams of data. The very nature of this data that makes it efficient to process and distribute also makes it incomprehensible for humans. To effectively communicate information, the numerical data that is produced and processed by computers has to be translated into a form that meets the abilities of the human cognitive system. As the term *information visualization* describes, this domain is focused on creating visual artifacts that support human thinking processes. Since the eye is the most powerful sense organ (Spence, 2007), it is reasonable to rely on visual representation techniques. As a consequence, both of increased demand and new technical possibilities, *information visualization* (IV) has become an increasingly popular field of study over the last years. The short form *infovis* is very common in literature and will be used equivalently to the term *information visualization.* The abbreviation IV will be used to maintain consistency with the abbreviations for the other subfields, which will be mentioned later in this section.

At the same time, a growing community of artists and designers is working on creative new ways to display those vast masses of data. There are several reasons for this. The Internet facilitates the exchange of personal data between people; additionally governments and companies start to make data available that have so far been unattainable for the public. A second factor of particular importance is the availability of new software technologies that have been specifically designed for the creation of artistic software, such as Adobe Flash and Processing (Viégas & Wattenberg, 2007). There are different terms for the sub-domain of art, working with the huge datasets of the information society. Examples are *data art*, *visualization art* or *artistic visualization*. I will use the term *visualization art* (VA) in this thesis.

Currently, there are various approaches to close the gap between the substantially different domains of information visualization and visualization art. Manovich (2002b) even sees the new narrative form, meaning the paradigm how to tell a story, that is characteristic for the information age situated between those two extremes. He points out that we currently have access to huge amounts of data, but not enough narratives to hold it all together.

In practice, there is a growing number of works that are dedicated to these objectives. Pousman, Stasko, and Mateas (2007) propose a new subfield of information visualization applications, coined as *casual information visualization*, which they identify to be situated at the edge of the field of infovis, while having a relatively close proximity to art. Lau and Vande Moere (2007) propose a more extensive approach. They created a triangular continuum between three influential factors: *aesthetics*, *data*, and *interaction*, to situate a new direction in the current data visualization practice: *information aesthetics (IA)*. There is an intuitive understanding about the value of information aesthetic visualization concepts. It seems self-evident that data visualizations with a higher aesthetical value should be able to engage users for a longer time and enable qualitatively different insights (Pousman et al., 2007). However, widely acknowledged empirical or experimental proof for this intuitive assumption does not exist so far.

1.2 Motivation

The information age brought a shift in the context of application of infovis, from expert domains towards a mass audience. This led to an identity crisis among field experts. The growing influence of design and aesthetic criteria in many works related to infovis, foster resentment in the established community. A movement of delimitation is currently rising, that advances a strict separation between information visualization and visualization art. Such delimitation would create a precarious situation for a lot of works that incorporate useful characteristics from both sides. At the same time, it seems that the frustration in parts of the "creative" visualization community is growing, due to the disrespect from traditional information visualization experts toward artistic approaches. One example is the insulting feedback Nathan Yau received for his blog post "5 Best Data Visualization Projects of the Year". Yau (2009) commented on the responses from the community and criticizes the lack of expertise that statisticians have outside of their own domain. He blamed this lack for the difficulties that those analytically minded people have, to recognize the qualities of the artistic information visualization techniques. Kosara (2009a) goes so far as to call the "pretty, flashy mash-ups", he encounters when searching for infovis in the web, "information porn". This is symptomatic for the lack of understanding and flexibility of the infovis community towards new forms of visualization, emerging from tasks and possibilities that are currently evolving.

Empirical evidence is needed to define the range of applications where IA visualization is beneficial. New fields of application and the growing factual influence of aesthetics require new evaluation techniques. Especially from the infovis point of view, the IA term is based too much on definitions, lacking empirical support. The first step to achieve this goal is to develop a robust methodology for the evaluation of aesthetic information visualization and traditional data visualization. This will constitute the base for a user study. The study aims to contribute to the consolidation of the field of information aesthetics. A scientific study of the strengths and drawbacks of information aesthetic visualization techniques will back up their potential use under appropriate conditions; further it will support the choice of other techniques when IA visualizations do not meet the requirements.

The recent trend in the evaluation of visualization from quantitative to qualitative methods supports the prospect that there is unused potential at the more *interpretative* and *extrinsic* (Lau & Vande Moere, 2007) periphery of the infovis field. New evaluation concepts start to focus on the investigation of the characteristics of the *insights* that a user generates during exploring visualizations of information. North (2006) even claims that *insight "has been commonly stated the broader purpose of information visualization by many authors".*

User Engagement is a measure that matches the specific context in which information aesthetics is applied and, hence, will be used as well. O'Brien (2006) illustrates that this idea is being used in human-computer interaction for several years, but still lacks a sufficient definition. Reviewing earlier work, the author gathered descriptions of dependencies on feedback, control, focused attention, motivation, novelty, and aesthetic and affective appeal. The engagement measure in particular focuses on the needs of web analysts and marketing experts by explaining how attractive a web-based service is to a surfing user accidentally passing by. This audience is fundamentally different from the experts that usually use information visualization at their workplace. Combining insight and engagement measurements in one study design promises to be the accurate methodology to analyze information aesthetic visualization.

1.3 Research Aim and Objectives

The aim of this research is to propose a concept for a study to evaluate the influence of information visualization (IV), information aesthetic visualization (IA) and visualization art (VA) on users, according to the measurements of insight discovery and user engagement. The results are planned to be set into practice in an extensive user study.

This aim is subdivided in the following objectives:

- the creation of design briefs for an IV-, an IA-, and a VA-prototype based on an identical dataset
- the implementation of those data visualization applications according to the briefs
- the design of an evaluation study to compare and evaluate those prototypes, in the context of insight discovery and user engagement

„Ideally, *we want to exploit the engagement, that data art seems to be able to produce on a user and apply it on more useful information visualization applications*“ (Vande Moere, personal communication). To illustrate this, the WEB2DNA project (Baekdal, 2008), is a good example. It uses the visual metaphor of gel electrophoresis, a technique that is used in DNA analysis, to create an abstract picture based on the HTML code of a user-specified webpage. The super ordinate aim is to understand what motivates people to spend their time on such a seemingly useless application that objectively only creates cryptic, data-driven images, and even share the results on Flickr. Details about WEB2DNA can be found in section 2.2.2.

Therefore, I propose that this study will analyze the factors that lead to such high user engagement, to then use them for making existing and future information visualization techniques more useful, accessible and engaging. The different qualities of insights, provided by the different visualization approaches, will be covered as well. The aim is to create a set of three prototypes that have maximum concurrence with the three fields, infovis, IA, and VA. The design and implementation of these prototypes will be the mayor part of the work. Then a study design shall be proposed that brings out those differences in detail and provide empirical evidence for their existence. The characteristics of insights, produced by AI visualizations, are essential for the justification of the use of those techniques.

1.4 Significance

The scientific contribution of this work is to make a first significant step towards an extensive study setup. The conclusive goal is to gather scientifically relevant results about the strengths and weaknesses of information aesthetic visualization techniques compared to the two extremes: traditional infovis and visualization art. To achieve this goal, it is necessary to develop a specific evaluation methodology, tailored to the particular demands of investigating information aesthetics. The anticipated features of information aesthetics, which will be measured, are quite complex to work with due to their subjective and ephemeral characteristics. Pousman et al. (2007) propose that the kind of insight, fostered by *casual* infovis, to be of a “different kind” and “less analytical” than that of traditional infovis. The same is likely to be true for the insights that are enabled by information aesthetic visualizations. Existing concepts of measuring insight discovery and user engagement will serve as foundation for my work.

I will provide three showcase data visualization tools, each representing the concepts of infovis, IA, and VA. The tools will be normalized towards the biasing influence of different interaction methods. The underlying data will be chosen so that it provides a strong potential for user engagement as well as sufficient complexity to enable insight on different knowledge levels. I will avoid using domain specific data, to broaden the scope over the borders of a specific group of expert users.

I expect the final results, for which I provide the foundation with this thesis, to point out specific features of information aesthetics. Thus this thesis will contribute to the establishment of this category as a complement to information visualization and visualization art. The analysis of strengths and shortcomings will allow for an adequate application of IA visualizations and hopefully encourage their increased usage.

2 Theoretical Background

The objective of this section is to create a deeper understanding for the fields of information visualization and visualization art as extremes of an aesthetic continuum. Particularly interesting is the area between those fields, where analytic and artistic influences mingle. For both, the design of suitable prototypes and the choice of valid evaluation methods, this theoretical work is an essential precondition.

Section 2.1 provides the outer frame for the taxonomy by introducing the domain of *visualization*. Several subfields are discussed to exemplify the range of this term. *Information visualization* is of mayor importance for the thesis and, hence, considered in detail.

To constitute the second border for the area of interest in this work section 2.2 describes the domain of visualization art. This field can be seen as artistic complement for analytic information visualization with a predominant emphasis on aesthetics.

The continuum that is delimited by those extremes is covered in section 2.3. With an emphasis on the concept of information aesthetics (Lau & Vande Moere, 2007), the state of the art in this area is described, together with the particular advantages that are expected from infovis techniques with emphasis on aesthetics.

The theoretical concepts require examples to be better understood. Especially the definition of the information aesthetics domain is strongly influenced by outstanding projects. Visualization art as well, is a term that is mostly defined by current practice. Therefore sections 2.1.2, 2.2.2, and 2.3.2 provide representative examples for the respective fields.

2.1 Information Visualization

2.1.1 Definition

Information visualization is a rapidly developing field that has attracted a considerable amount of interest over the last years. The theoretical foundation of this relatively new discipline consists of elements from diverse domains, such as computer science, cognitive science, and design. The list of disciplines that provide application scenarios for infovis techniques is even longer. Every task that involves the analysis of big datasets can be supported by infovis. In this section I will give an overview over the field of information visualization and related fields.

Visualization

Visualization is the umbrella term for all sub domains, mentioned in this thesis. It was recognized as a separate discipline as late as the mid 1980s. The establishment of visualization was supported by a long tradition of statistics and graphic design. Cognitive science influenced the field by providing concepts, how to involve the characteristics of the human mind. The definition for the term visualization, as given by Card, Mackinlay and Shneiderman, is:

> *"The use of computer-supported, interactive, visual representations of data to amplify cognition"* (Card, Mackinlay, & Shneiderman, 1999).

Spence (2007) provides a definition that does not rely on computer support and allows him to include several historical examples. They were first described by Tufte (2001) and since are frequently referred to as showcase examples for visualization.

The first example, shown in Figure 1, was created by Charles Joseph Minard and shows the advance and retreat of the Napoleonic army towards and from Moscow. Minard manages to combine a big number of different values in an intuitively understandable graphic.

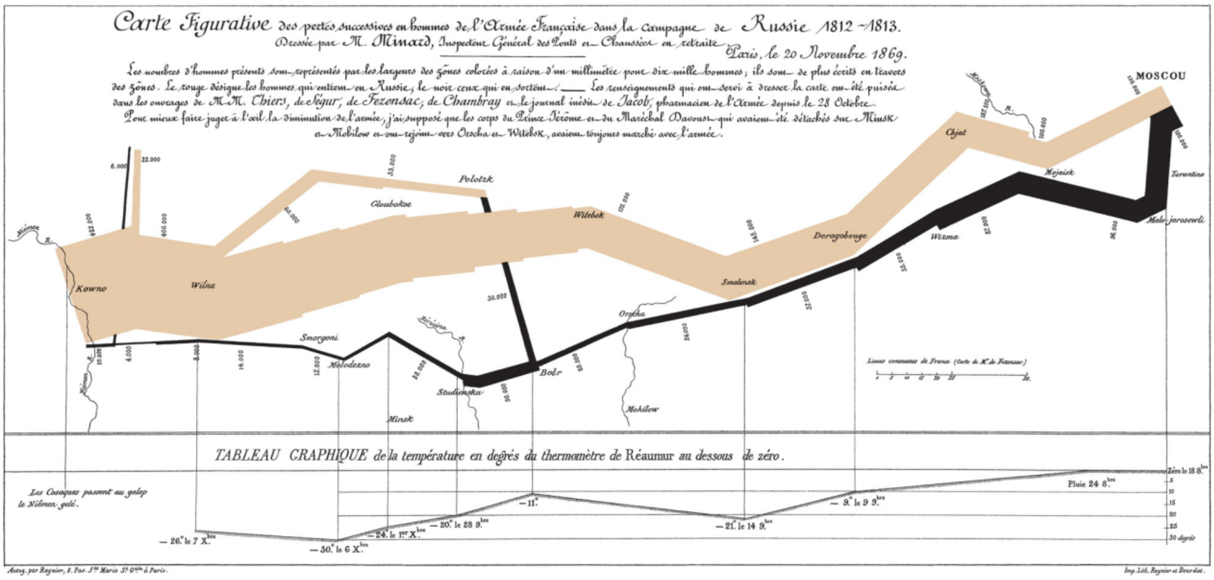

Figure 1. Minard's map of Napoleons invasion of Russia. Advance and retreat of the French soldiers are depicted as brown and black paths, overlaying a map of the area between the Neman River and Moscow. The thickness of the line illustrates the remaining number of soldiers.

Florence Nightingale shows the success of the reforms, she introduced in a military hospital during the Crimean war, in 1858, in the second graphic. The numbers of deaths per month are artfully arranged in a circular layout, see Figure 2.

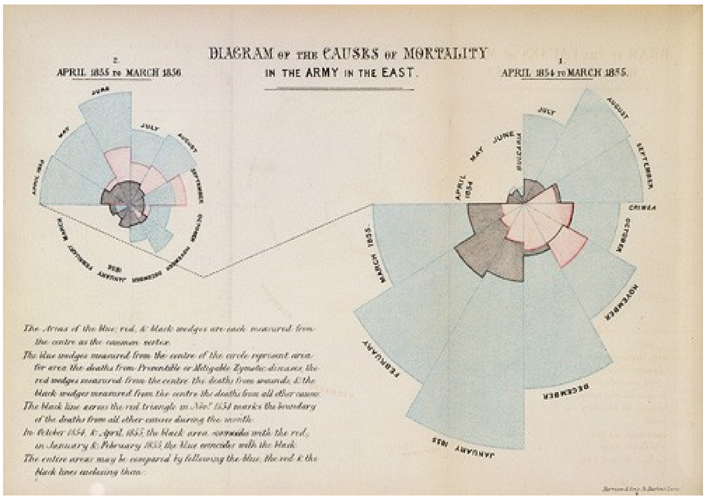

Figure 2. Nightingale's visualization of deaths in a military hospital. Each segment depicts the number of deceased soldiers during a certain month.

Figure 3. Snow's map of cholera deaths in London

Dr. John Snow managed to reduce the number of cholera deaths in Soho, London, in 1854, with the help of a map, comparing the location of deaths and the distribution of water pumps within that district, see Figure 3.

In 1931, Harry Beck realized the gap between the real topography of a city and its topology that is necessary for the orientation in the subways system. He created the famous distorted London Underground map that only represents the sequence of the stations and their intersection points correctly, while setting the distances between stations in a way that creates a clear layout. Nearly all modern subway maps follow this approach.

Spence points out, that all those examples do not require computer support to achieve their goal, which is to create an *insight* in the mind of the viewer. Although there is no consensus on the necessity of computer technology, it is undisputed that the advances of this technology triggered the rapid development of visualization. Additionally, the information age produces a big need for the efficient representation of huge datasets and a broad range of new application scenarios. Lev Manovich (2002a) argues that computer technology turned the graphical representation of quantitative data "*from the exception into the norm*". It also enables the processing of much larger datasets, compared to the data used for the historical examples.

The core principle of visualization is to create a visual representation of a dataset that is extremely difficult or impossible to interpret in unprocessed form. It makes use of the characteristics of the human sense of sight by abstracting the data in a way that supports the capabilities of the human cognitive system and avoids its deficiencies. The visualization and the human mind can be considered as one system. Each part performs the tasks that it is most efficient in. The human brain has amazing capabilities in classification and analytics. Visualization contributes the functionality to hold huge amounts of data simultaneously in an accessible representation. Computer systems can additionally perform huge numbers of simple classification operations and, hence, provide interactive filters for the human user.

A central concept in all visualization subfields is *mapping*. In this context *mapping* refers to the process of transforming raw data to a visual form. Here lies an important advantage of the application of computer technology. The mapping can be manipulated interactively and different representations of the same dataset can be generated. A detailed reference model of the mapping process is described by Card et al. (1999). Manovich (2002a) explains that visualization can be seen as a part of a super ordinate domain, called *mapping*. He further discusses the inherent suitability of computers for this task, since they internally keep all different forms of data in the same encoding. This facilitates a translation, for example, from grayscale images to 3D surfaces. The visualization art piece *Data Diaries*, described in section 2.2.2, demonstrates this fundamental quality of digital technology in an extreme way. Manovich builds the theoretical bridge to arts and categorizes all forms of representational art as kinds of *mapping*:

> *"...taking the wealth of the experiences of an individual and/or a community and reducing it to a single image, a narrative, or another artistic structure."*

As can be seen, this term offers a lot of potential. In this work I will use the more technical and basic interpretation of the term mapping.

Information Visualization

When the technological fields of human-computer interaction and computer graphics matured and became widely available they provided important impulses for visualization. Under this influence, visualization started to form distinctive subfields. In the early 1990s, the field of information visualization started to emerge as autonomous discipline. The essential feature of information visualization is the non-spatial and abstract character of the visualized data (Rhyne, 2008). Pursuing this concept, Card et al. adapt their definition of visualization and define information visualization as:

> *"The use of computer-supported, interactive, visual representations of abstract data to amplify cognition."* (Card et al., 1999)

The amendment of the term abstract defines the subset of visualization that satisfies the criteria for infovis.

The establishment of the new field became evident, when the Institute of Electrical and Electronics Engineering (IEEE) held the first Information Visualization Symposium as well as the first Information Visualization Conference in 1995 (Gershon & Eick, 1995).

Fields of Application

As mentioned before, information visualization is used in a broad range of fields. To give an impression of its versatility, I will describe some exemplary use cases in the following paragraph. Applications from very different fields were chosen deliberately to cover as much of the spectrum as possible:

Silicon chip design: *Texas Instruments* manufactures microprocessors on silicon wafers. Those are routed through 400 steps in a process that lasts several weeks. This process is monitored, gathering 140,000 pieces of information about each single wafer. Somewhere in that wealth of data, warnings about erroneous processes can be hidden. Infovis techniques make it possible to detect bugs early, before defective chips are produced (Spence, 2007).

Pharmaceutical industry: The pharmaceutical company *Eli Lilly* employs 1,500 scientists who are using the information visualization tool *Spotfire® (1996)* to support decision-making. With its capability to contrast multiple sources of information and to choose different perspectives, it is used to single out synthetic molecules that require further testing for medical risks (Spence, 2007).

Transportation: In the context of transportation infovis techniques are valid means for community planning projects, when it is necessary to combine data from several different sources, for instance geographical information systems, visual impact assessments, and transportation analyses (Rhyne, 2008).

Gene analysis: The complex patterns that are hidden in the massive datasets, which modern genetic technology is built upon, can only be interpreted by advanced information visualization applications. New, Kendall, Huang, & Chesler (2008) describe the design of a visualization tool that enables the examination of the connection between genotype and phenotype. The influence of certain genes within the DNA of an organism on the real organic structure of that organism is one of the most complex topics in that field.

Related Subfields of Visualization

The constantly changing taxonomy of the visualization domain reflects the dynamics of this field. Taxonomy has an especially important function in the scope of this thesis. Apart from infovis, several other subfields of visualization are described in literature. To provide a better understanding for the range of the visualization field and for the differentiation criteria between subfields, the most prominent varieties within this domain are examined in this section:

Scientific visualization: *Scientific visualization* is, together with information visualization, the most prominent subfield. The main difference to infovis lies in the underlying data. Scientific visualization deals with data that has a connection to real physical space, as it is produced by a variety of scientific experiments and simulations. Examples are wind-tunnel vector data or three-dimensional medical images. Infovis seeks to create a visual representation for more abstract data, e.g. financial data or sociological data (Spence, 2007). Tory and Moeller (2004) describe this relation in a catchy way: The data spatialization is given, for scientific visualization, or chosen, for infovis. Yet, they propose an alternative distinction between information visualization and scientific visualization. The authors claim that the most evident difference is scientific visualization being based on a continuous data model, whereas infovis follows a discrete model. This approach puts more emphasis on the mapping than on the data. Still there are cases were a distinction between infovis and scientific visualization is not possible according to any of the aforementioned criteria. Examples provided by Tory and Moeller (Tory & Moeller, 2004) are abstract mathematical functions and air traffic control systems. Mathematical functions often do not have a physical counterpart and their visualization layout is not given, still they should belong to scientific visualization. Air traffic control systems on the other side are clearly based on physically existing entities, and the spatial layout is predefined by the real world, still they should be categorized as infovis. These examples show the complexity of taxonomy within the visualization domain. Possible applications for scientific visualization techniques comprise, for example, the realm of transportation. Rhyne (2008) describes the depiction of traffic data for micro simulations of critical data. The results are used as base for decision-making in situations like evacuations, diversions or rerouting.

Geovisualization: In this field the central elements are geospatial data. The denotation of *geovisualization* (geovis) as an own field can be justified by the historical relevance of cartography, and the big influence it had on visualization in general. Geovisualization is different from cartography in one important point. While cartography aims for effectively displaying known information, geovisualization is designed to enable new insights and to explore new aspects of a dataset, concurrent with the aim of visualization. Geovis is especially useful for multivariate data with a spatial dimension. This is important, for example, when monitoring the spread of diseases (MacEachren et al., 2004). According to the definitions of scientific visualization by Spence (2007) and by Rhyne (2008) geovisualization could also be considered as subclass of scientific visualization. Recently this field has witnessed vivid activity, because of impulses from novel satellite technology, especially GPS.

The work on taxonomy is complex and often results in emotional debates, but the value of a clear taxonomy is immense. Taxonomy is an essential foundation for a scientific field. First, the explanation of the characteristics of the field to non-experts demands clear distinctions and a consistent terminology. Second, collaboration within the field is much more efficient when the taxonomy is consistent. Especially inherently multidisciplinary fields, like information visualization, depend on a consistent terminological framework.

2.1.2 Examples

As described in section 2.1.1 infovis is applied in a broad range of fields. I will focus on recent projects that are made available over the Internet. The mentioned projects are designed to reach a broad audience and can be used intuitively. This facilitates comparison with works from IA and VA. The *event tunnel* is an exception. It is discussed because of the influence of this technique on the design process.

Many Eyes, 2004 (IBM Visual Communication Lab, 2004)

Many Eyes is a web-based service that enables the upload, visualization, and sharing of data sets. The site follows a community concept to facilitate and encourage the collaborative work on visualization. A set of interactive information visualization techniques is made available to the public. The applicability of those methods, without expert knowledge, is a particular concern. Among the available technologies are bubble charts, stacked graphs, and tag clouds. Visualizations can easily be published and embedded into any kind of web-service, as can be seen in Figure 4. Viégas et al. (2007) state that the ambitious goal of this project is to *"democratize visualization technology"*. This objective is twofold. First, necessary technology is supplied with free access. Second, a culture of shared data access and public discourse is promoted. A special feature of the system is its sophisticated set of collaborative tools. When commenting on an interactive visualization, its state is saved as snapshot so that other users know exactly what the comment refers to. In addition, it is possible to highlight an arbitrary number of entities to illustrate their special importance. Given a sufficient user base, this platform can be used for *rapid user testing*. Visualization approaches can be made available, and popularity, and usage patterns can be analyzed (Viégas et al., 2007).

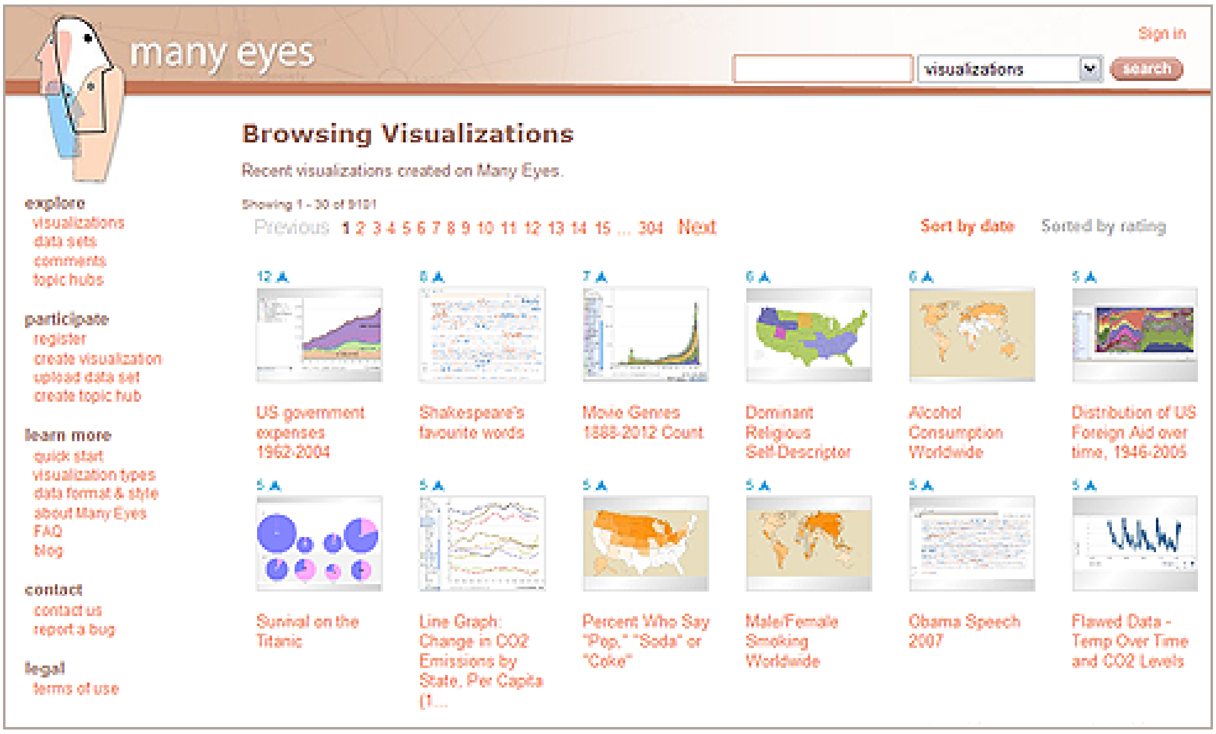

Figure 4. Many Eyes: visualizations overview

Gapminder World (Gapminder Foundation, 2006)

Gapminder World is an online service that provides interactive visualizations of statistical time-series data for all countries in the world. The aim of this project is to raise awareness for the true nature of social, economical, and political processes on our planet. To achieve this, a big variety of different datasets is provided, e.g. income per person, live expectancy, CO2 emission per person, or forest area. The data are visualized as scatter plot; Countries are represented as bubbles. For x-axis, y-axis, and bubble size different datasets can be assigned, see Figure 5. The fourth dimension, the time, can be controlled over a separate timeline. Optionally the time dimension can be run as animation, resulting in the bubbles moving over the screen, shrinking, or growing, according to the change of the underlying data. As the founder of the project, Hans Rosling, demonstrates in various talks this visualization can be used to construct a broad understanding of the current state of the world and its history that is based on statistical facts. Gapminder World has the potential to overcome many preconceptions and create awareness for the true problems of our times.

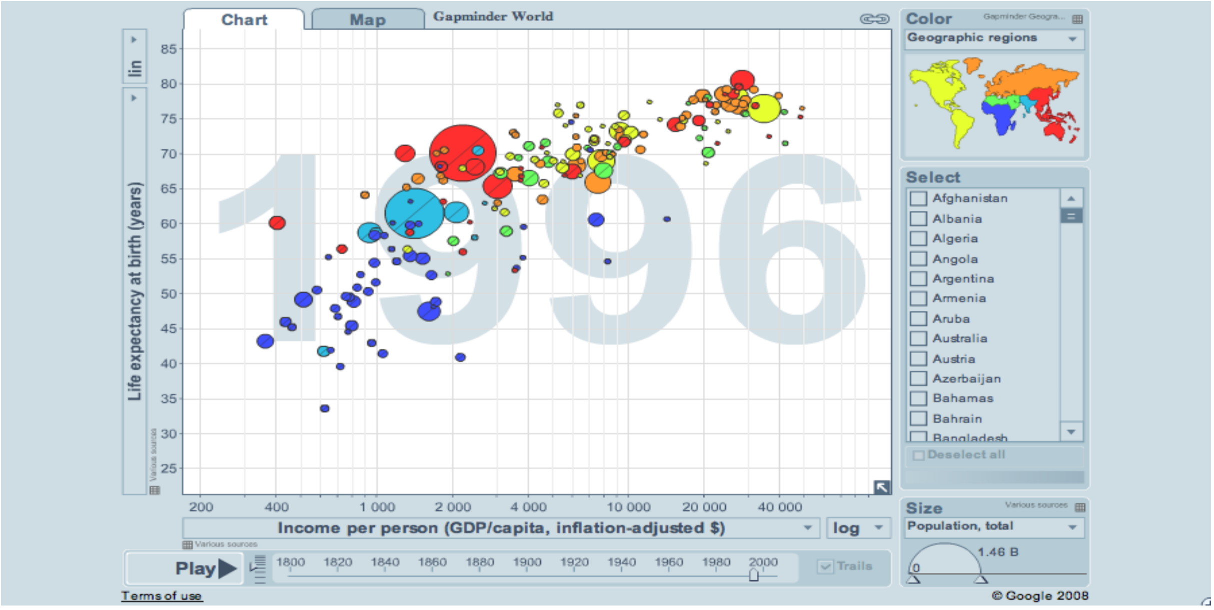

Figure 5. Gapminder World

OECD eXplorer

The OECED eXplorer resembles Gapminder World because of the country-related data it shows and the dominant scatter plot in the start view, see Figure 6, but it incorporates further visualization techniques. Color-coded maps are provided. The selected data can be investigated as bar charts or as plain table. Demographic and economic data are available, even on a regional level, but only for OECD (Organization for Economic Development and Co-operation) member countries. A lot of additional features are available, for instance exporting views as graphics, or saving a sequence of interactions with the tool that can be later replayed.

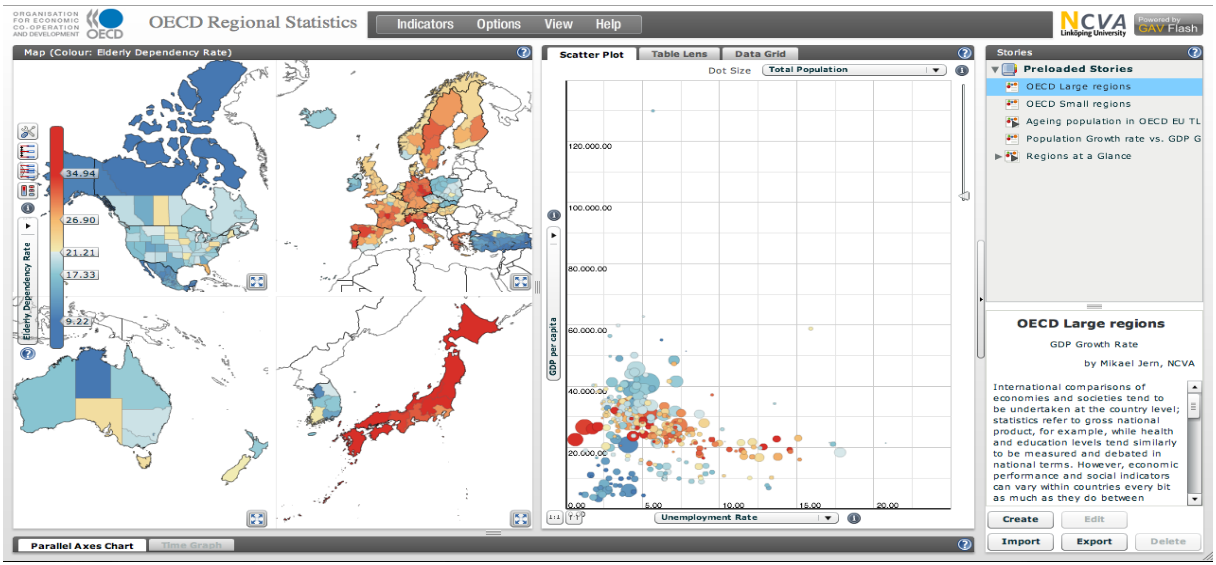

Figure 6. OECD eXplorer

Event Tunnel

Unlike the other examples in this section, this technique is no showcase application per se. It is mentioned because of its big influence on a VA design approach, see section 3.3.1. The Event Tunnel uses a cylinder as basic shape, see Figure 10. It is especially designed to illustrate time-series data of business activities. The data are mapped onto the surface of the cylinder, but the three-dimensional shape is never shown to the user explicitly. Two projections into 2D-space are available. The first view shows the cylinder from the side where it appears as rectangle and the data are arranged similar to a scatter plot with distorted y-axis. The second view presents the cylinder from the top, where it degenerates to a circle. To avoid overlapping of the data and to show the time dimension the tunnel metaphor is used. Younger data points appear at the outer border of the circle while older points are arranged successively further to the center and are scaled down, in accordance to perspective distortion. This layout strategy assigns more space for newer data while still showing older information in a gradually smaller scale and provides a novel implementation of the Focus + Context concept (Suntinger, Obweger, Schiefer, & Groeller, 2007).

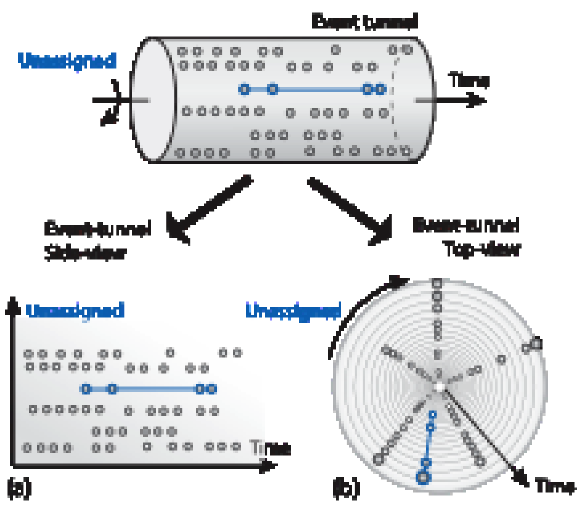

Figure 7. Event Tunnel: side-, top-, and 3D-view

2.2 Visualization Art

2.2.1 Definition

The technical revolutions, fueling the development of infovis, found their way into modern art practice as well, although with some delay. Today, the knowledge how to utilize new computer technology is inevitable in many professional and social settings. In parallel, supportive tools, for instance programming environments, are becoming user-friendlier.

While computer technology, on the one hand, provides useful tools for the creation of classical art forms, on the other hand, its consequences on society create a new topic for artists. In the information age, especially data proofs to be a fertile base for art.

Different terms are in use to describe the art genre that is focused on the work with data. *Information art* (Lima, 2009), *data* art (Whitelaw, 2008)*, artistic visualization* (Kosara, *2007)*, and *visualization art* are common examples. Those in general are used equivalently. The blurred boundaries of this field seem to allow a certain degree of ambiguity. Due to its centrality in the domain of visualization, one distinction that must not be forgotten is the difference between data and information. Data are raw and unprocessed. They only become useful for a human after being interpreted and put into a suitable context, thus making them information. The interchangeable use of those terms is common in the art domain. In several cases this is just the consequence of a vague theoretical concept. Whitelaw (2008) deliberately analyzes works that especially try to preserve the raw and uninterpreted character of the base data. This makes the usage of the denomination *data art* valid. In my work I will follow the terminology of the model of information aesthetics (Lau & Vande Moere, 2007) and use the term *visualization art (VA)*. This term emphasizes that the field is situated in the domain of art and establishes a strong connection to visualization. When discussing the definitions and considerations of other authors, I will quote their terminology.

Defining Art

Viégas and Wattenberg (2007) argue, that the difficulties in defining what is “artistic” visualization are connected with the complexity of defining art itself. They avoid getting involved into this ancient discourse by passing the responsibility to the artists:

> *“… artistic visualizations are visualizations of data done by artists with the intention of making art.”*

The authors acknowledge the apparent problem of their definition being tautological. The good results, however, that this criterion yields when used to classify real works, legitimates its application. Two features of this definition are worth mentioning in particular: First, it constitutes that the works have to be based on a kind of data mapping. This excludes a big number of pieces that are built around images and diagrams, but do not have any form of underlying dataset. Second, the authors emphasize that they have avoided to include any consideration of *beauty* into his definition. In this, they favor the conceptual idea over the aesthetic appearance. With a simple example this decision is justified: Microscopic photography, as it is used for experiments in cell biology, often yields pictures showing interesting structures and strong colors. Those pictures can be classified as beautiful, but the aforementioned definition does not classify them as artistic. Lau and Vande Moere (2007) address the issue of the disambiguation of aesthetics and beauty. They use a similar strategy as Viégas and Wattenberg. In accordance with their interpretation, I will use the term *aesthetic* to describe the degree of artistic influence on the visualization technique and the degree to which it facilitates interpretative engagement.

Growing Popularity

A strong growth of the number of works in this very young field can be observed since the beginning of the new millennium. Whole new museums are built for this genre and its related fields, like the *ars electronica* in Linz, Austria, or the *ZKM* in Karlsruhe, Germany. Why is the number of art works in this special field growing so rapidly? Viégas and Wattenberg (2007) have found two main reasons for this. On the one hand, the usability of the key technologies is constantly growing. Software development frameworks with a focus on graphics-heavy applications and easy use are flourishing. This makes it possible for non-programmers to use the capabilities of computer technology that are essential for artistic data visualization. On the other hand, the availability of data is growing dramatically. The Internet led to an explosion of available datasets. A new trend further fuels this. The Barak Obama administration in the United States took several important steps in using the Internet for the realization of the Freedom of Information Act (Obama, 2008), thus making governmental and administrative data transparent and easily available online.

Comparing Visualization Art and Information Visualization

According to Viégas and Wattenberg (2007), the methods used by visualization artists are very similar to those used in the scientific community, mainly in the context of information visualization. They locate the essential discrepancy in the different motivations, driving artists and infovis experts.

Whitelaw (2008) follows a different direction. He locates the difference between VA and infovis at the conversion from data to information. According to him art *"resists"* to perform the transition from data to information. This is an essential difference to infovis, where the most important aim is to produce information. This *"under-determination"* of many pieces of visualization art leads to a different interpretation. It directs the focus of the viewer more onto the inherit features of the data itself and away from an analytic consideration that are very close to a predefined task. The process of generating insights is indirect and vague, but still present. As Pousman et al. formulate it:

> *"...these systems have the explicit goal of challenging preconceptions of data and representation."(Pousman et al., 2007)*

This means that they deal with technological structures and their interweavement with society and individual perception on a higher level. Infovis systems, on the other hand, are designed to help finding the solutions for a set of predefined analytical problems.

Manovich examines the problem from a very subjective point of view, focused completely on the artist. According to him, the central task of visualization art is *"to represent the personal subjective experience of a person living in a data society"* (Manovich, 2002a). The opposing task of presenting abstract data in an understandable, objective, and pleasant way is handled well by economists, graphic designers and scientists, or in other words: information visualization experts.

In section 2.2.2 we will see both: Works, focused on the characteristics of data and others that use dataset and visualization technique to communicate a completely different issue.

Visualization Art Compared to Other Art Genres

Visualization art does not stand isolated in the arts domain. Manovich (2002a) draws a connection between visualization in general, and modernist painting. He sees abstraction as the driving force for both disciplines. The big difference is that modernism aims for reducing the diversity of everyday objects while visualization often yields an increase of diversity by providing a big number of perspectives on one single dataset. Visualization uses abstraction as a vehicle to transform data from concrete values to structures and patterns.

Manovich explains the high emotional impact that visualization art pieces have on the viewer, through the word pair *sublime – anti-sublime*. He points out an antithetic relationship to Romantic art. Romantic art reckoned nature as something sublime. It was desirable but impossible to completely capture its essence in a piece of art. Visualization art has exactly the opposite aim: to map the overwhelmingly complex reality into something that is comprehensible by the human mind. He calls this anti-sublime. Warren Sack (2006) draws a connection between the term *anti-sublime*, as used by Manovich, and the term *user friendly* from the context of computer science.

According to Sack, the problem is, that the contribution of visual art to visualization is in the center of attention. He argues that the impact of *conceptual art* is far stronger and deeper. This trail of thought is based on a definition of conceptual art by Sol LeWitt, who negates beauty and the sublime as driving forces. Instead the transfer of information to the viewer is dominant in the considerations of the conceptual artist. This definition establishes a common ground for infovis and conceptual art.

2.2.2 Examples

The VA domain provides a broad range of different works. It is a desideratum of artists to leave the familiar terrain and explore new methods. This variety is reflected by the selected subset of VA pieces in this section.

Running the Numbers, 2008 (Jordan, 2008)

Running the Numbers by Chris Jordan is a series of high resolution and large-sized pictures. Thousands of elements are placed on the canvas and arranged to form bigger patterns and shapes. The artist finds a visual language to translate statistical data into detailed pictures. He tries to overcome the gap between the big numbers that are needed to describe the problems and nuisances in modern society, and the limited comprehension that humans have of such dimensions. Figure 8 shows a 10x25 feet canvas (separated into 5 vertical panels) that depicts 3.6 Million tire valve caps, one for every SUV that was sold in the US in 2004.

WEB2DNA Art Project (Baekdal, 2008):

WEB2DNA is an online application that transforms html code into images. The visual concept is based on the artworks, sold by the company DNA 11. DNA 11 uses the DNA samples of customers to create customized artwork, unique for every person. The graphical design follows the style of scientific DNA-analysis results. WEB2DNA uses the same approach and transforms html code into similar pictures, see Figure 9.

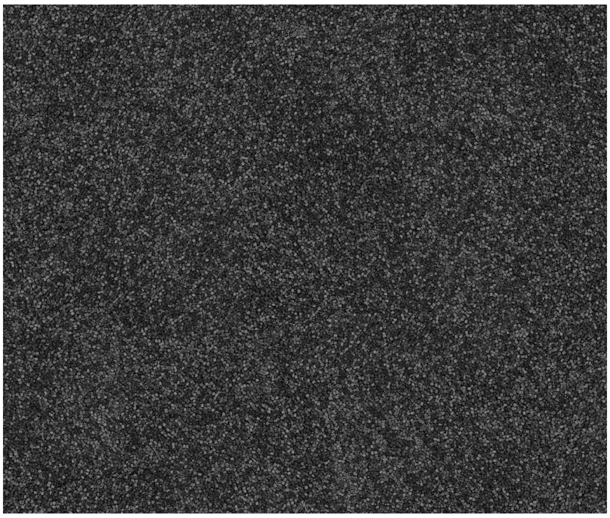

Figure 8. Running the Numbers: 3.6 million tire valve caps

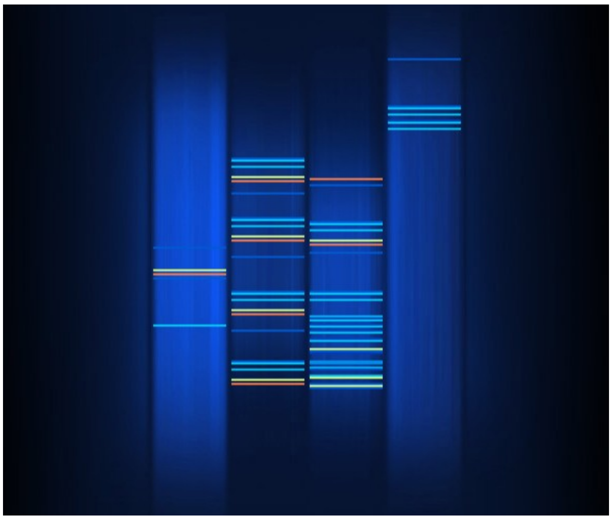

Figure 9. WEB2DNA html visualization

The layout elements in the visualization that represent the webpage structure are horizontal lines, arranged in several columns. The data are encoded in the line-color, the vertical distance between two lines and the line-brightness. Only html-tags are encoded as lines. The distance between two lines denotes the amount of plain text between two tags. The color encodes the tag-type. Brightness gives an indication of "new" or "old". For instance, newer tags are brighter than older tags; div layers are brighter than table layouts. Brightness can also depict hierarchical information, e.g. h1 is closer to white than h2 and TABLE is brighter than TR, which is brighter than TB. There is a super ordinate message the artist amplifies through the graphical design. He conveys a qualitative judgment about the html-code itself. Categories like "old" and "new" are very subjective and arguable and, hence, not suitable for infovis. This piece still has a practical value. It fosters reflection about the structure and quality of web pages. It connects social interaction with qualitative html coding. Artful structures that are usually hidden are incorporated in an interesting picture that can be shown to friends or framed and hung on the wall - something to be proud of.

Poetry on the Road, 2002-2009

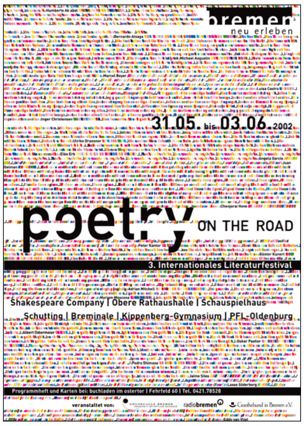

Figure 10. Poetry 02

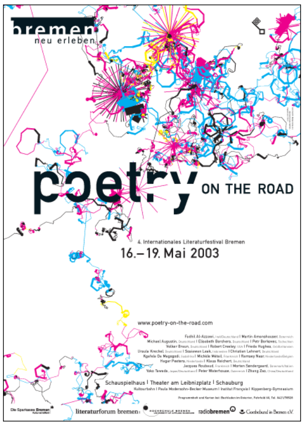

Figure 11. Poetry 03

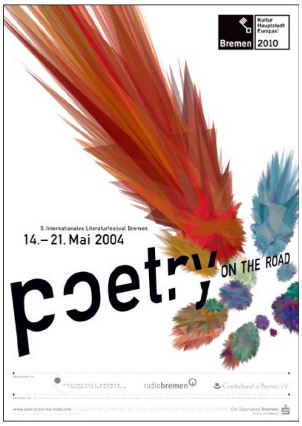

Figure 12. Poetry 04

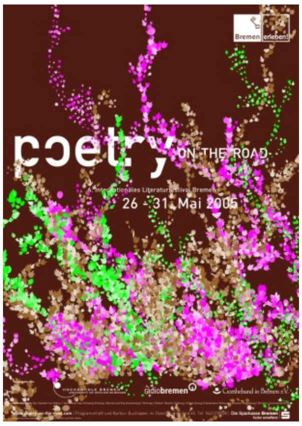

Figure 13. Poetry 05

Since 2002 the Poetry on the Road literature festival in Bremen, Germany, assigns the design of a visual theme for the event to Boris Müller. The fruit of this cooperation is a series of astonishing visual concept that are all based upon the same principle: the text of the poems is used as input for an algorithm that creates an appealing image. The resulting text visualizations have an appearance that is similarly lyrical than the visualized poems themselves. Figure 10 to Figure 16 show the pieces that exist so far in this series.

Poetry 06, displayed in Figure 15, was of high importance for my VA design. In this piece the content of each poem is arranged on a cyclical path around the center, creating a spiral shaped layout. The diameter is determined by the overall length of the poem. Every word is encoded as number, as sum of all the letter positions in the alphabet. This number is converted into an angle and describes the position of the word on the circle of the poem. Several words can share the same position. They are combined into one red circle with thickness according to the number of words at this position. Gray lines connect all those red rings in the correct order and thus reflect the sequence of the words in the poem. The beauty of this structure is increased by a well-designed edge routing (Mueller, 2006).

Figure 14. Poetry 07

Figure 16. Poetry 08

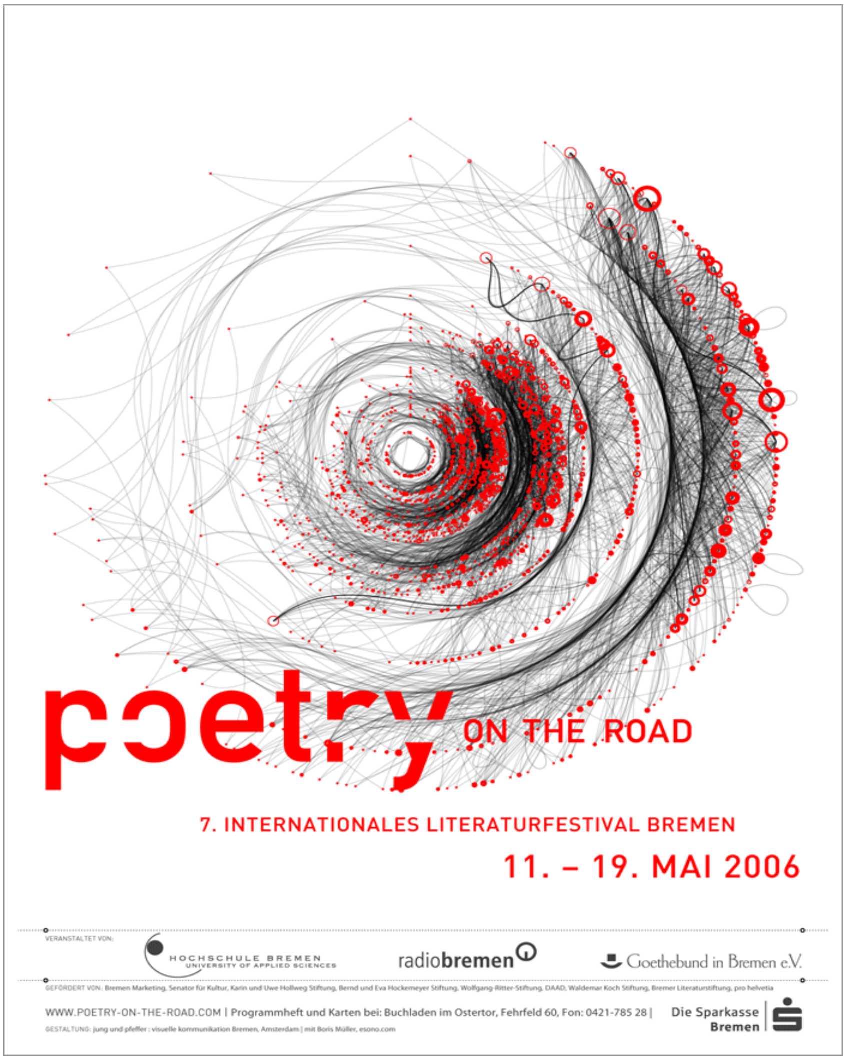

Figure 15. Poetry 06

Digital Monument to the Jewish Community in the Netherlands (Lipschits, 2005)

> „*The Digital Monument to the Jewish Community in the Netherlands is an Internet monument dedicated to preserving the memory of all the men, women and children who were persecuted as Jews during Nazi occupation of the Netherlands and did not survive the Shoah.*" (Lipschits, 2005)

This piece emotionally affects the viewer by creating a huge contrast between its neutral layout and the upsetting data it conveys. The unpretentious data mapping underlines the immanent cruelty of the data. Following the aim to depict every victim of the Holocaust, small vertical bars represent single persons. Age and sex of every individual are shown by the height and the color of that bar. Thousands of bars are arranged in hundreds of lines. The strict layout of the visualization invites to search for color patterns in an infovis way but the following insights are of unexpected emotional strength. When investigating the fragile green line in the center of the screen, for instance, we find that it depicts the deportation and killing of 74 mentally handicapped and wayward children from the Paedagogium Achisomog in January 1943.

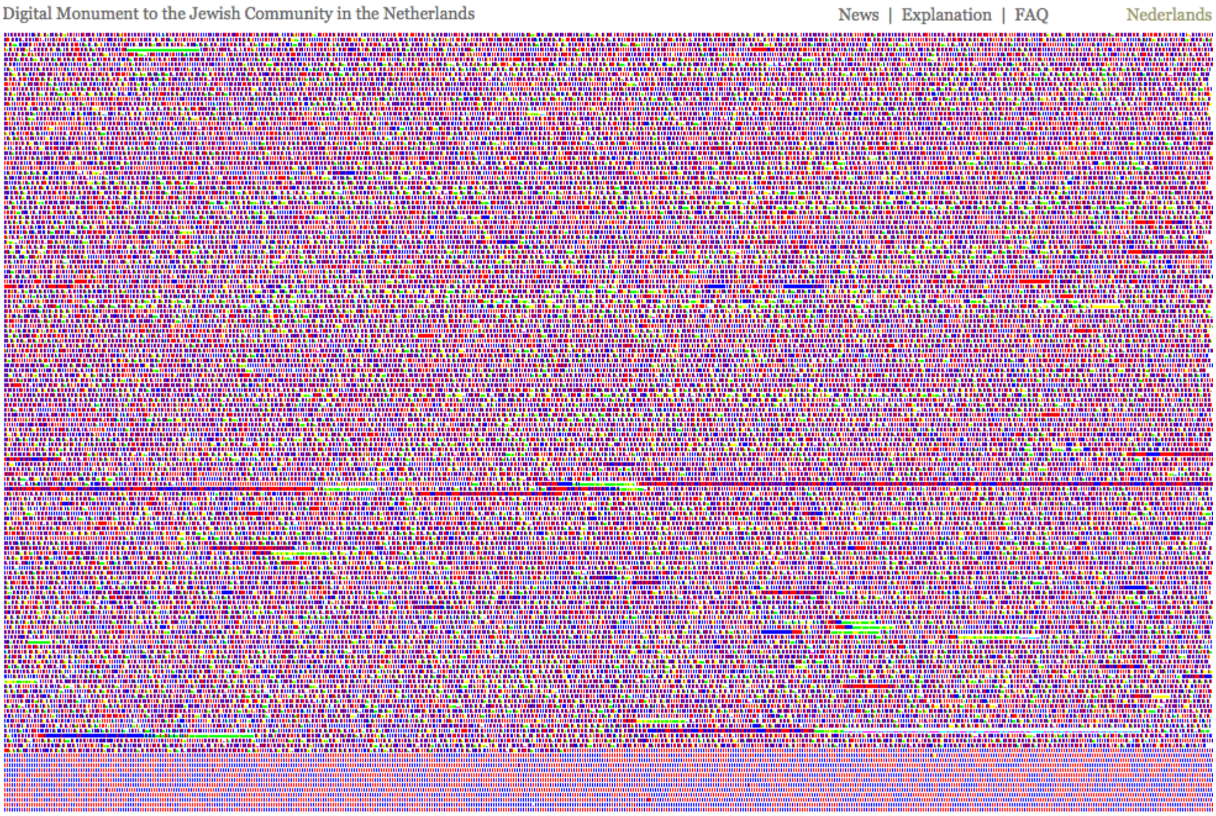

Figure 17. Digital Monument to the Jewish Community in the Netherlands, 2005

Bitalizer (Reavis, 2008)

Bitalizer is following a strikingly simple concept. It takes the binary data from an arbitrary file and transforms it into a picture that looks similar to a galactic nebula. The mapping algorithm is not very complex. A line is drawn, starting at the center of the screen. For every "0" in the bit sequence this line is bent up by 60 degrees, for every "1" it is bent down. The color of the line is determined by interpreting 8 bits, what is equal to one byte, as number. Animating the drawing process increases the aesthetics of this work. The true binary nature of digitalized data, that most computer users are not aware of any more, becomes visible in a beautiful way, see Figure 18. The most basic details are elevated to be the most dominant visual elements and, thus, are emphasizes more than information on a higher level.

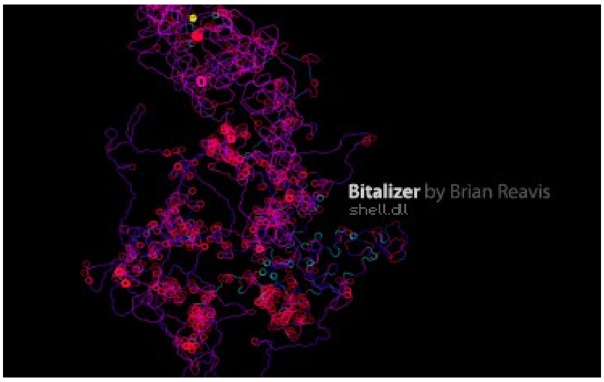

Figure 18. Bitalizer, 2008

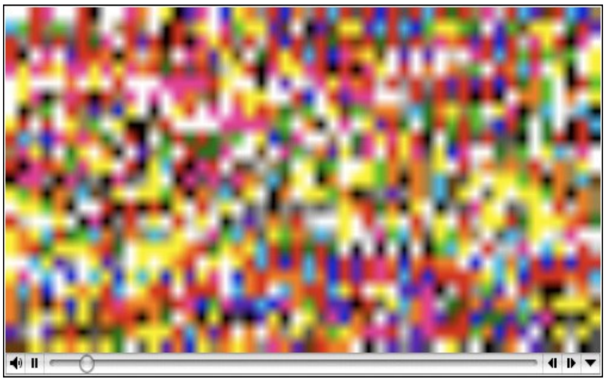

Figure 19. Data Diaries, 2002

Data Diaries (Arcangel, 2002)

Similar to Bitalizer, the appeal of this concept lies in its simplicity. Based on the insight that all data on a computer is saved in the exact same binary format, Arcangel takes a file that contains the current memory of his computer and uses the Quicktime Player to interpret it as video. The result is a video sequence of colorful patterns, see Figure 19, acoustically backed up by background noise. The original content of the data consists of recently written e-mail texts, word documents and of pictures, recently edited with Photoshop. This meaning is completely obscured by the mapping, and yet this representation is as close to the real structure of the data as any other form in which an average user might encounter them. A difference to Bitalizer lies in the complexity of the mapping. Bitalizer uses an intuitively comprehendible mapping technique, whereas Data Diaries de-contextualize an advanced video encoding.

Petals (Thorp, 2006)

Flowers are a very popular motive in arts in general. Computer generated pieces of art have a particular affinity towards plantlike shapes. Those shapes have an inherently pleasant effect on most people and convey a sense of beauty. In addition, they show clear structures and can be generated algorithmically. An appealing example that grows right from the heart of Twitter is *Petals*. This work takes a picture from Flicker according to a tag defined by the user. This picture is fragmented into pixel blocks. For each block a flower is automatically generated. Several features of the pixel block are encoded into features of the flower, as petal breadth, diameter, color, and petal count. The overall style of the picture seems naïve; the creation of a beautiful composition seems to be the driving force for the mapping decisions. Still the interesting shapes and the successive filling of the screen with more and more flowers engages the viewer, and after some time, deeper questions about the mapping come into ones mind. A desire is created to find out more about the structures in the picture that are able to produce such flowers.

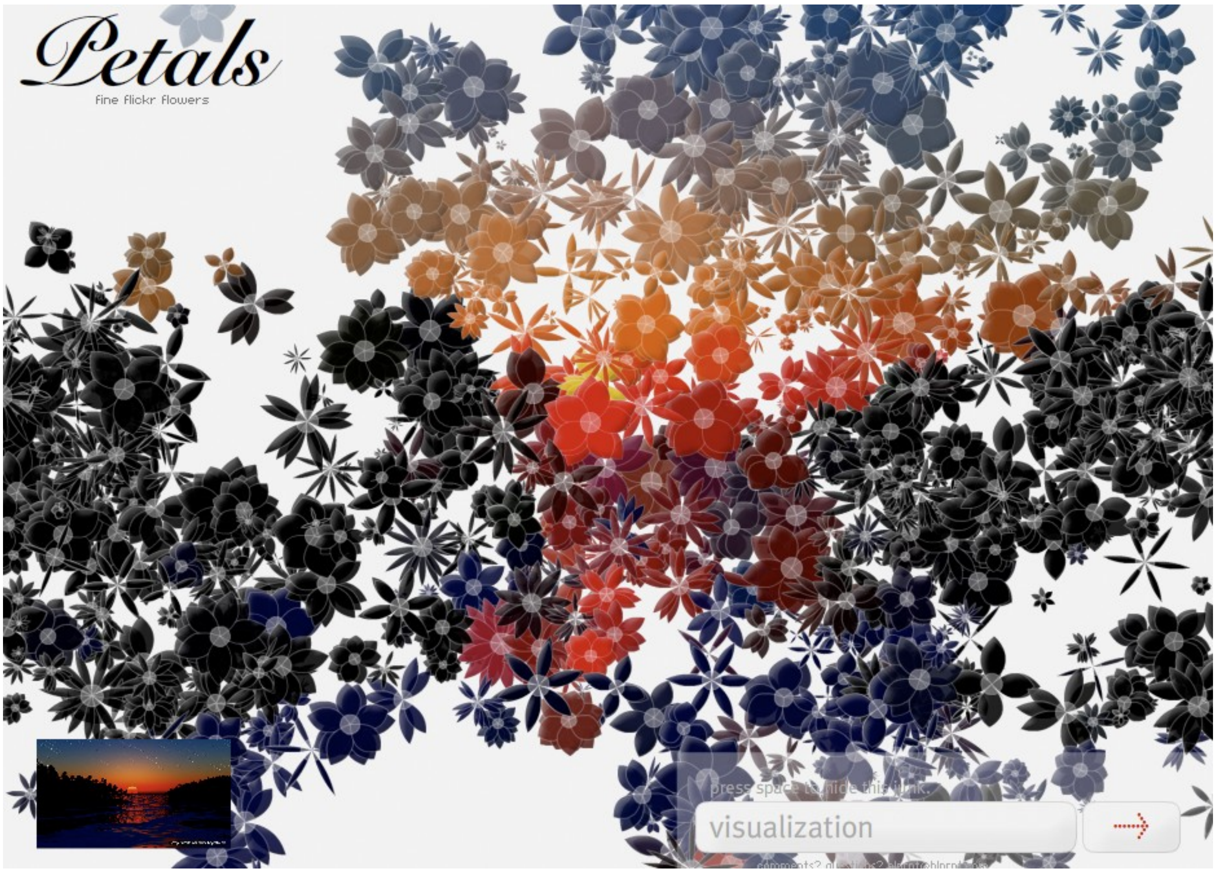

Figure 20. Petals, 2006

2.3 Information Aesthetics

2.3.1 Definition

The common goal to visually communicate an abstract message leads to a natural tension and attraction between the two fields IV and VA. So far, especially infovis experts are reluctant to embrace this connection, and exploit the new possibilities it holds. Calls for a strict delimitation are getting louder instead. Such a demarcation leads to a precarious situation for work that is situated in between. A sound terminological foundation and empirical evidence for positive synergetic effects between art and infovis are essential for an adequate discourse.

In this section, I will discuss different theoretical concepts that examine the intersection area of IV and art domain. Further, I will provide some insight into the current discourse about the role of aesthetics in IV.

Aesthetics

Being widely ignored by scientists in the early days of infovis, the term *aesthetics* gained importance when the area of application for the infovis techniques started to reach the average user. The definition of aesthetics is not trivial. Philosophers are maintaining a discourse about the exact definition for thousands of years now. Amongst the brilliant minds, which concerned themselves with this matter, are Plato, Aristotle, David Hume, Immanuel Kant, Jean-Paul Sartre, and Ludwig Wittgenstein. A central aspect of the importance of aesthetics is to provide a theoretical concept that enables for a discussion of topics like beauty and taste on a higher lever, less prone to subjectivity (Encyclopedia Britannica, 2009).

Fishwick et al. (2005) discuss the aesthetics in the context of computing. The term aesthetics is defined as *"a combination of cognitive and sensory modes of experience"*. They also point out that *"the representations of information and software could do with greater emphasis on a wider range of artistic expression, without sacrificing utility"*.

In infovis several approaches were made to establish a measurable and objective definition for aesthetics. Purchase (2002) follows a very technical approach. She describes aesthetic considerations in the scope of graph layout. In this work several, objectively measurable strategies are mentioned, how to increase the aesthetic quality of a graph. A minimum number of crossing edges, maximum overall symmetry and maximum angles between the edges of a node are noted. Those criteria contribute to an automated methodology that enables the calculation of an aesthetics measure for a graph. The criteria are deliberately correlated with the readability of the graph. Subjective human appeal is not considered. This automated approach allows to process big quantities of data, and can be used for the automated generation of graph layouts. The drawback is that the results are likely to have a technical and sterile visual appearance. In a similar approach, Ngo, Teo & Byrne (2003) propose an objective description methodology for the aesthetics of graphic displays is proposed. Fourteen measures are mentioned that are directly calculated, based on the geometrical properties of the elements on the display.

Apart from those objective analyses there are approaches that regard the subjective impression of the viewer. In the scope of this thesis a subjective definition of aesthetics is needed that correlates with the affect, sensed by the viewer. As mentioned in section 2.2.1 Lau and Vande Moere (2007) discuss the term aesthetics in the context of infovis, and also address the issue of the conceptual differentiation from beauty. I will use aesthetic, in accord with their interpretation, to describe the degree of artistic influence on the visualization technique and the degree to which it facilitates interpretative engagement. This concurs with the usage of the term artistic by Viégas and Wattenberg (2007).

Closing the Gap

Currently, there exist various approaches to fill the gap between infovis and visualization art. Manovich (2002b) even locates the new narrative form, accompanying the socio-cultural shift towards the information age, situated between those two extremes. He points out that we currently have access to huge amounts of data, but not enough narratives to hold them all together.

> "*Therefore, we need something that can be called "info-aesthetics" – a theoretical analysis of the aesthetics of information access as well as the creation of new media objects that "aestheticize" information processing.*" (Manovich, 2002b)

Phenomena like graphjam.com (Pet Holdings Inc., 2007-2009) support this theory. Here, basic charts are used to tell jokes. The infovis context yields an independent kind of humor and shows the high literacy of people in reading and creating visualizations.

A new expressive form that incorporate elements from art and infovis, would affect all aspects of western society. Warren Sack (2006) uses the term aesthetics for visualization in a political context; in particular he uses the formulation *aesthetics of governance*. Sack argues, that aesthetic information visualization could be the technology, suitable to support self-governance and hence democratic governance. Governance, in this case, denotes the technique to control the *Body Politic*, a homunculus that is composed by a huge number of people, for example a state. Visualization enables it for the smallest parts of the Body Politic to get an overview of the body as a whole. This is an essential precondition for the individual in a democratic system, to take over political responsibility. In his considerations, Sack relies more on the inspiring influence that conceptual arts could have on infovis.

Besides these theoretical approaches towards estimating the potential of the combination of infovis and arts, there are concrete concepts emerging to establish new domains in the area of overlap.

Pousman et al. (2007) analyze a set of works that are located at the border of the infovis discipline and propose an umbrella term: *casual information visualization*. This term includes three subfields: *ambient*, *social*, and *artistic* infovis. Their communality is a less intensive focus on clearly predefined tasks and a more casual usage. Four criteria are stated that distinguish casual from standard infovis:

- User Population: the range of users is not limited to experts. No background in data analysis is presumed.
- Usage Pattern: the visualization is not necessarily used in a professional context. It is used more sporadic and according to momentary moods.
- Data Type: the focus of the data is more on personal connection to the user than of any work-related matter.
- Insight: according to the different focus of the application the insights are presumed to be qualitatively different and less analytic.

Casual infovis is used in domains were the need efficiency is less dominant than in a standard infovis context, for instance the organization of the own home. It is, per definition, focused on personally important information.

Another infovis subfields that emphasizes aesthetic considerations, is introduced under the notation *ambient displays* (Mankoff et al., 2003). In this field the motivation to increase the aesthetic value is to keep the display out of the center of users attention, but still provide information in an unobtrusive way. For this concept noncritical information is best applicable. The fixed position of the physical display is an important feature as well. It makes the visualization an integral part of the environment and requires special design considerations. A possible setting is the display of the bus schedule at a station.

Even more apparent than the growing attention in the scientific community, is the exploding number of works that are recently created in this field. A set of remarkable examples will be described in section 2.3.2. Lau and Vande Moere (2007) identify several reasons why this field has gained so much momentum recently:

Software Availability: As mentioned in section 2.2.1, the art community benefits from more intuitive software development environments and well-engineered technology.

Data Availability: The Internet is not only the perfect forum to distribute data and make them available all over the world; it also initiates new processes and dynamics that themselves create huge amounts of data. Examples are social networking platforms.

Internet Speed & Distribution: The growing speed of data transfer promotes new ways of data usage. Many applications are only interfaces to databases, which are accessible over the Internet, e.g. *Google Earth*.

Interdisciplinary Skills: As in many other fields, a rapidly growing usage of computers leads to increased technical knowledge of artists and designers.

Evolving Aesthetics: Especially in the context of online media, the competition for user attention is very big. This constantly leads to new aesthetic concepts, conceived to stick out from the masses of other designs and ideas.

An additional point, not included in the original list, should not be forgotten:

Visualization Literacy: In a society where PowerPoint presentations are a substantial part of the business communication, information visualization techniques are used extensively. Most people are confronted with basic visualizations as bar charts, pie charts and scatter plots on a regular basis. It is assumed that this has enabled a big part of the western population to easily handle information, presented in this form. The success of the mentioned site graphjam.com affirms this assumption.

It can be observed how techniques, based on infovis, are increasingly spreading to other application areas, especially to a more casual and personal context. This tendency follows the general trend of information technology permeating the personal life of people.

For this work it is important to have a consistent terminology and a theoretical framework of criteria to identify and evaluate aesthetic information visualization works. Pousman et al. (2007) consider an interesting set of infovis related works, but the terminology of *casual information visualization* is not satisfying. It aims for providing an identifier to handle three inherently different, peripheral subfields of infovis, instead of incorporating them into a common concept. Lau and Vande Moere (2007) make a more extensive approach on defining a new domain. They propose a triangular model (Figure 21) that spans between the principles *aesthetics*, *data*, and *interaction* to establish a new domain in the current data visualization practice: *information aesthetics (IA)*.

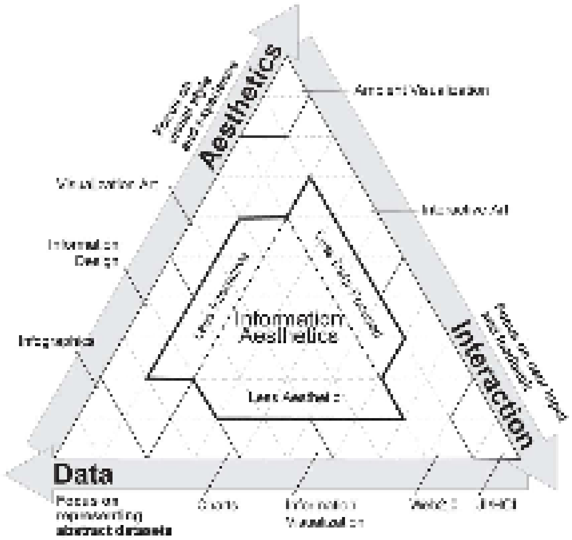

Figure 21. Information aesthetics domain model (Lau & Vande Moere, 2007)

A particular focus is put onto the relationship of IA to visualization art and infovis. To investigate the relationship between those three fields a second model is introduced, see Figure 22. The category of aesthetic influence is divided into two aspects: *Data Focus* and *Mapping Focus*. The authors test the applicability of their framework on existing works. According to data- and mapping focus, forty-seven IV applications are laid out on a two-dimensional field.

Mapping Focus: The scale of this measure reaches from *direct* to *interpretative*. A direct mapping makes it possible for a user to deduce the underlying data values from its representation in the visualization. An interpretative mapping is not invertible. Other considerations, than the direct visibility of the original values, influence the mapping. Subjective and stylistic decisions are dominant.

Data Focus: This value is defined to lie between the extremes *intrinsic* and *extrinsic*. It is an utilitarian category that investigates the question *"…what the visualization allows the user to accomplish…"*. The dichotomy of "art" and "tool", as discussed in (Kirsten, Phoebe, Medynskiy, & Gay, 2005), is used to clarify the abstract concept. An application with intrinsic data focus is especially effective to provide answers to specified tasks. This can be subsumed under the term *tool*. Extrinsic focus is meant to induce reflection on the meaning of data in a personal way. The insights here are on a higher level, e.g. unraveling social and cultural principles, what concurs with the term art.

An example that illustrates the terms *data focus* and *mapping focus*, and their correlation, is the illustration of climate change for a non-expert audience. To convey this complex process to a person with no deeper expert knowledge requires an extrinsic data focus. Here the choice of an abstract and interpretative mapping technique is valid. As long as it conveys the intended message it does not have to enable the exact reconstruction of original data values.

The resulting model forms a continuum that stretches from IV to VA, see Figure 23. It is interesting that the subfields described by Pousman et al. (2007), namely *ambient visualization* and *social visualization* and *informative art* form cohesive areas in this scheme.

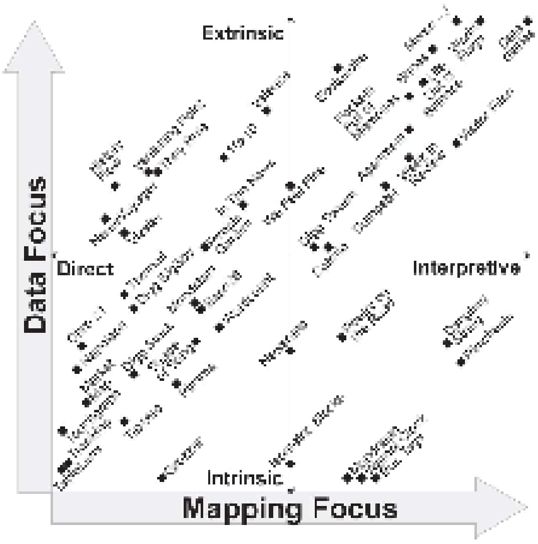

Figure 22. Model of information aesthetics

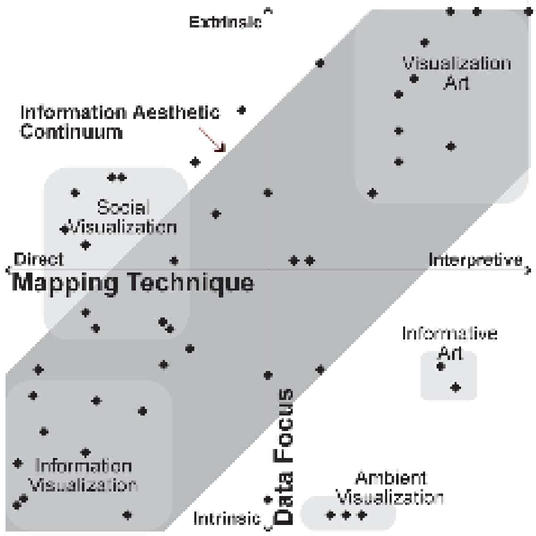

Figure 23. Categories within the model of information aesthetics

This classification methodology is groundbreaking for further work. The framework makes it possible to classify applications in the blurred field between infovis and VA, according to transparent rules. The assignment of defined values of data focus and mapping focus still underlies a certain degree of subjective judgment, but the discourse about such decisions obtains a common ground and vocabulary. All further work in prototype design and evaluation methodology will be based on this model.

To show how a specific work can be located in this model *Data Diaries*, described in section 2.2.2, will be used. As was mentioned earlier, the main idea is to display the raw content of the working memory of a computer as Quicktime video. Those memory data contain recently written e-mails and other recently altered files. Lau and Vande Moere assigned the highest orientation towards visualization art in both categories to this work. It is extreme in its extrinsic data focus as well as in its interpretative mapping focus. The extrinsic representation of the memory data of a computer in Data Diaries fosters considerations as “Why are the data represented by highly saturated colors?”, “The whole image seems to be a structured by some kind of grid. Where does this effect originate from?”, or simply “Why are the data so colorful now, when they originally were so dull?”. Whereas an exploration of the memory data in an intrinsic way might be focused on questions like: “To whom were the most e-mails sent during this working session?” or “How many pages of text did the user write within the last hour?”. The data mapping is highly interpretative. It animates to think about possible reasons for certain patterns but it does not provide any means to invert the mapping and find an explanation in the original data.

It is understood that this model is not necessarily final or concluded. When working in an emerging field it has to be regarded that the state of the art is subject to constant change. Several important questions remain unsolved. Empirical evidence is needed to define the range of applications where IA visualization is beneficial. Especially from the infovis point of view, the IA term is based too much on definitions, lacking empirical support. Approaches towards such evidence currently are tentative. Byron & Wattenberg (2008), for example, rely on a set of thirteen forum posts to illustrate the value of aesthetic factors in the visualization of time series data with *Streamgraphs*, see 2.3.2.

Advantages of Aesthetics

Similar to the shift, that happened when visualization techniques spread over the borders of the scientific community onto other professional fields, a second shift can be observed now. Visualization techniques start to be taken on by mass culture. Especially the Internet is a space where infovis is made accessible to a huge audience. This second shift once again comes with the affordance for new representation techniques. Aesthetics is the core concept in attracting attention in the visual world of the cyberspace. Besides the higher user acceptance of aesthetizised web services in general, and online infovis in particular, positive influence on learning behavior and insight generation is expected. It is important to investigate this in detail and to perform user studies to gain empirical proof.

Two concepts that are used in this work to discuss possible positive effects of aesthetic influence on infovis are *user engagement* and *insight*:

User Engagement: O'Brien and Toms give the following definition of *engagement*:

> *"Engagement is a category of user experience characterized by attributes of challenge, positive affect, endurability, aesthetic and sensory appeal, feedback, variety/novelty, interactivity, and perceived user control."* (O'Brien & Toms, 2008)

The authors state the importance of engagement in the context of information technology in order for a user to initiate and continue interaction. One of the benefits that are expected from the investment in aesthetics is to reach and engage a broader audience. Especially for IA it is interesting, how aesthetics lead to individual engagement of users and, further, to a longer and deeper examination of the data.

Insight: Insight is the central objective of all visualization applications. This manifold term is not easy to define. Based on the model from Saraiya, North & Duca (2005) that is focused on the evaluation of traditional infovis, Pousman et al. (2007) describe a set of four qualitatively different categories of insight: *analytic, awareness, social, and reflective insight*. While analytic insight reflects the traditional perspective on infovis, the other categories suit the new application areas of aesthetic infovis techniques. I want to clarify how aesthetic considerations in design can influence and change the quality of infovis insights. The assessment of insights in infovis is an important topic, and will be discussed in chapter 5.

When considering the new form of visualization as whole new media, the scope of the term *aesthetic* becomes broader (Manovich, 2002b). The aspect of *story telling* comes to the foreground. In (Gershon & Page, 2001) storytelling is described as strategy to communicate information. The value of the story is, that it provides a structure where the specific information is embedded. The structure as a whole is easier to remember than abstract junks of information. In this, there exists a similarity to the communicative qualities of pictures. However the picture might be not completely understandable without additional explanation. A single static image is inappropriate for the representation of a whole story. To show the time dependent aspects, animation is useful. Using annotations and animation together is the best way to eliminate any misunderstandings.

Many information aesthetic projects are built on a special kind of data that has a special emotional quality. *The Dumpster* (Levin, Nigam, & Feinberg, 2006) uses blog posts that describe breakups between teenagers. This motivates the user to recall similar situations from his personal memories. *We Feel Fine* (Harris & Kamvar, 2006) directly searches for the articulation of feelings in weblogs. A demographical and geographical context is provided for the very subjective snippets that are taken from the blogs. Again the user is guided to create a connection to his personal experiences. This personal experience works as a frame for the interaction with the application. The alternation between impulses from the visualization and associations from the user creates the desired flow and create a story. Both examples are described in section 2.3.2.

The Aesthetic Discourse

The recent and rapid developments have led to a vivid discourse about the benefits and problems that come with the usage of aesthetics in information visualization.

An intensely disputed question is the tradeoff between legibility and aesthetics. In most cases, measures for increasing the aesthetic appeal of a visualization at the same time decrease its legibility (Byron & Wattenberg, 2008). In the terminology of the model of information aesthetics, this issue is denoted as interpretative data mapping. As a result the reconstruction of original data values from the visualization is more complex or less exact; a main reason for parts of the infovis community to react repulsing towards such approaches.

Kosara (2009b) uses a quite drastic formulation for the difference between infovis and VA: *"Do you care about perceptual effectiveness or beauty?"*. This binary approach eliminates any graduations between both extremes. At a point of time, where cognitive science is only starting to unravel the ways our consciousness works, this is a bold statement. It implies the assumption that cognitive processes for aesthetic perception and analytic investigation are completely independent or even interfere with each other. The already mentioned approaches towards objective measures for aesthetics propagate a completely different perspective. Here the perceived aesthetics are correlated with measurable structural features of an image, graph, or layout. Cognitive science provides interesting results that lead away from such a polarity as well. *Positive affect* was found to influence analytical reasoning and increases the flexibility of the cognitive system, leading to more creative problem solving under certain circumstances. In the laboratories of cognitive scientists, positive affect is generated by giving small and unexpected gifts to the test persons, by showing cartoons to them or by letting them solve an ambiguous task (Ashby, Valentin, & Turken, 2002). In IA and VA the positive affect is created through the appeal of visual representation and interaction. I expect similar consequences on the problem solving process.

It is acknowledged that a tradeoff between aesthetics and legibility is not beneficial in many traditional infovis applications. But the progressing diffusion of infovis techniques into other domains and other usage contexts should be seen as motivation to embrace new techniques. The visualization of box office revenues in the New York Times (Byron & Wattenberg, 2008) for a big number of newspaper readers is a valid example. Here the IA technique of Streamgraphs is an attractive option. For details see section 2.3.2. The readers might not be willing to try to understand a technical and sterile graph; on the other hand they are attracted by a playful visualization, using the novel and fluent Streamgraph. In this case the user needs to be engaged in some way, the interest in the data has to be created.

Interpretative mapping should not be reduced to a diminishment of clarity. The designer of an information aesthetic work is often more focused on the communication of a message and uses a mapping technique that supports his views. The designer may take into account that the mapping technique lacks exactness, when trying to communicate a message. In terms of storytelling this can be reasonable. Lau and Vande Moere (2007) mention the possible problem of abuse, that can occur when the mapping technique is used in manipulative ways to distort reality. This problem is connected with some features of IA that do equally exist in traditional mass media. Journalists preselect the information that is presented to the reader in an article to support a certain message. If this is done in a thorough and sincere process, it is indisputably legitimate. The final responsibility rests with the reader to decide about the trustworthiness of an article. The same is true for an IA work. To facilitate a critical reflection by the user, it is important to provide a publicly available description of the mapping technique and, ideally, access to the raw data. This point does not apply only on IA. The crucial difference, once again, is the application area. Domain experts are difficult to deceive within their field, but readers of newspapers or visitors of web pages, for instance confronted with statistics about governmental activities, are susceptible both to IA and infovis. Tufte (2001) discusses several examples, were statistical charts were used to bend the truth and to push a certain point of view, in opposition to the facts. He argues that this is no specific problem of graphical data representation: *"...any means of communication can be used to deceive"*

The category of intrinsic and extrinsic data focus plays an important part in the discourse as well. Lima (2009) uses the illustrative example of a wooden chair. Seat, back, and legs serve as metaphor for the data. The author argues that the optimal composition can only be determined under consideration of the ultimate goal: to sit. This perspective concurs with an intrinsic data focus. From an extrinsic point of view, there might be other configurations of the chairs parts that are very useful, and no argument is provided why infovis should not be used to explore this space of possible configurations, without a predefined goal.

At the same time, it seems that frustration in parts of the “creative” visualization community is rising, due to the disrespect from established information visualization experts toward aesthetic approaches. The example of the abject response Nathan Yau received for his blog post “5 Best Data Visualization Projects of the Year” was already mentioned in section 1.2. The term “*information porn*” (Kosara, 2009a) is representative for the important part in the discourse as well. Lima (2009) uses the illustrative example of a wooden chair. Seat, back, and legs serve as metaphor for the data. The author argues that the optimal composition can only be determined under consideration of the ultimate goal: to sit. This perspective concurs with an intrinsic data focus. From an extrinsic point of view, there might be other configurations of the chairs parts that are very useful, and no argument is provided why infovis should not be used to explore this space of possible configurations, without a
lack of openness and flexibility of the infovis community towards new influences, emerging from tasks and possibilities that are currently evolving.

The central crux of this discussion is about taxonomy. Designer and programmer, working in the aesthetic gray area, aim for acknowledgement from the infovis community. This is a precondition for a scientific discourse and collaboration on the same level. By contrast, a central concern for many critiques is a clear delimitation of the fields of infovis and VA. The current discourse within the community shows that there is some vague fear that a big mass of projects of minor quality will damage the reputation of infovis as sincere field of science, expressed, for example, in (Kosara, 2009b). The calls for a clear separation of both fields grow louder, as Lima (2009) postulates in his information visualization manifesto. The attained banishment of ambiguous works entirely to the arts domain equals a shift of responsibility. IA works are difficult to evaluate by analytical categories, but the influence and criticism from established infovis is as important as aesthetic considerations.

2.3.2 Examples

In this section I will show the scope of the field of information aesthetic visualization by some remarkable works. Further, I will cover a couple of works that provided important impulses for the design of my own works.

We Feel Fine (Harris & Kamvar, 2006)

> *„We Feel Fine is an exploration of human emotion on a global scale"* (Harris & Kamvar, 2006)

Jonathan Harris and Sep Kamvar built this interactive online visualization on a data corpus of blog entries. From a big number of weblogs comments were collected that contain the fragment „I feel". A special data collection engine was created to automatically search all the blogs that are hosted on mayor hosting platforms, as *LiveJournal* and *MSN Spaces*. Specific feelings as "happy", "sad", or "tired" were extracted from the full text of the blog entries. Over the blog user profiles, demographic data are derived that create a context for the qualitative text snippets. Additionally, based on date and location, the weather at the time of writing is determined. Demographic data and weather are added to each blog post and function as filter criteria. The work provides different views on the data. The range goes from an analytic perspective, based on bar charts (Figure 24), to a vivid particle system (Figure 25). Feelings are color coded consistently throughout the application, with similar feelings having similar colors.

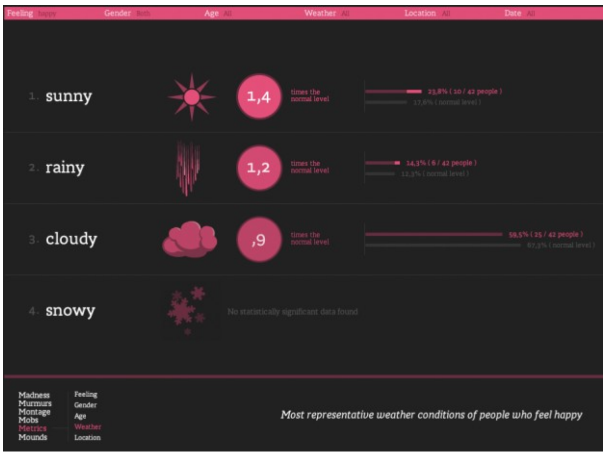

Figure 24. We Feel Fine - Metrics perspective

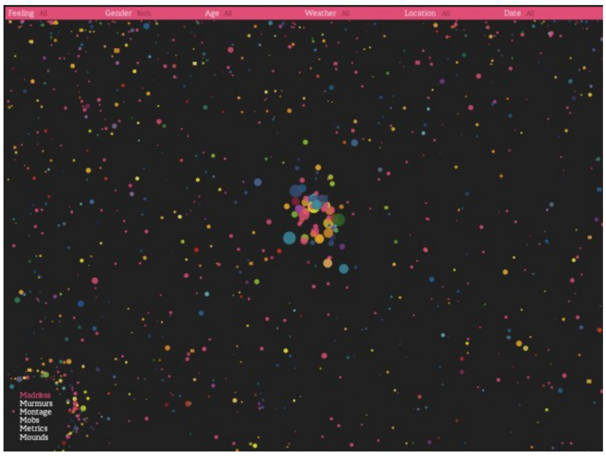

Figure 25. We Feel Fine: Madness perspective

This work fulfills several criteria of information aesthetics. The user is invited to interact in a playful way, to click on random elements and see what happens. On the other side, it is possible to find statistical information in a goal-oriented way. For example, how many female persons used the feeling *sad* in 2006 when it was raining. Of course, the used dataset has a high emphatic potential too. It enables a lot of detailed insights, but it also conveys a bigger message. Harris uses data mining and information visualization to extract the emotional, the subjective, the humane, from the widths of the Internet. He fosters awareness for the fact that, no matter how technical, frightening, and strange this new technology might seem, in the end every part of it was created by another human, not very different from ourselves.

The Dumpster (Levin et al., 2006)

Launched on Valentines Day 2006, the dumpster is a visualization of blog post gathered over the year 2005. With automated text analysis techniques there were 20.000 contributions isolated that tell about persons being "dumped" in the sense of "left by a partner". Over 50% of the authors of the weblog posts were American teenagers, aged between 13 and 19. In this the dataset creates the topic: the romantic live of teenagers. A random subset of the available blog posts is display as constantly moving bubbles on the screen, see Figure 26. Every bubble can be clicked to get the content of that post. All other bubbles then change their color according to a similarity measure, where dark means different and bright means alike. The perspective on those broken relationships is both analytic and personal. On the one hand side, there is abstract particle visualization; on the other, there are very personal statements from young people in a difficult situation.

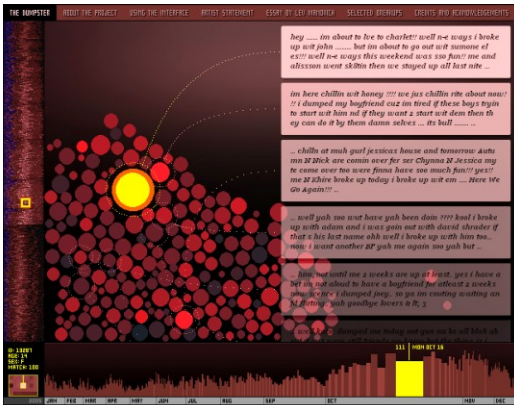

Figure 26. The Dumpster

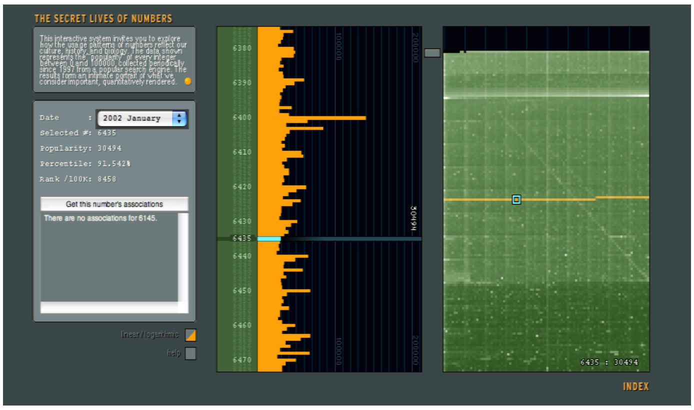

Figure 27. The Secret Lives of Numbers

The Dumpster makes use of the bigger degree of freedom that IA offers. The similarity measure for blog posts, for example, is not explained to the viewer, nor is intuitively understandable how exactly it is calculated, but it provides some intuitive guideline when browsing the information. This kind of irreversible mapping is not desirable in traditional information visualization, but in this case it initiates interest and engagement. It also provides a mean to create stories. After clicking an article, the user decides whether he or she wants more of the same posts or something completely different. This drives further interaction.

The Secret Lives of Numbers (Levin & al., 2002)

This work visualizes the frequency of numbers as they appear in the Internet. Frequencies for the integer numbers from 0 to 1.000.000 were accumulated over several years. Those frequencies are encoded as brightness values in a square matrix, see Figure 27. Some patterns that occur are immanent to the number system itself, e.g. repetitive numbers like 1111 and multiples of 10 are very frequent. Other patterns reflect socio-cultural circumstances, e.g. dates, postal codes or technical identification numbers. The concept of numbers is usually described as objective construct, based on logics. This work provides an impression of real usage, pointing out its subjective nature. As the author puts it:

> *"… the tool we would like to believe is separate from us (and thus objective) actually provides an intricate reflection of our thoughts, interests, and capabilities. One intriguing result of this symbiosis is that the numeric system we use to describe patterns, is actually used in a patterned fashion to describe."* (Levin & al., 2002)

Digg Labs (stamen design, 2006)

Digg is a successful online community project that provides a platform to share, rate, and comment on web resources. Links are marked as interesting, also called "to digg", and classified according to categories like Technology, World & Business, Science, Gaming, Lifestyle, Entertainment, Sports or Offbeat, and numerous subcategories. From the cooperation of Digg and the design and research studio *stamen design* the Digg Labs project emerged. Digg Labs aims for visualizing the activities on digg.com in real time. The project consists of five visualizations with differing degrees of aesthetic influence. A screenshot of each visualization is provided in Figure 28 to Figure 32.

Pics: visualizes photographs and images that were recently submitted by the community. For every category in the top level of the topic hierarchy exists a row of image thumbnails. These rows are filled from left to right. New pictures appear on the left edge in real time and push the existing content to the right. Hovering over a row makes the topic title appear. Clicking a row increases the size of its images. This view provides a well-structured and clear overview over the latest picture contributions.

Arcs: The basic layout of Arcs follows the Sunburst model (Stasko & Zhang, 2000). The hierarchy of digg topics and subtopics are represented in a ring-shaped structure, where higher levels are closer to the center. Elements are added to the hierarchy when matching links are newly added or visited by a community member. The center of the ring is not filled; leaving space for the title and some additional information about the entry that most recently changed. Additionally the usernames of the members, responsible for the activities, are arranged in a star-shaped layout next to the entry they affected. To depict the sequence of entries, visited by the same user, they are connected by orbital curves.

Big Spy: The headlines of recently digged entries are positioned at the top of the screen. Already existing entries are pushed downwards. A high number of diggs results in a big font size. The exact number is shown in red, attached to the right side of the headline.

Stack: Stacks is an animated bar chart. Contributions are initialized as bars with the same height. Rectangular blocks fall down from the top of the screen and pile up over popular contributions. In this, they represent the activity within the community. When the block hits the bar, the entries headline is pushed out of the bottom of the diagram, itself pushing older headlines further down.

Swarm: The most dynamic design is Swarm. Every entry that is visited by a user, is depicted as circle. The circles are distributed evenly over the display area and change their position in a floating way. Inside of each circle a cutout of the headline is visible as if peeking through a keyhole. When a new circle is added to the stage or the mouse is moved over it, the whole headline becomes visible. Users are represented by smaller, yellow circles. They move between entries and connect with them. When two stories are frequented by the same users a line connection is established between them, pulling them closer together. This line gets thicker for every shared user.

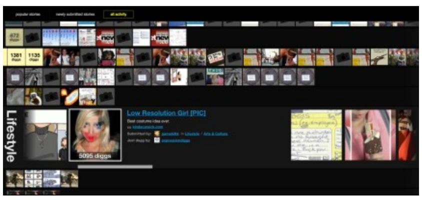

Figure 28. Digg Labs: Pics

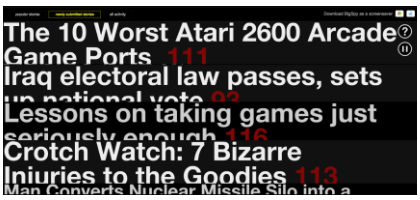

Figure 29. Digg Labs: Big Spy

Figure 30. Digg Labs: Arcs

Pics fulfills the criteria for infovis to a high degree. It effectively provides an overview of the most recent activities and does not contain many elements that increase the complexity of the visual representation without directly encoding data. Big Spy is a conservative approach as well. Animation and font color are used very directly to show temporal order and importance. As described by Stasko and Zhang (Stasko & Zhang, 2000) the Sunburst layout, as used in Arcs, is an effective way to make good use of the available space. Although being perceived by users as beautiful (Cawthon & Vande Moere, 2007a) the technique is to be assigned to the infovis domain. The curves connecting different articles that were digged by the same user show aesthetic characteristics. The curve radius is calculated, so that the curves bend is following a smooth track, even if this results in a loop that is much bigger than the display area and hence cannot be displayed as a whole. This makes it more difficult to follow the connection line in favor of visual appeal. The Stack design is strongly affected by aesthetic considerations. The animated blocks and the headlines that get pushed out at the bottom are fluently animated and very appealing but not efficient in communicating the simple fact that a user voted for an entry. Swarm is the most aesthetic visualization of this set. The mapping of the date to the behavior of the particles is very interpretative. The movement is fluent. The connection lines have an elegant bending and the cutout of the headline text inside the circle creates a more interesting visual impression. This keyhole metaphor does not only give a clue that there is more information to be accessed; it also reveals a very little part of it. Its might not be sufficient to communicate any meaning but it raises the desire for more.

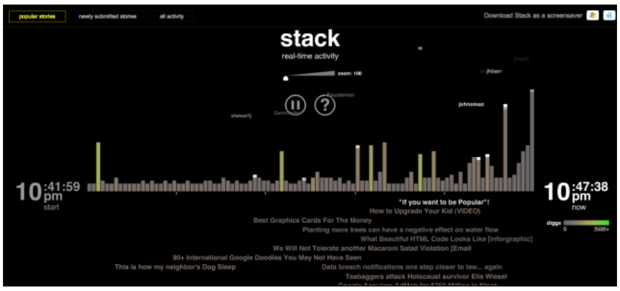

Figure 31: Digg Labs: Stack

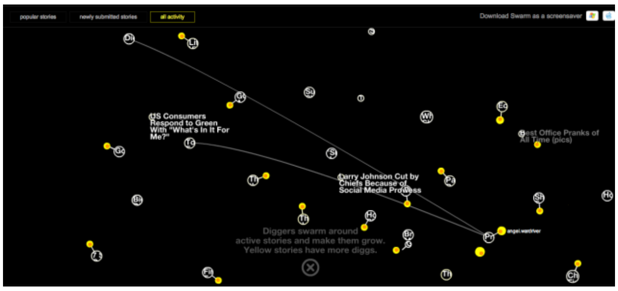

Figure 32: Digg Labs: Swarm

Artifacts of the Presence Era (Viégas, Perry, Howe, & Donath, 2004)

Artifact s of the Presence Era is a digital installation. The visualization is based on video and audio data that are collected in a museum's gallery. Those data are converted to create an image, following the visual metaphor of sediment layers, see Figure 33. The visualization does not aim for explaining details of the data. It focuses on bringing out the temporal patterns over a longer time span. The metaphor of geological layers harmonizes with the time dimension of the data. The viewer is put in the position of an archeologist, who explores the history of the museum through the stacked image and sound fragments of the past.

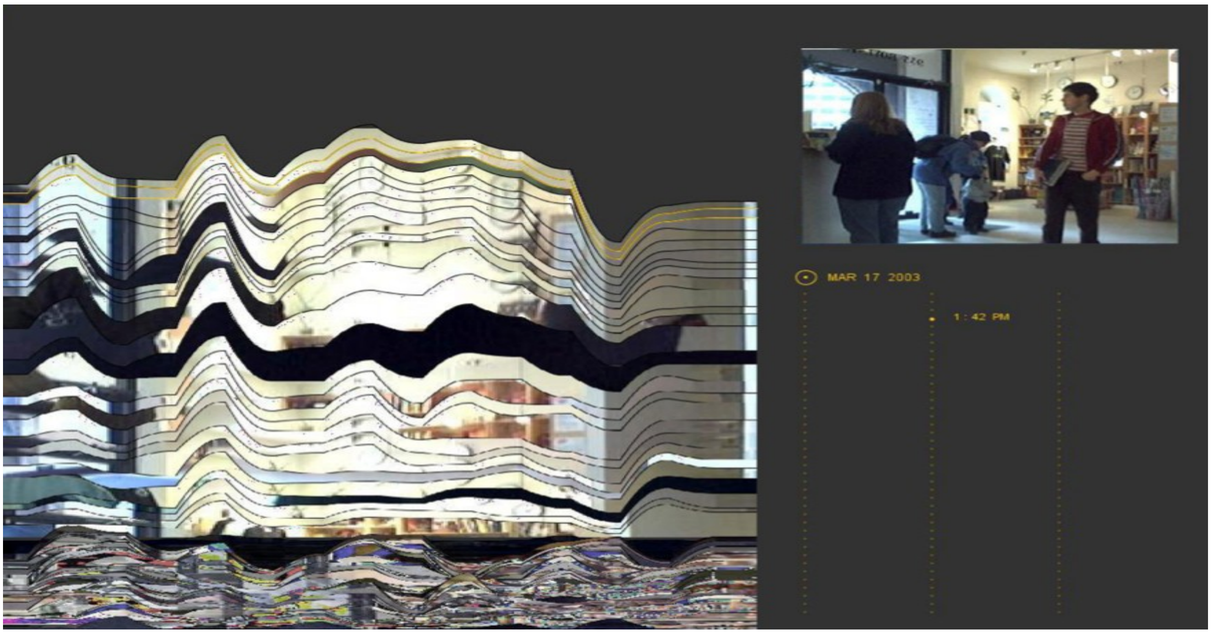

Figure 33. Artefacts of the Presence Era, 2004

The installation comprises a camera, a microphone and computers. Every layer represents an interval of five minutes. Its contour is derived from the wave representation of the recorded noise in the room during that time. As texture a special still from the video recording of those five minutes is used. The selection of the still within the timeframe has a random component, but stills that contain persons are favored to create a focus on the visitors. When the noise level in the room is high, the layer for that time gets thicker. In this way a visual representation of the degree of activity in the museum at a certain time is created. Following the analogy to geological structures, the lower layers in the visualization are exposed to higher pressure and hence compressed vertically.

No formal study was performed on the viewer reactions, but their behavior was observed informally. The authors identified the aspect of temporal evolvement as one of the most appealing features of the work. An element that breaks with traditional infovis rules is the random choice of the texture picture. It is possible that the most interesting moment in the interval is not depicted in the layer. There lies potential for broader application in this visualization design. All sorts of digital archives seem valid.

Shape of Song (Wattenberg, 2001)

The arc diagram technique (Wattenberg, 2002) is especially suitable to visualize repetitive patterns in strings of symbols. The resulting picture shows pleasant and expressive arc shapes, conveying the structure of the underlying data, as can be seen in Figure 34. Various applications are possible. *In Shape of Song* Wattenberg uses arc diagrams to visualize pieces of music. The combination of appealing arcs and the emotional engagement through the songs creates an aesthetic effect.

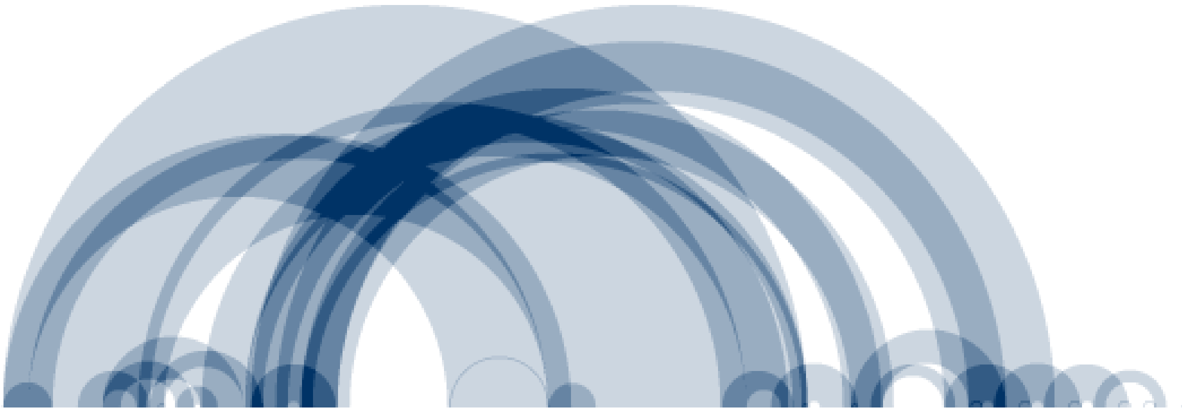

Figure 34. Arc diagram for Personal Jesus, Depeche Mode

reMap (Bestiario, 2009)

Visual complexity is a huge collection of network visualization projects. ReMap is a meta visualization of the projects that are collected on visual complexity. The core of reMap is an innovative interaction concept. A special engine is used to assign tags to every project. Navigation is possible through a list of those tags at the bottom area of the screen. The font is scaled according to the number of occurrences of every tag, so that more significant terms are more dominant in the layout. Additionally a fisheye-lens effect is applied. This effect makes it possible to display a long list of items in an appealing way. The main display area of reMap is filled with screenshots of visualizations. This layout can be seen in Figure 35. When clicking on a list entry, the main area is restructured so that only projects remain visible that connected to the selected tag. The selection of multiple tags is possible. When the mouse is moved over a thumbnail, project details are shown at the bottom instead of the tag list. Those details contain a list of all the tags that have been automatically assigned to the project.

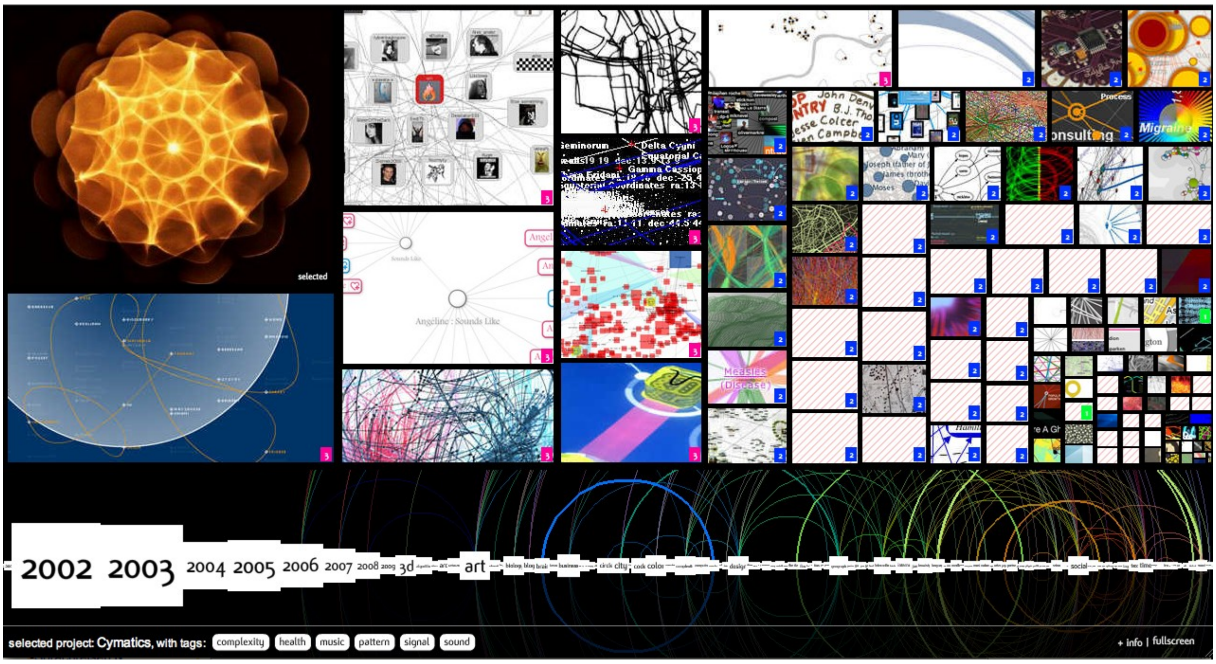

Figure 35. reMap

The reMap visualization is a browser for the data from visual complexity. The user is not expected to search for a particular entry but to enjoy the interesting pictures and to investigate some of them in more detail, according to his likings and mood. The main objective is to keep the user engaged for some time not to provide him or her with specific information as fast a possible. Therefore reMap contains a broad range of design techniques that are not mainly motivated by efficiency but by aesthetic reasons.

Streamgraph (Byron & Wattenberg, 2008)

The Streamgraph concept is based on the stacked-graph principle and displays important features of information aesthetic visualization. Stacked graphs are used to display the temporal change of the value of a measurement, with regard to its subcategories. Line graphs of the time series for the subcategories are stacked on top of each other. The overall contour of this stack shows the development of the super ordinate measure. The Streamgraph technique adapts this concept and changes the base line of the visualization, that traditionally coincides with the x-axis. In a Streamgraph, the base line is changed to maximize overall symmetry around the x-axis. This leads to a horizontally floating, and winding shape. Smoothing the graph contours to curved lines enforces the floating appearance. This technique was first used for the visualization of data from the online music platform *last.fm*

(Last.fm Ltd., 2009), see Figure 36. The frequency of different artists and groups, which were listened to by a user, were visually displayed to him or her by a stacked graph.

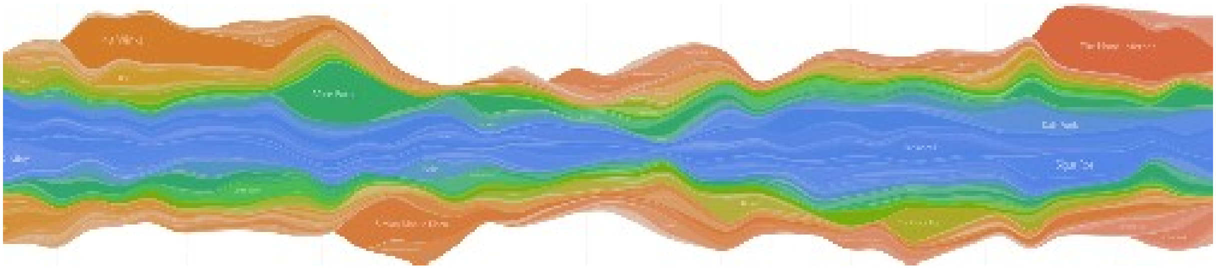

Figure 36. Streamgraph of a personal last.fm listening history

Qualitative statements from people who were confronted with those visualizations show how the emotional component of the underlying data has a special importance for information aesthetic visualization. The users are emotionally connected to the music they hear and they can draw lines between happenings and periods in their lives and their favorite music at that time. Byron and Wattenberg mention a person who was able to locate three different relationships on the timeline via the different music he was listening to. Another person found how the death of her dog had impact on her listening habits for about a month. There lies no analytic insight in this, but the possibility to find out something about the own personality. In some cases it can even tell the story of a particular chapter in a persons life.

2.4 Summary

In section 2.1.1 an overview of the scientific field of visualization is provided. A broad range of subfields with their specific characteristics was described, to show the diverse and partly inconsistent taxonomy of this field. The detailed description of the infovis domain, together with the taxonomic overview, constitutes the foundation to investigate one classification criterion in more detail: the influence of aesthetics on infovis. The examples for infovis, in section 2.1.2, are mainly focused on web services, targeted at a broad mass of non-expert users. Those projects show how public data sources are made accessible and understandable for a mass audience. This shows the new field of applications for infovis that emerged through recent developments.

Section 2.2.1 contains several concepts that contribute to the interesting interplay between infovis and visualization art. Abstraction as a tool to make reality understandable is central to both fields, as is the anti-sublime philosophy of creating images that are comprehensible by the human mind. Ultimately the transfer of information, a message to the user is the ultimate ambition. There exist several elementary concurrencies. The difference lies in methods and topics. To provide an overview over current visualization art practice a diverse set of works is presented in section 2.2.2. Some are following an anti-sublime approach, as described by Manovich (2002a), in directly depicting numbers that lie seemingly beyond comprehension. Other pieces are sublime and raise curiosity for a matter by obscuring it in an artful way that, on the other side, brings out features of the source data, which are rarely considered under conventional conditions.

Section 2.3.1 examines the transition area between art and infovis that is central for this thesis. After discussing different concepts for bridging the apparent gap in taxonomy, the domain model of information aesthetics (Lau & Vande Moere, 2007) is introduced. Based on this model, further considerations about the advantages of aesthetics in the visualization domain are made. To clarify the motivation for this work, the current discourse in the infovis community, about delimitation of VA and infovis and the harmful influence of aesthetics on the reputation of information visualization is described. The model of information aesthetics complies with all those concerns. It preserves infovis as analytic discipline, focused on solving concrete tasks and mapping data directly. Simultaneously it provides a robust frame for the transition zone towards visualization art. Data focus and mapping focus are instruments to position a work in the suitable context and make its intention transparent to the user. The aesthetic visualization examples are spread over the whole range of this field. Several examples are aesthetisized infovis techniques and hence very close to infovis. Others are built around topics that are more familiar from the arts context and use a much freer visual language.

All three domains are, per definition, very visual, what makes concrete examples and illustrations invaluable for a sound analysis. After explaining the most important theoretical concepts and analyzing the state of the art in practice, all necessary preparations are taken to start with description of the prototype design.

3 Prototype Design

As foundation for an extensive study about the specifics of information aesthetics and its relationship to information visualization and visualization art a set of three visualization prototypes was designed and implemented according to the characteristics of IA, VA and infovis. The practical work is the main part of this thesis and is described in chapters 3 and 4. This section provides a detailed description of the design process. The main structure consists of one section for the previous work on this topic and one section for each visualization prototype that was implemented:

3.1 AOL-Data Prototypes

3.2 Information Aesthetic Prototype Design

3.3 Visualization Art Prototype Design

3.4 Information Visualization Prototype Design

Section 3.1 is dedicated to the situation when I started working on the project. Section 3.2 describes the different stages and approaches of the information aesthetic design process. This was the most complex part of the design process and also provides a sound foundation for the design of the other prototypes. Section 3.3 is about the process of visualization art design and compares them to the results from the IA considerations. Section 3.4 illustrates how standard infovis techniques were used to create an appropriate representation of the *NYT* article dataset.

It has to be considered that the design processes for the VA and infovis prototypes were temporarily interwoven with the more extensive IA design process. They heavily rely on the results for the IA design, so they are covered in two separate sections after the complete description of the IA design process.

In general the exchange of ideas and information between the project members in Sydney and me was structured by videoconferences that took place in intervals of one or two weeks. A set of sketches and concept descriptions, and later program versions, was prepared and sent beforehand. These were then reviewed and discussed during the conference. By sorting out invalid concepts and investigating their flaws the criteria for our desired products became more and more clear. In the later stages of the design process the review conferences served the important but tedious purpose of improving all the minor flaws that deteriorated the visual qualities of and the fluent interaction with the prototypes.

3.1 AOL-Data Prototypes

The first part of this section describes the status quo of the project when I joined it. A considerable amount of effort was already put into the development of a study setup, but the results were not satisfying. Section 3.1.1 gives an overview over three already implemented prototypes, based on AOL data. Section 3.1.2 sums up the main problems that this approach showed. In section 3.1.3 the original AOL dataset is discussed and the New York Times article search API is introduced as alternative.

3.1.1 Prototype Overview

When I joined the project in spring 2009 there already existed a set of three prototypes that was created for the same purpose of performing a user study. They are based on the data stock of user search terms, released by AOL in 2006. The publication of those data led to a nation wide scandal. The data were seemingly made anonymous, but the search terms themselves often made an identification of the users possible, e.g. through searches for driver's license IDs (Arrington, 2006).
The conceptual idea was to make it possible for the viewer to compare two people, by comparing their search habits. Following this concept the data of two persons were taken from the dataset of search terms, further referred to as *user A* and *user B*. A hierarchical temporal structure was then applied to the data. There are several levels of detail. The first view is an overview over 14 weeks. A week can be clicked to show details about every day. Every day can be expanded to show the hours and an hour can be decomposed into intervals of 10 minutes lengths each. For each interval the overall number of searches together with the most frequent search phrase is displayed. In the most detailed view, all the search phrases are accessible. For the infovis prototype a bar chart design was chosen. The time dimension was mapped on the x-axis, the number of searches was shown via the bar height on the y-axis, see Figure 37.

The IA prototype has several aesthetic features. The general layout is not paraxial. The hierarchy of the dataset is arranged horizontally from left to right. At the beginning only two blocks are visible for *user A* and *B*. On click, lower levels in the time hierarchy can be expanded by the user, see Figure 38. The elements of the selected hierarchy level are shown as blocks. Inside these blocks exemplary search phrases are displayed, following a news ticker metaphor. On mouse-over the text scrolls horizontally, letter by letter. The typical click sounds-effects are played to strain the similarity. The transitions between different hierarchy levels are animated and smooth and enriched by acoustic stimuli.

The VA prototype is based on a flower layout. Every level in the temporal hierarchy is represented by a flower with a certain number of petals. At the peak of each petal lies the origin for a smaller flower, visualizing the next level. Tags, describing search terms and points in time, are displayed on top of the flowers. The whole layout is colored in shades of red and pink, see Figure 39.

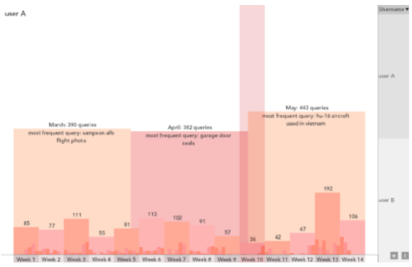

Figure 37. Original infovis prototype

Figure 38. Origianl IA prototype

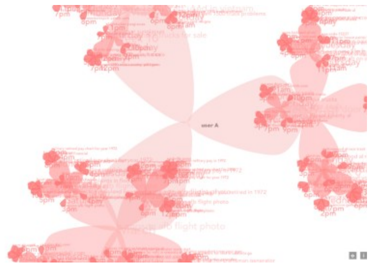

Figure 39. Origianl VA prototype

3.1.2 Main Problems

An important factor that complicated the realization of the initial approach was an overweight of design expertise in the project team, versus programming skills. This makes it very difficult to bring the high prospects and demands into accordance with the technical possibilities. Performance is another critical issue. Especially the visualization art prototype does not run fluently. A lot of experience is necessary to make a prognosis about the performance of a visualization concept. There are several techniques how the performance can be improved when the implementation of an application already is in an advanced state. They as well require a lot of previous knowledge about the technology in use. But if the desired fluency is not attainable after all, it can become necessary to redesign the whole application.

3.1.3 Data

In information visualization the dataset is usually given from the beginning of the design process. In the given situation it was beneficial to decide for a dataset at the beginning as well. This provided a fixed point that limited the vast design space. The dataset had to show some special features to be valid as a base for a showcase IA visualization. The awareness that only the same data set for all three prototypes can lead to a fair comparison was already stated for the first set of prototypes. When looking at the IA works in the related work section, it is remarkable that the underlying data often has a high emotional potential. It is data that most people have a personal connection to. The most striking examples are *We Feel Fine*, *The Dumpster*, and *The Secret Life of Numbers*, see section 2.3.2. To bring out the characteristics of information aesthetic visualization it is important to use a dataset that enables the same immersion. A second important point is mentioned by Chen in "Top 10 Unsolved Information Visualization Problems" as *prior knowledge* (Chen, 2005). For the study to be successful with non-expert test subjects the prior knowledge, necessary to understand the data, should be as low as possible. The knowledge that is needed to operate the visualization should be minimal as well.

Two datasets were considered at the beginning: the AOL search data (Arrington, 2006), used for the AOL-data visualizations, and data from the, at the time of design newly released, New York Times Article API (The New York Times, 2009a).

Both datasets seem suitable for the project. The NYT data is likely to be more intuitive since it is very similar to the widely known concept of printed newspaper articles. The work with this API is especially interesting because it is one of the boldest efforts of traditional print media to make a transition to the new ways of the Internet age. The simple reproduction of the print content on a website, as it is done by nearly all mayor newspapers, does not make use of the full potential of new Internet technologies, nor does it provide a useful concept for the financial compensation for the consumption of services. The *New York Times Article API* is one of several capacious and innovative services that have been recently launched especially for developers. Articles, activated since 1981, are accessible free of charge. It is possible to create complex search queries that are based on search terms and phrases and apply them on the whole article content or only on the headline. Those Searches can be limited to particular intervals in time. Additionally a big tag set is accessible to refine the queries as well as to structure the results, see section 4.1 for technical details and an example. Some restrictions do exist however. The articles full text is not accessible but the content usually is summarized in an accessible abstract. The number of detailed article descriptions within a query result is limited to ten. To get all the detailed results for a query, several requests have to be used with a changing offset parameter. And there is a limited number of queries per account and second, which can lead to bottlenecks, especially in combination with the need for sending several request to retrieve one big answer data set.

Several concerns, regarding the AOL dataset, promoted a change. At first it was problematic that the data was already discussed in a broad range of other works and publications, from blogs and newspapers, to movies. So there was no effect of exciting novelty about this dataset. Secondly the dataset is huge and most of the search terms merely reflect the average usage of search engines. It is true that very revealing user entries do exist but they are scarce. In the AOL-data visualizations this was solved by preselecting two users. This is a major interference with the dataset and could lead to criticism. Thirdly the dataset has a very specific structure. It consists of a big number of small qualitative data entries. To create a truly engaging visualization I consider it necessary to facilitate a way of semantic interaction with the data. Every search term would have to be analyzed on a qualitative level to make semantic patterns visible. For a data-analyst, for instance, a generalization of the search topics over a certain time span would be of high value. For example, when a user was searching for different models of cars over two hours an aggregation and simultaneous abstraction would be highly desirable. Probably due to the huge effort for the implementation of an automated system for the semantic classification of terms, this was not done. The strategy to structure the data was to apply a temporal hierarchy onto them. The qualitative information was covered by random samples of search terms on every temporal level. The main problem with this solution was that the contrasting element of the data was not clear in the visualization.

The decision about using the data from the New York Times Article API (The New York Times, 2009a) instead of the AOL (Arrington, 2006) was taken before the start of the design process. This fundamental change made a complete redesign of the AOL-data visualizations necessary.

3.2 Information Aesthetic Prototype Design

Since the characteristics of IA visualization are the core topic of this project, the design of the information aesthetic visualization prototype had the highest priority. An inconsistency in this concept could endanger the credibility of the subsequent study. The visualization art and infovis prototypes were synchronized with the results from the IA design process. So the subsequent proceeding was to design the VA and infovis prototypes, relying on the finished IA concept.

Section 3.2.1 is dedicated to the early phase of free brainstorming, where many different approaches were discussed to coordinate the agenda of the project supervisors, who will later perform the user study, and my own interpretation of information aesthetics. Later in this stage the focus successively shifted towards theoretical considerations. Section 3.2.2 addresses how technical aspects were included into the development process to handle the huge data set and to create realistic visual representation. At the end of this phase the most important design decisions were settled and the coarse concept was stipulated. In section 3.2.3 the final prototype is described and analyzed regarding its accordance to the major criteria for information aesthetics.

Design descriptions and sketches as well as theoretical considerations substantiate the conceptual progress that was achieved during each phase. It is important to show, how the design process affected my understanding of the field of information aesthetics and the features that have to be regarded in the subsequent user study.

3.2.1 Brainstorming and Sketching

After the decision about the data set, there was a phase of brainstorming. It was important to identify the boundaries of information aesthetics. To create a deep and complete overview for the field of information aesthetic visualization I examined it from various perspectives. This is reflected by the broad range of different approaches among the design ideas.

The design took place in parallel to the evaluation of existing works in the IA field, see section 2.3.2, and to the research of relevant literature. Consequently the criteria for information aesthetic design were not conclusively defined during a big part of the design process. Due to this, particularly the early design approaches may show severe flaws, regarding certain IA aspects. Those approaches will be mentioned nevertheless, since they substantially contributed to the definition of the criteria and vice versa.

In this section I will apply a structure on the big number of sketches and ideas that resulted from the brainstorming, and describe them in detail. The structure I chose is based on source of inspiration that fueled the design process. Three categories are used: *Existing Information Aesthetics Work*, *Information Visualization Techniques*, and *Visual Metaphors*.

I started by taking existing IA concepts and changing them according to the needs for the project. I moved to augmenting information visualization techniques because this was a better approach to generate independent and innovative work. With growing experience it became possible for me to use visual metaphors with as starting point for own concepts. It can be observed that the examples get continuously more abstract. This reflects the growth of independent contribution I was able to provide for the designs.

The determination of the NYT article API as source for the dataset was only a vague guideline for the exact structure of the final dataset. This made the design process volatile in the beginning. There were still infinite possibilities which part of the available data should be taken, what preprocessing should be applied and how the result should be structured.

Sketches Based on Existing Information Aesthetics Work

Considering the sophisticated works in the continuum between infovis and visualization art, of which some were described in section 2.3.2, I created my first own designs using them as starting point. While changing those existing concepts it becomes apparent which of their features are essential for an IA visualization work.

Last Clock:
An early approach was inspired by “Last Clock” (Cooper & Ängeslevä, 2004). The display area is round. A line from the center of the circular display to the border is the only active element of the concept. It moves like a clock hand and redraws the display content constantly.

The hand itself is a top view of a line chart; this looks like a line that has different colors, according to the chart line that's on top at that special point in space, see Figure 40.

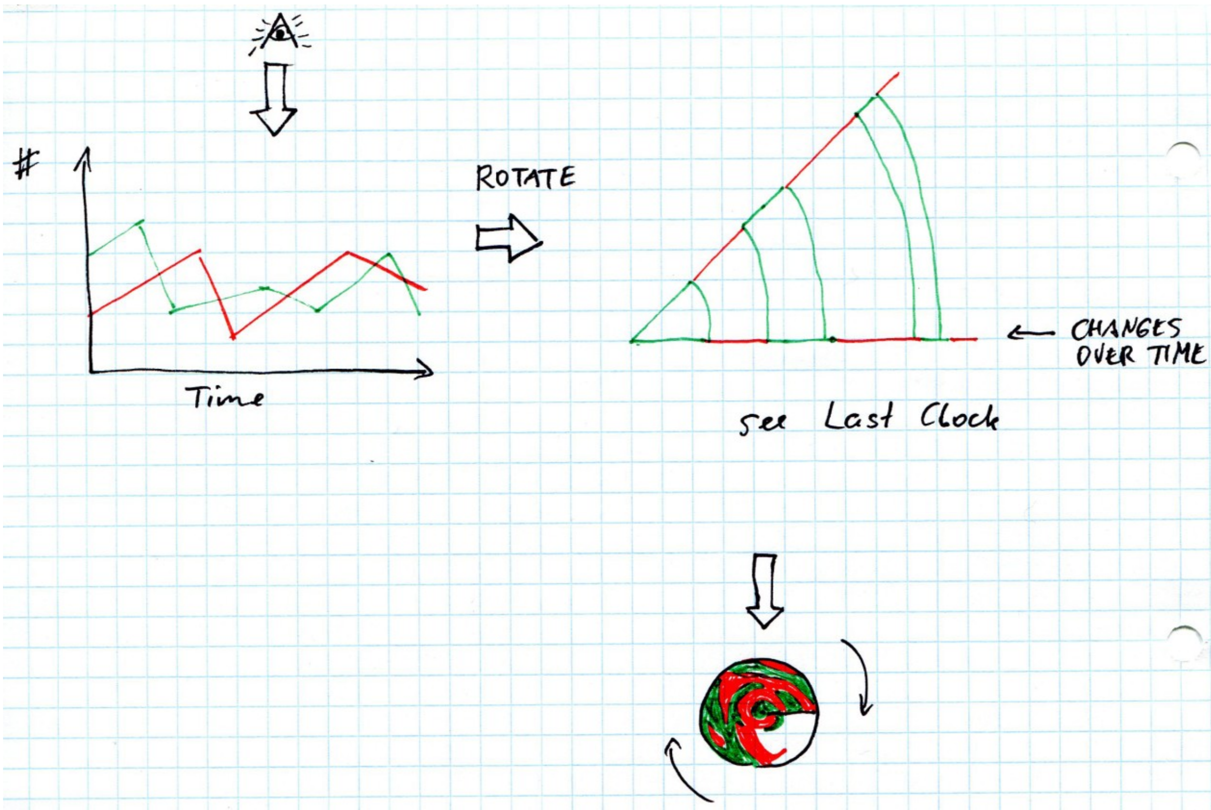

Figure 40. Design based on Last Clock

Growing Facet Tree:

The growing facet tree is a treelike structure that visualizes a growing degree of detail while following the branches from the trunk to their ends. A hierarchy of term proximities is necessary as data. The first level is formed by the most frequent terms in an articles subset. Then the words that occur most frequently in the same sentence are arranged one layer deeper. The next layer will be words that co-occur with the terms from both higher levels. For example: Obama is the most frequent term. In many cases he is addressed as Senator Obama. Sometimes it is mentioned that he is Senator of Michigan. The resulting tree could look like Figure 41. This design was inspired by *ecotonoha* (NEC Corporation, 2003).

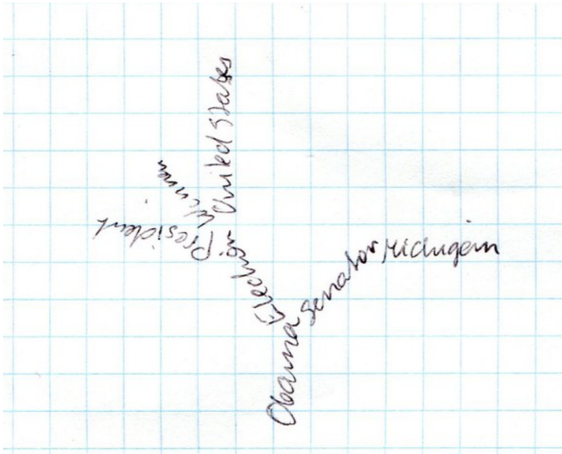

Figure 41. Growing Facet Tree

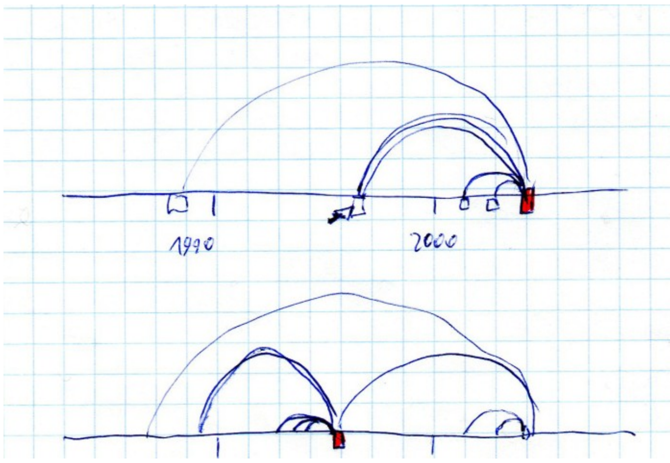

Figure 42. Time Travelers Guide

Time Travelers Guide:

The visual design of the time travelers guide is based on *The Shape of Song* by Golan Levin (Levin & al., 2002). The conceptual background is similar as well. When starting the visualization the user is presented a time line. The first step is to click on a specific date. Starting from that date arcs emerge, forming connections to earlier dates with similar characteristics. This similarity can be determined, for instance by the occurrence of the same person on both dates. To get more details about connected points on the time line, they can be clicked as well. Recursively arcs are displayed for them, pointing to semantically similar dates, see Figure 42. To show the intention of this visualization I formulated the following question: “If a time traveler would come to our time from a distant past, what would he need in order to understand what is happening right now?” or more prosaic “What previous knowledge is needed to understand today’s articles?” It is possible to follow people or constellations of people, like Kohl, Bush and Gorbachev, through time, to see how their careers started and with whom they were connected. The same is possible for other categories such as countries. The desired effect is to enable the creation of personal paths through the articles archive, by selecting the connections that are subjectively the most interesting ones.

Particle approaches:

From the beginning of the design process particle systems provided the base for many sketches. The concept of particle systems is used in several showcase IA works (BBC; Harris & Kamvar, 2006; Levin et al., 2006). It offers the possibility to show a big number of entities, preserving them as autonomous objects. Movement in two-dimensional space enables a big variety for design strategies. Possible techniques to use this to increase aesthetics are the simulation of swarm behavior or physically accurate behavior with ball-like bumping and collision detection. Through their big number even plainly designed particles can produce a rich and interesting image. This is an example of how information aesthetic visualizations make use of known techniques from other fields of science and de-contextualize them. Physical features, like momentum, are used to encode other information. For example all particles with a certain feature can be drawn to the same point on the screen. A practical application of this strategy is the *Mobs* perspective in *We Feel Fine*. Filter criteria are represented by symbols. When a symbol is selected, the blog-entry particles moved towards it and arrange themselves within the outline of that symbol (Harris & Kamvar, 2006). Particles are very versatile and can be easily combined with other concepts, as we will see in other concepts within this chapter.

Sketches Based on Information Visualization Techniques

Another approach to generate aesthetic visualization techniques in the early stage of the design process was to take standard visualization techniques and increase their aesthetic quality. Several basic designs emerged from this strategy.

Melting Bar Charts:

The change of values over time is often shown by *bar charts* with growing and shrinking bars. To increase the emotional engaging value, this change could be augmented by an animation of snow falling on top and snowmelt dropping from the bottom, see Figure 43.

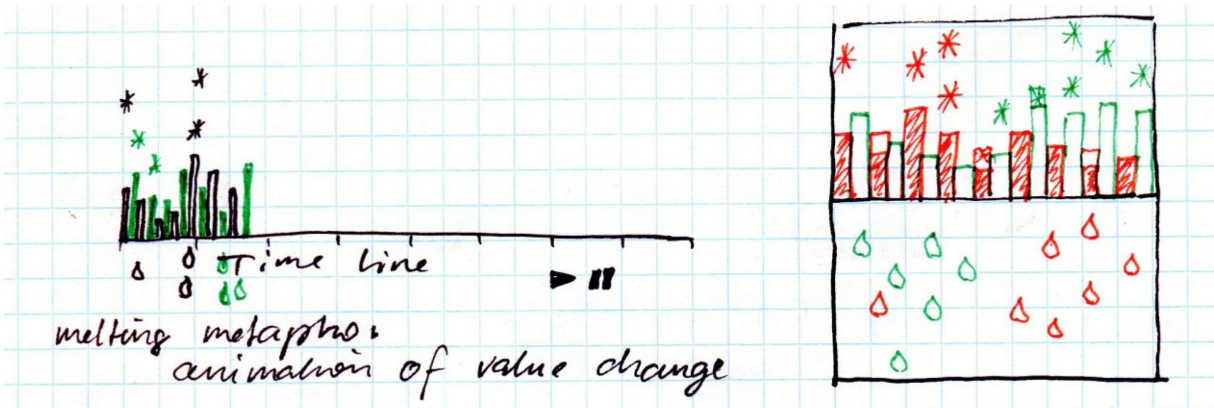

Figure 43. Melting Bar Charts

Information Avalanche:

Following the conceptual topic of weather, more precisely snow, I replaced the bar chart by a more fluid shape similar to *Streamgraph* (Byron & Wattenberg, 2008). Layers, composed of article headlines, are moved into the display area from the left side of the screen in a temporal order. The most recent layers sediment on top of the older ones, while those close to the very bottom start to melt end get thinner and thinner. The element of melting layers brings this approach very close to *Artefacts of the Presence Era* (Viégas et al., 2004). It happened several times, that a concept matured and got successively closer to an already existing work. Although it was frustrating to discard those approaches, this showed that I was following similar principles as well established designers.

Circular Treemaps:

Inspired by circular *TreeMaps* (Bederson, Shneiderman, & Wattenberg, 2002) a design was developed, that combined a set of circles, each representing an article, to a compound-eye-like structure. The iris in this eye metaphor was intended to be used for color-coded articles according to some categories. The pupil would show the active category with a highly saturated and dark color in the center.

From this approach a more graphic mapping was deduced. The concept was to use a human eye and its natural behavior to show the data.

Text Visualization:

To attract the attention of the user right from the beginning and to direct it onto the article content, it is reasonable to make parts of the text available in every perspective on the data. Techniques for direct text visualization hence are an interesting starting point. There are several prominent examples for that kind of text visualization, e.g. *Wordle* (Feinberg, 2009) - see Figure 55 and Figure 56. Based on those I created two concepts called Info Pollution and Info Rain. In Info Pollution the rough visual metaphor of a smog cloud is adjusted on a tag cloud. For a certain term other terms from associated articles are gathered and displayed around and over the original term. So the term is more and more obscured by the connotations that are supplied by the articles.

The combination of particle design and standard infovis techniques representation resulted in several concepts:

Word Rain:

Several search terms can be selected and are then displayed on the bottom of the display area. Article headlines start to rain down on fitting search terms. The terms start to grow, according to the incoming number of headlines, as depicted in Figure 44.

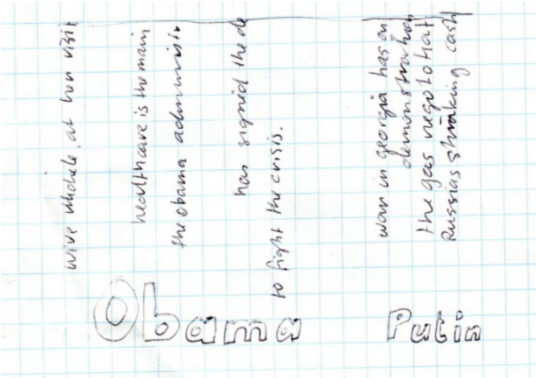

Figure 44. Word Rain

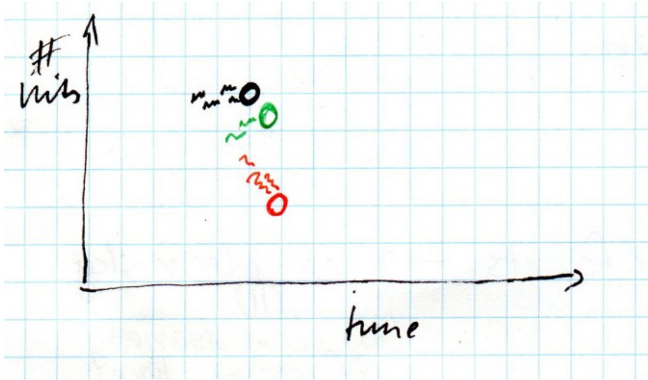

Figure 45. Line Chart Comets

Line Chart Comets:

For this design the general layout is similar to a line chart. The number of hits for a selected topic is mapped to the y-axis; the x-axis depicts a time scale. The essential visual clue is that the trend is not visualized through a line but through the movement of a round topic particle. This particle moves from left to right, making the change of the underlying value visible by its y-displacement. The development of the frequency of a certain search term in the NYT articles over time can be displayed with this concept. As the tag-particle traverses the timeline, related terms attach to it and follow it, forming a comet tail, see Figure 45. The degree of connection between two terms can be measured by evaluating the number of occurrences of both terms in one article. The comet loses those tags again, in times when no strong connection exists.

Visual Metaphors

After analyzing a large number of IA and infovis works, see section 2.3.2 and 2.1.2, it became more and more clear how the information mapping can be accomplished. This makes it possible for me to follow more independent design approaches that do not rely directly on other works. As starting point for my design considerations I use appealing images that have a certain level of detail. Sometimes structures within such images are especially suitable to display information. The essential step is to find similarities in the structure of the data and the image and to accentuate them. Design decisions are made with the aim to reduce the visual gap between the data visualization and the guiding visual *metaphor*. The aesthetic component from the original should be preserved as far as possible or even amplified. Metaphors are a useful concept in infovis, or as Vande Moere (2005) puts it:

> *"Metaphors in visualization are used to help users understand systems in conceptual terms they already know, by appealing to initial familiarity and experience."*

News radar:

One of those concepts is based on a radar screen. At first it might seem very similar to Last Clock but in fact it is only the visual metaphor that's alike, the concept differs considerably. With its round display, its constantly rotating clock arm and its typical sound a radar screen has the potential to create an aesthetic and interesting stage for information visualization. The arm that redraws the screen can be used to show the time dependency of the data by drawing visual entities on the display in chronological order. Older entities are fading away slowly. The clock arm can also act as filter, drawing entities according to certain criteria, for example if they contain a certain tag.

Dada visualization:

In the history of arts there exists an interesting movement that inspired a set of design concepts. The collages of *Dada* artists often include a lot of newspaper snippets. Together with other pieces of papers they were glued on a canvas. The resulting texture was used as ground for other shapes and motives that were painted with oil colors. For information aesthetic visualization the text of the articles from the API could be used to generate snippet like shapes. They would form the background. In the foreground statistical data in the form of line charts or scatter plots can be displayed. To enforce the analogy to the historical original painterly rendering techniques could be used (Hertzmann, 1998). In general, the *Dada* artists did not transfer the original rectangular outline of the newspaper articles into their pieces. They tore apart the newspaper pages, creating uneven shapes with zigzag contours. The resulting collages were far more dynamic, or even chaotic, than the original layout. The same technique could work in the context of information visualization techniques like *TreeMaps* (Bederson et al., 2002). In *Newsmap* a *TreeMap* is used to display news content (Weskamp, 2004). Combining the *Dada* style with the *TreeMap* idea would provide a good design, preserving the additional information that is provided by the *TreeMap*. So this approach is a combination of the visual appearance of an art style and the data mapping of an information visualization technique, see Figure 46.

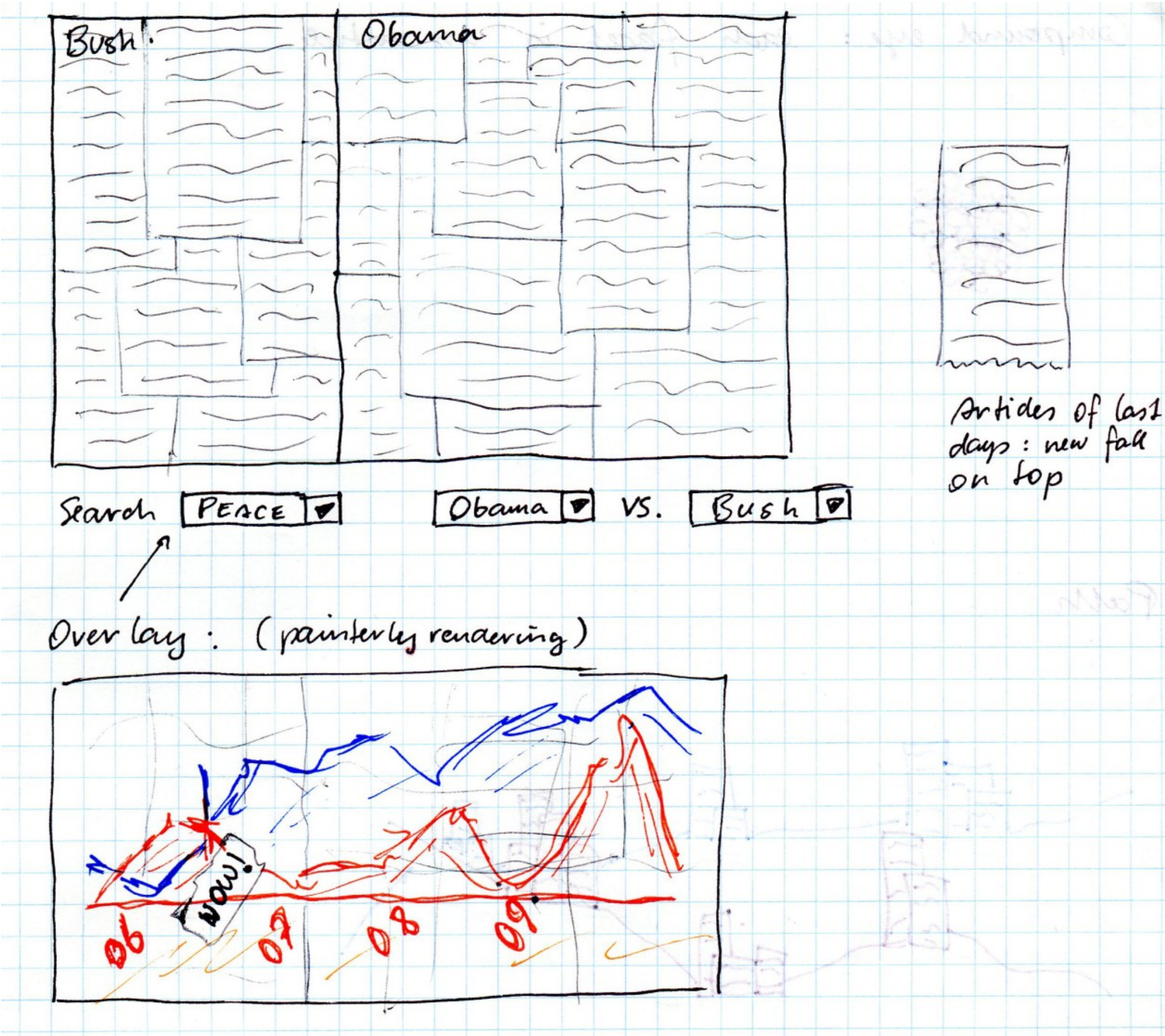

Figure 46. Dada art on TreeMap background

Bionic visual design:

It is common practice in contemporary science, to rely on concepts from nature when searching for efficient solutions for technical problems. In the context of information aesthetic visualizations, nature is a rich resource. Using examples from nature has several advantages that apply to IA in particular. Natural structures are often very detailed and diverse. There are many biological processes associated to them, like growing and movement that are interesting for the beholder and convey a sense of beauty.

For my task I found the compound eye of insects to be an interesting structure. Every one of the hundreds of ommatidae, bio-optical units, works as an autonomous entity. The combination of all their results produces the mental universe of an animal in its brain. Here a conceptual connection to the news topic can be established. For modern humans the mental image of the world strongly relies on the information they get from the news. Many little bits of information contribute to the way we see other countries, politicians, and enterprises. A compound eye with articles as facets was the result of this consideration, see Figure 47.

This concept was analyzed, discussed and then restructured, leading to a change of focus. I followed the promising idea of using eyelike behavior, like blinking and pupil movement, to encode information. To make this behavior more credible a redesign of the insect eye to a more human appearance was necessary. The articles are represented by circles and arranged inside the iris, sorted by topics, for example occurring people, occurring countries or newspaper sections. Every topics outline is circular as well. This design relies on the instinctual interpretation of eye movement by humans, see Figure 48. The eye movement metaphor implies immediacy, the reaction to current events, so the inclusion of a second data source that provides real time data is desirable. A valid solution would be to use the *New York Times Newswire API* (The New York Times, 2009b), which provides new articles the moment they are published online. The topics of currently added articles can be used to change the focus of the eye. Visually this would be realized by making the current topic in the eye denser or more saturated, giving it the appearance of a pupil. So the eye would change its line of vision according to breaking news.

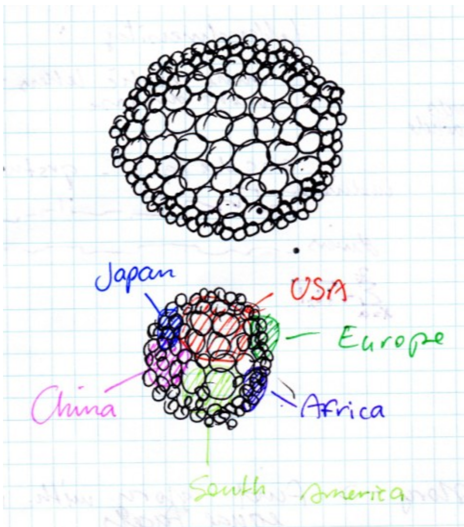

Figure 47. Compound eye

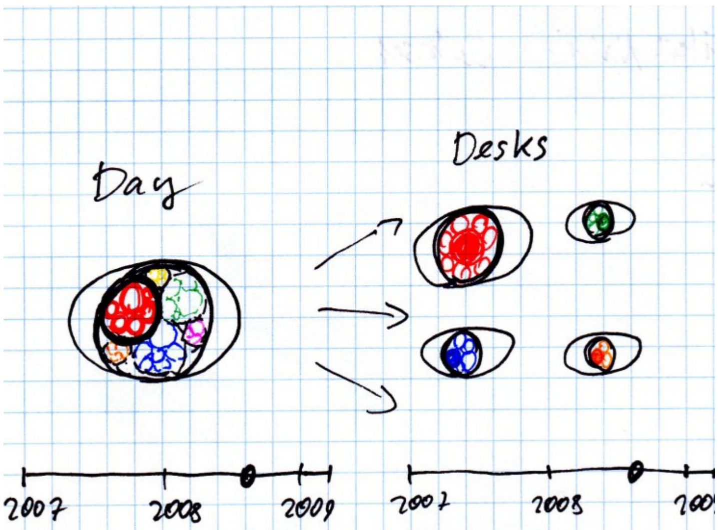

Figure 48. Human eye metaphor

For the encoding of blinking a technique from market analysis provides an interesting starting point. Here the blinking frequency is used to monitor the amount of attention of a test subject. A high frequency means low attention, while constantly wide opened eyes indicate a high degree of concentration. This strategy could be reversed so that the importance of a topic is reflected by the blinking frequency. Other ideas to intensify the eye metaphor included perpendicularly arranging headlines around the eye, to create the impression of eyelashes. Although the conceptual results are interesting, the visual qualities of the sketches do not match up.

DNA:

In the initial plans for the study setup only the VA prototype was planned to be redesigned. Infovis and IA prototypes should be maintained from the first concept. The project team members suggested to take *WEB2DNA* (Baekdal, 2008) as a guideline for the visual appearance of the new VA prototype. The advantage of this project is, that it achieves an impressive visual representation of data with a limited technical effort. The engaging effect is shown by the big number of users and by 193 *WEB2DNA* pictures that were posted on *Flickr* at the time of writing (Butterfield & Fake, 2006). At first I was searching directly for a way, how to map the *NYT* data to a similar visual appearance, but it became clear soon that their structure demands a substantially different mapping than the html-data in *WEB2DNA*, compare section 2.2.2. So the work on this topic had to start on a more basic level, regardless of the resulting visual representation. This also opened a perspective of using the DNA theme for IA design concepts. The broad term DNA has several useful properties. There is a strong connection between information visualization and genetic analysis (New et al., 2008). The representation of genetic data with letters is a strong analogy to news articles. And there already exist several examples of aesthetic works representing DNA data. Considering those preconditions there are several approaches how to use the topic DNA as base for the design of an information aesthetic visualization concept.

Depictions of DNA have become very common and in some cases even iconographic in western culture. This publicity is utilized by taking the commonly known structure of the double helix and embedding information visualization elements into it. Since a very noticeable feature is the contraposition of two chains, a comparison of two terms seems to be the intuitive mapping. The connections lines between the two chains would be representing particular features and depict a relative similarity measure towards the two terms in question, see Figure 49. This line of thought was abandoned because the conceptual link between the shape and the data is not strong enough. There is only an aesthetic reason for choosing this design but no concept that connects the meaning of data and shape.

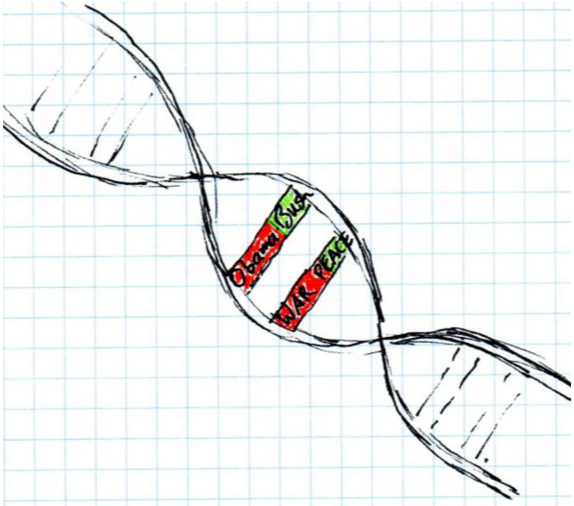

Figure 49. DNA bar chart

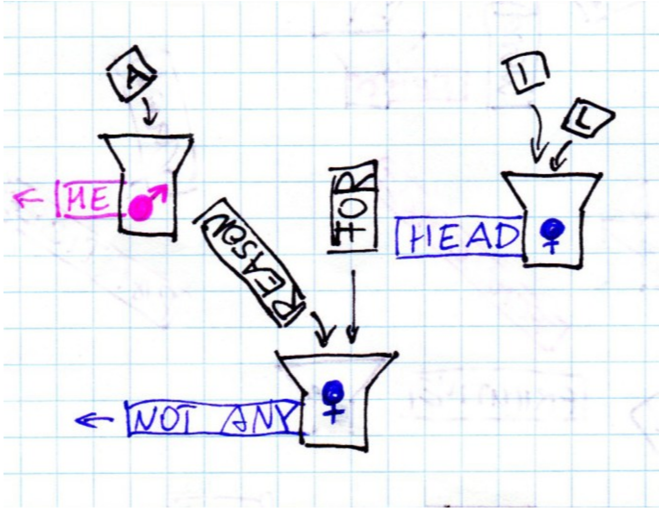

Figure 50. Text replciation factories

To create a more profound concept, I investigated the biological processes that involve DNA. Particularly interesting is the replication of DNA. For this process deeper connections to the news topic can be established. Special enzymes within the cells have the ability to generate huge numbers of duplicates of genetic information. They are acting like printing presses. Preexisting universal building blocks are combined to produce meaning. Little mistakes in the duplication process can result in huge semantic differences in the copy. The coupling process of base pairs can be transferred to the news domain, e.g. for similar terms or articles within the dataset. This is a promising ground for developing a data mapping that works on a conceptual and on a visual level. For the visual representation a particle system is an appropriate choice. Words, letters or amino acids can act as particles that are attracted by cell factories. Those factories create output according to the amount of incoming particles. Output could be headlines or complete article texts (Figure 50).

News Calendar:

By redirecting my focus back on the visual code the most advanced approach in the DNA field was created. It combines the matrix-like layout of a calendar with the appealing looks of *WEB2DNA*. The x- and y –axes are used to show two different scales of time, for example years and months. Several terms can be selected from a predefined set of relevant tags. The first example shows the terms Obama and Bush, each coded in a different color. The color value of a month rectangle is determined by the number of articles for a certain term and in general. In Figure 51 we can see green months that have a lot of articles about Obama and red months with overweight for Bush. A mix of both colors is possible as well. If no selected term was mentioned during the months, the field will be shaded in a shade of gray. The intended effect is to produce a very abstract image that expresses the structure underlying the distribution of news over time. Similar to Levin's *Secret Life of Numbers* (Levin & al., 2002) it is desired that patterns emerge where they were not expected, like more articles about poverty in December close to Christmas.

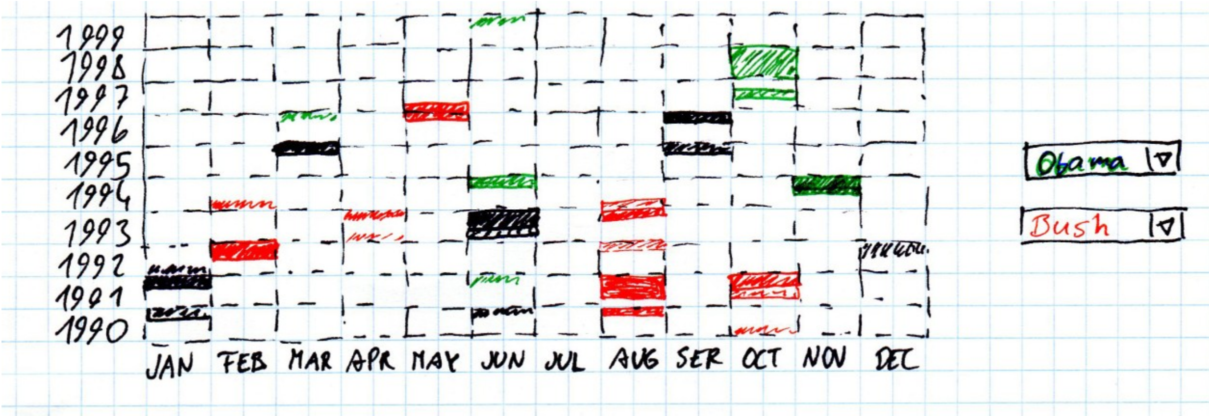

Figure 51. News Calendar 1

In Figure 52 a more refined version of this concept is shown. In order to emphasize the emotional quality of the story, the set of selectable terms has been changed towards subjective categories as *ugly*, *beautiful*, and *happy*. This brings the concept closer to *We Feel Fine*, compare section 2.3.2. Further a concept for navigating through time is introduced. A temporal hierarchy was established: years, months, weeks, and days. The axes always show time scales of two consecutive levels, e.g. years and months. When moving between two levels, one axis can be kept but has to be rotated, while the other one has to be newly created. This navigation by rotation is a promising concept for fluid and rewarding interaction and is likely to bring out the information aesthetic principles. This is an interesting line of thought but risky as well, since such patterns may or may not exist in the data. If they do not exist, the concept is useless. A second problem emerges through the basic layout that is very close to classical infovis applications, as timetables. If the user intuitively connects the IA visualization with known usage patterns, his interaction is likely to be affected and falls back to the learned procedures.

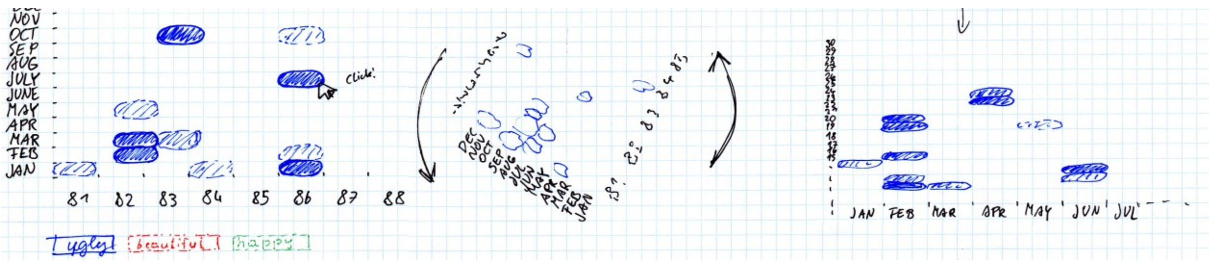

Figure 52. News Calendar 2

The work with different showcase applications, the free brain-storming, and the regular discussions about the details of my design ideas brought me to a level of understanding where I was able to focus more on the theoretical aspects of the information aesthetics realm. For the final prototypes it is essential that the theoretical concept of IA is clearly visible.

Sketches based on the Information Aesthetic Triangle

Since resulting prototypes are meant to support the model of information aesthetics by Lau and Vande Moere (Lau & Vande Moere, 2007) it is important to consider their theoretical concepts. I started to include the theory by working the corner points of the domain model of information aesthetics, see section 2.3.1, into my designs:

World Maps:
One of the features of IA that justifies its application is the capability to create images that are easy to remember and allow deducing information later on. So it is not necessary to remember any numbers or facts. The information can be accessed over the mental image. Here lies the potential to incorporate aesthetics in an effective way. An enticing visual metaphor is an important foundation for a memorable picture that is perceived and remembered in a very special way. Following this line of thought several approaches, based on world maps, were created. The world map has the advantage that it is familiar to most people. The idea is, that any superimposed information can be intuitively associated with the geographic area beneath. What made us ultimately leave the world map approach was the big number of existing applications with this theme. The high prominence can be derogatory as well. It is not deniable that world maps can produce a strong aesthetic impression, but the map has to be visually manipulated to catch any attention. Plain world maps are too ubiquitous nowadays, to be exciting.

Interaction:
I created a set of experiments that are heavily centered on their interactivity. Those concepts were designed to delimit this term in the IA context.

Spinning button: The spinning button is a round button component with an icon. On mouse click it starts to spin. The longer the button is pushed, the faster it spins. According to the spinning speed headlines, fitting the icon category, are tossed out of the button.

Burning calendar: this approach was inspired by *Calendar #4 "HANABI"* by John Maeda (Maeda, 1997). Every day of a time interval is represented as a square box with the day of the months as tag. The size of this box shows how many articles are in the data set for that day. The cursor looks like a match. On click it ignites. When the match flame touches a day box, the box evaporates, and for every article of that day a textbox exhausts into the air, see Figure 53.

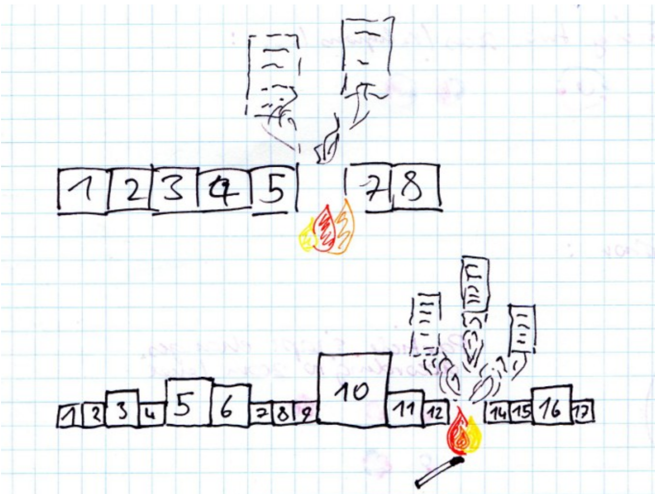

Figure 53. Burning calendar

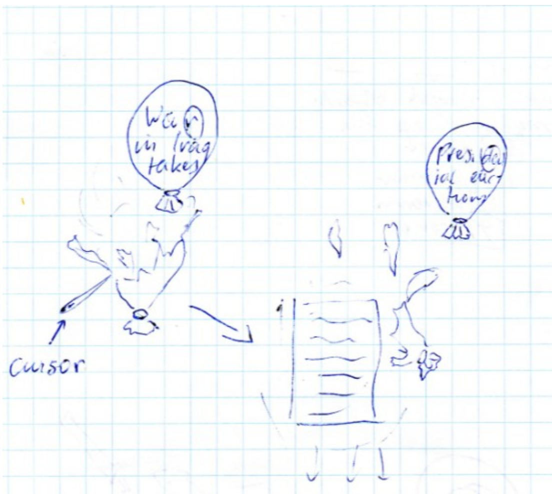

Figure 54. Balloon bursting

Balloon bursting: a balloon with the articles headline printed onto its surface represents one article. Those balloons ascend in chronological order. The mouse curser has the appearance of a needle. When touched with the needle-cursor a balloon bursts. A textbox, containing the full abstract, falls to the bottom of the screen, see Figure 54.

All those interaction concepts proofed to be too dominant. While a playful way of interaction is likely to produce user engagement, it must not get out of hand within the context of visualization. Once again the focus of attention is directed to a process that is not driven by data.

Data:

The data source was decided at the beginning of the design process, as was already mentioned. Based on this rich dataset a refined concept for the data has to be created. In information aesthetics the story is central to any concept. Before more specific design decisions can be made a story has to be found. Although story-like elements do exist in earlier approaches, they are clearly underdeveloped. The early stories, for example in the *Time Travelers Guide*, have to be created by the user. The assumption is that every user creates his/her own story from the provided set of articles. The visualization only supplies the means to efficiently navigate through the articles. It can be presumed that people within western culture have an emotional connection to news, be it sports results, be it reports about earthquake victims. The potential exists to leave the creation of emotionally engaging stories to the user. Since the objective is to create a showcase information aesthetic visualization, it is important to emphasize every feature as far as possible. As can be seen in the *Related Work* section, data with particularly high empathic potential are used frequently. So the task is to increase the emotional potential of the news data, or rather to concentrate the potential that is already available.

To get a better understanding for the story telling potential within the *NYT* efforts were limited on forming a plot from the available articles for some time. This procedure yielded one mayor result:

The ECG of death:
This concept was initiated by the tragic and early death of Michael Jackson and the huge response to it in the media. It occurred to me that the distribution of the news coverage of this death could be interesting. My idea was to compare the coverage of the deaths of several celebrities by the *NYT*. Every death has a characteristic pattern, but I assumed that similar ways of deaths have some common characteristics in the frequency of news covering them. A natural death after a disease is initiated by sporadic articles before the bereavement, for example about treatment, followed by a peak that will constantly and quickly vanish. A death due to drug abuse after the end of someone’s career, like Michael Jackson's, would result in a sudden peak after a period of no news coverage at all. Heath Ledger’s death is likely to show similarities to Jackson's in the shape of the distribution after the death. But in the period before the death, it shows more activity, leading to the conclusion that Jackson could not handle the end of his success while Ledger could not handle the success itself. Common patterns will occur between people who did not have any connections before their deaths: Michael Hutchence, the singer of INXS, and the US-actor David Carradine do not have any

outstanding commonalities except for their extraordinary deaths. Here the media reaction is likely to be disproportionately high, compared with their coverage before their demise.

The process of finding a valid visualization for this story was then very focused. The story limits the design space and supported conceptually matching visual metaphors. To create some freedom of interaction, I suggested to let the user chose different people, in the same view, to compare them. A way of linking or contrasting those persons would be to provide additional numbers or trends for terms such as "drug abuse", "murder", "suicide" and "peaceful death". For the visual design I introduced an ECG (electrocardiogram) metaphor. There are special properties that are likely to enforce a particular quality of visual and auditory memory: a moving light dot that specially emphasizes the shape of the graph and a characteristic beep signature for the redrawing of the graph. The biggest peaks should be represented by beeps, with frequency according to their value.

This is an interesting approach but it is extreme as well. It is lurid and opportunistic. The topic is banal, compared to other works in the IA field. Additionally the impact of the strong emotional component of the topic death on the study is difficult to estimate und control.

It turned out that the optimal story is situated in the middle between the underdeveloped approaches from the beginning and the *ECG of Death*. I wanted to provide some guides in an environment of news articles that encourage the spontaneous browsing through those articles. When talking about the interplay of data and story, Jonathan Harris is an excellent example, who provided important impulses for my work. In *We Feel Fine* he uses language processing to distillate the emotional component of the blogosphere. He uses knowledge about the system of language to structure emotional blog comments. The premise for the preprocessing is simply that the sentence fragments “we feel” or “I feel” is followed by a term that describes a feeling. So the preprocessing of the data consists of searching for the sentence fragments and logging the following term. The resulting list of terms can be analyzed further, false results can be removed and multiple occurrences of the same term can be aggregated. The final result is a list of the most frequent feelings from the dataset. To provide a suitable context for those feelings Harris includes additional information. Demographical data as sex, age, and nationality increase the personal quality of the feelings even more. Information about the weather at the place and time of writing enable interesting assumptions about the influence of the weather on the moods of people.

Emotions in News:
Unfortunately, feelings cannot be expected to be a prominent part of the vocabulary of newspapers. Especially, newspapers with an intellectual claim as *The New York Times* are not likely to operate on such a subjective level. An example how newspapers do affect their audience on an emotional level is by trying to raise hopes and fears. For the final database I queried two sets of articles from the *NYT Article Search API*. The first set contains all the articles comprehending the word “hope”, the second comprises all the articles containing the word “fear”. By contrasting those two sets a tension is generated that evokes the desire to investigate patterns in the data in detail. To reduce the size of the dataset the time span for the results was limited to the year 2008. Data for 2009 was available as well, but it was considered necessary to reflect a whole year from the start to the end to bring out seasonal patterns.

The data set given, the remaining task was to create an image of hope and fear. The resulting visualization should show, in an engaging way, what topics are connected to hope or to fear. Times of fears and hopes should become visible and comparable. The news content should provide possible explanations for dominance of one principle, or the other. The greater goal is to trigger thoughts about how newspapers affect and manipulate the readers’ opinions by influencing their emotions.

So at the end of the brainstorming phase a deeper understanding of the story concept was reached. Regarding the design of the visualization technique, the space of possibilities had been explored without any ultimate result. To create further impulses for the design process a shift in the methodology was performed.

3.2.2 Experimental Programming

After the advance that was made towards a consistent story concept, further progress was only possible with the support of automation. The determination of the dataset was the necessary precondition for applying visualization techniques as part of the design process. It is one of the main objectives of infovis to handle huge amounts of data that are not comprehendible by the human mind in unprocessed form. The same is true for IA visualization and, to a certain degree, for VA. To identify patterns in the dataset it is often necessary to already use visualization before final design decisions are made. The first step is to use readily available infovis tools to get a first visual impression of the data. Figure 55 and Figure 56 show two images generated by *Wordle* (Feinberg, 2009) based on results from the *NYP* API, for the queries after "hope" and "Europe" respectively "hope" and "Africa".

Figure 55. Wordle, query for "hope" and "Europe"

Figure 56. Wordle, query for "hope" and "Africa"

To gain more control over the representation I started to program visualizations myself. Here the choice of *Adobe flash* as platform proofed beneficial. The *flash* technology makes it possible to quickly bring shapes to the screen. The infovis library *flare* facilitated these first steps. The first real depiction of the data was a standard line chart. When I realized, that *flare* was not flexible enough to be used for the final prototype implementation, I dropped it completely and started to write sketch programs from scratch. The first of those sketches were mere scatter plots. Still this advance was important, since this was the first realistic impression I received of the structure of the *NYT* data. The feeling for quantity and diversity of the data is important for graphical decisions as well. The degree of detail of the final visualization is often by far too big to be accurately depicted in a hand-drawn sketch. Often aesthetic concepts rely on quantity. In lack of sufficient experience to extrapolate the sketches mentally, to include the real number of entities, I relied on the results from those first visualizations to get a feeling for the visual wealth of the final product.

This detailed analysis of and work with the data from the API led to new insights and refinements of the design. It became apparent what features are the most important ones and how they are to be shown effectively.

Article Scatter Plot:

From the combination of older particle concepts with newly found knowledge about the structure of the data, a new concept emerged. The idea was to connect articles with countries, derived from their content. Every article is depicted as a bubble with horizontal position according to a time axis and vertical position according to a second measure that can be selected by the user. Possible options for the second measure are the GDP and an index for democracy or for life quality. The color-coding of the bubbles depends on the country information. As it turned out, the bubble approach has some severe drawbacks. The most grave is the high similarity to standard scatter plots. Even the particle-system approach of giving the bubbles freedom of movement on the y-axis would not solve this issue satisfyingly.

An interesting strategy to avoid the similarity to scatter plots is to combine different shapes of the same category, in this case country, to a bigger shape. The arrangement of the data suggests a layer-like shape, following the original graph line. Figure 57 shows an illustration that is based on a scatter plot generated by *flash*, that was post processed in *Adobe Illustrator* to create blobby shapes.

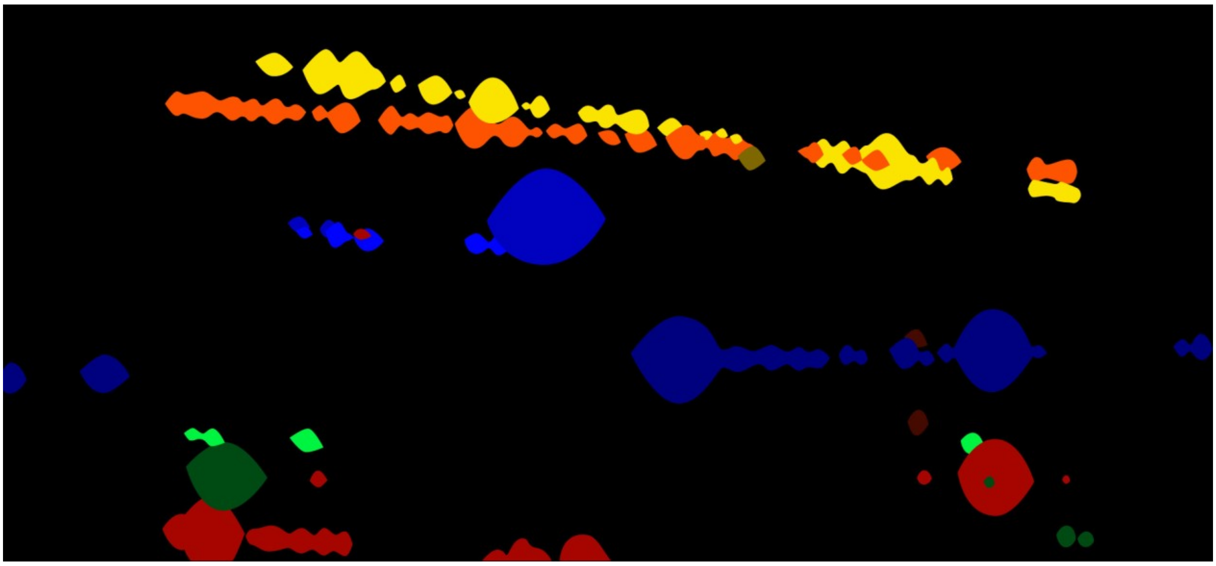

Figure 57. Blobby layer design. Automatically generated from the NYT-API data, post-processed in Adobe Illustrator.

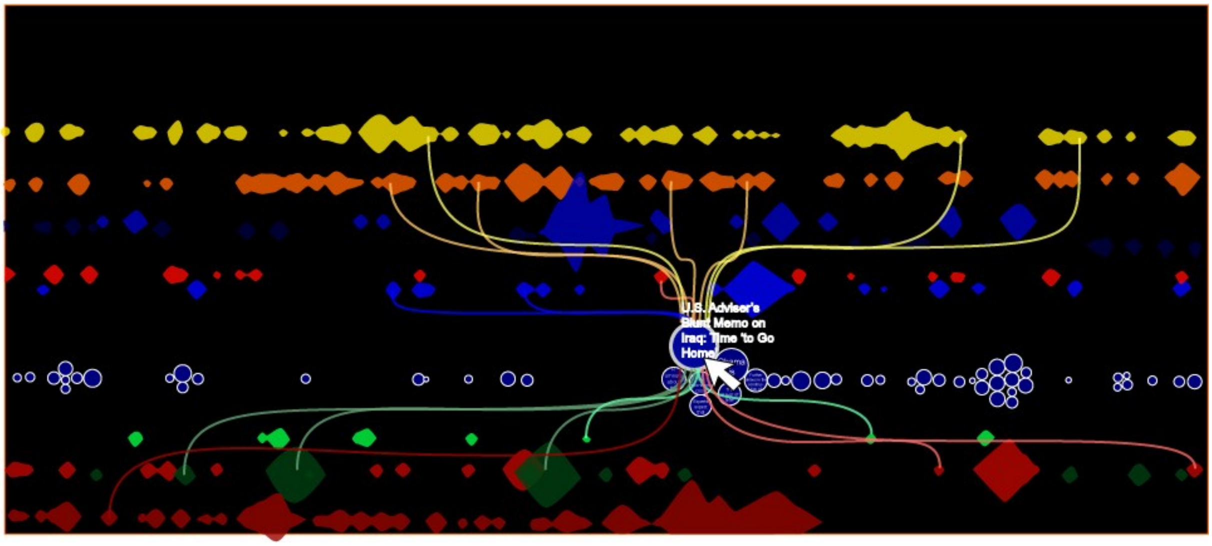

Figure 58. Blobby layers with interactive edges.

To extract geographic information from the article abstracts or headlines, as it would be necessary for the last approach, can only be accomplished by extensive preprocessing. The NYT Article Search API provides functionality that saves us this effort. For every article in the database additional metadata is available. The system supports so called *facets* for people, companies and organizations, and for geographic locations (The New York Times, 2009a). The number of *facets* in each of those categories is abundant. There exist about 1,500 tags for geographic locations, 7,500 for organizations and 15,000 for people. At first I focused on the geo facets mainly. I considered additional geographic information to facilitate the engagement that American news could imply on users from other countries. Conceptually I aimed for a world map of news. The central assumption was that every country would have its own footprint in the articles data. I wanted to create an image that shows how African countries are very rarely covered, usually in the context of war or disasters. Other countries are most frequently mentioned in the sports news. The United States are receiving a very dense news covering in every topic.

In general, all the facets make it possible to superimpose a graph-like structure over the articles. This inspired some designs, apart from the main train of thought, that were based on graph layouts. One sketch displays several countries as circles with a diameter according to the number of articles mentioning them. Two countries are connected if they have high news proximity. This proximity is calculated from the frequency of the co-occurrence of those two countries in the same article. The result is a map with a new topology according to the international relations, as they are conveyed by the New York Times. The United States and

Afghanistan are likely to be neighbors while Germany and the Czech Republic might not even end up on the same continent. After reviewing this idea, it proofed to be not very promising in regards of visually aesthetic potential. Figure 58 shows how a second layer of semantic connections is superimposed over the blobby scatter plot from Figure 57. This concept of a superimposed network of edges survived and was used for the final prototype.

Often the data represents a limiting factor. It is true that modern machine learning and automated classification make it possible to extract a considerable amount of additional information from complex data, as can be seen in *The Dumpster* (Levin et al., 2006). The automated decision whether the author of a blog post was "dumped" or he/she "dumped" someone else is very complex. To incorporate such advanced technology into this project however is not realistic. It is reasonable to focus on the information that is directly provided by the API so that the complexity does not exceed a manageable degree. This said, I will describe a line of thought in more detail that was meant to increase the engaging potential of the news data. Jonathan Harris (Harris & Kamvar, 2006) demonstrates how the enrichment of blog posts with demographic details facilitates a connection on a personal level. It could be argued that this gives a human dimension to the data. Harris uses this effect specifically to communicate his core message. He makes visible that the Internet is no faceless monstrosity; it is a huge structure of entities that were all made by humans. To establish such a personal bond to the data is very desirable for this project as well. The crux is how to assign demographic data to news articles. Only one way seems feasible. A matching of the person facets for each article with additional data from a second source like Wikipedia would provide demographic data for most of the articles. Age, sex, nationality and ethnicity could be retrieved. I integrated this additional information in several prototype designs but found that the engaging factor is not comparable to Harris' work. The explanation for the problem could be that, on the one hand, the demographics of the people in the news is implicitly known to the majority of the audience, on the other hand, there is a felt distance towards those famous people that occur frequently in newspapers. The approach hence was dropped.

3.2.3 Final Information Aesthetic Visualization Prototype

In this section the final result of the design process is described in three mayor parts: *Theoretical Concept, Application Description*, and *Meeting the Criteria of Information Aesthetics*.

The theoretical considerations that were ultimately used as base for the application design will be explained. Afterwards a detailed description of the final information aesthetic prototype application, as it can be seen in Figure 59, will be provided. Conclusively, a comparison of the final prototype with the *Information Aesthetics Model* by Lau and Vande Moere (2007) is performed, to show its applicability for a study in this field.

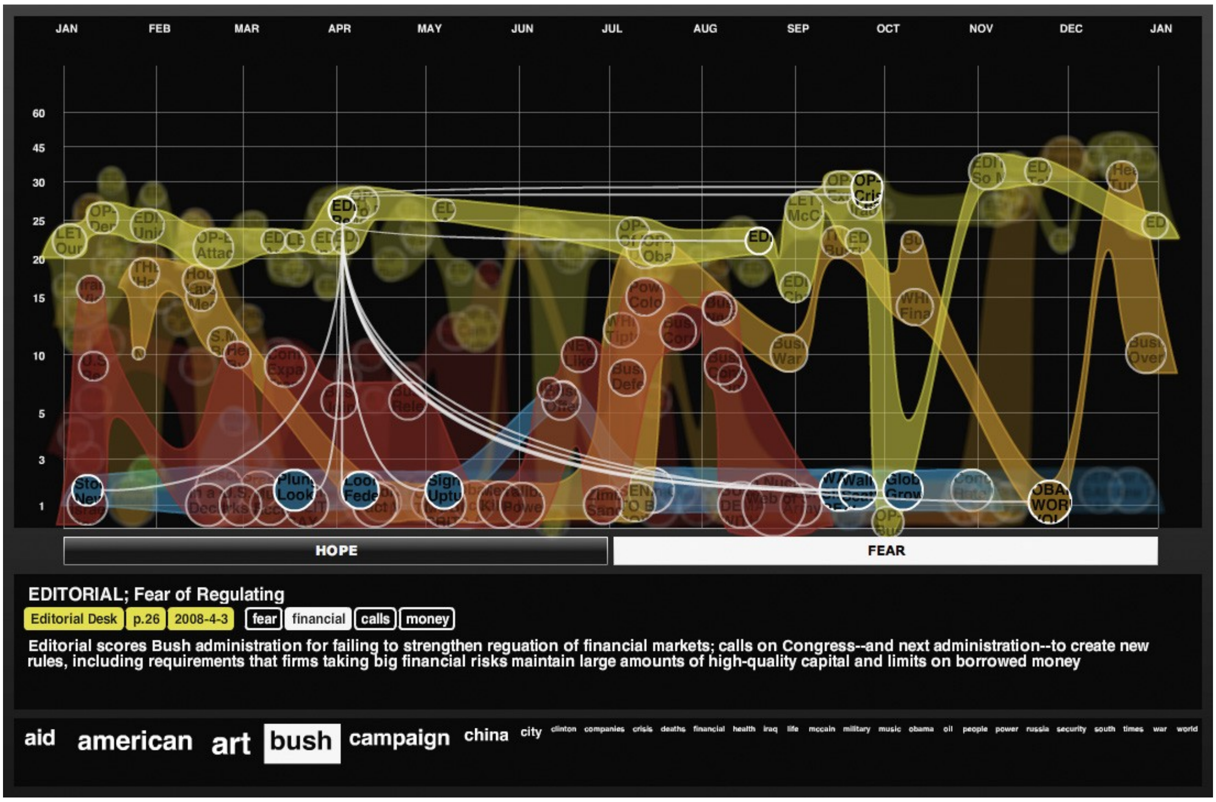

Figure 59. Final IA prototype

Theoretical Concept

Final Dataset:

I refined the rudimental concept of two opposing datasets for *NYT* articles, containing the word *hope* or *fear*, to create an interesting and innovative foundation for the visualization. Initially it was planned to include a second data source to create a context for the articles. When working with the API results in more detail, it became evident that patterns within those data are very interesting as well, and deserve further consideration.

The fields included in the final dataset are listed in Table 1.

Name	Data Type	Description
title	String	Headline that is published in the newspaper
abstract	String	Short version of the article, created by indexers
date	Date	Publication date
desk_facet	String	Times Desk responsible for the story, e.g. *International* or *Business*
page_facet	String(sic!)	Page number of the printed article
word_count	Integer	Number of words in the articles full text
term	Boolean	Article contains fear or hope

Table 1. Data structure for the final dataset of hope and fear. The most fields were recieved from the API, only the *term* Boolen was added during postprozessing.

Especially promising, in combination with the concept of comparing *hope* and *fear*, is the meaning of the page number. The page an article is published on reflects how important it is, according to the judgment of the newspaper's editorial staff. Low page numbers denote a higher importance. The API additionally provides information about the editorial office, responsible for each article. This data field is called *desk*. The desk provides a very news-specific thematic category. Page number and desk are the two features that are included in the final dataset to enable for insights into the internal structure of the NYT. By introducing an additional field for a Boolean value distinguishing between fear and hope, it was possible to join the two opposing article sets.

Visualization:

The design process resulted in several criteria for the final mapping of the data. I will summarize and combine them to a conclusive visualization concept in the following paragraphs. One of the early criteria is that every single article should still be present as independent unit in the final design to make the specific access to article content possible. It is a common strategy in IA to use a particle system to create a dynamic context for such indivisible units. I investigated this possibility but abandoned it in lack of a consistent concept for mapping base data to movement. Although arbitrary movement is used in several reference works, I avoided it due to theoretical concerns about arbitrary mapping.

In (2002a), Manovich discusses the problem of arbitrariness in data mapping. According to him the infinite number of mapping choices for every data set makes this decision arbitrary. Manovich clarifies this problem by examining the *Jewish Museum* in Berlin, planned by Daniel Liebeskind. To create the furrowed facade Liebeskind used a map of the homes of Jewish citizens, living near the location of the museum before World War II. He connected the homes and projected the resulting net onto the building. Manovich criticizes that, while the net is conceived in a very analytic and scientific manner, the projection happens completely arbitrary. An infinite number of other projections would be just as appropriate or inappropriate.

The problem of arbitrariness became evident in several of my own approaches. Every visual property that is designed according to random is wasted from an information-visualization point of view. It could have been used to encode information. In the worst case the viewer even searches for information in the random pattern. In any case the cognitive potential dedicated to this feature is lost. The usage of random motion, for example, is very tempting when the visual effect is more important than the underlying data. In the terminology of the *information aesthetics domain model* (Lau & Vande Moere, 2007) this would be described as a high focus on aesthetics and a low focus on data. The emerging problem is illustrated comprehensibly by one of my earlier design concepts. The basic idea to use the DNA-transcription process in cells as visualization metaphor was mentioned in section 3.2.1. Inside the cell amino-acid building blocks are floating around arbitrarily until they collide with a fitting counterpart of a DNA sequence. This process seems to have a lot of potential as metaphor for IA visualization. It is very dynamic and the growing structures of text probably fulfill the aesthetic requirements. The randomness of the block movement however is problematic. The attention of the user is likely to be drawn to this process and hence away from the elements that really display information. The strategy to use movement for encoding information in an appealing way is appropriate, but the balance between data focus and aesthetic focus has to be maintained. This finding eliminated several DNA-based approaches; at the same time it contributed to narrowing the information aesthetic term down.

My conclusion is, that the most important visual features of the final visualization have to be directly based on the data. In the given case this especially applies to the encoding of x- and y- position. A second consideration that supports this decision is the generation of memorable images. Only by fixing the position of the article units in space, this information can potentially be recalled from the mental image.

Regarding the design of the article units themselves several conceptual guidelines were constituted as well. During the earlier work on direct text visualization the precondition emerged that a part of the articles content should be visible from the start. Later on, it became obvious that for the hope and fear concept to be effective, the inherent antagonism of the two datasets has to be clearly recognizable through a strong visual stimulus. For the outline of the article units sketches and related work strongly promoted a circular shape, also referred to as bubble.

When separate entities for every article are used and simultaneously the x- and y-mapping is direct, a high risk of producing a standard scatter-plot exists, as discussed in section 3.2.2. To resolve this issue I implemented an additional level, where subsets of those units are combined to bigger shapes. A subset consists of all articles, created by the same editorial department, also called *desk*. Byron and Wattenberg (2008) describe the *Streamgraph* as aesthetic visualization technique with the potential to engage mass audiences. Inspired by that design I developed a layer concept for the IA prototype. Fluent horizontal layers enclose circular article entities and produce a similarly engaging effect. Additionally my design relies on the study results from Cawthon and Vande Moere that show a correlation of the subjectively perceived beauty of a visualization technique and its proximity to the term *organic* (Cawthon & Vande Moere, 2007a). The layer outlines add a strong organic component to the visual appearance of the prototype design. In this I stress the creation of memorable images that enable the user to later reproduce information from memory. A consistent color-coding for the desk layers is essential for this as well.

Interaction:

To enforce engaging interaction it is important to build a visualization work upon an interesting topology. A set of tags was extracted from the article full text to create a network of semantic relations amongst the articles. The tag set contains the most frequent words within the articles dataset. This set can be used to browse through the data in two ways. First, a user selects a number of tags that work as a primary filter. Only articles that include all selected tags are displayed in the visualization. This gives the user the first opportunity to express his or her subjective interests. For a detailed search this mechanism is not suitable. The selection of three or more terms produces very small result sets. The solution is to incorporate a way of identifying semantically related elements within the selected subset of articles. For every article on the screen the attached tags are accessible. When such a tag is selected, all other articles with the same tag are highlighted. This enables the user to create and investigate detailed patterns within a bigger and richer image.

To explain the interplay of the two ways how the tag set can be used to navigate through the articles I will give a short example: A user who is interested in articles about the financial crisis would select the terms *financial* and *crisis* as filter criteria. The dataset that is visualized after this selection only contains articles incorporating both terms. After choosing a particular article from the displayed set, and reading its details the user might get interested in one of the other tags that are associated with the article, e.g. Bush. On choosing this tag from the articles details, all other articles in the current view that contain this term are highlighted. In this way the user can construct a context according to subjective interests and freely follow diverse associations.

Fear and Hope:

The visual distinction between *fear* and *hope* articles was a major challenge. Problems with this disambiguation reemerged several times. The distinction between the two terms has to be very expressive and convey their empathic quality. To draw an image of fear and hope, the standard mapping techniques, e.g. color coding, proofed to be not effective. A filter mechanism, for independently activating and deactivating the two article sets, was the solution for the problem. In this, an interactive and engaging opposition of both terms was implemented. The articles belonging to a deactivated category and their enclosing layers are still visibly in an unobtrusive way to provide contrast and facilitate comparison.

Application Description

The description of the final application outlines how the theoretical concept was put into practice. This is structured according to the different components of the user-interface, see Figure 60: *Display Area*(1), *Fisheye List*(2), *Article Detail Area*(3), and *Fear and Hope Buttons*(4).

Figure 60. IA user-interface components overview

Display Area (1):

The display area is the biggest component of the application. It covers the whole width and about two third of the height of the user interface. To provide a fixed frame for the visualization, x- and y-scales are shown at the border. In the final layout the display area shows one circle for every article in the selected subset. The circle border is white; the fill is assigned according to a direct mapping from desk to color that was adopted from *reMap* (Bestiario, 2009), see Table 2.

Desk Name	**Web Color**
Foreign Desk	9C1F1F
National Desk	DD961F
Editorial Desk	DDDD2F
Metropolitan Desk	54CC2F
Sports Desk	1F9C66
Business/Financial Desk	1F86BC
The Arts/Cultural Desk	421F9C
Science Desk	9C1F8B

Table 2. Color mapping for article bubbles and desk layers.

To avoid an overweight of arbitrariness, I decided to set the x- as well as the y-coordinate for all circles directly based on underlying data. I used the x-axis to depict the time of authoring to underline the importance of the time component for newspaper articles. The standard conform choice of a horizontal timeline was contrasted by mapping the innovative page number feature to the y-axis. This creates a compromise between familiar and unusual data. The y-scale is distorted, giving more space to the lower page numbers, where a high density of articles exists.

All the articles from one desk are enclosed within an organic horizontal layer shape. The color of the layer is derived from the direct mapping as well, with slightly reduced opacity. In comparison with *Streamgraph*, my design shows higher dynamics on the y-axis. This is achieved by a direct mapping of page number to y-coordinates. The resulting layers may intersect or leave a gap between them. This creates a bigger visual variety of different subsets of data, see Figure 61.

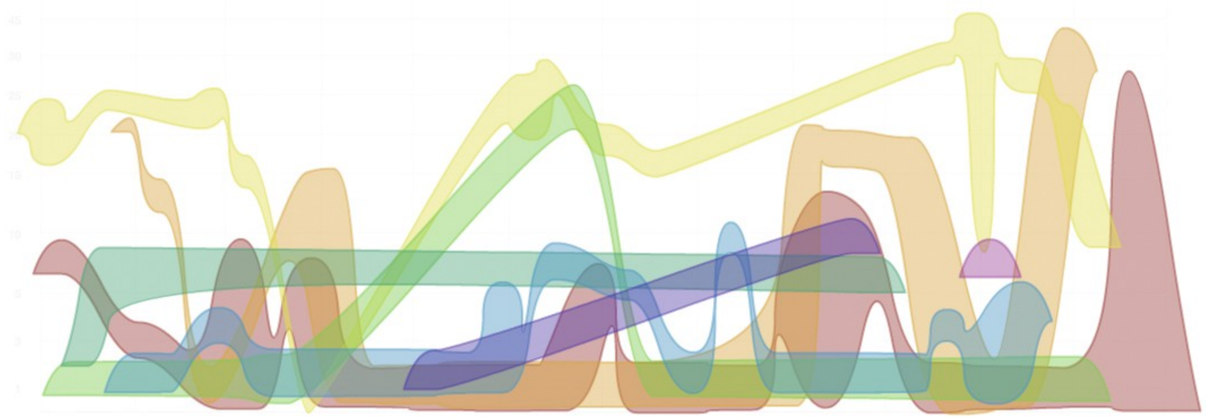

Figure 61. Final layer design

Combining this circular shape and the condition for a immediately visible text preview leads to the *Swarm* design in Digg Labs (stamen design, 2006). In this work a small cutout of the headline is shown that exactly fits into the circular particle outline. The part of the headline that is visible, in most cases, is too small to convey any useful information. The keyhole perspective, however, creates a sense for a hidden level of information and generates curiosity. This is in accordance with the main idea of information aesthetics of using design to foster interaction. I modified this concept to fit our needs and use the same approach for the articles in the prototype. To make fluent and engaging data browsing possible, a mouse-over effect is added that exposes the whole headline, see Figure 62 and Figure 63.

Figure 62. Article bubble with croped text.

Figure 63. Extended article headline on mouse-over.

By showing the page number on the y-axis this measure of importance is integrated into the overall image of hope and fear. The usage of colored layers for the desks substantially contributes to the creation of an image that depicts the interrelation between hope and fear, the selected term(s), and the rough topical category, provided by the desk. Additionally curiosity is nurtured through the keyhole metaphor. Those elements together constitute my approach to an information aesthetic data mapping.

Fisheye List (2):

The fisheye list is the user-interface component that enables the selection of a subset of articles. The list items are a set of key terms of which one ore more can be selected. After the user selects or deselects any list items, the visualization is redrawn, displaying only articles that contain all currently selected key terms.

The set of *key terms* or *tags* is derived by extracting the most frequent words from the article data set. The API provides only access to the headline and, in the majority of cases, an abstract of each article, not to the full text. So when I am referring to an “article” this means the combined text of headline and abstract. As base for the tag set, I create a list of words, sorted by the frequency of their occurrence in the articles data set. Then the forty most frequent words of the English language are removed. They are so common that they do not reflect interesting information about an article. The resulting set contains twenty-eight names, countries, and other abstract terms: *aid, american, art, bush, campaign, china, city, clinton, companies, crisis, deaths, financial, health, iraq, life, mccain, military, music, obama, oil, people, power, russia, security, south, times, war, world.*

Graphically this component is realized as horizontal word list with fisheye-lens effect. All the tags are printed in one line beneath the display area. On mouse-over the tags are rescaled according to their distance to the cursor. The closest tags get the biggest scale. This enables the display of a big number of terms that would usually not fit into one line. The outmost tags get scaled down to a size that is not readable, but they can be made visible by simply moving the cursor near. This follows the *Overview + Detail* concept (Card et al., 1999) and exaggerates it to a degree where the context visualization is too small to provide information but still makes an aesthetic contribution.

Article Detail Area (3):

When an article is selected on the display area, the article detail area directly beneath gets filled with a compilation of all available information about that article. This contains the headline, full abstract, all associated tags, the publication date, page number, and the publication desk. Here the exact values for the data are accessible that are encoded in the display area in a much more interpretative way, see Figure 64.

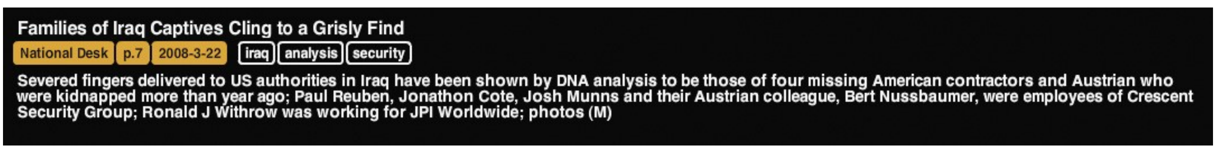

Figure 64. Article detail area

These article details form a starting point for further interaction. All the tags that are assigned to the selected article, except the ones that already work as filter criteria within the fisheye list, are placed as buttons beneath the headline. When a certain tag is activated, all the bubbles of articles that share this tag are connected to the selected bubble through curved edges. Connected bubbles are placed in the foreground and their opacity is set to 100%. A user can follow a line of thought over time and over different desk categories. This should keep him engaged in finding stories within the data. The proposed way of interaction strongly concurs with information aesthetics. The focus does not lie in conveying a greater pattern in the dataset; it lies in starting to explore some random details and subsequently getting lost, while following diverse connections.

Fear and Hope Buttons (4):
Preliminary the affiliation of an article to fear or hope was encoded by a brightness difference within the range of the color encoding of the desks. Darker bubbles were connected with the *fear* term, brighter ones with *hope*. There is an intuitive link between darkness and fear, as well as between bright light and hope. When this color encoding was set into practice, it became obvious that it did not have the expressive power to show a sufficiently strong distinction between hope and fear. This is critical for the whole project since a big part of the concept relies on the emotionally engaging capabilities of this dichotomy. Including additional filter functionality solves this problem. Two toggle buttons, for hope and fear, were added to the user interface. They make it possible to activate or deactivate each term separately. The articles and layers for a deselected term are moved to the back and blurred. Interacting with them is not possible. Their approximate distribution is still visible but the focus clearly lies on the active bubbles in the foreground. This change ultimately leads to a strong visual representation of the tension between hope and fear articles. The final result can be seen in Figure 59.

I will illustrate the usage in an example supported by Figure 65: To get information about the war in Iraq a user would selects the terms *war* and *Iraq* in the fisheye list. A visual representation of all articles that contain those two terms is generated, as can be seen in the display area of Figure 65. The user then selects a random article bubble and reads the abstract in the article detail area. He or she finds that Obama played an important role and wants to find more about his involvement in this topic. After selecting the Obama tag in the article detail area, at the bottom of Figure 65, white edges are drawn to all other articles that mention

Obama. The user can then construct an individual story. Maybe the preliminary events to the read article are interesting, then an older article will be chosen. Maybe details about the consequences of the event in the US are of higher interest. Then a slightly newer article can be chosen, that is included in the *national desk* layer. We see that the user can connect the data and his personal interests in manifold ways.

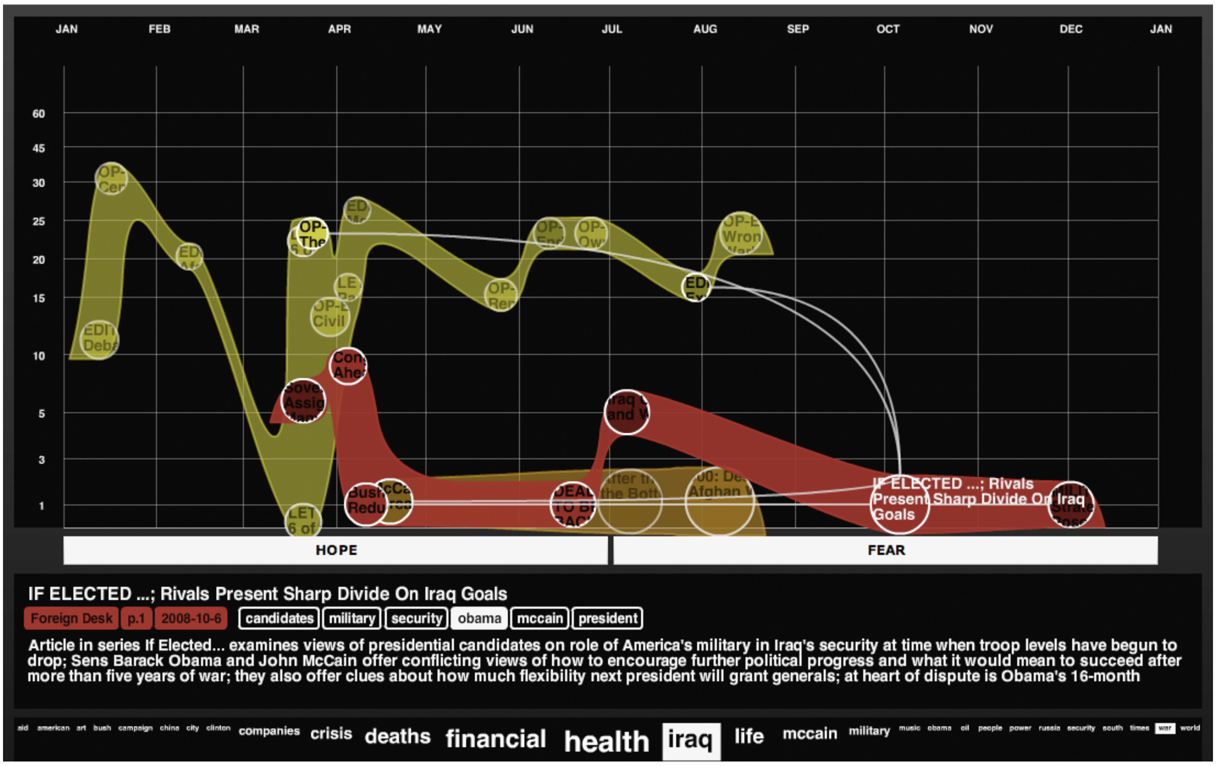

Figure 65. Information aesthetic interaction example

3.2.4 Meeting the Criteria of Information Aesthetics

The influence of the triangular domain model of information aesthetics, by Lau and Vande Moere (Lau & Vande Moere, 2007), on the design process was already described in section 3.2.1. This is important to delimit my approaches against bordering fields. To evaluate the results of the IA design process I matched them with the more detailed Information Aesthetics Model (Lau & Vande Moere, 2007). The final design has to fulfill the criteria, stated in this definition.

Mapping Technique:

The mapping techniques, used in the IA prototype, can be separated into two parts. First, the mapping of the bubbles: the position of each bubble is directly determined by the page number and the publication date. A small amount of indirection is added by a little offset on the y-axis, dependent on the desk of an article. This was done to better spread out the articles from lower pages. The diameter of the bubbles is determined by a direct mapping of the word count of the complete article. Second, the mapping of the desk layers: here the creation of an organic and fluent contour that encloses all articles of a desk was the main objective. The reconstruction of the underlying data points from the contour is not possible. This can be considered as interpretative. The combination of both designs yields a best-of-both-worlds approach that fulfills the criteria for Information Aesthetic Visualization.

Data Focus:
The judgment whether the data focus is intrinsic or extrinsic is difficult beforehand. In this context the layer concept has a second function. It is meant to direct the focus of the viewer from the small patterns of article bubbles towards the bigger scale. The layers create a unique image for every desk and every term. Sometimes the contours are straight, sometimes strongly fluctuating. They remain on a low level, or rise to a high one. This should animate the user to consider the development of a term over the whole time span of the visualization, rather than to focus on punctual patterns. Accumulations are not accentuated by this visualization technique while a few bubbles from the same set that are, temporally or according to page number, far apart create a big shape. Such contradictions disturb the habitual analysis patterns and might lead the user to a more extrinsic perspective.

Other important factors that were mentioned by the authors but were not included into the model are:
Interaction: The interaction possibilities are twofold. The *fisheye list* and the *hope and fear buttons* are designed to create impressive images on the display area and to confront the sets of hope and fear articles. The visual appeal of the produced image is a driving force for the usage of those user-interface components. This supports the *extrinsic* quality of this work in the category *Data Focus*. The connection edges for the article tags work in a different way. They invite the user to engage in detailed information but on the basis of arbitrary or subjective decisions. Finding particular information is hardly possible but finding an interesting story is probable. This is comparable to an *interpretative* mapping focus, applied to interaction.
Dataset: The dataset was chosen beforehand under considerations about its applicability for IA. Since the other prototypes will use the same dataset, a strong emphasis on IA criteria

could decrease the credibility especially of the infovis prototype. The dataset has the potential to emotionally engage people, but not predominantly.

3.3 Visualization Art Prototype Design

As mentioned in the introduction to this section, the VA prototype was subordinated to the information aesthetic prototype. I created several concepts in the earlier stages of the design process but the development accelerated considerably after the IA design was narrowed down. Nonetheless, I will describe some early design approaches in section 3.3.1 before I explain the final prototype in section 3.3.2. The third subsection, 3.3.3, is dedicated to a theoretical evaluation that is comparable to section 3.2.4 for the IA prototype.

3.3.1 Data Art Design Approaches

Line Bending:
Similar to the early IA approaches, the first visualization art design was also directly based on existing work from the same field. The concept of Bitalizer (2008), described in section 2.2.2, is very intuitive and versatile. It produces striking images with a high degree of abstraction. Still it preserves the basic patterns of the underlying data and even highlights some of them. It is straightforward to adapt this strategy for other data. The big advantage is that the visual qualities of the original can be preserved easily. The concept of one single line that is bent up and down by some influences can be adapted to show the time component of the *NYT* data. In my opinion, this time dependence of the data is very important so I try to express this in my work. Keeping in mind the story element that is central for the whole setup, the bending influences are a very critical choice. One promising strategy is to contrast two oppositional terms, like “love” and “hate”. A set of articles is processed chronologically, while every occurrence of “love” bends the line upwards and every occurrence of “hate” bends it downwards. The main flaw of this concept is that the frequency of any opposing term pair is bound to be considerably lower than the frequency of bits, even in a small file. The resulting shapes, hence, are much less detailed and diverse.

DNA:

Many of the DNA designs, mentioned in Section 3.2.1, can be transformed into visualization art by adjusting the data mapping. A mapping that is more interpretative, abstract, and focused on visual appeal often makes a transition between the two domains possible. I followed this approach in particular in the scope of the *News Calendar*, see section 3.2.1. In this idea I see the potential for an enticing overall image that gives a feeling of the wealth of the underlying data. I also created computer-generated sketches as a base for further considerations, see Figure 66. As can be seen, the visual style is appealing and suitable for a piece of art. The metaphor is clearly visible. The possibilities for data mapping, however, are limited to very direct measures. The x- and y-value, the height of a block and the color can be used to encode information. This leaves not many options for interpretative mapping. A shift towards a more advanced and rich visual concept was necessary.

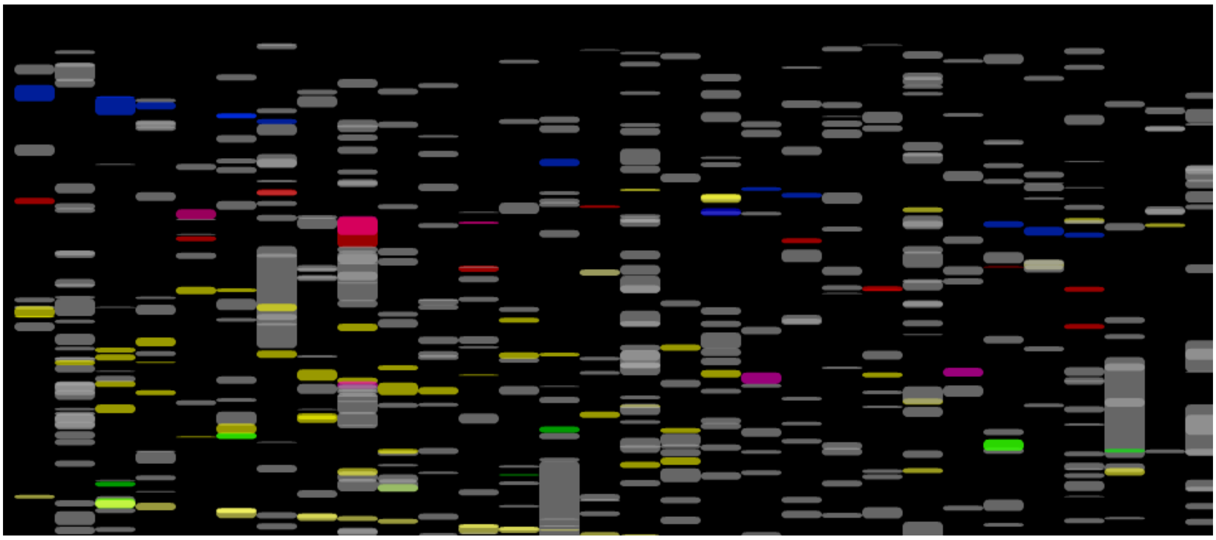

Figure 66. DNA style scatter plot

Artistic Text Visualization:

The *Poetry on the Road* series is an interesting starting point for aesthetic text visualization, see section 2.2.2. One remarkable feature of *Poetry on the Road* is that every single word of the given set of poems is depicted in the final visualization. This is similar to my objective, hence, the poetry on the road series contains very suitable examples. The *NYT* data stock, although mainly consisting of plain text as well, is different in that there is a bigger number of articles with less content each. Still every article should be preserved as independent entity. That way it is possible to access the article abstract. Particularly the spiral-shaped structure of *Poetry 06* (Mueller, 2006) proofed to be fertile. I created a concept that combines the visual appearance of *Poetry 06* with the mapping of space and time from the *Event Tunnel*

(Suntinger et al., 2007), described in section 2.1.2. A black spiral line that winds around the center of the circular display represents the timeline. Articles are represented by circles that are attached to the timeline at the appropriate point of time. Navigation through time leads to a hypnotic rotation of the spiral with new points appearing at the center, while older articles are disappearing at the edges of the screen. Allowing an offset of the center of the spiral line creates an additional dimension for data encoding, as can be seen in the right part of Figure 67.

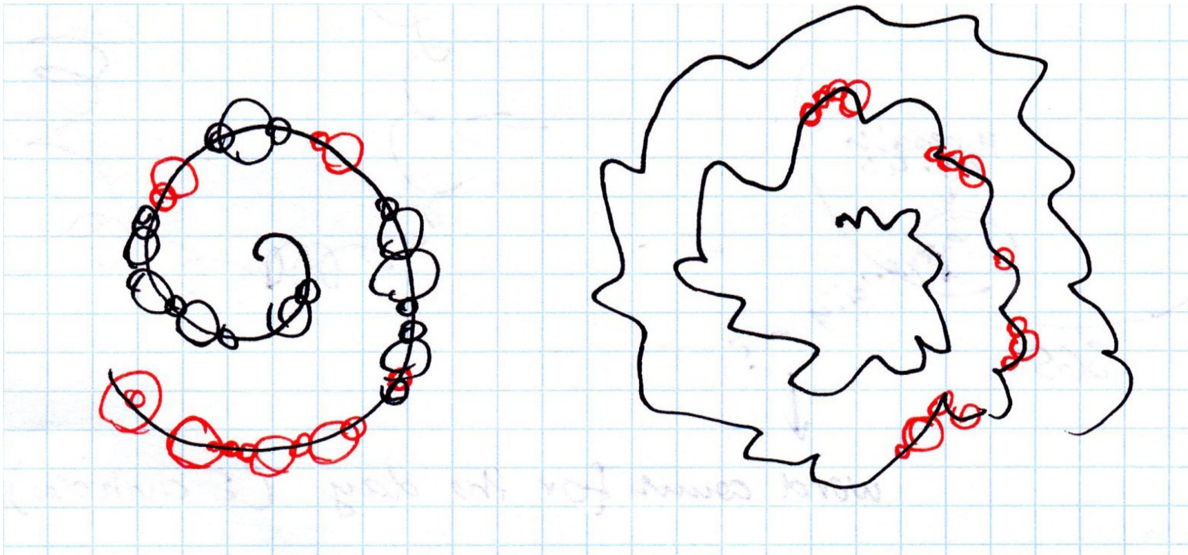

Figure 67. Spiral layouts based on Poetry 06. The left sketch shows a standard spiral as time line with articles added in the form of circles. The right sketch shows a variety of the spiral concept were an offset of the regular spiral path is used to encode additional information.

Spirographic design:

The visual appearance of *Poetry 06* and the derived design concept strongly resemble the geometric shapes produced by the drawing toy *spirograph*. This toy creates hypotrochoid and epitrochoid shapes, highly detailed structures with strong symmetries. There are three parameters that can be chosen almost without restriction. Those are: the diameter of the outer circle, the diameter of the inner circle and the displacement of the pen position from the center of the inner circle. In the mechanical version inner and outer circle have cogs, the inner circles has several holes at different distances from the center. To draw a shape a pen is forced through on of those holes. Then the pen is moved, following the border of the outer circle. The displacement of the drawing hole from the center results in a repetitive variation of the underlying circular shape. This drawing process has a temporal character and therefore can be used to encode temporal data, for example the change of the number of search results for a particular term over time. One revolution around the outer border represents a year, starting and ending at twelve o'clock. The displacement in the inner circle then changes, according to the number of results for a certain day. The resulting shape is more diverse and less symmetric. Changes of trends are depicted as intervals of different dynamics. This concept was then extended, enforcing the influence of the Time Tunnel principle. To represent longer periods of time it makes sense to use the z-axis as well. Older data are further away in the z-dimension and become subject to perspective projection. The overall impression will be that of a maelstrom. A common strategy to enforce the depths-impression is to successively blur objects, the further they are from the viewpoint. This increases the visual appeal as well as it helps to intuitively distinguish between small objects close to the screen and large objects in the distance.

3.3.2 Final Visualization Art Design

It is remarkable that the final design follows a very similar visual metaphor as the AOL-data prototype for VA. This resemblance emerged very late in the design process and was never intended. After some fundamental decisions about the mapping technique were made, plantlike shapes turned out to be the most reasonable choice for the visual design. A complex mapping algorithm was created to convert the plain text of the article headline and abstract into a flower shape, for details see section 4.4.1. The flowers should convey some characteristics of the underlying text but in a very interpretative and abstract way. The first version of the mapping algorithm created a point for every word. The distance of the point from the flower center is calculated as a multiple of the word length, for details see Figure 69. The angle of the point's direction vector, in respect of the center, is taken from a word probability. This probability equals the sum of the frequency of every letter of the word in the English language, divided by the total number of letters in that word. The result is than mapped to an angel between 0° and 360°. Conclusively all those points were connected in the correct order. The resulting flowers can be seen in Figure 68.

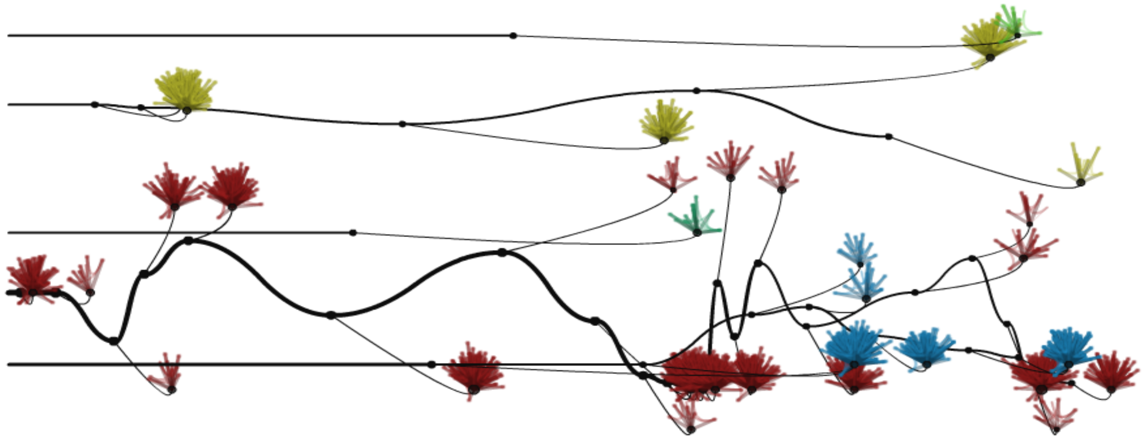

Figure 68. Early flower design

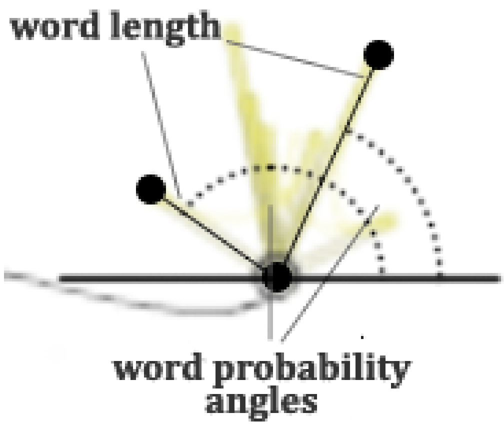

Figure 69. The calculation of the petal endpoints from wordlength and probability angle.

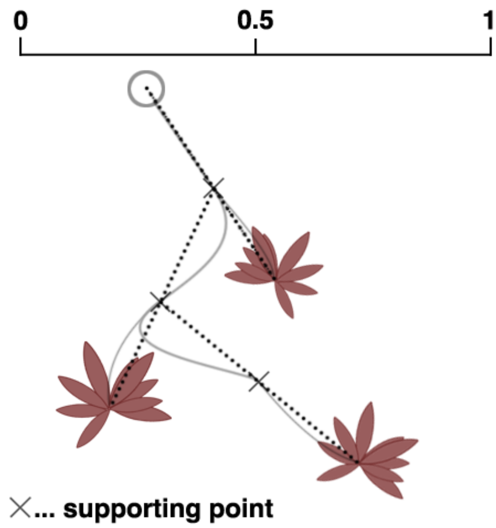

Figure 70. Construction of a stem that connects all articles, containing the same tag. The first supporting point is calculate on the upper screenborder according to the wordprobability (between 0 and 1).

A major optical improvement was achieved by replacing the peaky lines with more authentic petal shapes. Additionally, it became possible to encode the belonging of a flower to the fear or hope dataset into the petal shape. Hope articles are depicted by boat-shaped petals, while fear articles have petals with three spikes, see Figure 71.

In consistency with the flower metaphor, the semantic connection of articles with common tags is represented by stems. Articles with common tags are connected by delicate dark lines. The tags defining the visualized subset are not depicted in that way, otherwise a redundant stem connecting all articles would occur. The starting point of each stem is determined by the word probability of the line tag. This value lies between 0 and 1, and is mapped to the upper border of the display area, 0 denoting the left upper corner, 1 the right upper corner. Then all the flowers for the stem are ordered by descending y-values. From that starting position, successive supporting points are calculated as mean points between the last supporting point and the coordinates of the next flower containing the stem tag. Smoothed lines, connecting all those supporting points, create the flower stems. Details of this concept can be seen in Figure 70.

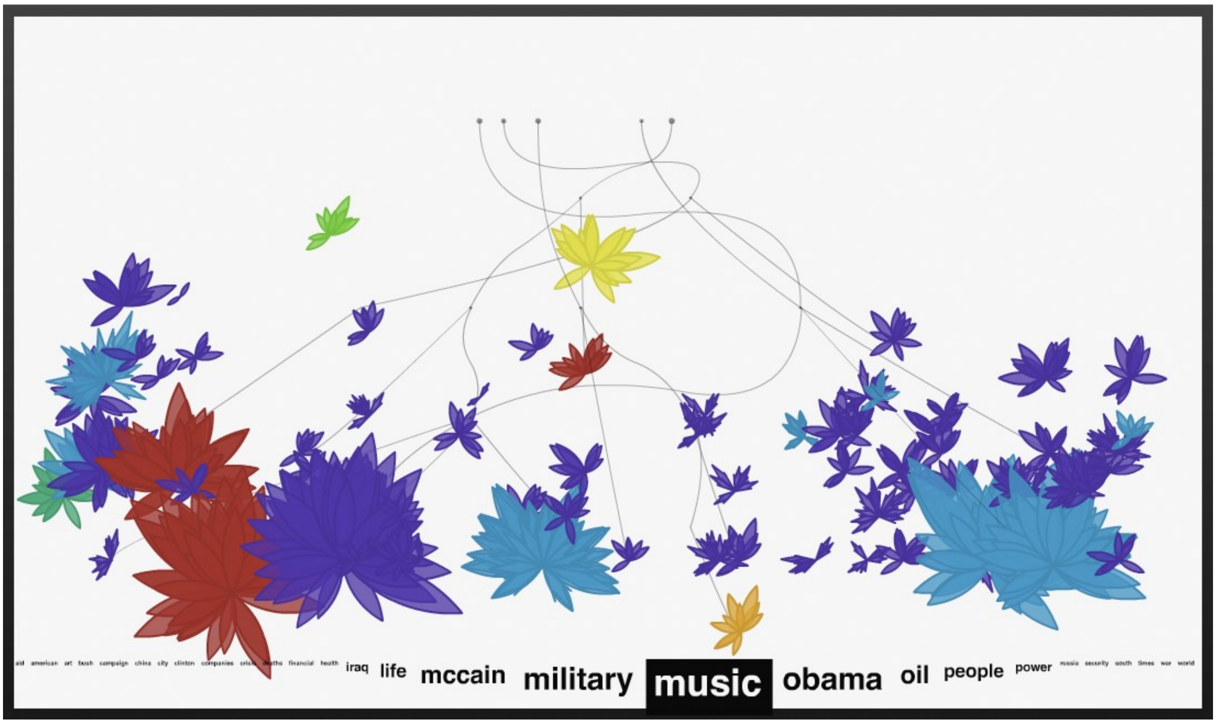

Figure 71. Final VA prototype with new article design.

Following the decision to use a design that is based on a flower metaphor, the already mentioned aspect of “organic” design became important once again. It was crucial to create a coherent overall picture. Plantlike shapes have to show plantlike behavior. An organic appearance is intuitively connected with processes like growth and expansion (Cawthon & Vande Moere, 2007a). To implement this in the prototype the screen is built up successively. Flowers are drawn petal-by-petal, starting with the oldest entries in the dataset and progressing over time. This kind of animation resembles time-laps recording of plant growth as they can be seen in nature films.

Keeping in mind the study, a consistent way of interaction with the visualization art prototype had to be implemented. It was necessary to make the whole content of the articles visible so interaction comparable to that for the IA prototype can take place. The *fisheye list* is sufficiently aesthetic to be used for the VA prototype as well. To create a layout that is more suitable for a piece of art, I applied no strict structure with separate areas for the list and the article details. All three elements, the flowers, the list, and the article details, were arranged on the same canvas, see Figure 72. The list was placed at the bottom, slightly overlapping the flowers, without affecting their accessibility. To integrate the article information, in this case the headline and the abstract, I followed the style of posters for exhibitions in museums. They often show a dominant title and a smaller detail description on the base of a fitting background image. To reproduce this I used a prominent font and a background in the desk color for the headline. The abstract text is smaller and has a black background.

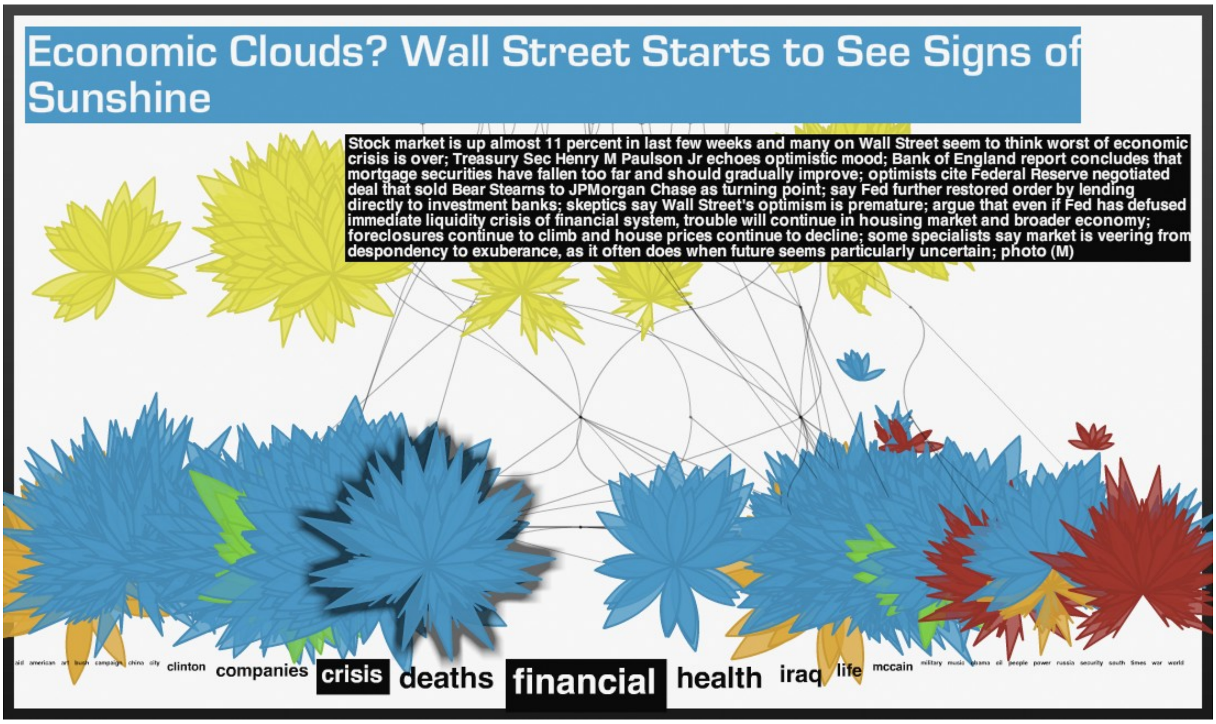

Figure 72. VA prototype with selected article. Headline and abstract are layed out following the style of exhibition posters.

A very important property is rewarding interaction for the user. Interacting with the piece should trigger visual and acoustic stimuli. Common techniques for this are animation and sound effects. In this piece I use a jingle sound as reward for the selection of an article. The selection is accompanied visually by redrawing the article flower, petal by petal, and by drawing a dark glow effect around the flower to accent it.

Concept Versus Performance:

In several cases the graphical concept turned out to be very demanding in performance. When a streamlining of the algorithms did not suffice to solve the performance issues it was necessary to drop the concept because fluent interaction was impossible. Since user experience has a high influence on the outcome of the study, this could not be tolerated. Especially the visualization art prototype was susceptible to such issues. Here I wanted to show the wealth and size of the data in a graphical way, what often led to a big number of graphical objects on the screen. The algorithm for the enclosing layer for the IA prototype showed some deficiencies in performance as well. In this case it was possible to improve the algorithm to a degree, where fluent operation of the program was ensured. In early versions of the concept for the edges connecting bubbles in the IA version, it was planned to show all connections between all bubbles at once. This would lead to a huge number of edges for some subsets. The improvement of this concept, towards interactively selecting tags for a certain bubble and only showing edges for those, simultaneously solved the performance problem.

3.3.3 Meeting the Criteria of Visualization Art

As was done for the IA prototype in section 3.2.4, I will analyze the location of the VA prototype in the model of information aesthetics, according to the factors *mapping technique* and *data focus*. Additionally I will explain how the interaction concept contributes to the artistic qualities of this work.

Mapping Technique:
The mapping techniques that was used in the VA prototype is considerably more abstract than the one used for IA. The flower concept shows only a vague impression of the dynamics and size of the data for a particular article. This is mainly due to the complex algorithm for the generation of the flower shapes that is not meant to be invertible but rather to take unexpected features of the data and use it as base for a beautiful shape. The resulting visualization can only be comprehended in an interpretative way and it encourages the viewer to do so.

Data Focus:
The big number of flowers and the smooth and fragile connection lines produce a rich image. Another element that works on an emotional level is the edged petal design for fear articles. They give regions of high fear concentration an aggressive appearance. The round petals of hope articles on the other hand create a harmonic and calm picture. Qualitative associations with the data, like aggressive or harmonic, are features of visualization art and denote an extrinsic data focus.

Whitelaw describes how data art takes part in constructing *data subjectivity*. Especially data art, more than information- or visualization art, has the capabilities to generate a meta discourse about the real meaning and potential of data (Whitelaw, 2008). The visualization art prototype fulfills this criterion as well, to a certain degree. The abstract mapping provokes considerations about the structure of the data, uncoupled from the evident content of the news articles. The apparent semantics of the data is not sufficient to explain the mapping to the flower shapes. This is a highly extrinsic feature as well.

Interaction:
The interaction concept relies strongly on rewarding the user for his actions. Animation and sound effects should motivate interaction for its own sake, just to see the pleasant consequences. The data gets secondary in this process.

3.4 Information Visualization Prototype Design

Since the basic structure of both the IA and the VA prototypes shows several similarities to scatter plots it was self-evident to use a classic scatter-plot design for the information visualization prototype. The details of the visual design are based on the implementation of scatter-plots on Many Eyes. All articles are depicted as circles with a color-coding according to their respective desk, see Figure 73. Fear articles have a hole in the middle, hope articles are completely filled. To explore the data a set of filter functionalities is provided. All the available features can be included or excluded from the visualized dataset. It is possible to show only fear articles, only hope articles or both. Every single desk can be chosen separately to be present in the result set. The same is true for the tags. Analogous to the fisheye list, the selection of multiple tags leads to a result set of articles that include all selected tags. This is different for the desks. Since every article is assigned exactly one desk a filter for articles with multiple desks is not reasonable. Checkboxes are used to select the settings for the article subset that will be displayed. This provides a familiar way of interaction together with a permanent visibility of the current state of the application. Additionally, the articles can be filtered for their word count. Sliders are provided to set the minimum and maximum for the word-count interval to be shown. Once again, the interaction concept follows well-known principles. On mouse-over, details for an article are shown. Those contain the headline, page number, and date. On click an article detail box is displayed on top of the visualization area. This box shows all available information about an article: headline, abstract, desk, page number, date, and a list of all associated tags.

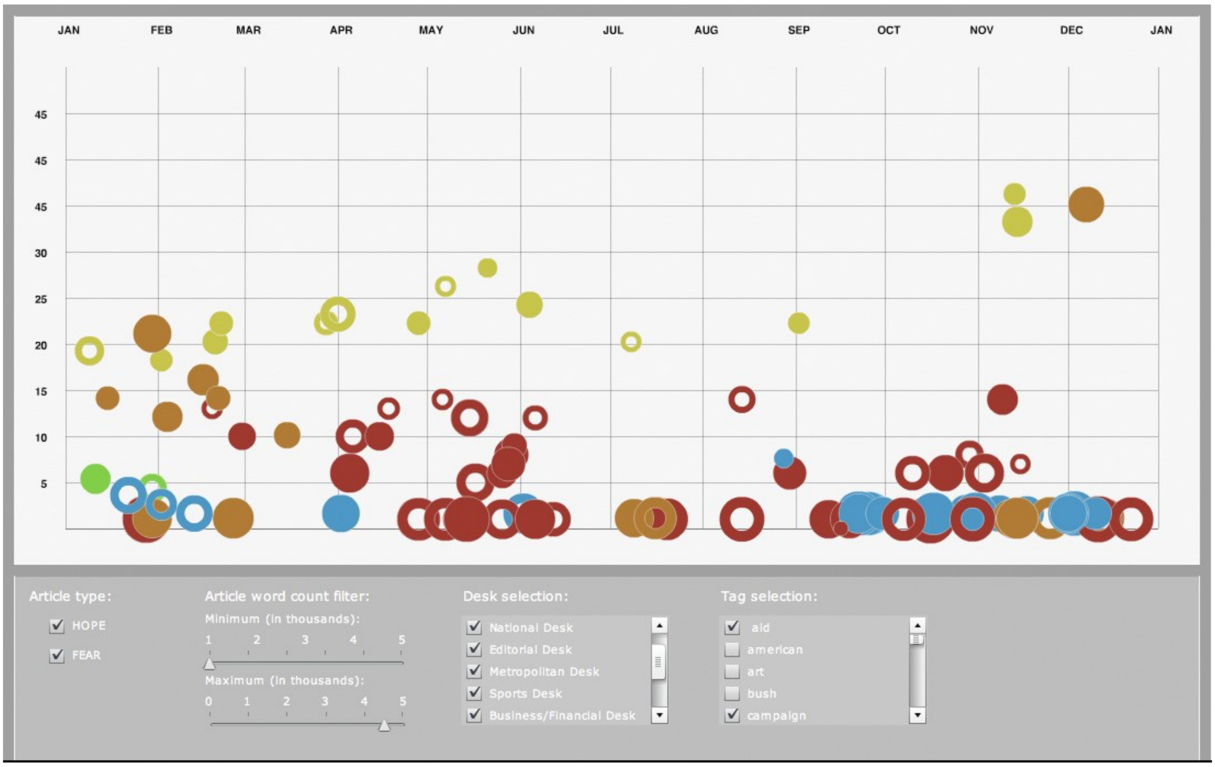

Figure 73. Final infovis prototype

3.4.1 Meeting the Criteria of Information Visualization

To ensure the correct location of the infovis prototype in the *model of information aesthetics*, the factors *mapping technique* and *data focus* are evaluated for this tool as well. This is the least extensive evaluation since only standard techniques were used that undoubtedly belong to the infovis domain and are used in a broad range of other applications.

Mapping Technique:
The mapping is direct and intuitive. The horizontal time axis is a known element. The linear mapping of page numbers on the y-axis is straightforward to understand, as is the mapping of word count to circle size.

Data Focus:

The infovis prototype can be described as tool. It is tailored to select subsets according to clearly defined criteria and to generate results for specific tasks. The ideal task is to locate a data point with very specific features. Hence, the data focus can be classified as *intrinsic*.

Interaction:
The interaction concept follows a common scheme. All GUI components belong to a standard compilation that is available on most programming-platforms and is frequently used. The same is true for the mouse-over article details and the article-detail popup. The main goal in the design is to create a clear layout with components that are known to most users. The usage follows familiar patterns and produce exact and predictable results.

3.5 Summary

This chapter describes in detail the extensive design process that resulted in three showcase prototypes for the three domains: information visualization, information aesthetics, and visualization art. It is shown how the analysis of related work, theoretical concepts, and technical challenges contributed to a thorough understanding of the realm of information aesthetics. Relying on this, at first the critical information aesthetic visualization prototype was designed. The IV and VA applications were then adjusted to complete the aesthetic spectrum.

All three designs are covered by a detailed description, illustrated with screenshots of the final products. To ensure that all prototypes are concurring with the criteria for information aesthetics proposed by Lau and Vande Moere (2007), every one of them is compared to those criteria and positioned within their model of information visualization. The final result is a unique troika of related visualization applications, based on the same data that are only separated by their variation of aesthetic influence.

The extensive investigation of related work and the design concepts in use, in combination with a thorough theoretical analysis of the fields were necessary groundwork for the implementation of three visualization prototypes that form a sound foundation for the planned user study.

4 Prototype Implementation

The objective of this chapter is twofold. First, I want to provide an overview over the technologies, used for this project. Those technologies contribute to the current spread of infovis and related fields and, hence, deserve more detailed explanation. Second, I want to underline that the prototype implementation was a big part of this project, which should be reflected by the description of the prototype implementation provided in this chapter. Since the prototype concepts were already discussed in-depth in chapter 3, this description will provide exemplary amendments to create an impression of the implementation process and to point out some important details. It should be seen as complement to the description of the design process in chapter 3.

In section 4.1 the communication with the NYT API is described. Section 4.2 gives an overview of the technologies, used for the implementation, in especial ActionScript and Adobe Flex. Section 4.4, 4.4, and 4.5 provide implementation details about the prototypes, their program structure and the most important algorithms. The description of algorithms is supplemented by parts of the original code when this seems reasonable to foster understanding. Black frames will accentuate sections of program code, API requests, and encoded data.

4.1 Data Base

The first step in the implementation process was the generation of the dataset. This set consist of all the articles from the *New York Times* Article Search API (The New York Times, 2009a), that include either the word “hope” or “fear” and were published during the year 2008.

4.1.1 Article Search API

This API allows keyword search for headlines, abstracts, and other data, within the article database of the NYT, reaching back until 1981. An additional feature is *facet search* for a large set of predefined terms, called facets, including geographic locations, persons, and companies and organizations.

The communication with the API works through HTTP-get commands with particularly formatted URIs, which incorporate search terms, time interval, facets and other details about the search. The request that is used for this project can be seen in Code Snippet 1.

```
http://api.nytimes.com/svc/search/v1/article?query=hope&fields=title,ab
stract,date,geo_facet,per_facet,word_count,page_facet,desk_facet&begin_
date=20080001&end_date=20081131&order=oldest&offset=x&api-key=your-API-
key
```

Code Snippet 1. New York Times Article Search API request, used to generate the dataset.

This cryptic text needs to be examined in detail. The *query* parameter can be set to one or more search terms, or facets can be used. I use "hope" and "fear" in two separate queries. The data fields, that are included in the response from the API, can be specified, as can be begin and end date. Order denotes which results are arranged at the beginning of the result set. The offset parameter is necessary because only ten data entries are returned per request. By iterating the offset parameter, all data entries for a result set that has more then ten entries, can be retrieved through multiple requests.

The query result is returned in *JSON* (JavaScript Object Notation) (Ecma International, 1999) formatting. This format is easy to read for humans and can be handled by ActionScript via the *as3corelib* library. A JSON entry for an article looks like the example in Code Snippet 2. As can be seen, the encoding of the data is intuitive and easily understandable.

```
{
"abstract":"Conservatives who dominate talk radio, after eight years of
    playing defense for Pres Bush, are energized by return of
    opposition status with election of Sen Barack Obama as president;
```

```
    five of most popular syndicated names in news-talk radio--Rush
    Limbaugh, Sean Hannity, Glenn Beck, Michael Savage and Laura
    Ingraham--signed new contracts, all but guaranteeing they will be
    rallying listeners for duration of Obama's term; photos (M)",
"per_facet":["BUSH, GEORGE W","SAVAGE, MICHAEL","THOMPSON, FRED
    DALTON","LIMBAUGH, RUSH","OBAMA, BARACK","HANNITY, SEAN","BECK,
    GLENN","GIULIANI, RUDOLPH W","INGRAHAM, LAURA","HUCKABEE, MIKE"],
"word_count":"1540",
"date":"20081222",
"title":"For Conservative Radio, It's a New Dawn, Too"
}
```


Code Snippet 2. NYT-API result for one article in JSON format.

During the generation of the dataset two issues occurred. First, each request only contains ten article data entries. To get all entries an offset parameter has to be iterated, and for each iteration a separate query has to be launched. Second, the number of requests per second is limited. To solve this, it was necessary to time the query launches. By experimenting I found a rate of ten queries per second to be optimal.

In the final implementation the data set is provided as separate file with the prototype applications. The access happens locally, due to the considerable size of 3 megabyte.

4.2 Implementation Technology

Several technologies were essential for this project. The specific features that make them suitable for the implementation are explained in detail. The biggest emphasis is put on the ActionScript script language that was used for the implementation.

4.2.1 ActionScript

Adobe Flash, originally developed by Macromedia, is one of the core technologies supporting the Web 2.0 paradigm. Its success is substantially based on the fact that it lowers the barrier for designers to create own program code. The Flash development environment provides exhaustive tools for creating graphical content by hand, but since the automated generation of images is one of the core elements of our project, I will work with the script language ActionScript 3.0 exclusively. As development environment Adobe Flex 3.0 comes into use.

ActionScript experienced a rapid development in the last years. Successively the object-oriented capabilities of the language were adjusted and increased. At the time of writing, ActionScript 3.0 is close to a fully developed, object-oriented programming language (Sanders & Cumaranatunge, 2007). In this section I will describe the influence of object-oriented programming (OOP) on my work. Then I will mention some features of ActionScript that are of special importance for the development process.

Object Orientation

Object-oriented programming (OOP) has become the leading programming paradigm over the last years. Under this influence, ActionScript developed from a small scripting language to a nearly full-fledged object oriented language. There are still some flaws in the implementation of the OOP-concept, for instance the lack support of abstract classes, but the ActionScript community is creative in finding work-arounds for those issues. Literature is available, how to apply programming patterns in Flash (Sanders & Cumaranatunge, 2007). This mirrors the growing programming knowledge and experience in the art community.

OOP techniques proof to be inevitable for this project. They provide the base for a dynamic and cyclic development process. Especially the frequent recombination of design elements would have been an unsolvable task without object-oriented programming. With a well-structured Class hierarchy it is possible to maintain different subclasses of a visual component in the project. They can be used interchangeable without modifying significant parts of the code.

This programming paradigm affords a lot of discipline and has drawbacks as well. In the cyclic development process, many graphical classes are subclassed several times to integrate additional functionality or visual assets. The readability of the code suffers in the latter stages of the implementation since the relevant code is spread over several classes, and functions are overridden somewhere in the middle of the class hierarchy. Refactoring of the class hierarchy, what would improve the clarity of the program structure, is a laborious process.

Sprite Class

The *Sprite* class is one of many subclasses of the *DisplayObject* class. The abstract *DisplayObject* class serves as parent for all objects that can be displayed in any way. The Sprite class is very versatile. Sprite objects support standard drawing functionality and can be used as containers for other graphical objects, including other Sprites. The classes for article bubbles, desk layers, flowers, scales, etc. were derived from the *Sprite* class. A big advantage is that this class automatically handles the most important events.

Events

The backbone of the interaction concept of all three prototypes is the ActionScript 3.0 event model. Events are function calls that are passed between different objects in a computer program. Event sources are objects that send events, for instance as reaction to interaction. Event listeners are objects that are listening to events from specified sources. The *Sprite* class, by default, triggers a lot of useful events that cover the majority of behavior needed for the prototypes, e.g. reactions on click and mouse over. Event listeners have to be added to the *Sprite* object to assign functionality in response to certain events.

In several cases the standard event classes, like *flash.events.Event* and *flash.events.MouseEvent,* are lacking functionality. It is very common that additional data is needed in the function handling the event. An object-oriented solution for this task is to create a subclass of *flash.events.Event* that contains additional data fields. To integrate the new events into the existing structure it is necessary to catch the original mouse events before they are passed to other classes. For every event that is caught a subclassed event is created and triggered.

A plurality of event sources and listeners can be a challenge for the automated garbage collection mechanisms. Hence, a very useful extension to the standard event capabilities of sprites is an event manager. When multiple listeners are added to an object over time, a listener-list can be used to keep track of them. When the object is disposed, all listeners from the list can be deleted as well. This avoids memory leaks and circular dependencies.

Bitmaps vs. Vector Graphics

Standard drawing functionality, as incorporated by the *Sprite* class, produces vector graphics with a set of predefined commands as *lineTo*(…), *curveTo*(…), or *drawCircle*(…). The *DisplayObject* class provides a special functionality that is inherited to children, as *Sprite*: after the property *cacheAsBitmap* is set to true a rasterized copy of the DisplayObject instance is created in working memory. When correctly used, this feature can provide significant performance advantages, especially for complex vector graphics. It has to be considered that processes, like scaling or rotation of the display object, make it necessary to create a new bitmap for every timeframe. This leads to a performance loss, rather than an advantage.

4.2.2 Frameworks and Libraries

For the implementation I made use of the Adobe Flex 3.0 framework. For rapid prototyping and as inspiration for my own program structure I examined the Flare infovis library for ActionScript. I will introduce both of them briefly in this section.

Adobe Flex

Adobe Flex 3.0 is an extensive framework for the creation of rich Internet applications (RIA). Compared to the Flash technology, that serves a similar purpose, Flex is directly targeting software developers. Flash is widely neglected by software experts due to its strong rootage in the design field. Flex uses the markup language MXML for the definition of the user interface. Interaction and other computational tasks are performed by ActionScript. Flex Builder is an integrated development environment that was created by Adobe especially for the authoring of Flex applications. A set of standard components as buttons, lists, or tables is supplied and can be easily extended by new components. For details see (Adobe Systems Incorporated, 2009).

Flare

Flare is an information visualization library for ActionScript (UC Berkeley Visualization Lab, 2008). It emerged from the *prefuse* project that is based on the Java technology. Flare provides out-of-the-box implementations for most standard infovis techniques. The framework also incorporates more advanced concepts, as stacked graphs, circular graph layouts, and treemaps. A rudimental documentation is provided, but the lack of detail makes the extension of the framework difficult. However, the usage of standard functionality is straightforward. This makes the library valuable for the exploration of complex datasets at the beginning of the design process of a infovis project, as mentioned in chapter 3.

4.3 Technical Details for IA

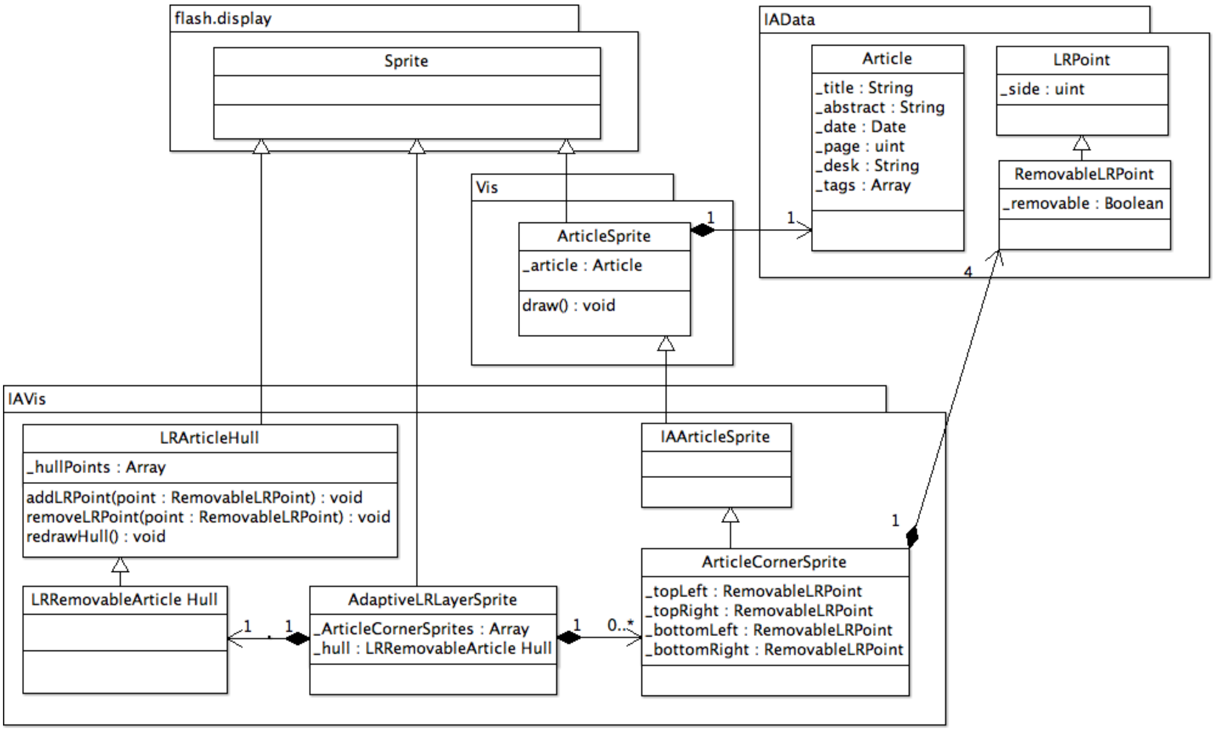

Figure 74. UML diagram for the core of the IA prototype

As described in chapter 3, the IA prototype was the first that was designed as well as implemented. Figure 74 shows an UML diagram of the core classes from the IA prototype. A complete documentation of the program exceeds the scope of this work. For this reason, I focus on particularities, mainly contained in the graphical objects on the display area. It can be seen that all graphical elements are derived from ActionScript's Sprite class. Those classes are internally pooled in the *IAVis* package, with one exception: *ArticleSprite* lies in the general *Vis* package. This class is a universal parent class for visual entities based on the data for one article and is used for all prototypes.

The class hierarchy of *ArticleCornerSprite* shows how the object-oriented concept of inheritance was used within the cyclic design process. After the implementation of the article bubble was already completed, a redesign of the layer algorithm made it necessary to add corner coordinates to each bubble. This is conveniently accomplished by creating a subclass of *IAArticleSprite*.

The *IAData* package contains data classes. The most important one is the *Article* class, encapsulating all data for a single article. When the application is started, for every article in the dataset an *Article* object is generated. *LRPoint* and *RemovableLRPoint* are extensions of the standard point concept. Their purpose will be explained in the scope of the layer algorithm in section 4.3.1.

Apart from the display area, the fisheye list was the most extensive component to implement. In section 4.3.2 the central algorithm of this component is explained. The rest of the application consists of standard elements and concepts, and does not require any particular consideration.

4.3.1 Layer Algorithm

The most challenging algorithmic task during the implementation process was the enclosing layer concept. The positive effect of organic design on the aesthetic perception of visualizations together with the need to establish a strong delimitation of a scatter-plot like appearance made the design concept of enclosing layers very interesting. The desired result is a smooth shape that encloses all elements of one category, in this case of one desk. The shape should vertically enclose the whole space from the topmost point of the highest element to the bottommost point of the lowest one. The layer should not be disconnected between the leftmost and the rightmost point, see Figure 75.

On the first view, the given task seems similar to a convex-hull problem. Various algorithms for the computation of convex hulls do exist. The essential difference to the enclosing-layer idea is that in our case concavity is not only possible, but required. Only layers with concave silhouettes can produce the desired fluent and organic appearance.

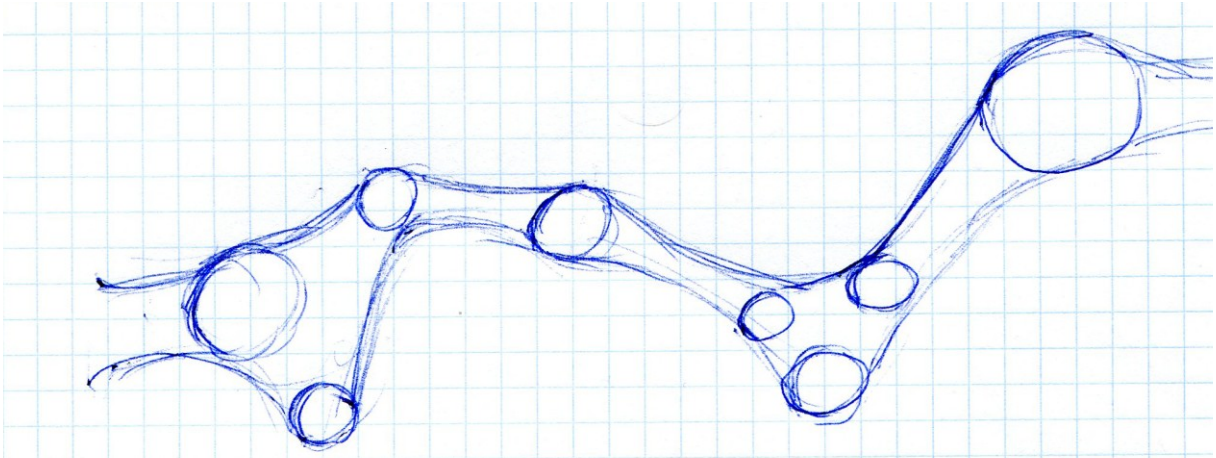

Figure 75. Layer concept

A concept that allows concavity are *metaballs* (Hearn & Baker, 2003). Other related concepts, e.g. gravity fields in tow dimensional space, were considered as well. It is very likely, that the desired results can be achieved with these techniques. The approach was dropped before results were produced because of technical reasons. The necessary calculations would have to be performed on a pixel-per-pixel base. Then the results would have to be converted to a vector format for further use. The computational workload for those procedures is very high, and not likely to be suitable for a Flash application with a big data stock.

The first step towards the solution of the problem is an approach, based on supporting points that are uniformly distributed along the x-axis. All those points are initialized with a negative y-value. For every article bubble that is added to the screen, the supporting points that are within its extend, are checked for their y-values. If those are lower than the upper border of the circle, then they are raised to the new value. After all the circles are processed the chain of support points is filtered. Only points adjoining a change in height are transferred to the result set. Based on this point set a smoothed curve is drawn. The big advantage of this technique is its scalability. The amount of computational workload can be reduced considerably by limiting the number of supporting points. This, in return, affects the accuracy to which the layer border coincides with the circle border. Some early tests produced promising results, as can be seen in Figure 76. After all, for a satisfying resolution the calculation time was still to long.

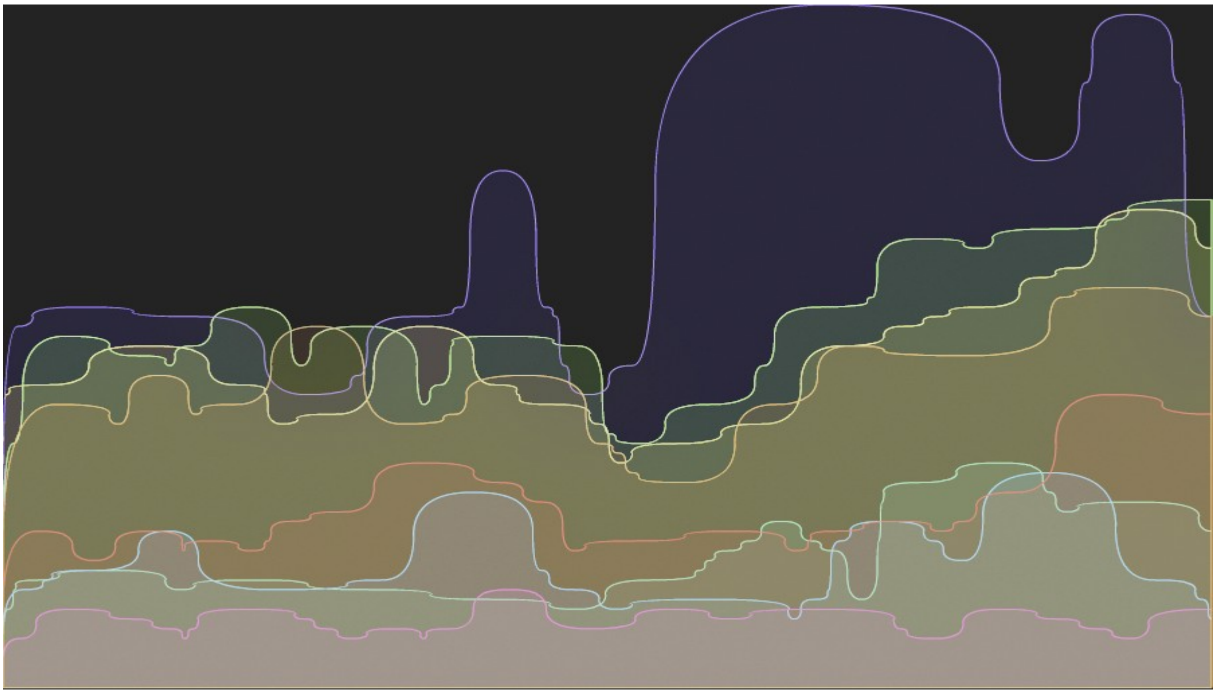

Figure 76. Support-point layer algorithm

A severe weakness of the supporting-point concept is the big number of points that have to be checked and modified just to be discarded before the calculation of the final border. Efficiently reducing the number of supporting points is a promising approach to improve performance and reduce code complexity. The optimal solution is to dynamically build up a set of supporting points, containing the rightmost and leftmost point of every circle. This reduces the number of points and ensures that only x positions are considered that have a high probability of incorporating a change of height in the final layer shape.

It is necessary to add an additional attribute to the corner points that denotes whether a point is a left or a right edge point. This produces pairs of points on the same y-level. In the resulting layer the x-range between those two points has to be on their y-level or higher. To enforce this condition, the interval for every pair of points is traversed and lower points are removed. This concept was extensively tested and redesigned several times. Severe bugs appeared until the end of the implementation phase.

To provide some insight into the technical details of the implementation, I provide the source code for the function that is critical in the generation of the layer outline in Code Snippet 3.

```
override protected function createHullPart(points:Array, pos:uint):Array {
	var result:Array = points;
	//a is further right
	var a:RemovableLRPoint;
	//b is further left
	var b:RemovableLRPoint;

	//upper boundary is calculated
	if(pos == UPPER) {
		for(var i:int=0;i<points.length;i++) {
			a=result[i];
			//remove double corners (they produce hard edges)
			if(i>0) {
				b = result[i-1];
				if((b.y==a.y)&&(b.x==a.x)) {
					b.removable = true;
				}
			}
			//traverse range of current bubble and remove lower points
			if(a.side == LRPoint.RIGHT) {
				for(var j:int=i-1;j>=0;j--) {
					b=result[j];
					if((b.y==a.y)&&(b.side == LRPoint.LEFT)) break;
					if(b.y>a.y) {
						b.removable = true;
					}
				}
			}
		}
	}
	//lower boundary is calculated
	else if(pos == LOWER) {
		for(var i:int=0;i<points.length;i++) {
			a=result[i];
			//remove double corners (they produce hard edges)
			if(i>0) {
				b = result[i-1];
				if((b.y==a.y)&&(b.x==a.x)) {
					b.removable = true;
				}
			}
			//traverse range of current bubble and remove higher points
```

```
                    if(a.side == LRPoint.RIGHT) {
                          for(var j:int=i-1;j>=0;j--) {
                                b=result[j];
                                if((b.y==a.y)&&(b.side == LRPoint.LEFT)) break;
                                if(b.y<a.y) {
                                      b.removable = true;
                                }
                          }
                    }
              }
        }
        //cleaning of the points that were earlier marked as removable
        var rlrp:RemovableLRPoint;
        for(i=result.length-1;i>=0;i--) {
              rlrp = result[i] as RemovableLRPoint;
              if(rlrp.removable == true) {
                    result.splice(i,1);
              }
        }
        return result;
}
```

Code Snippet 3. Calculation of the supporting points for the layers.

Explanation of Code Snippet 3:

The function has three mayor parts. The first two parts are symmetrical, with interchanged leading signs. For the calculation of the upper and the lower boundary the logical operators are oppositional, apart from that the algorithms are identical. An array of all upper or lower corner points, sorted by ascending x value, is traversed, element-by-element. At first every point is compared to its predecessor and removed, if it is identical. The second part of the code inside the loop is essential. Here the left-right strategy unfolds. For every article bubble one left and one right corner point exist. They are on the same level on the y-dimension. All corner points in-between have to be on a higher y-level, to be included into the result set. This is realized in the algorithm by taking every right point and iterating through all his neighbors on the left side, until the complementing left point is found. Every point in between is marked as removable, if its y-value is lower. The points cannot be removed completely because they still could be the complement of another point that was not processed yet.

The last part of the function traverses all points once again and removes those marked as removable, from the result set.

4.3.2 Fisheye List

For the fisheye list a special Flex user interface component was created. It can be embedded directly into the MXML part of the main Flex application file. The data to be displayed in the list is set in the ActionScript code via the *dataprovider* attribute. Two parameters can be set: the maximum magnification of a list element under the cursor and the range of the magnification effect on both sides of the cursor. Every list item is represented by a separate *TextField* object. Using the predefined *onMouseMove* event, every movement of the cursor is monitored, and leads to a call of the *updatedDisplayList()* function. This function handles the resizing of the TextFields. To achieve exactly the desired behavior, it was necessary to create a new implementation of this function. This code can be seen in Code Snippet 4.

```
protected override function updateDisplayList(unscaledWidth:Number,
unscaledHeight:Number):void {

	var index:int = _textfields.indexOf(_activeTF);
	var scale:Number;
	_widthSum = _tagSpacing;
	for(var i:int=0;i<_textfields.length;i++) {
		//scale for the current TextField, dependant on the distance from
		//the mouse cursor
		scale = Math.max(1,1+_scaleFactor*(_range –
			Math.abs(index-i))/_range);
			//the new scale is saved in a number array in the first loop,
			//for efficiency reasons
		_dimensionsX[i]=scale;
		_dimensionsY[i]=scale;
		//overall sum of all TextFields together, needed for normalization
		_widthSum += (_textfields[i].width * scale / _textfields[i].scaleX +
			_tagSpacing);
	}

	var normalize:Number = (Math.floor((this.width/_widthSum) * 100)) * 0.01;

	var xPos:Number = 0;
	var oldXPos:Number;
	var oldXScale:Number;
	var oldYScale:Number;
	for(var j:int=0;j<_textfields.length;j++) {
```

```
                _dimensionsX[j]*=normalize;
                _dimensionsY[j]*=normalize;
                //tween effect for rescaling
                TweensyZero.to(_textfields[j], {x:xPos, scaleX:_dimensionsX[j],
                       scaleY:_dimensionsY[j]}, 1.0, Sine.easeOut);
                //new x-position for the next list element
                xPos += (_textfields[j].width * _dimensionsX[j] /
                       _textfields[j].scaleX + (_tagSpacing*normalize));
                }
        }
}
```

Code Snippet 4. Resizing of the elements in the fisheye list.

Explanation of Code Snippet 4:

All elements from the *TextField* array are traversed twice. In the first run, a scaling factor according to the distance from the mouse-cursor is calculated for every field in the list. Those factors are temporarily saved in an array. In the second run, all elements are normalized in size, so that the overall width matches the width of the GUI component. This two-run strategy is necessary because the different number of letter in every word results in different effects of rescaling on the overall width. The rescaling of the list elements is animated with motion tweens. This functionality is supplied by an external library called Tweensy (McCartney, 2009). Interaction becomes more fluent and engaging through the animation, at the same time it increases usability by avoiding leaps that make the selection of tags difficult.

4.4 Technical Details for VA

Compared to the structure of the IA prototype, shown in Figure 74, the VA class hierarchy is more linear. An *ArticleFlowerSprite* class is directly derived from *ArticleSprite*. The different design concepts for the flowers are implemented as subclasses of *ArticleFlowerSprite*, see Figure 77.

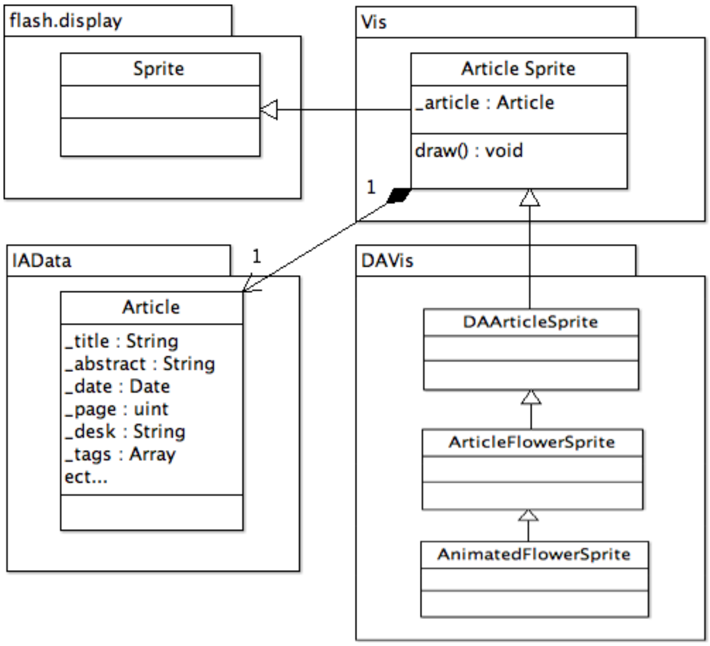

Figure 77. UML diagram, showing the core of the VA class hierarchy

The important graphical elements are flowers and stems. I will describe some details of their implementation. The already described fisheye list serves as navigational component for this prototype as well, see section 4.3.2.

4.4.1 Flowers

A high degree of abstraction is realized by the mapping of article text to flower petals. Every petal is the encoded representation of one word. The length of the petal is defined by the word length. The second parameter is the peak coordinates of the petal shape. Those are provided by the word probability. To calculate this probability the normalized frequency of every letter of the word in the English language is summed up and divided through the total number of letters. To adapt the result to a range between 0 and 1, the result is divided by the highest probability for one letter, 12.702% for the letter e. This probability is no mapped to a direction vector. This vector is multiplied by the length and added to the center point of the flower shape. After applying this procedure to every word in an article, the resulting set of endpoints can be converted to an interesting flower shape. To reduce the number of petals I excluded the most frequent words from these calculations. The code in Code Snippet 5 performs the calculation of these endpoints.

```
//the parameter filter enables for the headline words to be excluded from the
filter-rules
private function generateEndPoint(word:String, filter:Boolean):void {

     var length:Number = Math.sqrt(word.length);
     var wordProp:Number = WordStatisticsUtil.getWordProbability(word);

     //filte very frequent words
     if(_frequentWords.indexOf(word)>=0) return;

     if(length > _maxWordLength) _maxWordLength = length;
     var endX:Number = Math.cos(((_blossomOrientation+wordProp)*PI2*2)-(PIhalf));
     var endY:Number = Math.sin(((_blossomOrientation+wordProp)*PI2*2)-(PIhalf));
     _endPoints.push(new Point(endX*length,endY*length));
}
```

Code Snippet 5. Algorithm for petal endpoint calculation.

Regarding that there can be hundreds of such flowers for one visualization perspective, performance considerations have to be made. The key to making this huge number of complex flower possible was the cacheAsBitmap property. All flowers were saved as rasterized bitmaps, what increased the speed of the application to an acceptable level. As mentioned earlier, the scaling of bitmapped objects is highly ineffective. As a consequence, several growing effects that relied on scaling could not be implemented.

4.4.2 Text Animation

On clicking an article flower the abstract of a selected article is printed to the screen in an animated way to reward interaction. This is realized with a Timer object that adds letters to the abstract TextField until the complete text is displayed.

4.5 Technical Details for IV

The infovis prototype was conceived using familiar components in a standard way. This was achieved by using standard components from the flex framework. The data bubbles are a simplified version of the IA bubbles. Big parts of the code for this application were taken from earlier tests or the IA prototype.

Here the support of the Flex environment unfolds. The development process, using predefined components, was considerably faster and less error-prone than the implementation of new graphical components from scratch. The usage of customizable components, for instance *mx:HSlider*, proofed to be unproblematic. For the lists of checkboxes with multi-selection support, the open-source component *toolbox:CheckBoxList* was used (Tynjala, 2007).

5 Evaluating Information Aesthetics

The discourse about the value of aesthetics within the infovis domain shows the lack of empiric evidence. In chapter 3 and 4 the three prototypes for infovis, IA, and VA were described in detail. This chapter is dedicated to considerations how they can be used in the scope of a user study to produce empiric evidence about specific strengths and flaws of the three visualization subfields and the significance of aesthetics in this context.

With the spread of information visualization and its related fields from expert domains to mainstream applications, a new discourse about the evaluation of these techniques has started. The recent trend in the evaluation of visualization from quantitative to qualitative methods supports the position that there is unused potential at the more *interpretative* and *extrinsic* (Lau & Vande Moere, 2007) periphery of the infovis field.

The overall strategy for the conception of a study design in the domain of IA follows the approach of Lau and Vande Moere:

> *"…information aesthetics is analyzed from an information visualization perspective, in terms of functionality and effectiveness, and from visualization art, in terms of artistic influence and meaningfulness."* (Lau & Vande Moere, 2007)

This illustrates the need for a very versatile evaluation strategy that incorporates utilitarian measures as well as methods to evaluate aesthetic qualities.

In section 5.1 the theoretical background for an IA specific study is provided. The current practice of usability testing is described, followed by new techniques for measuring insights in infovis. User engagement, a concept from web analytics, is investigated according to its applicability for our study setup. Related studies in the infovis domain are discussed to provide examples for practical applications. Section 5.2 describes a possible study setup, based on the background provided in section 5.1. The study design is meant to incorporate state-of-the-art infovis evaluation methods and extend them to cover the important aspects of information aesthetic visualization and visualization art as well. To ensure the applicability of the setup, it is suggested to evaluate prototypes and study concept in the first part of the study using expert reviews and a pilot study.

5.1 Evaluation Theory

This section describes the theoretical concept behind different evaluation methods that are needed for the study design. Examples are provided as orientation point for autonomous considerations.

Section 5.1.1 provides an overview of the current practice in usability evaluation that is based on benchmark tasks and mainly relies on measure for *effectiveness* and *efficiency*. Section 5.1.2 describes a recent trend towards *insight* evaluation that provides means to examine visualization techniques more deeply and in a more qualitative manner. Section 5.1.3 mentions varieties of the original insight idea that are especially interesting for the field of IA, where we expect to find qualitatively different insights. Section 5.1.4 discusses the measurement of *user engagement* and its possible value for the study design. In Section 5.1.5 the possibilities for measuring aesthetics are reasoned. This measure is important to verify the precondition that VA is perceived as more aesthetic than IA, and IA exceeds infovis in that quality. The last section, 5.1.6, describes three related studies that are suitable as practical examples for the IV evaluation.

5.1.1 Usability Studies

Usability Studies are the state of the art method to evaluate information visualization tools (Spence, 2007). Hornbaek (2006) analyzes 180 usability studies regarding the applied measures, and structures the resulting set into three categories:

- Measures for effectiveness
- Measures for efficiency
- Measures for satisfaction

Effectiveness describes a degree for the achievement of a certain desired effect. Examples for measures are whether a task was completed or not, how many error occurred in a task completion process, or the quantity of information a user can recall after the interaction with an interface. The most frequent measure within the 180 studies is the error rate that was used in 26% of all cases when effectiveness was measured.

Efficiency is focused on the performance of task solving. The most frequent measure in this category is the time to complete a predefined task. Other measures are the time before the first key press or the input rate of text. An interesting variety of efficiency is the mental effort that the usage of a tool costs the user. The task completion time was used in 57% of all studies that evaluated efficiency.

Satisfaction is a term that can be interpreted in several ways. Hornbaek writes about usability in general: "…what we mean by the term usability is to a large extend determined by how we measure it." (Hornbaek, 2006). This is especially true for measures of satisfaction. What is noticeable in Hornbaek's comparison, is the high consistency in the measurement methodology. User satisfaction is always evaluated through a questionnaire. The author remarks that the used questions are frequently not mentioned in the works, making a comparison difficult. A second point of critique is that, although standard questionnaires for user satisfaction exist (Chin, Diehl, & Norman, 1988; Davis, 1989), they are only used in 7% of all studies.

The standard procedure to measure effectiveness and efficiency metrics is to use a controlled experiment. A set of basic benchmark tasks is defined, for instance finding extreme values. The test persons then have to solve several of those tasks as fast as possible. Benchmark tasks show weaknesses when used to measure insight:

- They have to be predefined by the test designer.
- They must not exceed a certain completion time to ensure that a sufficient number of repetitions or different tasks can be performed.
- They must have an answer that is known and indisputable.
- This answer has to be simple and easy to describe or select. (North, 2006)

Often the paradox situation exists, that benchmark tasks can be solved in a short time by a simple query or a sorting function, rendering the complex infovis system useless. In general the usage of basic tasks could be explained by arguing that the more complex tasks that really justify the usage of infovis, are compositions of those basic tasks. This approach however requires a valid decomposition of a complex task into smaller benchmark tasks. The resulting minimal tasks could be used in the study. A second issue is the problem of comparing opposing results for performance and accuracy. How to compare two visualizations, of which one has a better performance but a lower accuracy, is a difficult question.

Plaisant (2004) draws a connection between the unsatisfying evaluation practice in infovis and the hesitant adaptation of infovis techniques by a broader range of people. According to her, one quality is especially neglected: *"Answering questions, you didn't know you had"*. This means, finding patterns in the data that you were not searching for. It is one of the big strengths of good infovis but it is nearly impossible to measure with task-oriented evaluation techniques. Predefined tasks that have to be solved in minimum time even tend to decrease the awareness for other findings. This is especially harmful for the field of IA visualization. The exceptional nature of the data, underlying IA works especially enforces subjective and abstract consideration of the data, what is impossible to describe with benchmark tasks.

A solution for the mentioned problems is the application of more complex tasks as base for benchmarks, ideally with textual instead of multiple-choice answers. This brings up new problems. Textual answers need much more effort to score. The resulting tasks take longer to solve, have a bigger range of completion times and degrees of correctness and it is difficult to define equivalently difficult questions, what is necessary to reproduce an experiment several times with the same user. A bigger number of test persons is usually needed to perform a study under those circumstances (North, 2006). A combination of predefined tasks and a phase of free exploration could considerably improve the results of evaluations (Plaisant, 2004). North proposes a more radical solution: the complete removal of benchmark tasks. The alternative is a qualitative evaluation of the *insight* obtained by the test persons.

5.1.2 Insight

North (2006) claims that *insight* *"has been commonly stated the broader purpose of information visualization by many authors"*. To place this term in such a prominent position has a big advantage. It makes all infovis techniques comparable through the insight they provide, a task that is very difficult to manage with standard measures as accuracy and efficiency (Hornbaek, 2006). To make traditional usability measures comparable with insight studies, the result of predefined benchmark tasks simply can be declared as insights. To measure the full potential for insight generation that infovis tools have, a more complex approach is needed.

In (Saraiya et al., 2005) insight is defined, in the context of infovis evaluation, as:

"…an individual observation about the data by the participant, a unit of discovery."

To measure insight the focus has to be shifted towards observing the spontaneous behavior of the user. An open-ended protocol is essential for this. The user is invited to think of some initial questions and then explores the data freely. The experiment ends when the user reaches a point where he or she does not expect to gain any more insight. All findings that occurred until then are logged. The resulting data are of qualitative nature. A common way to collect them is the *thinking-aloud* method, where the test person verbalizes thoughts as they appear. To structure the data, several categories can be applied: depth, thematic categories, error, time to generate. This approach can be used to show weaknesses in the visualization concept by conversely examining what kind of insights did not occur to the user.

Several new demands appear with the innovative study setup:

- Longer duration of the experiments
- More work in logging and encoding the results
- Test persons that are motivated and qualified to produce own insights
- Domain experts to interpret the domain specific results

All those problems can be solved with sufficient resources.

Apart from the extraordinary importance of the term *insight* for the field of infovis in general, this concept has a big potential for showing the specific features of information aesthetics. Pousman et al. (2007) make an approach to extend the scope of the term insight for the related field of casual information visualization. They argue that the insights, produced by casual information visualization, are different from the insights that are requested by traditional infovis. I expect the same for the information aesthetics domain. The reasons for substantially different insights are manifold. The data is emotionally engaging for the user and fosters a different perspective. The location of IA applications in a non-working context amplifies this. Not only the data but also the way of interaction and the reaction of the IA visualization are designed to be emotionally loaded. The interaction is *rewarding*. VA can be included into this approach in the same way as IA.

5.1.3 Varieties of Insight

The understanding of the term *insight* in the infovis domain is strongly influenced by the aftermath of the benchmark tasks that dominated the field for a long time. The value of the analytic insights that are based on these earlier methods is beyond doubt, but qualitatively different insights deserve to be taken into account as well. Pousman et al. (2007) describe a set of four different types of insights:

Analytic insight: The locating of regularities and patterns, the finding of extremes and similar insights can be classified as analytic.

Awareness insight: This kind of insight is more superficial and consists of an awareness of trends and rough changes within a certain information base. Examples are keeping track of the news, to be able to contribute to a conversation, or the quick look at the weather forecast, to check if it will be raining tomorrow. The benefits from this awareness are not analytical results but social and cultural interaction with others and a cross-domain perspective on certain topics, although on an informal level. I would like to add a point that was not mentioned by the authors: awareness is a base for decision-making. Constantly being aware of certain processes as the weather or the public transportation schedule leads to a form of experience that often serves as aid, when a fast decision has to be made and no exact data is available, e.g. if it takes less time to wait for the bus or to walk. An important feature of awareness insight is its low effort in cognition. A human maintains awareness of multiple sources without any noticeable working effort.

Social insight: The understanding of the dynamics of a social network and the personal location within this structure are referred to as social insight. The main characteristics of social insight can be observed when exploring a social network tool. Most observations about activities within the social group concur with a subjective model of that group. Information exchange between certain persons and the structure of the social networks of other members of the group are usually not surprising to the individual. This process is not analytic, due to its lack of task focus, but still can have considerable impact on the behavior in the given social context.

Reflective insight: The fourth type of insight sets focus on reflecting the own character and the own position in the surrounding world. The obscuration of familiar circumstances is a valid mean to induce this and is often used as technique by artists.

Depending on the dataset, all those varieties of insight are presumed to occur through the usage of IA and, except for analytic insight, VA. The application of the open-ended insight evaluation protocol, as proposed in (North, 2006), provides enough flexibility to identify such varieties within the insights that are generated during a user study.

5.1.4 Engagement

User engagement is a mostly qualitative measure with focus on the involvement of the user in his or her task. I consider this concept promising to bring out specific features of information aesthetics. O'Brien (2006) investigates the usage of measures for engagement in the domain of human-computer-interaction. She points out that different concepts of *engagement* have been used recently, without providing a sufficient definition. Possible dependencies are described on factors as feedback, control, focused attention, motivation, novelty, and aesthetic and affective appeal.

A field where engagement measures are used extensively is *web analytics*. Web analytics were initially designed to investigate the success of e-commerce web sites, through monitoring customer behavior and purchases. The engagement measure in particular is used by web analysts and marketing experts to describe the strength of the connection between a user and the web service. This point of view has the big advantage that the supposed audience is fundamentally different from the experts that usually use information visualization at their workplace. This concurs more with the different application context of IA and VA. The drawback is that web analytics as a field is often not up to scientific standards. Terms are used without clear definition or boundary. Nielsen NetRatings is a global online measurement service that provides data about the usage patterns of online users. Their strategy to measure engagement includes two metrics. The *average time per user* and *average number of sessions* are used to get a hold of the engagement of a big number of users (Nielsen NetRatings, 2007).

There are hardly any conclusive results about how to measure engagement in an infovis context. It is expected that further work will investigate this issue in detail. O'Brien and Toms (2008) outline an evaluation strategy that consists of two parts. They propose the subjective measurement of user perceived engagement. Additionally an objective evaluation, based on behavioral and psychological methods, like heart rate and galvanic skin response, is recommended. This approach is promising in providing holistic results for this complex issue.

5.1.5 Evaluating Aesthetics

There is a general development in the realm of information visualization from expert applications to tools that are useable by a broader range of people. This makes more detailed investigations about the function of aesthetics important. It is a common problem that in a commercial context additional effort and costs are difficult to justify if there are no measures to proof that they are beneficial. In section 2.3 I described the difficulties in specifying the term “aesthetic”. The task to represent aesthetics by analytical measures is even more complex. Cawthon and Vande Moere (2007b) describe two different ways how to quantify visual aesthetics:

Objective Aesthetic Interpretation: The focus here lies in the analysis of visual features of an image. The results are quantitative and connected to terms as proportionality, complexity and variety. An early and extreme example is Birkhoffs measure M for aesthetics as a ration between complexity C and order O (Garabedian, 1934). In a more recent work Ngo, et al. (2003) propose fourteen quantifiable metrics for the aesthetics of screen layouts

Subjective Aesthetic Interpretation: This refers to the fact that a viewer can perceive objects as beautiful, without being able to specify a reason for this. The complex configuration of personal experience and socio-cultural context produce a big range of aesthetic value systems. This perspective on the term is more accurate, but makes the evaluation significantly more difficult. Current practice in user studies are scaled questions for the aesthetics, subjectively perceived by the test person (Cawthon & Vande Moere, 2007b).

5.1.6 Related Studies

Before proposing an approach for a user study based on the three prototypes, I will describe some studies with related objectives. This will give an understanding for the methods in use and for the results that can be expected.

Is a picture worth a thousand words?: an evaluation of information awareness displays (Plaue, Miller, & Stasko, 2004)

This study investigates the efficiency of peripheral awareness displays, also called ambient displays, to efficiently communicate information in a short period of time. The goal of this technology is to provide at-a-glance information awareness. The displays are only suitable for non-critical data. It is arguable that in pure perceptional tasks, speed and effort are closely tied. Fast comprehension of data means a limited cognitive effort. The peripheral display approach achieves a reduction of the cognitive effort by reducing the degree of detail for the displayed data. Numeric values are displayed as vague screen positions of iconographic elements. This is consistent with the concept of awareness. For many decisions an exact value is not necessary. For example, the decision about wearing a jacket on the way to work can be made upon vague information, such as “warm” or “cold”. Knowledge of the exact temperature is not necessary. The authors compare the efficiency of information representation of a peripheral-awareness-display prototype with a web portal and a text-based representation of the same data. In sessions of about 45 minutes lengths, the participants are confronted with all three displays. The order of the different display types is counterbalanced. After a test round without time limit, the visualizations are shown to the participants for 8 seconds. Afterwards they have to complete a questionnaire about the information visualized. In general multiple-choice questions are used. The answer possibilities are exact numbers, about evenly distributed over the range of possible values. Only for those values, originally presented as ranges, the answers are given as ranges as well. An interesting element of the questionnaire is an additional scale for the confidence level of the answer, ranging from low over middle to high. Then a Likert scale was used to document the personal opinion of the participant about the different alternatives, to which degree they support the memorability of information, represent information effectively and are visually appealing. The survey ends with an open question about the willingness of the test persons to actually use one of the displays for themselves.

This study is interesting, because it evaluates a field that is related to IA. Visual appeal is set into a context with cognitive processes, in particular learning. IA and peripheral awareness displays make use of similar strategies in the early phase of user interaction. The user should be engaged in an effortless way. After this initial phase, IA follows a different aim, it draws the user in and motivates to intensify the interaction. Exact values are not dominant in the design, but they are accessible, when the user wants more detailed information.

The Effect of Aesthetics on the Usability of Data Visualizations (Cawthon & Vande Moere, 2007b)

In this work the authors perform a comparative study on the aesthetics of eleven different visualization techniques. Their aim is to examine the correlation between the two usability measures *task abandonment* and *erroneous response latency*, and the degree of aesthetics, subjectively perceived by the user. An online survey is performed, where eleven pictures of different infovis techniques are compared. They are normalized under several aspects to minimize bias. The same information is shown on every picture, the color scheme is the same, textual annotations are completely removed and the position and dimension of the depictions is held consistent as well. Those pictures were presented to voluntary participants in the scope of an online survey. Participants were asked to locate the aesthetic appeal of each visualization technique on a scale that ranges from "ugly" to "beautiful" and does not show any other orientation marks. The second task was to think of the three terms that most accurately describe the visualization. Terms directly describing shapes, color, or the overall layout should not be used. At the end the participants had to place all the visualization pictures simultaneously on a scale that again was delimited by the extremes "ugly" and "beautiful". To evaluate the usability metrics additional benchmark tasks were defined. 14 analytic questions about the data were defined and randomly assigned to a visualization. The questions then have to be answered, according to the information from the visualization screenshot. The results show a considerable range of perceived aesthetics among the visualization methods. Techniques like *Sunburst* (Stasko & Zhang, 2000) received a very high rating while *BeemTrees* (Van Ham & Van Wijk, 2002) were ranked very low. The authors point out interesting correlations between the metric for aesthetics and the usability measures. The term 'organic' is of special importance in the qualitative part of the study evaluation. It was used most often to describe a visualization technique and is tightly coupled to a high value of aesthetics.

This study is highly relevant. First, it is an example for the measurement of aesthetics in the infovis domain. Second, the applied usability metrics are interesting for the evaluation of engagement. The combination of *task abandonment* and *erroneous response latency* is designed to describe how long a user is willing to occupy him or herself with a difficult task, given the possibility to stop the task at any time. This frustration tolerance is tightly connected to the engagement of a user. An engaging interaction is likely to foster a higher tolerance towards frustration.

5.2 Proposed Study

The aim of this study design is to investigate how a different degree of aesthetic influence in IV, IA, and VA, produces various effects on the user. I will propose a possible setup for a user study, based on the implemented prototypes. The objective of the study is to provide measurable evidence for strengths of IA that justifies its application in suitable circumstances.

After a formulation of the study hypotheses in section 5.2.1 and some considerations about the structure of the groups of test persons in section 5.2.2, section 5.2.3 describes the concrete methods to be used to perform the study. At first I suggest the usage of inexpensive and informal techniques to find flaws in the prototypes and refine the study procedure. *Usability inspection techniques* and a *pilot study* are recommended for this. The main part describes he modification and recombination of existing evaluation techniques to meet the specific conditions for measuring insight and engagement under the given circumstances. Following the measurement of subjectively perceived aesthetics is covered by a scaled question. I conclude this chapter with remarks about standard usability metrics, and justify why they are not included in the study design.

5.2.1 Hypotheses

The hypotheses for this study are:

Hypothesis 1: The prototypes reflect the specific features of the respective *subfields. In particular: VA is more aesthetic than IA and IA is more aesthetic than infovis.*

Hypothesis 2: The users perceive qualitatively different insights from the infovis, the IA, and the VA prototype.

Hypothesis 3: A higher degree of perceived aesthetics leads to a higher user engagement.

5.2.2 Participants

Every test person should interact with all three prototypes, to make a comparison possible. Since the sequence of the prototypes could affect the subjective judgment of the test persons, several groups have to be arranged. It has to be ensured that in every group a significant number of members are present.

5.2.3 Methodology

Usability Inspection Techniques

In usability testing, *usability inspection* techniques are used as a fast and inexpensive means to locate major flaws in a user interface. The test is not performed in cooperation with exemplary users but with inspectors who have an expertise in the particular field. Experts are more likely to find problems and errors (Zhang, Basili, & Shneiderman, 1999). *Heuristic Evaluation* is one variety of usability inspection that fits the specific conditions of this project best. Nielsen (1992) describes this method in the context of usability testing. According to him, the central part of the evaluation is that inspectors compare the application with a set of usability rules. The success of this method depends to a high degree on the expertise of the inspectors. In our case it is important to verify hypothesis 1 at the beginning of the study in a fast and inexpensive manner. Since there is a considerable amount of domain knowledge accessible through the other members of the project team, the results are likely to be of high quality. To adopt this method for our specific needs, the usability rules can be substituted by the criteria from the *model of information aesthetics* (Lau & Vande Moere, 2007). The reviews of design approaches and prototype versions in the team conferences were a kind of heuristic evaluation and as such an integral part of the design process. Still the inclusion of additional inspectors would improve the results and is highly advisable.

Pilot Study

Due to the complexity of the insight study design and the multitude of misconceptions that can emerge from this, a *pilot study* is an effective way to support the success of a considerably more laborious main study. Several details, especially affecting the encoding of recorded insights, heavily rely on the specific nature of the prototype dataset and the implied user reaction. The pilot study is suitable to solve those issues.

Insight Evaluation

The insight evaluation process is proposed to be open-ended. No tasks are predefined. I suggest that the user ends the experiment according to his or her personal decision. This has two reasons. First, the duration of voluntary interaction is an important value for the measurement of engagement, see section 5.1.4. Second, the motivation of the user is extremely important for the gathering of insights, so the experiment should stop when the motivation ceases.

The “thinking aloud” method is best suited for recording the insights with minimum interference in the usage flow of the test person. The user is asked to use the prototype freely and verbalize every observation he or she makes. To structure the insights, collected that way, and to evaluate their importance a coding scheme is necessary. Saraiya, et al. (2005) have developed a set of quantifiable insight characteristics, which they deem to be applicable in different domains. I slightly adapted this scheme to the given situation and propose the following set to be used for this study:

- Observation: The description of the actual insight.
- Time: The time elapsed before the occurrence of the insight.
- Complexity: In the original set this was a measure for the domain value of the insight. The choice of our dataset makes it possible for everybody to judge the complexity of an insight. It is important to keep this judgment consistent. To avoid any bias it would be ideal if this measure was always assigned by the same person. The encoding to values from 1 to 5, where 5 is the most complex insight, is reasonable and can be adopted from the guiding concept.
- Hypotheses: This describes the special ability of insights to produce new hypotheses about the dataset, a very important process in all scientific fields.
- Direct versus Unexpected: Was the insight an answer to a question, the user had already defined for him or herself or did it occur without any specific intend?
- Correctness: This value is difficult to apply on the news data, since it is very subjective. It depends highly on the conclusiveness of the insights that are given by the test persons. The pilot study is the beast mean to investigate the applicability of this point.

- Breadth versus Depths: Is the insight focused on one or very few data entries or does it aggregate information from several elements?
- Category: In the example study four categories were defined based on the results from the pilot study. I expect the *NYT* article dataset to be more diverse so it could be necessary to add additional categories after the insight evaluation.

So far, the set is universal for the field of infovis. To include the specifics of IA into the evaluation methodology the *model of information aesthetics* (Lau & Vande Moere, 2007) provides crucial metrics. Visualization works are classified according to mapping focus and data focus. Mapping focus is immanent to the visualization tool but data focus can be measured in the scope of the insight evaluation. Hence, I propose to include an additional characteristic.

- Data Focus: The value of this measure ranges from intrinsic to extrinsic, see section 2.3.1. To appoint a resolution for the scale between both extremes is also more reasonable after the pilot study.

Every insight has to be quantified by the experimenters according to these criteria. The resulting dataset provides the base to compare the complexity and quantity of insights produced with the different prototypes. The Category feature can be used to bring out the qualitative differences between insights. Here a comparison with the categories defined by Pousman et al. (2007) is advised. Data Focus is assumed to show a strong correlation to the prototypes, with a majority of extrinsic insights for VA and a majority of intrinsic insights for infovis.

Measuring Engagement

I propose a measurement methodology for engagement that combines the qualitative approaches from HCI (O'Brien, 2006) with the analytic techniques from web analytics (Nielsen NetRatings, 2007). The result will be integrated into a consistent study design together with the insight evaluation. To retrieve a subjective estimation from the personal point of view of the test persons, I propose the implementation of a Likert questionnaire item. The question of interest is, how engaging the user perceived the interaction with the prototypes. The scale should range from “not engaging” to “very engaging”.

To complement the subjective judgment I suggest to use the overall interaction time for the holistic assessment of engagement. This metric is widely used in web analytics and can be integrated seamlessly into the insight evaluation process. The open-ended protocol has the advantage that the user has a high degree of freedom in choosing the duration of his interaction with each prototype. The engagement term, as used in web analytics, refers exactly to this self-motivated and prolonged interaction with a tool or service. There is a second metric that is frequently used in this context: the number of web page views. This factor is normalized within the study setup, since each prototype is examined in exactly one session per user and, hence, is not included in this study design.

Measuring Aesthetics

A correlation of insight, engagement, and aesthetics can only be detected, when a measurement for aesthetics is included into the study setup. In comparable studies aesthetics is measured by querying the subjective opinion of the user (Cawthon & Vande Moere, 2007b; Plaue et al., 2004). I am following a concept of aesthetics that is connected with cognitive processes in the user, generating effects as extraordinary insights and engagement. Those processes are likely to depend on the degree of aesthetics, as the user subjectively perceives it. Consequently a subjective evaluation method is needed. A Likert scale, in the form of a slider component, is successfully used for the purpose of surveying user opinions about aesthetics by Cawthon & Vande Moere (2007b) and, hence, is applicable for this study as well. Since the same component was used for the engagement evaluation a consistent workflow is provided for the user.

Traditional Usability Evaluation

It is not planned to integrate the evaluation of measures for effectiveness and efficiency into the study design. The measurement of insights is expected to produce a sufficient quantity of analytic results for the infovis prototype so that an extensive comparison can be performed. An additional problem is that the VA prototype cannot be evaluated by those metrics, since most information that is interesting in the scope of analytic benchmark tasks, is not directly available in the VA prototype. The indirect mapping hides those values inside the flower shapes.

For the case that low-level benchmark tasks will be needed at a later point of time, I formulate some recommendations. In a study that contains both, task based usability measurements and an open-ended insight evaluation, it is important to measure insight first. The predefined tasks could otherwise influence the way users perceive the visualization. The usage of the most common measures is a viable strategy. Those are, according to (Hornbaek, 2006), *error rate* for effectiveness and *task completion time* for efficiency. In the scope of the measurement of error rate and task completion time, the additional gauging of *erroneous response latency* and *time to task abandonment* is a minor effort. The combination of those values creates a measure for the frustration tolerance of a user (Cawthon & Vande Moere, 2007b). It can be argued that this is a valid measure for engagement, by depicting the readiness of a user to engage in a supposedly difficult task.

5.3 Summary

This chapter provides an overview of the state of the art in the evaluation of infovis with a focus on aspects that are relevant to IA and VA. The theoretical background is provided to facilitate qualified choices for the methodology of a study on the different strengths and drawbacks of the three fields infovis, IA, and VA.

Further a study design is proposed that covers all the theoretical considerations. It is understood that this setup is extensive and requires considerable resources to realize. This is why inexpensive and fast evaluation techniques are proposed at the beginning of the study to localize problems early on.

The main part of the study is dedicated to the evaluation of insights with an open-ended protocol in combination with the thinking-aloud method. This versatile technique is promising to bring out qualitative differences in the insights, produced by the different prototypes. Since the test persons subjectively choose the duration of the usage, engagement can be deduced from the duration of interaction. A personal and qualitative measurement of engagement is surveyed at the end of the study by a Lickert questionnaire item. The same procedure is used to measure the subjectively perceived aesthetics for each prototype.

The proposed extensive study design relies on a sound evaluation methodology. It covers a broad range of the supposed characteristics of information aesthetic visualizations and the resulting insights. In addition the evaluation methods are versatile and can be adjusted to various scenarios.

6 Discussion

The topic of aesthetics in infovis is complex due to the broad range of different influences that affect it. Infovis itself is based on several disciplines. The subject aesthetics additionally includes artistic and philosophic considerations. Still, the benefit of this new perspective could be huge. It could transform infovis from ancillary science to a cultural phenomenon. Tendencies in this direction can be seen both in theory, see section 2.3.1, and in practice, see section 2.3.2.

IA Design

The design stage for the IA visualization was far more time-consuming than planned in the beginning, what is reflected by the extensive description in section 3.2. I initially appreciated the change from the AOL- to the NYT-dataset as possibility to create a wholly independent approach for the topic. However, the range of possibilities that emerged was huge and it was difficult to find a specific topic that NYT articles covered in an extraordinary way. Considering the related work in section 2.3.2, this is an unusual starting situation for an IA project. Usually the message is the driving force in the design process. *We Feel Fine* and *The Dumpster* make use of data mining techniques over several months to produce datasets that are valid for the visualization projects and incorporate the right information to show the intended message. The fear and hope concept was a step towards such a message, but it still lacked expressiveness. The NYT proofed to be a balanced news source: a good feature for a newspaper but a bad foundation to tackle controversial topics like propaganda and the distorted world view produced by the media. To obtain more contrasting data, a set of articles from different newspapers, reflecting the reading habits of a population, would be more interesting.

The different datasets for fear and hope were originally expected to show a strong correlation with important events in the news. This correlation was not as distinct as anticipated. General accumulations of articles after certain events automatically lead to a higher probability for the occurrence of both terms. Additionally, the extensive and error-prone preprocessing that is necessary to distinguish between sentences like: “all hope is lost” and “there still is hope after the lost primaries” lies outside of the scope of this thesis.

Still the concept of fear and hope was maintained, but not to show any specific patterns. The final concept behind the IA prototype and the incorporated navigation model is to bring out and support subjective interests of the user. The presence of the categories of fear and hope introduce an emotional quality to the objective news articles, and increases the extrinsic value of the visualization. The user should reflect on the meaning of hopes and fears in direct connection with newspaper articles. It is not important whether a hope article concurs with the subjective perception of the user; it still induces an examination of this topic. I think that this is an adequate way of applying IA methods. One drawback of this general approach is that more specific concepts are likely to evoke a stronger emotional reaction by the user.

VA Design

When working on the VA concept, see section 3.3, I followed a less ambitious strategy. It did not seem reasonable to join the art discourse and to compete with the outstanding works of current artists, especially from the conceptual point of view, so I maintain a close connection to established works to create an application that complies with the requirements of the field. The flower motive is very common in arts and hence was used as foundation for the VA design. A set of other VA pieces, see Petals in section 2.2.2, back up this choice and proof it to be in accordance with the respective field. Analyzing works like *Running the Numbers*, see section 2.2.2 once again, provided insights into a category that is used in several theoretical works about visualization art: the *anti-sublime* (Kosara, 2007; Manovich, 2002a). Manovich argues that, in contrast to Romantic art, data visualization artists are rendering something that is to complex for the human mind into a representation that is comprehensible by the human cognitive system. In my VA prototype I implemented this principle, by creating a picture that contains every word from a perspective of several hundred abstracts. The emotional impact on the viewer cannot be compared to works like *Running the Numbers* and *The Digital Monument to the Jewish Community in the Netherlands*, both described in section 2.2.2. Still I think that the aesthetic appeal is strong enough to produce significantly different perspectives on the data and reasoning processes.

IV Design

After several important advances in the IA as well as the VA design, the information visualization prototype was surprisingly fast to conceive and to implement, see section 3.4. Here it became obvious how much more effective the development environments, in this case Adobe Flex, work for standard desktop applications. Regarding the IA design, the choice of a scatter-plot layout for infovis was self-evident. Additional filtering functionality for a broad range of data features is included to accentuate the intrinsic data focus. The aim is to create a tool that allows for efficient and effective solution of predefined tasks. To emphasize the tool-like character some real use-cases from the work with article archives could be analyzed and incorporated into the design.

Performance

ActionScript was used for the implementation because of its high importance within the design community. A second consideration was the distribution over the Internet that could become important in the scope of a latter online study. This choice has a drawback. Although the Flash player has strongly improved in terms of performance, it is still susceptible to performance problems. The large number of graphical objects on the screen that occurred in my experiments, proofs to extend its capabilities in several situations. In comparison, the *We Feel Fine* project, developed with Processing, works fluent with a huge number of particles. In the Processing documentation it is argued that in many cases programs written in Processing will outperform programs written in ActionScript. It is mentioned as well that ActionScript has a performance advantage in 2D drawing, due to highly optimized algorithms (Fry & Reas, 2004). So the choice between the two technologies depends on the specific project. A thorough comparison of both technologies in terms of performance would facilitate this decision for future projects.

Study

For the study design in chapter 5 the methodology to evaluate IV insights, proposed by Saraiya, North and Duca (2005) was central. Many other elements fitted into place automatically. Most important, the different qualities of insights are difficult to anticipate. I expect them to be very subjective for every user. With the given method, anticipation is not required. Users will express their insights and a structure can be created, based on those results. The measurement of engagement is possible without significant additional effort as well. The longer a user voluntarily interacts, the higher the degree of engagement. One limitation is that exactly one session will be considered per user. In web analytics the user behavior is monitored over a longer period of time. Daily interaction for 5 minutes over one month, for instance, could be valued higher than one single usage of a prototype for 30 minutes. It is impossible to make that distinction in the current setup. In the scope of an online-study this more complex user behavior could be evaluated. The initial plans for such a study are difficult to perform with the implemented prototypes. The main problem is the large size of the dataset that would have to be transferred over the Internet connection. In the completely voluntary context of the web the resulting waiting time can reduce the number of participants significantly. The remaining test subjects would start with a certain level of impatience or frustration. Nevertheless, an online study offers the possibility to collect longtime results and should be considered within the scope of future work.

As was mentioned in section 5.1.1, Saraiya, North & Duca (2005) propose to use effectiveness and efficiency measures as complement for insight evaluation. I neglected those completely in my study design. This was mainly because of the fact, that it is not possible to evaluate them for the VA prototype, which does not depict several underlying data values explicitly, for instance page numbers or publishing dates. Still, it is possible to analyze IA from an information visualization perspective in terms of functionality and effectiveness, and from visualization art, in terms of artistic influence and meaningfulness, as Lau & Vande Moere (2007) describe it. This means in this specific case to compare only the IA and IV prototypes in terms of effectiveness and efficiency. The complexity of the study would be increased by such a separation. To cover the strengths of infovis under equal terms, this would be necessary. I decided to not include this extra step because I observed that the strengths of infovis are not challenged in the current discourse.

I am optimistic about the methods in the study. They are versatile and should provide interesting results as long as the prototypes produce the desired effect on the users. Whether the prototypes match the high requirements is a more critical point. Little flaws in the implementation or the graphical design can have a big impact on user engagement or perceived aesthetics. Such flaws have to be removed before the insight evaluation. In an extreme case even a redesign has to be considered. It is important to keep this possibility in mind, even though it increases the workload considerably.

7 Conclusion

This thesis documents the design and implementation of three prototypes that are representing the specific characteristics of the three domains: information visualization (IV), information aesthetics (IA), and visualization art (VA). The motivation for this thesis originates from a recent strand of scientific discourse amongst researchers and designers. Due to a growing influence of aesthetics on infovis works in practice and the blurring boundaries towards visualization arts, the current categories of IV and VA are not suitable to describe numerous novel and interesting projects that combine aspects of both domains. There are several approaches to incorporate a category of aesthetics into infovis taxonomy. The model of information aesthetics (Lau & Vande Moere, 2007) is an extensive and promising approach towards closing the gap between infovis and visualization art.

The core of this work is the design and implementation of three visualization prototypes, for IV, IA, and VA. This effort was necessary to provide the means to isolate the effect that the different amount of aesthetic influence has on cognitive processes, like user engagement and insight generation. Other design elements, like dataset and interaction concept, were normalized. The detailed description of the design process in chapter 3 shows how elements from related work and theoretical concepts were combined to produce representative prototypes. The degree of compliance of the prototypes with the respective domain characteristics has to be taken into account. Any following evaluation results are only significant if each prototype really incorporates the aesthetic quality that is required for the respective field. To ensure this, the visualizations were reviewed according to the model of information aesthetics during the design process. The influence of related work was kept at a high level. This accommodates the importance of current innovations in practice for the need to establish new subfields. Due to the novelty of this domain, especially the IA prototype was challenging in its design as well as its implementation.

Furthermore, I propose a study design that best incorporates peculiarities of the given prototypes. It is split into two stages. The first stage should be focused on the evaluation of the suitability of the prototypes and the applicability of the study concept. As a second stage, I suggest an open-ended thinking-aloud approach that is focused on insight generation. This approach is apt to gather insights with a broad range of qualitative differences. User engagement is included into the methodology by measuring the duration of voluntary interaction. This compact but flexible evaluation methodology promises to produce results about the range of qualitatively different insights, depending on a different degree of aesthetics.

The conclusive evaluation of the quality of the three visualizations and the study setup in this thesis will only be possible after the performance and evaluation of the comparative user study. It is anticipated that the results will be an impulse for the establishment of IA as a category between VA and IV that is acknowledged by both sides. To fully comprehend the interdependencies between reasoning, visual perception, and perceived aesthetics, a huge amount of interdisciplinary scientific work is necessary, but to initiate such efforts, a consensus about the importance of this matter has to be established. With the implemented prototypes and the proposed study, this thesis makes an approach towards scientific results that are meant to form the ground for such a consensus.

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