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CASUAL INFORMATION VISUALIZATION

ON EXPLORING SPATIOTEMPORAL DATA

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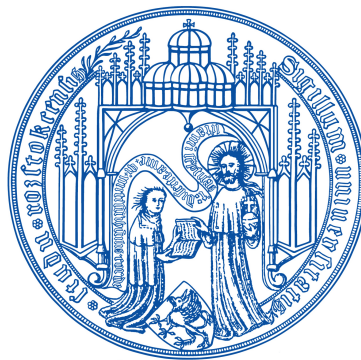
ON EXPLORING SPATIOTEMPORAL DATA

DISSERTATION

zur Erlangung des akademischen Grades

Doktor-Ingenieur (Dr.-Ing.)

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In loving memory of my aunt,
Tran Thi Loan

ABSTRACT

Today, a great amount of data is constantly provided on the World Wide Web. In that regard, visualizations to support everyday users to explore Web data is of special interest. This can be considered in terms of Casual Information Visualization research. While there exist works in that research area focusing on the questions about aesthetics, design, and the contexts of usage, it is still the challenge to investigate casual visualizations in terms of the characteristics of the diverse data as well as their different perspectives. Thus, it is the goal of this thesis to study how the diverse data on the Web which are familiar to everyone can be visualized, and with a special consideration on their spatial and temporal information. This is particularly challenging because existing research on spatiotemporal data visualization on the Web almost exploits only either the spatial or the temporal aspect of the data, while dealing with the both aspects is hardly well-considered.

To that end, novel approaches are introduced in this work. And various visualization techniques are developed to deal with the different types of data contents and the expected tasks in the spatiotemporal frame of references: interactively browsing large amount of tags linking with geospace and time, navigating and locating spatiotemporal photos or videos in collections, and especially, providing visual supports for the exploration of diverse Web contents on arbitrary webpages in terms of augmented Web browsing.

With the user studies, it is shown that the developed techniques are favorably applied to support everyday users to explore different spatiotemporal data contents on the Web.

ZUSAMMENFASSUNG

Heutzutage werden über das WWW große Mengen an Daten zur Verfügung gestellt. Damit gewinnt auch die Entwicklung von alltagstauglichen Visualisierungswerkzeugen für jedermann an Bedeutung. Während sich die Forschung in diesem Bereich bisher zumeist mit Fragen der Ästhetik, des Designs und der Berücksichtigung des Anwendungskontextes beschäftigt hat, treten nun verstärkt Fragen nach der Berücksichtigung spezieller Datencharakteristika sowie nach verschiedenen Perspektiven auf diese Daten in den Vordergrund. Diese Arbeit untersucht daher, wie verschiedene Typen von Daten geeignet für jedermann visualisiert werden können, wobei das Hauptaugenmerk auf der Veranschaulichung des räumlichen und zeitlichen Kontextes der Daten liegt. Bisher werden im Web zwar verschiedene Visualisierungstechniken angeboten, die entweder den räumlichen oder den zeitlichen Aspekt genauer kommunizieren. Dagegen gibt es aber kaum Ansätze, die beide Aspekte unterstützen.

In der Arbeit werden deshalb hierzu neue Ansätze eingeführt. Diese sind in konkreten Tools implementiert, die verschiedene Typen von Daten und Aufgaben im spatio-temporalen Zusammenhang unterstützen. Hierzu zählen das interaktive Arbeiten mit großen Mengen von "Tags" mit Verknüpfungen in Raum und Zeit, das Navigieren und Lokalisieren im Kontext großer Photo- und Videokollektionen mit Raum- und Zeitbezug, sowie die Unterstützung der Exploration diverser Webinhalte aus verschiedenen Quellen mit Hilfe von "augmented Web browsing".

Nutzerstudien belegen, dass die entwickelten Ansätze geeignet sind, um den verschiedensten Nutzern einen interaktiven visuellen Zugang zu verschiedenen spatio-temporalen Daten im Web zu ermöglichen.

Give a man a fish and you feed him for a day;
teach a man to fish and you feed him for a lifetime.

— Proverb (Laozi)

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ACRONYMS

2D	Two Dimensional
3D	Three Dimensional
API	Application Programming Interface
CSS	Cascading Style Sheets
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical User Interface
HCI	Human Computer Interaction
HTML	HyperText Markup Language
PC	Personal Computer
SVG	Scalable Vector Graphics
TOI	Time of Interest
URL	Uniform Resource Locator
UTC	Coordinated Universal Time
WWW	World Wide Web

PUBLICATIONS

Some ideas and figures have appeared previously in the following publications:

P1 – Dinh Quyen Nguyen and Heidrun Schumann. Taggram: Exploring Geo-data on Maps through a Tag Cloud-based Visualization. In *Proceedings of the 14th International Conference Information Visualisation* (IV'10), pp. 322–328, London, UK. IEEE Computer Society, July 2010. DOI: 10.1109/IV.2010.52.

P2 – Dinh Quyen Nguyen, Christian Tominski, Heidrun Schumann, and Tuan Anh Ta. Visualizing Tags with Spatiotemporal References. In *Proceedings of the 15th International Conference on Information Visualisation* (IV'11), pp. 32–39, London, UK. IEEE Computer Society, July 2011. DOI: 10.1109/IV.2011.43.

P3 – Dinh Quyen Nguyen and Heidrun Schumann. PhotoTima: Visual Exploration of Photos with Spatiotemporal References. In *Proceedings of the 8th International Conference on Web Information Systems and Technologies* (WE-BIST 2012), pp. 332-341, Porto, Portugal. SciTePress, April 2012.

P4 – Dinh Quyen Nguyen and Heidrun Schumann. Web-based Exploration of Photos with Time and Geospace. In J. Cordeiro and K.-H. Krempels (Eds.): *Web Information Systems and Technologies* (*Lecture Notes in Business Information Processing*, volume 140), pp. 153–166. Springer Berlin Heidelberg, 2013. DOI: 10.1007/978-3-642-36608-6_10.

P5 – Dinh Quyen Nguyen and Heidrun Schumann. Visualization to Support Augmented Web Browsing. In *2013 IEEE/WIC/ACM International Conference on Web Intelligence*, pp. 535-541, Atlanta, USA. IEEE Computer Society, Nov 2013.

INTRODUCTION

Categories such as time, space, cause, and number
represent the most general relations which exist between things;
surpassing all our other ideas in extension,
they dominate all the details of our intellectual life.

— Emile Durkheim, 1912

Graphical skill is a hallmark of humanity. It has been used as a mechanism for communication since before the formalization of spoken and written language. In fact, one of the vestiges indicating the beginning of mankind civilization is that our ancestors used imagery to describe the surrounding world. In the recesses of caves discovered in many parts of the world, from Europe to Africa to Australia, dozens of thousands years ago, the Stone Age people decorated on rock faces important themes about their *daily lives*, such as bison and reindeer from their hunting activities (Figure 1a). Together with those carvings, archaeologists also discovered petroglyphs depicting *hunting calendar* and *hunting sites*. Figure 1b shows petroglyphs dated from as far back as 500 B.C., which were found near the Grand Canyon, at a site believed to be used as a temporary hunting camp. Although the images look somewhat like the skeleton of a fish, they are often thought to represent a hunting calendar (Wills, 2011).

imagery in daily life

Throughout history, depictions of data in *daily life* linking with *geospace* and *time* are used in various application scenarios, in particular in visual narratives and arts. In Figure 1, we present some more examples about those graphics, from illustrations in the pre-computer age to infographics in nowadays computing designs. Figure 1c is an interesting image about the *Popillia japonica Newman* (the Japanese beetle). A two dimensional graphics is sketched to present various steps in a complete life cycle of the beetle in space and time: the horizontal indicates the timeline, and the vertical depicts how the beetle changes its forms over space (see Tufte, 1990). Figure 1d is an example about gastronomies with a "map of France of wines". This kind of map is today very popular in cards, disc plates, or souvenir towels for places around the world. And in Figure 1e, we show an infographics – created by Alberto Antoniazzi – which employs icons and words to constitute a mental map of Italy.

linking with geospace and time

Those graphics are examples in illustrating how the world are visually described in terms of *thematic contents + geospace + time*. Space and time, like quoting at the beginning of this chapter, are utilized as relations between things. Thus, they can be subjects for work in graphical and other visual-related areas.

(a) Petroglyphs on Newspaper Rock near Canyonlands National Park, south of Moab, southeastern Utah, the U.S.

(b) These petroglyphs, also near the Grand Canyon, are often thought to represent a *hunting calendar* (Wills, 2011).
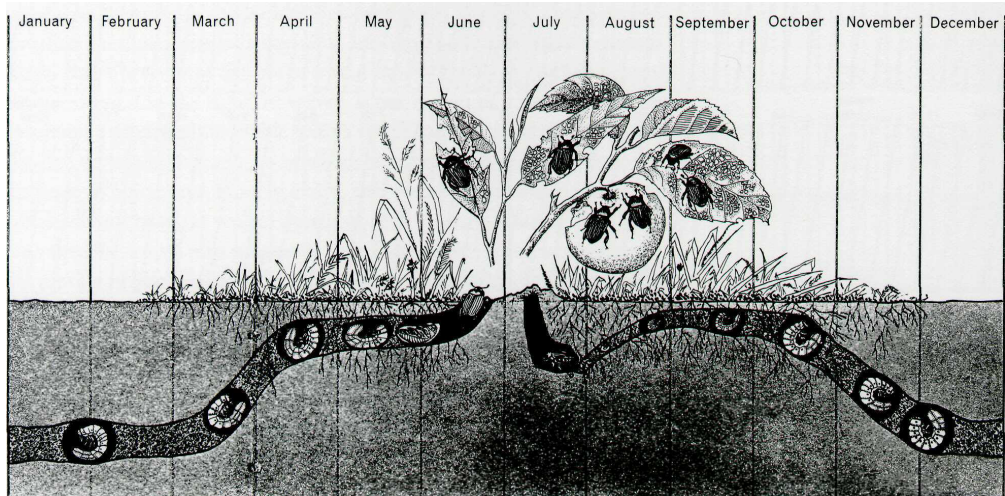
(c) A complete life cycle of the *Popillia japonica Newman* (the Japanese Beetle), cited in (Tufte, 1990).

(d) *La France des Vins*, a map of French gastronomy.

(e) Infographic map about Italy. Albertoantoniazzi.com, © 2009.

Figure 1: Examples about daily life depictions linking with time and geospace.

In this thesis, we consider a topic in an emerging branch of Information Visualization, known as *Casual Information Visualization* (casual Infovis), for the exploration of spatio-temporal data on the Web.

1.1 VISUALIZATION FOR THE MASSES

This section presents the scope, motivation, and goal of this thesis. Today, with the advancement of computers and Internet technology, we can, more than ever, communicate and experience the real world on the cyberspace. The world of online data is undetachable from daily life of many people. People leave traces about their daily activities because of the wealth of digital devices and tools they use. Photos, text, and many other personal and community-integrated data are created and shared online. In recent reports about the digital universe, IDC estimates that the amount of data created in 2011 is about 1.8 zettabytes (Gantz and Reinsel, 2011); and according to IBM, today about 2.5 exabytes[1] of data are created everyday (IBM, 2013). There, 75 percent of the data comes from individuals who write text, take photos, or upload videos and music.

margin: why this topic?

Information Visualization is the research area dealing with "computer supported, interactive, visual representations of abstract data to amplify cognition". (Card et al., 1999, read more in Chapter 2). In that concern, Infovis research focuses on creating visual mappings of data, where novel visual encodings and visual means are typically reached. In addition, insights for tasks are often taken into account. According to Zheng et al. (2011), however, visualization can also be considered through two different application scenarios. On the one hand, visualization supports data mining and information analysis, where its goal is to represent mainly perceptual information and knowledge from data, such as relations, patterns, or rules emerged for specific domains. But on the other hand, visualization is also considered for contents browsing, where text, images, videos, and other popular data in their media forms are preferably displayed. Zheng et al. (2011) also indicate that those two directions are almost not applied "AS-IS" one for another.

margin: data and tasks...

Visualization for the masses, considered in the context of individual, community integrated, and everyday usage data contents, falls into the second direction. It, therefore, would not completely be considered in terms of traditional Infovis (with regard to the definitions of e.g., Card et al., 1999). However, many of visualization techniques developed for non-work situations and for non-expert users still have some of the properties of traditional Infovis, such as representing information visually to change or facilitate a user's thinking. In this regard, Pousman, Stasko, and Mateas (2007) categorize them as *Casual Information Visualization*:

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1 one exabyte (EB) = 10^{18} bytes, one zettabyte (ZB) = 10^{21} bytes

> *"Casual Infovis is the use of computer mediated tools to depict personally meaningful information in visual ways that support everyday users in both everyday work and non-work situations." (Pousman et al., 2007)*

what to be solved?   PROBLEM STATEMENT   With the availability of everyday data, more and more casual Infovis techniques are being developed within the last few years. However, research on Casual Information Visualization focuses mainly on aesthetics, design, and usage contexts of visualization techniques (Grammel et al., 2010; Segel and Heer, 2010; Moere and Purchase, 2011; Sprague and Tory, 2012), while the many types of contents (especially those in association with geospace and time) of everyday data have not been specifically considered. As presented previously, presenting the world in association with space and time communicates meaningful values. This takes to the goal of this thesis: analyze and develop casual Infovis techniques to aim the tasks of visual *navigating* and *browsing* various kinds of data contents in the spatiotemporal frame of references.

thesis' goal

1.2   SUMMARY OF CONTRIBUTIONS

An important issue about everyday data visualization is that novices and non-expert users typically prefer to interact with familiar visual items rather than new-introduced visual objects (Sprague and Tory, 2009; Grammel et al., 2010). Concerning personal and community integrated Web data, everyday users therefore prefer to explore data contents in forms of text, images, or videos, rather than learning new visual representations. However, without visual aids, users could miss a lot of useful information and insights from data or data collections. As a result, designing and presenting everyday data must be well-considered in situ, which is unavoidably carried out in a trade-off but compromised manner of combining raw and abstract representations of data contents. To this end, we come to a guideline for developing visualizations: to support *browsing*, media contents in raw forms are at highest priorities for displaying, and to support *navigating*, overview of information has to be considered first. Ideas are carried out through specific designs for specific kinds of data on the Web.

browsing vs. navigating

One of the most popular data which are of special interest on the Web is user-generated tags. Tags are used for marking and describing personal and community integrated data resources, also known in terms of folksonomy. Today, a large amount of tagged data are provided in the spatiotemporal frame of references. And thus, geospace and time are obviously useful means for the examination and exploration of tags and related data. However, dealing with the visual exploration of tags in association with both geospace and time is a challenge.

We firstly consider the task of browsing tags with regard to geospace. On the Web, Tag Cloud is used as a common technique for the browsing of tags' resources. However, many tag clouds techniques do not communicate the geospatial frame of references, or they do not support exploring geographical areas in terms of territories and administrative levels. To deal with it, we present strategies for the communication of tags inside geographical areas by the so-called "interactive mental maps" (following the ideas of Milgram's mental maps (Milgram and Jodelet, 1976)). In this regard, the visualization technique Taggram (Nguyen and Schumann, 2010) is developed, which allows the arrangement and browsing of tags in geospace.

browsing tags in geospace...

Following that, temporal information of tags are also taken into account. One of the common tasks in examining tags is to find out how tags and related data resources are created, shared, and used in time. In terms of the seven questions based on (MacEachren, 1995)'s time-related tasks, we provide particular ways to visually encode temporal information through tag's appearances or additional visual artifacts (Nguyen et al., 2011). In this regard, the tags which are visually embossed or emphasized with visual cues carry various temporal information, and thus communicate both geospatial and temporal meanings as arranged on geographical areas using the Tempo-Taggram technique.

...and time

Later on, we go on with photos and videos, two other common data on the Web which are also interesting objects for casual Infovis research. Because pictorial contents have meaning themselves, communicate further information together with photos or videos is the challenge. In that concern, we provide solutions that visually represent and support the task of visual navigating on a visual interface and locating (seeking for) specific photos or videos of interest in geospace and time. Following Peuquet's triad framework (Peuquet, 1994), the three aspects of photo data (which are pictorial contents, geospace, and time) are simultaneously represented and combined at various granularity levels of abstraction to make an integrated visualization approach. To this end, relevant ideas are developed for the exploration of Flickr photos and similar ideas are proposed for videos visualization (Nguyen and Schumann, 2012, 2013a).

navigating and locating spatiotemporal photos or videos

In a general consideration, we continue with visualizations for diverse data contents on the Web in association with geospace and time. Different with stand-alone developed visualizations (i.e., those depend only on specified contexts or websites), visualizations to support augmented Web browsing are expected to be provided onto any webpage with unspecified page-layouts and contents – and thus, it is more challenging because of the diversity of today's many websites. To deal with that, we approach in the ways that visual supports are to be added to particular hypermedia items (micro level) or flexibly provided onto browsed webpages (macro level). The Firefox add-on VizMe is developed to illustrate the ideas with demonstrated examples in interacting

diverse data contents with geospace and time

with Web contents, with a special consideration on Web snippets with spatiotemporal references (Nguyen and Schumann, 2013b).

1.3 THESIS OUTLINE

The above sections has briefly presented the overall context, research problem, as well as a short list of contributions of this thesis. In the next chapters, we will go into details about the work through three main parts, as follows:

FUNDAMENTALS — The first part of the thesis is covered in Chapter 2 and Chapter 3, providing fundamentals and discourse for the work. In Chapter 2, we describe the current state of the art of Information Visualization with a focus on casual Infovis and visualizations for spatiotemporal data. In this regard, basics in Information Visualization are shortly mentioned, driving to the concepts in the sub-area of casual Infovis. The chapter ends with related background about spatiotemporal visualization, which raises questions for our casual Infovis developments.

ANALYSIS — Following that, Chapter 3 gives an overview about a discourse, in which the diverse community integrated data and their spatiotemporal references are mentioned. The world of second-generation and social Web raises challenges in communicating the diverse types of data contents in association with both geospace and time. A general view on approaches for the visual navigating and browsing of diverse data (data with various types and aspects, including geospace and time) is provided.

TAGS — The second part of this thesis is from Chapter 4 to Chapter 6. This constitutes the main contribution of the thesis. In Chapter 4, tags are the first type of data in our casual Infovis development. In that chapter, we present problems and strategies for the visualization of tags in association with geospace (tags are spatialized inside geographical contours) and time (tags are emphasized with temporal information though their appearances or additional visual artifacts). To illustrate our solutions, the tool Tempo-Taggram is provided for the browsing of Flickr tags.

PHOTOS & VIDEOS — Chapter 5 continues with another common data on the Web: pictorial data such as photos and videos. We present problems and strategies for the combination and representation of pictorial data: the triplet of contents (*what*), geospace (*where*), and time (*when*) are visually combined through the design of time-referenced tag plots, maps-based pictorial thumbnails, and time glyphs. To illustrate our solutions, the tool PhotoTima is provided for the exploration of Flickr photos.

DIVERSE DATA — Chapter 6 deals with Web data with many types of contents in association with geospace and time. Webpages, where data contents are diverse, are interesting everyday data. In supporting casual Infovis users, solutions where visual cues and interface layers are addable and manipulatable on existing webpages are provided. The concepts are illustrated through the Firefox add-on VizMe for the exploration Web snippets linking with geospace and time.

CONCLUSION — The last part of this thesis is presented in Chapter 7 with thesis summary, discussion remarks, and conclusions. The summary gives once again the whole view of our research problems and contributions. And then, discussions regarding casual Infovis in terms of data perspectives are included, which lead to open ideas for future work.

FUNDAMENTAL CONSIDERATIONS

*To envision information
is to work at the intersection of image, word, number, art.*

— Edward R. Tufte, 1990

Working at the intersection of image, word, number, and art, after excellent resources of Tufte and other pioneers in visualization design, is an anchor point in visualization research. Today, we see many achievements in visualization benefiting by those inspirations. However, research is always open so as to adapt the endless requirements of this information age.

The focus of this thesis is connected to the design and development of casual Infovis techniques for everyday spatiotemporal data. We therefore use this chapter to provide a closer view to the topic, presenting necessary and important ideas in the areas of consideration. The concepts of *Casual Information Visualization* are clarified in the context of Information Visualization research. And thus, the chapter begins with a short introduction concerning data and visualization pipeline in Infovis. The visualization for the masses of casual Infovis continues the chapter with usage context, aesthetics, utility, and data concerns. The chapter ends with background in visualizations of spatial and temporal data, the two important data aspects for our casual Infovis developments.

2.1 THE POWER OF INFORMATION VISUALIZATION

PhotoMesa (Bederson, 2001) is one of the first tools in visualization research   *an example...*
for the exploration of personal photos, the very common everyday data. In PhotoMesa, Bederson designs to arrange photos on screen as a grid of items placed close together with regard to their relative attributes (which are directory location, nearness in time, and shared word in filenames). Using the tool, users can navigate and zoom through photo collections to explore their photos of interest. There, steps in Shneiderman (1996)'s *visual information seeking mantra* are carried out. At the first glance, a user can get an overview about photosets regarding their topics, and then select to zoom to a set of photos of interest, and examine the photos. He or she can navigate through the sets through relate & history mechanisms (see Figure 2).

PhotoMesa has characteristics of Infovis design. However, it is considered as a technique at the "margins" of the research area, instead of as a "core"
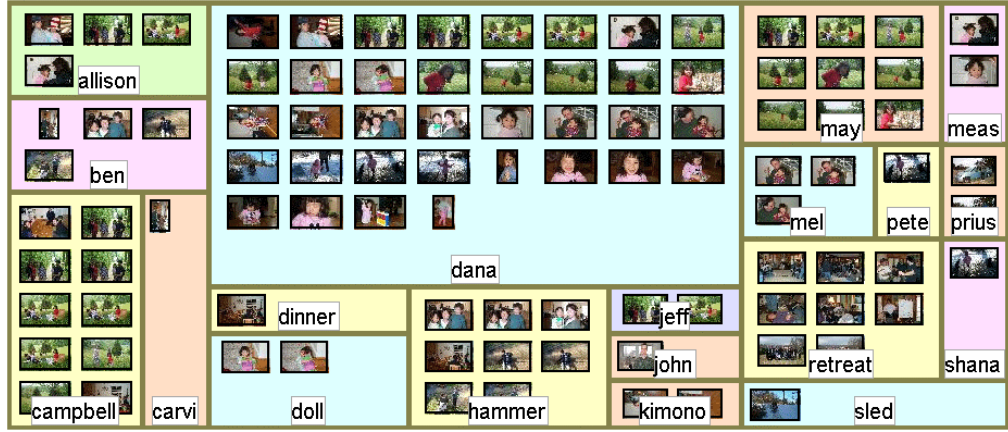
Figure 2: The tool PhotoMesa showing photo thumbnails grouped by shared words, captured from (Bederson, 2001).

Infovis technique (Pousman et al., 2007). This is due to the fact that Infovis is conventionally considered for work domain with analytical tasks and expertise knowledge, while PhotoMesa is a technique about photo browsing in non-work and everyday scenarios. In the following subsection, we will learn more about them when considering the perspectives of visualization in visual data analysis and visual data browsing.

2.1.1   Visual Data Analysis vs. Browsing

In a general manner, visualization is known as the process of representing data, information, and knowledge in a visual form. However, the definitions of data, information and knowledge in visualization research are often exten-

data in visualization?

sively used in an interrelated context. Because of this, in order to work with casual Infovis for everyday data, we would need to examine the notions of *data*, *information*, and *knowledge* in visualization.

According to (Chen et al., 2009), data, information, and knowledge can be differentiated in terms of perceptual and cognitive space (human side – as normally we can read data, grasp information, and acquire knowledge) as well as computational space (computer side – as data, information, and knowledge are all storable in the computer). In this regard, they denote the perceptual and cognitive space as $\mathbb{P}$ with $\mathbb{P}_{data} \subset \mathbb{P}$, $\mathbb{P}_{info} \subset \mathbb{P}$, and $\mathbb{P}_{know} \subset \mathbb{P}$ for data, information, and knowledge subsets of human memory; while $\mathbb{C}_{data} \subset \mathbb{C}$, $\mathbb{C}_{info} \subset \mathbb{C}$, and $\mathbb{C}_{know} \subset \mathbb{C}$ are considered as all possible representations of data, information, and knowledge in computational space $\mathbb{C}$, respectively.

In the perspective of human perception (Ackoff, 1989), despite the lack of an agreeable set of definitions, $\mathbb{P}_{data}$, $\mathbb{P}_{info}$, and $\mathbb{P}_{know}$ are assumed to be not mutually disjoint and not a subset one of another. But since everything on

computer can be treated as data, we can consider $\mathbb{C}_{data} = \mathbb{C}$, $\mathbb{C}_{info} \subset \mathbb{C}_{data}$, and $\mathbb{C}_{know} \subset \mathbb{C}_{data}$. This is extendable so that to indicate data in specific areas of visualization such as volume visualization, information visualization, geo-visualization, and so on, where data could be specifically taken into account with notations of raw data as $\mathbb{C}_{rawdata}$, volume data ($\mathbb{C}_{volume}$), flow data ($\mathbb{C}_{flow}$), software ($\mathbb{C}_{software}$), mathematical models ($\mathbb{C}_{mathmodel}$), visual data ($\mathbb{C}_{image}$), and so forth.

With those notations as the basics, we now reconsider the formal definition of Information Visualization. According to Chen et al. (2009), the statement of Card et al. (1999) about Infovis is described as:

> "[*Information* [$\mathbb{C}_{info}$] *visualization is*] *the use of computer supported, interactive, and visual representations* [$\mathbb{C}_{image}$] *of abstract data* [$\mathbb{C}_{info}$] *to amplify cognition* [$\mathbb{P}$]."

Obviously, data in the "core" definition of Infovis can be any data which are visually representable, and thus they could be $\mathbb{C}_{data}$. But they are there considered as $\mathbb{C}_{info}$ due to the perspectives of data in Infovis developments. In traditional Infovis, the main goal of a visualization technique is to support users to grasp information ($\mathbb{C}_{info} \subset \mathbb{C}_{data}$) represented from the data ($\mathbb{C}_{data}$), and therefore in many cases raw forms of data ($\mathbb{C}_{rawdata} \subset \mathbb{C}_{data}$) are set aside. Data selection is at the first step of a visualization process (see Section 2.1.2) which decides the data to be mapped to visual forms ($\mathbb{C}_{image}$). In traditional Infovis, data are normally selected based on analytical tasks and knowledge of developers and users on work domains (supporting $\mathbb{P}_{info}$ and $\mathbb{P}_{know}$). With those emphases, work in "core" Infovis research is typically developed to support information analysis (Keim, 2002; Fayyad et al., 2002; Thomas and Cook, 2005; Keim et al., 2010), with tasks falling into three main kinds of explorative analysis, comfirmative analysis, and presentation of analysis results (Ward et al., 2010). *data analysis in traditional Infovis*

That is the first direction in data visualization according to (Zheng et al., 2011), where $\mathbb{C}_{info}$ and $\mathbb{C}_{know}$ are mainly visualized in the context of data mining and information analysis applications. However, visualization techniques are also developed for contents browsing, where raw forms of text, photos, audio, and so on ($\mathbb{C}_{rawdata}$) are preferably focused. This second direction in visualization is also what we want to concentrate more in this thesis; in particular, data are in non-work situations and are familiar data contents for everyone, such as personal photos mentioned in the above example of PhotoMesa. *data browsing focuses on raw data presentation*

Zheng et al. (2011) believe that those two directions (visualizations for data analysis vs. browsing) are different, which almost cannot be applied "AS-IS" one for another. In our opinion, though they are not exactly "AS-IS", the two application directions in visualization can be hybrid, combinable, and even

switchable. It would be arguable to clearly differentiate the two. In visualization for analysis, data selection would be $(\mathbb{C}_{info} \cup \mathbb{C}_{know}) \gg \mathbb{C}_{rawdata}$, while for data browsing, we would concentrate on $\mathbb{C}_{rawdata} \gg (\mathbb{C}_{info} \cup \mathbb{C}_{know})$. We will mention them again when taking the visualization pipeline into account, as presented in the next subsection.

2.1.2 *The Context of Visualization Pipeline*

data in visualization process

Visualization research has been being carried out with various perspectives and scenarios. Our job is not to examine them here. However, some important concepts are needed for our techniques development. In this subsection, we would look into the *visualization pipeline* and what is called *information-assisted visualization*.

Visualization is a process "from data to view". That process from $\mathbb{C}_{data}$ to $\mathbb{C}_{image}$ is generally known as the *visualization pipeline*. Due to the diversity of visualization purposes, there are some variants of visualization pipeline in literature (see e.g., Chi and Riedl, 1998; Card et al., 1999; Carpendale, 1999; dos Santos and Brodlie, 2004; Tominski, 2011). In this work, we examine the basic visualization pipeline following (Card et al., 1999).
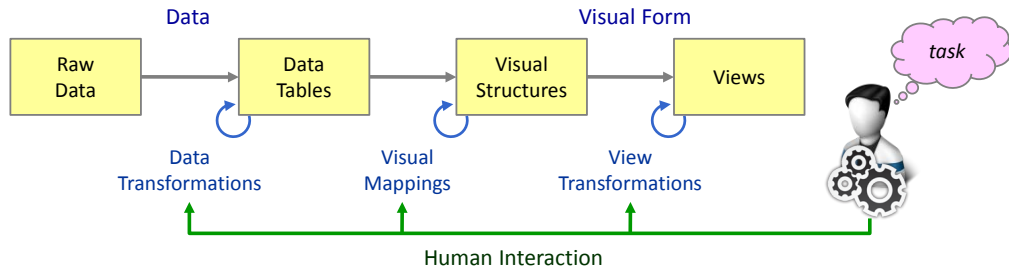
Figure 3: The visualization pipeline according to (Card et al., 1999).

A visualization pipeline is a multiple chained transformations of data states. In Figure 3, the visualization pipeline by Card et al. (1999) contains three processing steps chained by four consequent data states. The four data states divide the visualization process into two sides, the *Data* ($\mathbb{C}_{data}$) linked with the *Visual Form* ($\mathbb{C}_{image}$) by step *Visual Mappings*, forming a picture of $\mathbb{C}_{data} \rightarrow \mathbb{C}_{image}$. On the left hand side, $\mathbb{C}_{data}$ covers all types of data needed for later visual processing, including $\mathbb{C}_{rawdata}$ selection, analytical abstraction, information $\mathbb{C}_{info}$ and knowledge $\mathbb{C}_{know}$ organization, as well as other parameterized data, such as interaction control $\mathbb{C}_{ctrl}$ (explained later). On the right hand side, *Visual Mappings* and *View Transformations* perform so that to reach the *Views* with $\mathbb{C}_{image}$ displayed to the users.

Although visual mappings (visual representations) are at the heart of a visualization technique, selecting and cooperating data to be mapped into visual forms decides the scope of that technique (Rhyne et al., 2003). At the first processing step *Data Transformations*, *Data Tables* with values and metadata are typically extracted from *Raw Data*, and then reorganized and transformed into a relation or set of relations that are more structured so that they can easier map into visual forms. What make different between *data browsing* and *data analysis* can be particularly considered at this step. In visualization for analysis, data selection could lead to $(\mathbb{C}_{info} \cup \mathbb{C}_{know}) \gg \mathbb{C}_{rawdata}$, while for data browsing, we would hypothesize that $\mathbb{C}_{rawdata} \gg (\mathbb{C}_{info} \cup \mathbb{C}_{know})$.

With selected data, a visualization technique is then carried out with regard to three principle functions: *representation*, *presentation*, and *interaction* (Spence, 2007). By *representation* it is meant that for a technique, a set of data $C_{data} \subset \mathbb{C}_{data}$ are transformed into geometry and corresponding visual attributes like color, position, size, or shape - also known as *visual variables* (Bertin, 1983; Mackinlay, 1986). By *presentation* it is meant that we need to provide ways so that the representational structures are suitably displayed. In that regard, methods like "overview and detail", "focus in context", or "zoom and pan" can be contextually applied. A visual presentation process does not change the information contained in the representation, but highlight or clarify the content. At the end, we have $C_{image} \subset \mathbb{C}_{image}$ communicated to the users. In order to get a satisfactory collection of visualization results C_{image}, users normally need to *interact* with data and all steps in the visualization process, controlling visual styles, layout, viewing position, color maps, etc. to get a *show me* (Yi et al., 2007). The control parameters are also a part of the data space, i.e., $\mathbb{C}_{ctrl} \subset \mathbb{C}_{data}$.

Putting everything into the perceptual and cognitive space $\mathbb{P}$ and computational space $\mathbb{C}$, according to Chen et al. (2009) a typical visualization pipeline can be redrawn as in Figure 4a. Research in Infovis follows that typical process to get visual representations of datasets, where the successfulness of a technique should rely on the expressiveness, effectiveness, and appropriateness of information in communication (Schumann and Müller, 2000). A visualization process can be seen as a search process to get the P_{info} and P_{know} from the data space $C_{data} \rightarrow C_{image}$. However, due to the growing amount of data and visualization usage scenarios, the search space for a visualization process is also expanding. As a result, visualizations in today research require a shift toward the trend of information-assisted, knowledge-assisted, and visual analytics, where information and knowledge in $\mathbb{P}$ and $\mathbb{C}$ spaces are combined to support the search process $\mathbb{C}_{data} \rightarrow \mathbb{C}_{image}$. Event-based visualization (Tominski, 2011) is one example in this trend, where events (e.g., temporal patterns) are specifically visualized to aid the visual exploration and analysis of many data. The adaptation model of such *information-assisted visualization* is

information-assisted visualization
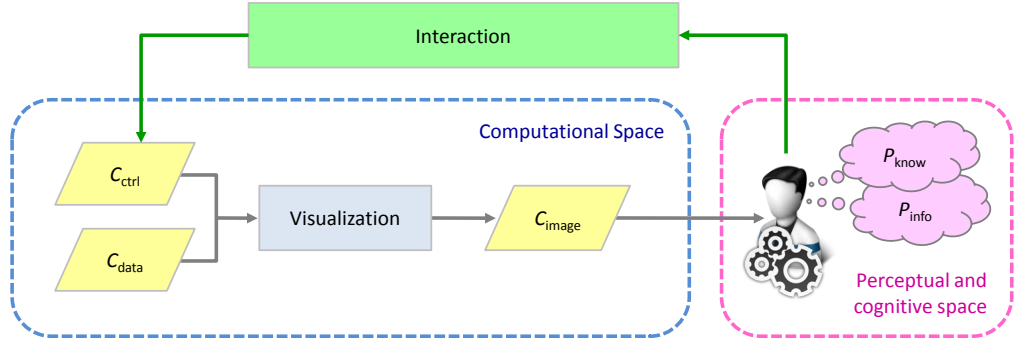
(a) The visualization process, where interaction provides the primary means for visual exploration. C_{data}, C_{ctrl}, and C_{image} denote input data, control parameters and visualization results stored in computer memory, respectively. P_{info} and P_{know} represent the information and knowledge acquired by the user.
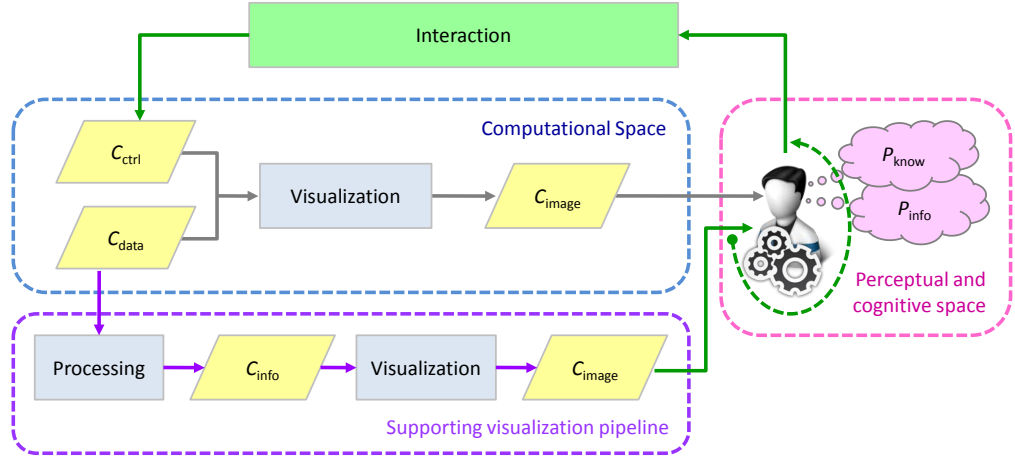
(b) Information-assisted visualization, where an additional pipeline displays information about the input data to help the user reduce the search space in the main visualization process.

Figure 4: Visualization processes in a typical formulation vs. in an information-assisted adaptation. These models are from (Chen et al., 2009).

illustrated in Figure 4b. Also, in the viewpoint of visual analytics, initial analysis is exceptionally needed for the selection of $\mathbb{C}_{data}$ to be visualized, while P_{info} and P_{know} are, through interactions, employed for further processing and visualization for details on demand, following the *visual analytis mantra* (Keim et al., 2008).

To this end, visualization in the trend of data browsing should also be considered with regard to the perspective of information-assisted visualization. Taking this into account means that (1) we consider the presentation of everyday data browsing (raw forms) as the main process $\mathbb{C}_{data} \rightarrow \mathbb{C}_{image}$, and (2) information from the $\mathbb{P}$ and $\mathbb{C}$ spaces can be supplementally visualized to

support the main process. By the way, they are also considerable in the context of casual Infovis research, we will therefore continue this fundamental chapter with the state of the field of Casual Information Visualization.

2.2 CASUAL INFORMATION VISUALIZATION

Visualization development is task- and data-dependent (Shneiderman, 1996). In reality, visualization techniques are usually custom-made to suit particular visualization problems. A technique developed for the analysis of genetics data in revealing biological underpinnings to a medical problem would be different from a technique showing weather forecast on television. Generally, according to Pousman et al. (2007), much of work in Information Visualization targets the population of information workers and information analysts who have knowledge and expertise in work situations of specific domains. Those techniques frequently follow criteria in traditional Infovis evaluation (such as *expressiveness*, *effectiveness*, and *appropriateness* as mentioned in Schumann and Müller, 2000; Carpendale, 2008). However, there are also techniques with Infovis characteristics but not designed for these user populations or these work situations. Those techniques, e.g., the aforesaid tool PhotoMesa for the exploration of personal photos, are recognized as Casual Information Visualization.

the diversity of visualization techniques...

> *"Casual Infovis is the use of computer mediated tools to depict personally meaningful information* [$\mathbb{C}_{\mathtt{data}}$] *in visual ways* [$\mathbb{C}_{\mathtt{image}}$] *that support everyday users in both everyday work and non-work situations." (Pousman et al., 2007)*

Casual Infovis, as defined, supports the transformation of $\mathbb{C}_{\mathtt{data}} \rightarrow \mathbb{C}_{\mathtt{image}}$. However, it does not require the same degree of task focus, user focus, cognitive purposes, and processing steps of typical Infovis. In other saying, casual Infovis covers a more flexible view than "core" Infovis and can be considered as "ambient" Infovis. It includes research on artistic Infovis (Viégas and Wattenberg, 2007), social Infovis (Viégas and Wattenberg, 2007), narrative Infovis (Segel and Heer, 2010), amongst some others.

...and the space for casual Infovis

In the following subsections, we do not intend to cover a complete view of casual Infovis but to provide current prominent considerations in the area, including: aesthetics and utility (Moere and Purchase, 2011), users and usage context (e.g. Sprague and Tory, 2012), or vernacular considerations (Viégas and Wattenberg, 2008), after which our work on spatiotemporal data could be seen as a supplementation.

2.2.1   *In Consideration of Aesthetics and Utility*

Pousman et al. (2007) provide a list of four main differences that we can base on when considering whether a system or a technique is *casual* or not in comparison to *traditional* Information Visualization:

USERS Broader than traditional Infovis, where user population is primarily linked with expertise communities, the user targets in casual Infovis cover a wider spectrum with regard to their diverse levels of familiarity in information analysis and visualization knowledge. Users here are not necessarily experts in analytic thinking, nor are they required to be experts at reading visualizations. They are mainly novices and some are savvy users (in general, they are everyone), according to (Heer et al., 2008).

casual vs.
traditional
Infovis

USAGE CONTEXT Systems and techniques in casual Infovis, as a result, are not intended for professional contexts. They are not considered for work domains, where tasks typically concern data analysis. Instead, casual Infovis techniques are used for non-work and everyday situations. This means that users can use a technique with any degree of willingness, in many cases just for fun and curiosity. They can look at a tool for a while, unintentionally, or without interaction. In the later paragraphs, we will learn research considering usage patterns and context of casual Infovis.

DATA The data in casual Infovis are typically personally important and relevant, as opposed to work-motivated. This means that a user's relationship to the data is often a more tightly coupled one. The data is not merely the photos or messages, but additionally the meanings that these tokens convey, such as a wedding day, or a child's first steps. Accordingly, in many cases, raw forms of the data express the meanings, rather than analytical insights. This, together with the views on community integrated data, such as folksonomy data on the Web, is the topic that we want to address in this thesis.

INSIGHTS Finally, the most critical point in developing casual Infovis is the called *insights*. Analytical insights are considered as the main criteria in traditional Infovis. Card et al. (1999), Thomas and Cook (2005), Keim et al. (2010) and other researchers have been being developed theories and concepts in Infovis carried out around analytical insights. Many visualization techniques performing the transformation of $\mathbb{C}_{data} \rightarrow \mathbb{C}_{image}$ but argued to be Infovis due to these "insights" perspectives. To this end, insights which are non-analytic are the foci to be presented in this subsection, but we will return to them after the examination on research about users and usage context.

Research on Users and Usage Context

Information Visualization is typically used in work scenarios. However, the role of Infovis is not constricted to that usage concern. In that regard, studying the contexts which are casual (i.e., non-work, everyday life) is another focus in casual Infovis research. Casual Infovis also needs to address/ be aware of issues such as limited computing power, restricted bandwidth, small screens (sometimes, mobile usage settings on hand-held devices), which pose specific requirements to processing, rendering and interaction. And thus, when and how Infovis is more popularly employed; how to engage more people to Infovis, especially people who are not expected to have knowledge or interests in data analysis or visualization use (Heer et al., 2008); how the novices understand and construct Infovis (Grammel et al., 2010); how developers create Infovis which are casual (i.e., not necessarily adapting characteristics of "core" Infovis); and how Infovis are used in casual environments (Skog et al., 2003) are main research questions for the study of users and usage context of Casual Information Visualization.

The studies of Infovis used in casual contexts show that there is a large amount of non-expert users who use a visualization technique or a system if that tool satisfies their personal interests and self-reflections (e.g., Viégas et al., 2007). Interestingness, pleasingness, or appealingness are some amongst prominent factors to attract non-work users. According to (Sprague and Tory, 2009), intrinsic factors promoting casual Infovis use include "personal interest, curiosity, personal challenges, control, fantasy, boredom, aesthetic appeal, and novelty"; and extrinsic factors are "social pressures, peer recommendations, competition, and recognition seeking".

user interests

However, how novice users use casual techniques or systems is a complex matter. In a test, Sprague and Tory (2009) asked two women with no computer science training to look at a casual Infovis design. The women expressed their interests ("sooo cute" and "I like the animation") during the first minute, but later changed to "cute but not practical" after few minutes. In that regard, designing and evaluating casual Infovis is the challenge.

Generally, fun and utility in casual Infovis are mutually exclusive. On the one hand, designers are expected to provide tools that are nice and easy-to-understand to users (because non-expert users normally react to new systems or techniques; Grammel et al., 2010). But on the other hand, utility is what a tool needs to compromise as well. In this context, traditional Infovis' usability metrics would not completely be applicable for casual Infovis guidelines and evaluations.

To this end, Sprague and Tory (2012) suggest some methods that can be followed when designing and evaluating casual Infovis techniques. Based on that, they conclude some guidelines for the design of a casual Infovis technique: visual encodings would always be used to achieve some goals of the

technique, even if it is just to alleviate curiosity; designers should consider
the goal type (extrinsic, entertainment, utility, and learning) and the intended
duration/number of uses; they need to reduce costs to initial use (especially
learning effort), increase initial personal relevance of the data when possible,
provide clear utility, organize information topically, and provide context and
related information so that to better support non-expert users.

Though the above suggestions are not mandatorily required for the devel-
opment of a casual Infovis technique, they are at least considerably useful for
the knowledge in Infovis research, in the manner that "design issues and eval-
uation questions on the edges of Infovis can apply back to the more traditional
systems in the field as well, enriching not just the margins, but the centre [of
the field]" (Pousman et al., 2007).

Insights and the Case of Aesthetics and Utility

Benefits in Information Visualization can be categorized into three dimensions
of insight generation, externalized cognition, and communication. But levels
of benefiting to be achieved in between traditional and casual Infovis are not
generally similar. Though insights are complex and ambiguous (North, 2006),
insights in traditional Infovis, especially Infovis for visual analytics, can be ex-
amined with regard to data analysis and extraction. There, they present the
hidden, the true, and the inward information in the computational space $\mathbb{C}$.
However, insights in casual Infovis shift toward user space $\mathbb{P}$. Insights in ca-
sual Infovis are not necessarily analytic, but awareness, personal-reflective, and
social driven (Pousman et al., 2007).

insights in
casual Infovis
shift toward
user space

Said that, casual Infovis research often seeks values in aesthetics than task-
oriented goals. Taking this into account means that researchers cannot merely
apply techniques from Infovis wholesale to casual Infovis systems. This con-
firms the discussions about usage context mentioned above. They need to bal-
ance the requirements on usability and efficiency metrics (as of Infovis) and
user satisfaction. In (Skog et al., 2003), Skog, Ljungblad, and Holmquist design
an Infovis technique used in an ambient environment about bus departure
times at a university. The technique addresses utility goals, but experiments
show that aesthetics is the main point to be considered. In that regard, there is
a strike to balance the aesthetical appeal and the utility of the technique.

As mentioned, a technique in casual Infovis can be multi-faced interpreted,
instead of objectively reflecting the data and tasks at hand. To this end, there
are studies to explain the role of design for insights, aesthetics, and utility in
Casual Information Visualization. Based on the architectural design model by
the Roman architect Vitruvius in 25 B.C, Moere and Purchase (2011) reconsider
the concepts of design surrounding the interrelations of *utility*, *soundness*, and
attractiveness (see Figure 5). It is shown that aesthetics is not just to satisfy users
in casual contexts, it can influence the utility and soundness of a technique as
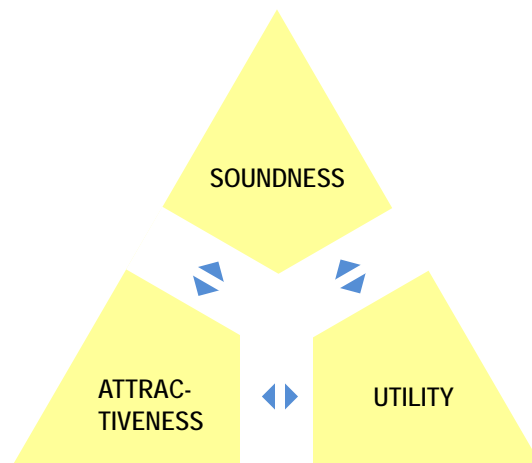
Figure 5: Designing in visualization is the balance between aesthetics, utility and
soundness (Moere and Purchase, 2011).

well. However, accurately defining, measuring, and quantifying aesthetics are
still far from their expectations in current Infovis research.

Designing visualizations is not only for functionality, usability, and reliabil-
ity, but also for fun (Shneiderman, 2004). For that, casual visualization tech-
niques today can be raised not only in Infovis community, but also from art
designers (Viégas and Wattenberg, 2007) or everyday users (e.g. Tag Cloud is
raised by Internet community following the trend of folksonomy), who share
interesting work on sharing sites such as Information Aesthetics Weblog[1] or
Visual.ly[2].

2.2.2 *In Consideration of Data Perspectives*

According to Lau and Vande Moere (2007), the aforementioned issues on in-
sights, aesthetics and utility are also considerable in connection with map-
ping solutions and data perspectives (see Figure 6). *Visual mappings* (see Sec-
tion 2.1.2) are at the heart of a visualization technique, and control the levels
of interpretation that a technique focuses. In core Infovis, mapping solutions
must reflect the intention of the tasks; while for casual visualization, mapping
solutions involve more subjective decisions and stylistic influences of design-
ers. For *data focus*, users' reflection is taken into account. For more intrinsic
data focus, it is meant that analytical insights and patterns are expected to
be reached; while for more extrinsic data focus, awareness, personal-reflective,
and social motivations of users are important.

*insights,
aesthetics
and utility
...vs. data
perspectives*

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1 http://infosthetics.com/
2 http://visual.ly/
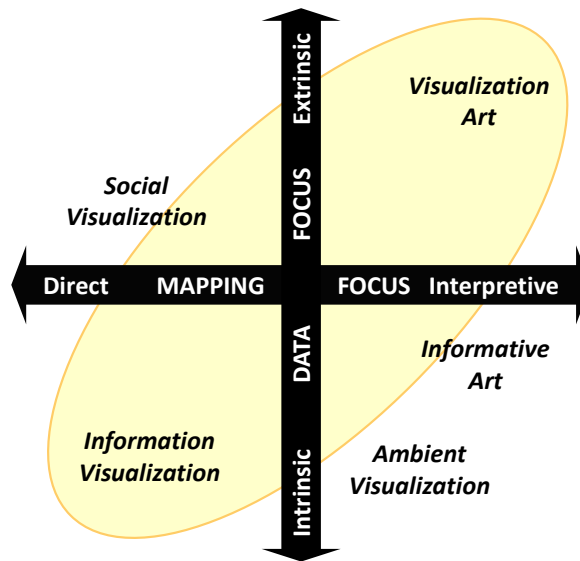
Figure 6: Categories of visualizations in terms of mapping and data foci (Lau and Vande Moere, 2007).

At this very moment, however, only users, usage contexts, and kinds of insights of "data focus" are carried out in literature (as presented above). The focus of data with regard to their types or aspects is still an open research question, as indicated in (Lau and Vande Moere, 2007). To this end, our work on data with spatiotemporal references will be a supplementation to the research on casual Infovis. Data types, the criterion for the classification of traditional Infovis techniques (Shneiderman, 1996), will be also the criterion for the examination of casual Infovis research. "The choice of what information [and data] to visualize is obviously important when designing casual information visualizations" (Skog et al., 2003).

The data in casual Infovis go from contexts of users and usage scenarios (such as personal, community, or interplay-oriented, Heer et al., 2008) to specific types and forms. The presentation of simple words in Baby Names (Wattenberg, 2005), kinds of common visual objects in story telling (Segel and Heer, 2010), in edutainment (Sorapure, 2010), or the customized personal data displaying in Many Eyes (Viégas et al., 2007) express the values of raw contents in visual presentation.

The data contents always have meanings themselves. However, casual Infovis is not just for a Flickr photo, a Twitter tweet, a set of words, or a spreadsheet (as in Andrews and Lessacher, 2010). In our perspective, they combine with other meaningful features in Infovis to facilitate the visualizations, in the direction of *information-assisted visualization* (see Section 2.1.2). In this regard, a

*...recalling the
research statement*

"what does the user want to see and what do the data want to be?" question (Pretorius and Van Wijk, 2009) should be prompted.

Information in data, such as events for time-referenced data, places for geo-referenced ones, and other stuffs can be used to facilitate the casual reflections of data. In Chapter 3, we will present our discussions on data visualization with spatiotemporal references before going on to the later chapters with detailed developments. Therefore, to get into those analyses and developments, we would need to learn the concepts of *time* and *space* in visualization research in the next section of this chapter.

approaching...

2.3 VISUALIZATION WITH GEOSPACE AND TIME

Space and time are two special dimensions that form the world in which we live. As mentioned in Chapter 1, data in our everyday life are naturally connected with time and geospace. "What", "where", and "when" are subjects that we often include in almost all our everyday situations. In that regard, in visualization research, geospace and time are two crucial branches for investigation. This section presents basic concepts about time, geospace, and their visualizations.

Though time and space are very often tied together, each of them has its own space to study. Thus, in the following subsections we will present each of them in turn, and then talk about the combination of the two in visualization research.

2.3.1 *Visualization of Time-Oriented Data*

Time is linked within any piece of data or object. It communicates the fact that a datum exists, occurs, or changes at a point of time, over a period of time, or for an event in history. The formulation and expression of time, however, are manifold, because we human beings observe the universal, describe the world, and use various artifacts concerning time. Thus, our job here is not to communicate the many concepts of time, but just the very basic considerations for our developments. To this end, we selectively summarize the ideas from Aigner et al. (2011).

visualizing time: a broad topic

The Features of Time

Time is a conceptual matter that is symbolically developed and used. By reformulating our observations on processes in nature, time is modelled in various ways. But according to Frank (1998), there is no single model of time that can be used in all systems. Modelling time depends on work context. In that regard, in order to deal with time-oriented data visualization, design aspects for

a model and issues about time data are expected. Aigner et al. (2011) describe a design space of time with regard to (1) aspects of time, (2) data in association with time, and (3) the relation of data and time (Figure 7).

TIME   The characteristics of time are complex in terms of its design aspects and the definition of time granularities and primitives.

The *design aspects* address a time domain with specifications on scale, scope, arrangement, and viewpoint. *Scale* can be relative, absolute, or density relations of time elements (indicated as ordinal, discrete, and continuous in Figure 7). *Scope* is connected with the discrete or ranged values used for time data (point-based and interval-based). *Arrangement* supports the way that we contemplate time values that exist from the past to the future (linear) or periodically (cyclic, e.g., hours, weeks, or months). And, *viewpoint* expresses things that happen one after the other (ordered), in multiple strands (branching), or allows more than one point of view at observed facts (multiple perspectives).

In addition, time is also specified through granularities, time primitives, and relations and determinacy of temporal elements. Basically, *granularities* can be thought of as (human-made) abstractions of time in order to make it easier to deal with data (like minutes, hours, days, etc.). If a granularity is supported by a calendar system in the time model, it is categorized as of multiple granularities. Otherwise, time domain can be specified with only one simple granularity (e.g., time value is just given in terms of milliseconds), or none of those abstractions (e.g., in the case of abstract ticks). *Time primitives* are basic elements used to relate data to time, which can be instant (a single point in time), interval (a portion of time with a beginning and an end), or span (a directed duration of time, e.g., 4 days). Time primitives can be defined at all levels of granularity, and form various temporal topological relationships, as presented in (Allen, 1983). Lastly, *determinacy* concerns the uncertainty of time data. Time is determinate if it communicates complete knowledge of all temporal aspects, while indeterminacy is about the domain with incomplete knowledge, where one would come to a "don't know exactly when" information from time data.

DATA   While time aspects constitute the model of time, visualizing time is about representing (time-oriented) data. In this case, aspects on data values associated with time are to be communicated. This can be expressed in terms of scale, frame of reference, kind of data, and number of variables. *Scale* concerns how data values can be compared: quantitative data variables are numerically comparative, while qualitative variables deal with relational comparisons (ordered or unordered). The *frame of reference*
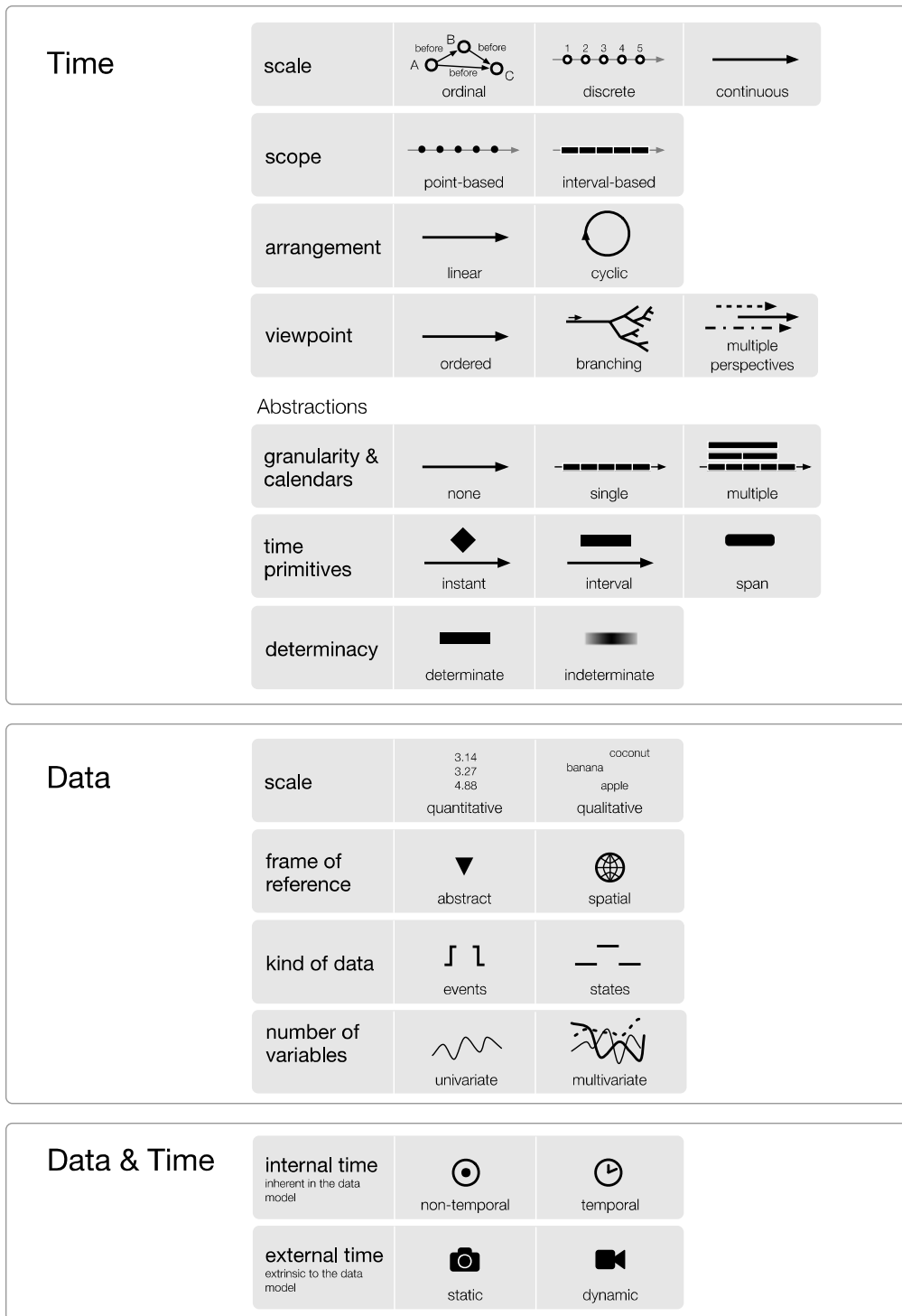
Figure 7: Design aspects for modelling time (Aigner et al., 2011).

indicates the fact that data values are inherently spatial or abstractly exist. *Kind of data* expresses time as states or events. States mean that data are characterized as phases of continuity between events, while events are the markers for state changes. For example, the fact that a plane departs can be seen as an event, when it is in the air we have a phase, and it lands communicates another event. And, *number of variables* is about the number of time-dependent variables in the data domain. Data can be univariate (time is associated with only one single data value) or multivariate (it is associated with multiple data values).

DATA & TIME The last perspective in defining time is about how time and data are related in a particular setting. *Internal time* is considered to be the temporal dimension inherent in the data model. Conversely, *external time* is considered to be extrinsic to the data model. Depending on the number of time primitives in internal and external time, time-related datasets can be classified as static non-temporal data, static temporal data, dynamic non-temporal data, or dynamic temporal data.

"visualizing time is about representing time-oriented data" ...and?

We have seen specifications and concepts in modelling a time domain. Next, we will learn about the ideas of visualizing time-oriented data in the sense of $\mathbb{C}_{\texttt{data}} \to \mathbb{C}_{\texttt{image}}$.

Mapping Time in Visualizations

Similar to any other kind of visualization, visualizing time-oriented data, according to Aigner et al. (2011), is carried out as we examine the three following questions: *what is visualized* (time and data), *why it is visualized* (tasks at hand for a visualization), and *how to represent that* (the mapping of time data to visual form).

Concerning *data*, time is one of the seven kinds of data classified for visualization research (Shneiderman, 1996). In this regard, following the data model mentioned above, we can map time data to visual primitives and objects based on the aspects of time and data. For example, for numerical and quantitative data, we can represent them as items in point plots, line plots, bar graphs, etc. Time primitives, granularity specifications, and other time aspects control the visualization of time data. However, as time is a specific kind of abstract information, mapping time data is flexible in terms of designing or creating visual representations.

Secondly, in order to communicate conceptual meanings to users, *tasks* expected by the users are needed. Tasks in the perspective of temporal context, according to MacEachren (1995), can be examined by a set of important questions that users might seek to answer with the help of visual representations, including (i) the existence of data element (e.g. "Does a data element exist at a specific time?"), (ii) temporal location, (iii) time interval, (iv) temporal pattern,

(v) rate of change, (vi) sequence, and (vii) the synchronization of time data. This list of tasks covers the searching for time primitives that exhibit data values (defined as *localization*) or discern the data values associated with time (*identification*). For a more theoretical point of view, formal task descriptions can be described based on Andrienko and Andrienko (2005), where tasks are described in terms of *references* (concerning both time and geospace domain) and *characteristics* of data values. There, detailed tasks include *look up*, *comparison*, and *relation seeking* of data values or patterns, for both single values (elementary tasks) or sets of values (synoptic tasks).

With the exploitation on time, data aspects, and tasks, the visualization of time data is accomplished when we put them into the visualization pipeline. The data and tasks are specified together with *mapping* possibilities. To this end, we can find many time visualization techniques in the literature, as presented in the survey chapter of Aigner et al. (2011). Practically, there are two types of mapping time: *mapping of time to space* and *mapping of time to time*. When speaking of a mapping from time to space, it is meant that time and data are represented in a single coherent visual representation. This representation does not automatically change over time, and known as *time-oriented data static* (e.g., in classic charts, time is often mapped to the horizontal x-axis and time dependent variables are mapped to the vertical y-axis). In contrast to that, *dynamic representations* utilize the physical dimension of time to convey the time dependency of the data, that is, time is mapped to time, where several visualizations (also called *frames*) are rendered successively for the time steps in the data.

visualizing time and the visualization pipeline

The development of mapping solutions, in that case, benefits by knowledge in design, perception, as well as all other concepts about Infovis. It is necessary to cope with issues on the dimensionality of the presentation space (2D or 3D), interaction issues, or analytical problems to get insights from the visualization.

2.3.2 *Visualization of Geospatial Data*

Together with time, knowledge about geospace is another outstanding human intellectual. Geospatial data depict the surrounding world in which we touch and move. We identify the realities and put them into visual forms of cartography and other geometric objects. This subsection presents basic concepts about the features and issues for the visualization of geospatial data.

The Features of Geospace

Similar to the previous subsection, aspects for geospatial model are expected. Based on it, the representations of geospatial data are describable (the representations are multipurpose, as they allow us to learn, think, and reason not only about places and times, but also about any visualized object).

An exhaustive summarization of geospatial and geo-data characteristics is out of the scope of this thesis. Thus, we manage to communicate herein just very basic concepts with regard to (1) aspects of geospace and (2) data in association with geospace.

GEOSPACE According to Longley et al. (2005), the geographic world is extremely complex and almost *ad infinitum*. GIS developers usually describe geospatial data in terms of raster vs. vector models, about which the data are organizable and stored in databases. We, on the other hand, do not focus on modelling databases, but consider geospatial aspects such as scale, scope, granularities, and relationship, working around spatial entities and attributes.

One of the most important criteria for the usefulness of a representation of space is its accuracy. Because the geographic world is seemingly of infinite complexity, there are always choices to be made in building any representation - what to include, and what to leave out. *Scale* is an essential aspect which decides the spatial resolution and the level of geographic detail that elements are included; and *scope* is used to define the range in which they are included (i.e., local or global).

Locational relation deals with the arrangement in geospace. The Tobler's *First Law of Geography* is the centre for the examination of spatial relations. "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970). In that concern, *position* (location) and *distance* are defined. Locational relations are comparative and combinable. They form topological representations with intersection, overlap, and containment. Elements are directional or omnidirectional, forming routine (from - to) as well as navigation (e.g., to north, south, west, east).

Extending the resolutions and topological relations, geospatial information can be communicated through hierarchical structures with various granularities. They depict the conceptual formulation of social aspects for geo-referencing, such as addresses, places (locality, city, state, etc.); and geographic elements (points, lines, areas, surfaces, and volumes) are realized in the *dimensions* of the cartographic space of 2D or 3D.

DATA Geospace is concretized in terms of the data that the space covers. There, geospatial data are normally described through (i) the geographical structures and elements, (ii) abstract attributed data elements (which are geo-referencing), and (iii) time as a special dimension that data elements can be linked with (Haining, 2003).

The geographic elements and structures are realized with aspects mentioned above. In the *frame of reference* of geospace, abstract element is anything on the earth. In a typical usage context, data elements are created

to mimic physical or environmental objects in nature, and some are social or economic influenced. Longley et al. (2005) classify geo-referenced elements as nominal, ordinal, interval, ratio, or cyclic attributes. The simplest type of attribute, termed *nominal*, is one that serves only to identify or distinguish one entity from another (e.g., names of houses, or numbers on a driver's license). Attributes are *ordinal* if their values have a natural order. Attributes are *interval* if the differences between values make sense. Attributes are *ratio* if the ratios between values make sense. For instance, "weight" is ratio, because it makes sense to say that a person of 100 kg is twice as heavy as a person of 50 kg; but "Celsius temperature" is only interval, because 20 is not twice as hot as 10. Lastly, data can be directional or *cyclic*, including flow direction on a map, or compass direction, or longitude (e.g., the degree following 359 is 0).

There are some data that are unchanged over time, or changed at a very slow manner. But some other data update their states (or values) frequently (e.g., temperature in examining global warming). In the latter case, time is the mandatory dimension that forms a 3- to 4-dimensional spatiotemporal referencing space.

Mapping Geodata in Visualization

Representing geo-data is performed to express many things in this world on computer. In that concern, the visual mapping of geodata must deal with (1) the representation of geo-data following the geospace's aspects, (2) user tasks, and (3) categorical mapping solutions.

geo-visualization and the visualization pipeline

Following the aspects mentioned above, the representation of geospatial information is geographically dependent, i.e., in 2D or 3D cartography. There, geo-data are visually communicated through *visual variables* (about which the human retina is particularly sensitive). Figure 8 lists again the visual variables, after (Bertin, 1983). Also, temporal values are mapped as abstract variables, with aspects presented in Section 2.3.1.

Regarding tasks, visual representations of data could be carried out based on user's intents and purposes. This includes tasks on locating (looking), seeking, querying, questioning (incl. comparing), and decision-making (Dodge et al., 2008; Andrienko and Andrienko, 2005). Carpendale (2003) provides five characteristics that allows the selection of visual variables to support tasks decisions, which are *selective*, *associative*, *quantitative*, *order*, and *length*. The first four are about visual interpretation tasks, and the last one addresses the issue of how many changes in a particular visual variable which is effectively used.

Geospatial data and tasks are encoded in terms of *mapping solutions* with a large amount of visualization techniques existing in the literature. According to Roberts (2008), visualization techniques for geospatial data can be divided into seven categories of maps/cartograms, networks, charts/graphs, ta-
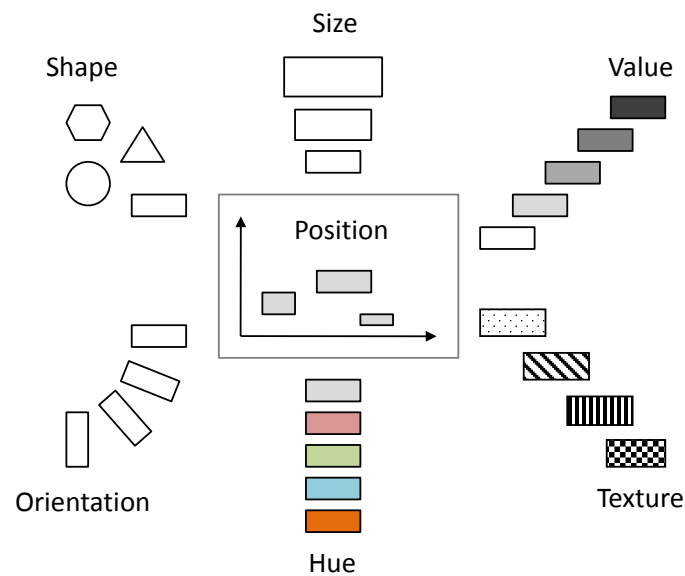
Figure 8: Bertin's visual variables used for encoding data.

bles, symbols, diagrams and pictures. *Maps* communicate spatial meaning and there is a direct association between the physical space and the represented space, including geometric maps, choropleths, and cartograms. *Networks* describe relational and associational information, e.g. that a connects to b and then c. Networks include trees, hierarchies, routing diagrams and graph visualizations. The well-known London underground map belongs to this category. *Charts* display statistical or mathematical information, including line graphs, histograms, circular histograms, pie charts, surface plots, scatter plots and parallel coordinate plots. *Tabular* and matrix layouts are popular for displaying statistical quantities and numerical information contained within geographical databases. *Symbols* may be used in two ways: either they are used to identify individual aspects of the information, such that objects or buildings can be located on a map, or they are used to notify trends. *Diagrams* realize some process, concept or phenomenon; most are hand-crafted to display a particular phenomenon or result. And *pictures* are raster data associated with geographical datasets, such as site photographs or aerial photographs (as can be found e.g., in Google Maps).

Often different visualization techniques in terms of the above-mentioned categories such as maps, diagrams, etc., are combined in a single display. For example, maps with embedded diagrams are quite usual. But in addition, maps can also contain multiple information layers that share a common spatial reference system as well.
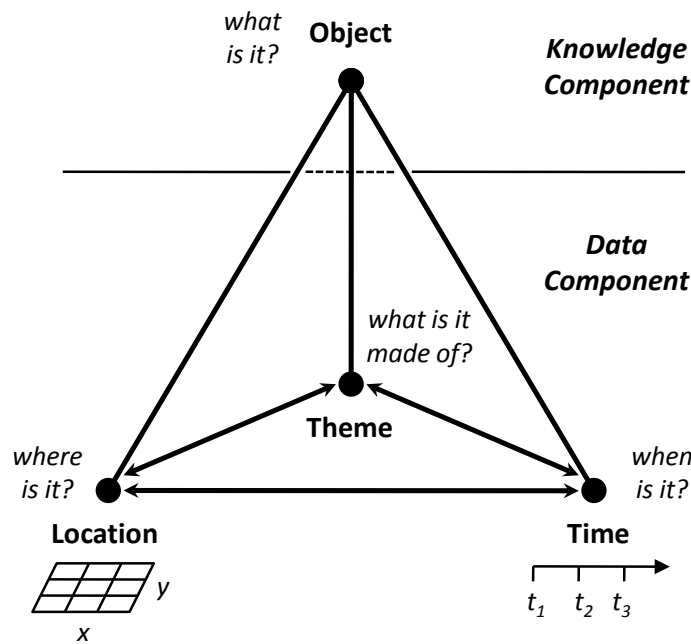
Figure 9: The pyramid framework of spatiotemporal data, adapted from (Mennis et al., 2000).

2.3.3 Geospace and Time in Combination

The above subsections cover almost everything about geospace and time, but separately. In this subsection, we will present more about the combination of them with ideas and visualization solutions in communicating spatiotemporal data.

According to Peuquet (1994), this world is conceptualized along the three perspectives of location (*where*), time (*when*), and theme (*what*), those constitute the holistic view of spatiotemporal data. One can reach the data object (*what it is*) through the examination of the three subcomponents: *where is it*, *when is it*, and *what is it made of* (Mennis et al., 2000) (Figure 9).

The three components of spatiotemporal data are interrelated. Examining the relations amongst the three depends on the existential changes of time references, the changes of spatial properties, and the changes of thematic values. It leads to various combinatory patterns for data exploration, explanation, prediction, and planning. For example, one can examine two of the tree components to analyse for the third one in form of $X + Y \rightarrow Z$ (Peuquet, 1994):

space & time are interrelated

- *when + where → what* - Describe the objects or set of objects that are present at a given location or set of locations at a given time or set of times.

- *when + what → where* - Describe the location or set of locations occupied by a given object or set of objects at a given time or set of times.

- *where + what → when* - Describe the times or set of times that a given object or set of objects occupied a given location or set of locations.

To illustrate, an event denotes some change in some location(s) or some object(s) is an instance of *where + what → when*. In the viewpoint of *exploratory tasks*, Andrienko et al. (2003) analyze deeper with kinds and scopes of combination for visualization solutions.

In that regard, to identify, compare, query, and making decision on spatiotemporal data, various visual representation techniques have been being used. Cartographic representations are used to communicate the spatial framework. Based on it, abstract data values and their time references are mapped. *Animation* is used as a means for displaying temporal data at a place (e.g., color scheme can be used to represent the age of the data). Though it can show temporal changes explicitly, it can be hard to compare data at various time points (e.g., in Blok, 2006). *Small multiples* are alternative solutions in statically displaying sequential moments and changes in time simultaneously (e.g., in Guo et al., 2006). Extending from those two approaches, the *space-time cube* (Hägerstrand, 1970) emerges, allowing time changes to be traced spatially, via the third dimension (Kraak, 2008). It has been used in analytical applications (Gatalsky et al., 2004), cartographics (Kraak and Koussoulakou, 2005), or storytelling (Eccles et al., 2008). More flexible, maps are augmented with supplementary graphs or charts depicting the change in a specific variable in specific locations or over the entire region. Such kind of *glyphs* can be found in e.g., Tominski et al. (2005), Thakur and Hanson (2010), or Tominski et al. (2012b).

When the data are too complex (large, multivariate), using glyph-based or animation solutions could be problematic. Multiple views are therefore suitable alternatives. These are typically used not only for the exploration, but also for the analysis of the multivariate data. The views are brushed and linked together, as can be found in e.g., Guo et al. (2006) or Ho et al. (2012). It is also beneficial to consider interactive operations that manipulate the appearance of visualizations. One example is visual comparison that changes symbolization for emphasizing differences to selected values/ objects or changes over time.

2.4   CLOSING REMARKS

This chapter covered the fundamentals for our research on casual Infovis for spatiotemporal data. In Section 2.1, fundamentals on *data*, *information*, and *knowledge* in Information Visualization and the *visualization pipeline* $\mathbb{C}_{data} \rightarrow \mathbb{C}_{image}$ clarified the direction of our casual Infovis, concerning *information-assisted visualization*. The existing research about casual Infovis in visualization

community has been focusing on user, usage context, design, and the matter of insights as described in Section 2.2. That leads to the confirmation that our concentration on visualizations in terms of diverse data types is a new and supplemental research problem.

Time and *geospace* are two crucial aspects for visualization research. Section 2.3 selectively presented models and issues for the developments of visualizations of spatiotemporal data. The concepts are general. Their viewpoints typically deal with general Infovis, where analytical exploration and analytical insights are main targets. As a result, casual Infovis for *diverse data types + geospace + time* was chosen as our final research problem.

In the roadmap of Vismaster - the European community partners on Visualization and Visual Analytics[3], the current challenges for studies on space and time focus on four main directions (Keim et al., 2010):

- Dealing with diverse data,

- Support for analysis at multiple scales,

- Understand and adequately support diverse users,

- And, reach the users.

Problems in dealing with diverse data and supporting diverse users require studies in both traditional as well as those at the "margin" of Infovis (i.e., casual Infovis). Our identified research problem satisfies these directions. Visualization of data in association with geospace and time will be widen from work domains to everyday scenarios with data contents on the Web for diverse users, especially for the novices and non-experts.

it is it, the thesis' goal...

Though there exist a lot of visualization techniques dealing with spatial and temporal data, the combination of the two with non-work and community-contributed data (on the Web) is challenging. In the next chapter, Chapter 3, we will motivate and discuss issues concerning the development of casual Infovis for *diverse data contents* on the Web with *geospace* and *time*. Various types of data in association with geospace and time are to be visually browsable and explorable. In doing so, tighter coupling traditional and casual Infovis is the solution: advanced strategies in Infovis are to be examined for the navigating and browsing of diverse data contents. Different (possibly contradicting) basic requirements for the representations of aggregated data and raw data are to be considered to arrive at meaningful visualization techniques.

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3 http://www.vismaster.eu/

ON CASUALLY VISUALIZING SPATIOTEMPORAL DATA

Melody and harmony are like lines and colors in pictures.
A simple linear picture may be completely beautiful;
the introduction of color may make it vague and insignificant.
Yet color may, by combination with lines, create great pictures.

— Rabindranath Tagore, 1930

Space and time are two outstanding aspects for the depiction of the world, dedicated in work from arts to sciences. In the area of Information Visualization, the visual communication of space and time has been being well considered over the last two decades, focusing on the exploratory and confirmative analysis of spatiotemporal data (see Chapter 2). Currently, research on visualization of space and time challenges us to deal with diverse data (many of them are personal and community-contributed on the Web) and to support diverse users (from novices to experts) (Keim et al., 2010).

In the context of Infovis research, we believe that, by *combining* advanced solutions in visual data analysis with the manipulation of raw contents in visual data browsing, it would create useful techniques for the exploration of personal and community-integrated spatiotemporal Web data. Isn't it mirror the way that Tagore uses the phenomena of "colors and lines in combination to create great pictures" to talk with Albert Einstein about music?

Casually visualizing data in the spatiotemporal frame of references is the direction that we will follow for the development of our visualization techniques, as presented in details in the next chapters. But before going on to elaborate them, we will present in this chapter the discourse of studying, the challenges, and the bottom line of our developments.

3.1 SPATIOTEMPORAL COMMUNITY INTEGRATED DATA

As presented in Chapter 2, studies in casual Infovis have been being carried out in terms of users and usage contexts, aesthetics and design, and insights. Meanwhile, casual Infovis research about data characteristics and perspectives is still an open topic (Lau and Vande Moere, 2007). In this regard, this section presents a discourse, in which the diverse data contents on the Web and their spatiotemporal references are described. Based on that, opportunities and challenges for the visualization of social and community integrated data in association with geospace and time are provided.

the discourse of research?

3.1.1 *The Data are Diverse*

In the conclusion of the innovating paper about casual Infovis, Pousman et al. (2007) state that "There are potentially fruitful domains for casual Infovis researchers to explore. [...] A final domain that is ripe for casual Infovis is the increasingly common practice of digital travelogues that include text, images, and video."

data on the Web – the research opportunity...

Common data for everyday usage, especially personal and community integrated data shared on the Internet in the trend of social Web are therefore suitable targets for casual Infovis research, because the data are multivariate, multi-model (i.e., from multiple sources), real time contributed, and explored and manipulated by diverse users (most of them are non-expert users).

In a recent survey about usage trends on the Internet, Pew Research Center (Rainie, 2012) shows that two-thirds of Internet adult users in America (80% of all American adults) use social networking site (for teens, it is three-quarters), more than half of them share photos online, and more than one-third contribute rankings and ratings or create content's tags (see Table 1). Reuters' polls also provide similar statistics for Internet users in many other regions around the world (Reaney, 2012).

WHAT INTERNET USERS DO ONLINE	PERCENTAGE
use a social networking site like Facebook or MySpace	66
share photos online	55
contribute rankings and ratings	37
create content tags	33
share personal creations	30
post comments on sites and blogs	26
have personal website	15
are content remixers	15
are bloggers	14
use Twitter	13
use location services	6

Table 1: Statistics about American adults on networking activities (Rainie, 2012).

The fact that more than six in 10 Internet people use social networks or more than five of them share photos online suggests a transformation in how people communicate with each other. Nowadays, the world of online data is undetachable from daily life of many people. With 75 percent of everyday data

currently created on the Internet from individual or online social community (Gantz and Reinsel, 2011), ways to support users to interact with those large amount of text, photos, or videos are of special requirement.

Everybody can now participate in the cyberspace, but many of them are not experts in creating and manipulating with data. In that regard, how sites, applications, and services are built decides the success of the online society. This is also acknowledged to the achievement of the WWW and Web Intelligence, a success of this information age (Zhong et al., 2000).

Most of personal and community integrated data currently created and shared on the Web are popular in forms of common media such as text, photo, video, etc. In addition to that, what makes nowadays Web data so special (in comparison to Web data at its beginning days, i.e., Web 1.0) is that users are provided with mechanisms to interact with existing data contents. Users not only share photos, videos, or messages, they also give comments, rate, like, tag, bookmark, and authorize the contents. The data on nowadays Web are thus numerous in types and forms through various kinds of sites and services, including: messages or micro-contents like Twitter[1], personal weblogs (*aka* blogs), media sharing (photo sites like Flickr[2], video sites like Youtube[3], etc.), collaborative contents like Wikipedia[4], social networking like Facebook[5], besides millions of other websites and resources.

Today, Internet users not only search, explore, or query data contents as in Web 1.0, they leave traces together with the data to form the online society. And thus, all types of today Web data (i.e., Web 2.0 data with messages, photos, videos, tags, comments, and so on) are objects for casual Infovis developments.

Below we summarize the characteristics of everyday data on the WWW, which match well to our objectives in developing casual Infovis techniques:

...but, also the challenge

- *Casual, subjective, and user-centered*: While data on Web 1.0 are generally limited to content-providers, data in today second-generation Web are mainly from end-users. And thus, they are popularly created, subjective, and casual. Visualizations of those data would therefore reach casual Infovis users and casual usage contexts.

- *Participatory, community-contributed*: Blogs are not secret diaries, tags are not stickers, webpages are neither places nor documents. They exist and last on the Web in association with the communication of the community. And thus, interactions (e.g., browsing on existing webpages) to support diverse users will bring more visualization techniques to the community.

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1 https://twitter.com/
2 http://www.flickr.com/
3 https://www.youtube.com/
4 http://www.wikipedia.org/
5 http://www.facebook.com/

- *Short data are preferred*: Users are interested in bookmarks, tags, or likes not only because they link the users with the data contents, but also because of the joyfulness, interestingness, and convenience that those pieces of data bring up. They are informative objects which can be arranged on screen for exploration, such can be testified e.g. in tag clouds.

*Web data
are considered
because of
the diversity in
types and quality...*

- *Remixable, combinable, and shareable*: Web data are annotated and linked with multiple cross-references and individual perspectives. The data are multivariate, multi-model, and heterogeneous. Thus, to deal with the diverse data contents, those data are expected to be as interoperable as possible. In other words, data are expected to be nemixable, combinable, and shareable across websites and services.

- *Computational intelligence as the long goal*: Analyses and decision-makings are tasks specifically developed for work and expert users, but with the increasing amount of data and the development of computational intelligence, trend of information analysis progressively reaches non-expert users as well. Everyday users will be analysts in their possible roles. And thus, casual Visual Analytics will be a coming trend in which Visual Analytics and socio-semantic Web (ambiguously extended to Web 3.0, Shannon, 2006) are combined.

3.1.2   *Geospatial and Temporal References*

Geospace and time are prominent aspects, together with personal and community integrated data contents, they form the world of today Web data. All data on the Web are created and manipulated over time and many of them contain geo-referenced information. Recalling the pyramid framework about space-time-theme (Mennis et al., 2000, see Section 2.3.3), the world of Web data needs to be examined through the whole triplet of *what* (data in diverse forms and types), *where* (geospatial references), and *when* (temporal references).

GEOSPATIAL REFERENCES   We consider Web data concerning geospatial references. The fact that 66 percent of American Internet adults use social networks (recalling Table 1) is still lesser than some non-networking activities; where, according to the February 2012 survey of Pew Internet Research (Pew Internet Research, 2012), the top three Internet activities of American adults are: using a search engine (92%), sending emails (91%), and searching a map or a driving direction (84%).

In other words, we can say that geographic referencing is the very important factor in everyday usage scenarios. Nevertheless, in many today Web applications, spatial knowledge still remains hidden in small information fragments such as addresses on Web pages, annotated photos with
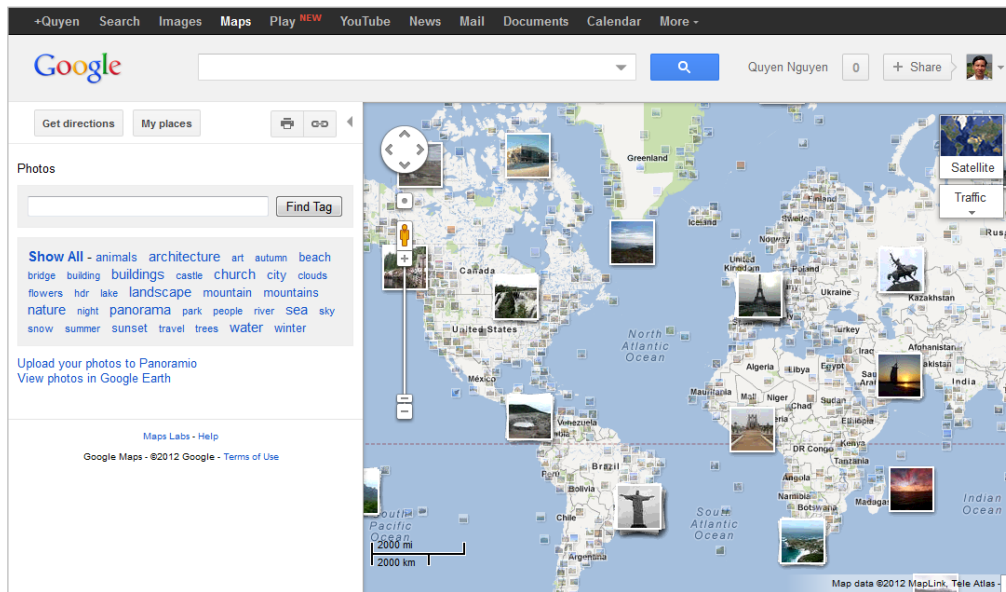
Figure 10: Google Maps with photos exploration.

GPS coordinates, geographic mapping applications, or geotags in user-generated contents. Accordingly, users typically find geo-information from data contents rather than be engaged in examining the data in terms of geo-visualization. In that regard, communicating Web data in terms of geospatial references is a mandatory.

As one of the efforts to deal with that, location-aware Web has been taken into account in recent WWW research and development (Boll et al., 2008; Wilde et al., 2009, 2010). And, applications and services are recently provided with tasks such as geo-indexing, mining, and mashing-up social Web (such can be found e.g. in Google Maps[6] – see Figure 10, and some other tools). With those services, users can now be involved more in creating maps and location-based media (e.g. using Google Map Maker[7]) in addition to using just GPS coordinating or geocoding.

In other words, location-aware Web opens new sights for making maps, also referred to as "Web mapping 2.0" – a way for "rethinking" maps (Gartner, 2009). To this end, Human Computer Interaction and Information Visualization are taken into account to drive users more to making and living with maps, where: "location is not just a concept, it is presented to the users; location is no longer encapsulated in devices or applications, it is openly exposed and shared" (Wilde et al., 2009).

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6 http://maps.google.com/

7 http://www.google.com/mapmaker

Figure 11: Facebook with a Timeline Profile.

TEMPORAL REFERENCES   Time exists within all pieces of data on computers. Time-referencing is thus another significant aspect for Web data communication.

Communicating the time-dependency of data has been being taken place in content-management systems and services on the Web. But, similar to the requirement of location-aware Web, time-oriented data exploitations require research leading to advanced Web applications (for instance, Timeline has recently introduced as a useful way to organize and access user profiles over time on Facebook - see Figure 11).

Visualization makes it easier for users to associate data with time, and vice versa. But, communicating time-references is not limited just to the placement of contents around a time axis. Time exists in social communication through events and other temporal data as well. Thus, they are subjects for casual Infovis research for diverse data contents on the Web.

3.2   PROBLEM DISCUSSION

As presented in Chapter 2, there have been many useful techniques and tools for the visualization of geospatial and time-oriented data. However, visually representing Web contents in association with geospace and time is still the

challenge. This section will present the problems that we want to address in this thesis.

3.2.1   *What and Why*

Our goal is to develop novel approaches for the visualization of spatiotemporal community integrated data. There are problems that we will deal with when visualizing diverse data contents on the Web. Here, we consider the two important questions when developing any visualization technique:

- *What* do we need to visualize?

- *Why* do we need to visually represent them?

What has to be visualized?

As introduced in the previous section, data to be visualized in our work involve three components: (1) *what* – community integrated diverse data on the Web (the data are diverse in types, including tags, photos, videos, and so on), (2) *where* – the geographical references of the data, and (3) *when* – the temporal references of the data.

the whole triplet of what, where, and when...

In the viewpoint of visualization, geospace and time have their own spaces for visualization designs (see Chapter 2). In addition to that, text, photos, or videos need to follow specific criteria if visually representing to users. In that concern, it can be said that, for diverse data (i.e., data with different content types and aspects), it requires an exhaustive study in order to develop suitable visualizations for specific *data contents + geospace + time*.

Why does it have to be represented?

We develop visualization techniques so that to support everyday users (many of them are novice) to explore data in terms of tags, photos, videos, and so on, and with regard to their spatiotemporal references. In more details, our casual Infovis techniques are to be developed concerning tasks about visually *navigating*, *locating*, and *browsing* the existing Web contents (on webpages) in association with geospace and time.

common tasks: browsing, navigating, and locating...

Web data are diverse in types and forms and are associated with geospatial and temporal references. Each kind of data or frame of references can be visually encoded and represented with its own constrains. And thus, in this case of diverse data and aspects (i.e., geospace and time references), it is challenged to visually encode all of them harmonically together, or present all of them in a stand-alone view. The data are expected to be specifically examined for different contexts.

For browsing the contents, data in their raw forms are especially considered in the visual communication, but for visual navigating and locating the data, the representations of aggregated data are expected to be fulfilled (see Section 2.1). Casual Infovis for Web data contents therefore must be settled in a combinatory way. In that concern, how to communicate data from raw contents to abstracted representations is challenging: this is the trade-off in between choosing how raw contents and the aggregated information to be visually and interactively communicated on the interfaces.

3.2.2 *Challenges*

To visually explore the triplet of *what* (data contents), *where* (their geospatial references), and *when* (time references), we face problems in visualizing every of those three components: (1) representing the diverse data, (2) communicating their geo-references, and (3) conveying their temporal references.

Problems in representing data contents are due to the fact that data are diverse in types and are expected to be representable in various granularity levels (from raw to various abstracted granularities). Problems in representing geo-references are due to the constrains of geography (for example, to present tags inside a geographical area to communicate geo-referencing tags, it is problematic to fit tags into arbitrarily-shaped areas). And, problems in representing temporal references are due to the fact that time is multiple-perspective representable (i.e., having more than one point of view at observed facts – see Chapter 2).

In summary, to develop novel visualization techniques, we face different challenges in terms of representing diverse Web data together with their spatial and temporal references:

BOTH GEOSPACE AND TIME –   Although there exist visualization techniques and tools considering either geospace or time for the exploration of specific Web data, dealing with diverse data contents in association with *both* geospace *and* time is the challenge.

VISUALLY COMBINING –   Talking about the visualization of spatiotemporal data, Aigner et al. (2011) state that "from the visualization point of view, all aspects need to be taken into account". Thus, in this case of visualization techniques for Web data with diverse contents and references (i.e., including geospace and time), our hypothesis is to flexibly represent and combine data contents and geospatial and temporal aspects together. This raises challenges in identifying suitable forms of the data to be visualized, and how to combine them to make the holistic, interactive, and associated views – especially

when the data are interconnected in terms e.g. of *what + when → where*, or are available on different webpages.

LEVELS OF GRANULARITY –   In supporting visually navigating, locating, and interactively browsing, to communicate data from raw forms to more abstracted representations, data are to be encoded in different ways in terms of different granularity levels of representations. This raises challenges in tighter coupling traditional and casual Infovis: how to employ advancements in Infovis to visually encode information, support interaction, and pose visual insights, and how to keep data in raw forms and preserve contents' contexts so that everyday users can easily comprehend and manipulate with.

3.3   TOWARD THE APPROACHES

This section presents a bottom line of own solutions in developing casual Infovis techniques for the exploration of spatiotemporal Web data: our techniques are developed based on the examination of the types of data contents and with respect to specific tasks at hand.

data and tasks!

Spatiotemporal community integrated data on the Web are diverse in types, and thus it is irrelevant to develop a single visualization technique that can cope with all of those data. Diverse types of data can lead to a variety of designs and visualization solutions. In that regard, our approach here is to develop workable solutions for specific data contents. To this end, we aim at the tasks of *browsing* selected raw contents and visual *navigating* and *seeking (locating)* for data in the spatiotemporal frames of references.

...Web data

...common tasks

Recalling the visualization pipeline (Section 2.1.2), this is done following the manner of *information-assisted visualization*, in which we propose to deal with the two main directions: (a) *supporting browsing*: raw contents get highest priority in the visual communication, and (b) *supporting navigating*: overview of information has to be considered first.

approaching: information-assisted visualization

a. Supporting Browsing - Content First

By "content first" it is meant that the data in their raw forms are the foci in the visual communication (amongst many data aspects to be communicated), while other information can be additionally provided when possible.

Why do we need to do like that? – As presented in Section 3.2.2, it is a big problem to explore data with so many aspects represented all together. In this case where the data are complex (containing tags, photos, videos, etc. in association with geospace and time), it is better to select only specific data aspects to be the foci in the visualization. To support the task of browsing data contents, the data in their raw forms must be chosen as the most important ones. This

is especially suitable for casual Infovis developments (see Section 2.2.1), because data contents in raw forms are easily comprehensible and manipulable by everyone.

But, casual Infovis is not just about the placement of familiar visual items on screen to support everyday users. Deriving from Infovis, it is expected that examining information in association with data contents should be considered as well (especially in the manner of *information-assisted visualization*). In this work, geospace and time are such information for communication; and thus it opens challenges in how to visually combine the contents with geospace and time.

To this end, because geographical maps are popularly used in communicating geo-information (amongst many kinds of geovisualizations – see Section 2.3.2), they are examined so that the data contents can be combined with. The challenge here will be the matter where data contents could be irrelevant to geographic structures (with complex territories and hierarchical levels). In the same manner, temporal references of data contents are objects for visual combinations. This is challenging to show raw data contents with time, because we typically abstract the data to visually communicate with time, as presented in Section 2.3.1.

The *pro* of this approach is that by taking advantage of familiar visual forms of data contents, casual Infovis users could easily get the points on the interfaces. But the approach has *cons* in being dependent heavily on the forms of the data contents. In many cases, it is not simple to employ advanced solutions in Infovis to communicate further information linked with the raw contents.

Taking those problems into account, we need to analyze for strategies in combining Web data with visual cues in appropriate ways. A visualization technique can be accomplished based on general forms of raw data, but it also depends on developers' viewpoints (see Section 2.2.2) in reorganizing data objects so that additional visual encodings can be integrated. In other words, novel casual Infovis techniques can emerge as the compromise in between novel visual encodings of information following the enhancement and placement of data contents on the interfaces.

b. Supporting Navigating - Overview First

In a different manner, another approach in visualizing spatiotemporal Web data with various types and aspects is to leverage the overview representation of aggregated data on the interfaces (where data in raw forms have lesser roles, e.g., being displayed following interaction on demand).

Representing aggregated data, instead of contents spatialization, is the focus of this approach. By doing so, the task of navigating on the interfaces and locating for data of interest is to be supported. In this regard, this second

approach can be examined following the viewpoint of traditional Infovis development (see Section 2.1). Developers are benefited by work in Infovis for the development of techniques: Shneiderman's *visual information seeking mantra* – "overview first, zoom and filter, then details-on-demand" (Shneiderman, 1996) – and other Infovis knowledge are to be applied. At this point, one can examine to develop visualization in terms of a single overview combining space and time, multiple overviews from different perspectives or at different scales, and so on.

But notice here is that developers need to take care the matter of casual Infovis in communicating Web data so that everyday users can handle the visualizations. In other words, developers need to carefully consider possibilities in Infovis to provide suitable solutions for the representation of diverse Web data, and provide ways to combine and show further data contents of interest in the form of chosen overview(s).

Developers can investigate various alternatives in abstractly representing the aggregated data. But to present further raw contents on the interfaces, it is the challenge since raw data depend strongly on specific visual forms, and in many cases it is irrelevant to position them together with typical Infovis solutions.

To develop techniques for spatiotemporal Web data, all data aspects (which are contents – tags, photos, videos, etc. – and their geospatial and temporal references) should be examined for the overview communication. This is carried out to support the tasks of visual navigating and locating the data, where spatial and temporal information give hints for the tasks. To illustrate the ideas, we show an example: giving sets of tags, each links with a time point, a parallel coordinate plots can be developed to show the overview of temporal development, and tags are located on each coordinate following interaction (i.e., presented on the fly).

The *pro* of this approach is that by taking advantages of Infovis in choosing the visualization solutions and designs, developers can communicate aggregated data in flexible ways and pose various insights and actions from users. But the *con* is that this can lead to problems in impelling users (many are not experts) to accept and use the unfamiliar visual objects.

Taking those problems into account, in this case (close to typical Infovis developments), we should think about developing appealing but useful and comprehensible visualizations so that casual users might accept: the developed visualization should not be so complicated, but must be utility-oriented. And, the visualization should be flexible to integrate with raw data contents following the interactive tasks of casual Infovis exploration.

so,
is that everything?
...

c. Remarks

At this point, together with the above-mentioned objectives and approaches, it is also necessary to consider the matter about information uncertainty in spatio-temporal Web data for casual Infovis developments.

Generally, casual Infovis developments for Web data with geospace and time are challenging not only because of the diversity of data context, types, and quality, but also due to the fact that spatial and temporal references in Web data are extensively imprecise. For instance, geospatial references are often provided as geo-names (e.g., Berlin) or have imprecise geographic coordinates marked or linked by users community or devices; or, when a photographer takes a photo, the coordinates of the photo can be assigned by the position of the camera instead of the position of the objects taken in the photo. In a similar manner, for temporal references, community-contributed data may refer to a wrong time zone, such that in the case that tourists travelling overseas forget to adjust clocks in their devices; or in the example of Flickr photos, records would have multiple temporal references with capture time and upload time.

In that regard, casual Infovis developments should not only deal with the visual communication of the diverse data types and aspects. They should also cope with solutions for the visual exploration of data with uncertainty, where, in addition to the two main directions emphasizing on the tasks of browsing or navigating, it is the possibility that casual Visual Analytics is another direction. In terms of Keim et al. (2008)'s *visual analytics mantra*, it would be the solutions to start with detecting and visually highlighting specific (often, analytical) information, and then supporting the navigating or browsing for further data and information on demand.

casual Visual Analytics?

3.4   WHAT'S NEXT?

In this chapter, we have presented a discourse in which spatiotemporal data on the Web are provided. The discourse shows that personal and community integrated Web data are diverse in types and quality and very often associated with geospace and time. This causes many challenges for the visual communication of those data with regard to both geospace and time to everyday users. This can be tackled following the direction of casual Infovis developments.

Based on the analysis of the types of data contents and common expected tasks, we presented two general directions for the development of casual Infovis techniques: (i) to support browsing: data contents get highest priority in the visual communication, and (ii) to support navigating: overview of information must be considered first.

In the next chapters, we will go into specific cases for the visualization of specific Web data with geospace and time. In Chapter 4, the guidances of

the above-mentioned first direction are realized in a visualization technique for spatiotemporal tags. The tags are the focused objects to be explored, and with the task of data browsing; and thus they can be arranged as tag clouds inside geographical areas to deal with geo-references. Based on that, temporal information of tags is encodable to tags to form the so-called interactive Tempo-Taggram technique.

In Chapter 5, we follow the second direction in visualizing spatiotemporal photos or videos. We support the task of navigating on the visual interfaces to seek for photos/videos of interest. Geographical maps, together with time glyphs, photo thumbnails, and time-referenced tag plots are developed to show the overall interface. There, to seek for photos or videos of interest, the visualization is explored and photo contents are presented on the fly.

And, in Chapter 6, in a general consideration, we study to cope with the visualization on the Web with diverse contents. The diverse spatiotemporal Web data are visually communicated and explored in terms that the both tasks of visual browsing and navigating for Web contents are supported. Web contents are not only browsable in traditional ways but will be leveraged by additional visual supports in terms of augmented Web browsing to support everyone.

4

TAGS WITH GEOSPACE AND TIME

*I have now come to believe that the order of words in time or space
is an ineradicable part of much of their significance
– in fact, that the reason they can express space-time occurrences
is that they are space-time occurrences.*

— Bertrand Russell, 1926

As personal and community-integrated data are created and shared widely on the Internet, tagging is a common practice to structure them for easy access. A large amount of nowadays tags is provided in the spatiotemporal frames of references. Therefore, geospace and time are important aspects for the exploration of tag data on the Web. In this chapter, we present a study for the visual exploration of spatiotemporal tags in terms of the first direction proposed in Section 3.3. We support the task of *browsing* tags, which link with geospace and time, accomplished by taking advantage of cartographic contours as geo-references to build up the "mental maps" of tags (Nguyen and Schumann, 2010) and exploiting visual cues to communicate temporal information of tags (Nguyen et al., 2011).

*first type
of Web data
in consideration*

The chapter is organized as follows. In Section 4.1, the situational context of *what* tags and tag clouds are is given. In that concern, we present objectives for the visualization of tags with both geospace and time. With the motivation and problems, we come to solutions on *how* to spatialize tags inside geographical areas (Section 4.2), and *how* to encode time through tags' appearances and additional visual artifacts (Section 4.3). The chapter goes on with examples for the browsing of spatiotemporal Flickr tags in Section 4.4, and ends with a summary in Section 4.5.

4.1 GENERAL REMARKS

Tags are a set of words that abstractly and linguistically depict contents from photos, videos, audios, or other data collections on the Web. Commonly tag clouds are used as the means for the visual communication of a set of tags. This section presents the state of the art of tag clouds visualizations, leading to our objectives in visualizing tags as tag clouds in association with geospace and time.
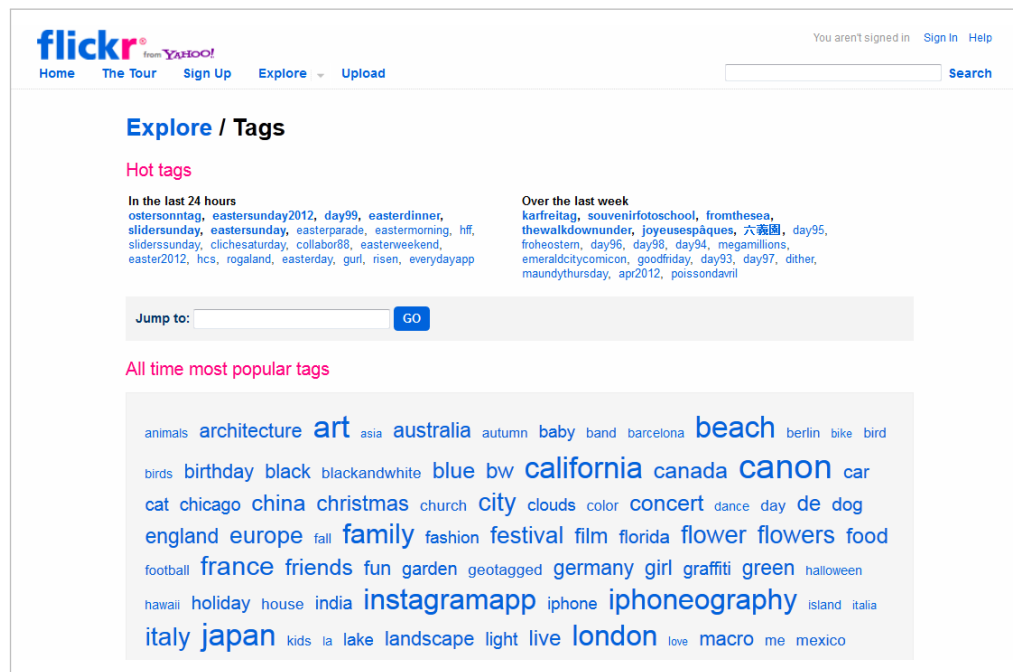
Figure 12: Tag Clouds on Flickr.

4.1.1 *Tagging and Tag Clouds*

A very common activity in online social communication is sharing personal and community data in the manner of collaborative tagging and bookmarking (Li and Lu, 2008). This simple way of data sharing has been being attractively used by many Web users. Generally, people can get information about documents, photos, videos, and so on, through the referenced tags, and be able to navigate to the data through this kind of bookmarking. Tagging is thus known in terms of *folksonomy* (folk + taxonomy): establishing the taxonomy (of contents) for data by the folk.

Tag cloud is the common visualization to present tags on the screen (see an example in Figure 12). It is accepted by many people due to the simplicity and expressiveness of the visual component: a set of words is arranged inside an area, where their sizes, colors, and other visual cues are included to communicate the tags set.

So far, research on tag clouds has been considered in various contexts. According to Hassan-Montero and Herrero-Solana (2006), tag clouds are suggested for information retrieval interfaces, since the visualization promisingly supports the overview of indexed and clustered data. But in many other cases, tag clouds are just considered as a kind of decoration: "the social signaler", instead of being seen as a visual analysis tool (Hearst and Rosner, 2008). In

that regard, work on tag clouds mainly focuses on the spatialization of a set of words on a view and the matter of usage evaluations.

For spatializing algorithms, tag clouds are typically placed in rectangular regions (such as Kaser and Lemire, 2007) or convex polygons (such as Seifert et al., 2008). For usage evaluations, it is empirically confirmed that users prefer to *browse* tags in alphabetical order (Halvey and Keane, 2007), and are interested in and affected by tags' font size, then font styles (Rivadeneira et al., 2007; Bateman et al., 2008), while color and position of tags are lesser important (e.g. in the case of clustering tags, or centric-based browsing of tags) (Lohmann et al., 2009; Schrammel et al., 2009).

tags are often visualized in simple polygons of tag clouds

In summary, tag clouds have been developed for the visual exploration of data in terms of data bookmarking. But due to the fact that tags are meaningful with various relationships (see Collins et al., 2009a), studying for the visualization of tags should be further examined. In this work, we take the two important aspects of tags (geospace and time) into account for a novel technique in visually communicating this kind of interesting Web data.

4.1.2 *Objective*

A photo sharing site such as Flickr is a prominent application scenario for spatiotemporal tags. When a photo is taken or uploaded it is automatically equipped with a time stamp. Additionally, many photos are also outfitted with spatial information such as precise geo-positions (i.e., latitude and longitude) or coarser areal information (e.g., west coast or city of Munich). When the photo is tagged with keywords, those tags are no longer just abstract linguistic objects. Instead, they carry meaning and embed this meaning into a spatiotemporal frame of reference.

Given such spatiotemporally referenced tags, a user might want to find out where certain tags occur, or how the tags are linked across different areas. He or she might also be interested in browsing the tags with regard to a specific time point or time interval of interest, or with regard to special temporal relations (e.g., consecutive Sundays of a month). Examining how tags have evolved over time is also an interesting task.

visualizing tags with both geospatial and temporal references?

While there are useful tag clouds in visually communicating user-generated tags, there is hardly any visualization that communicates *both* spatial *and* temporal references of tags. In that regard, our objectives here are to propose and develop solutions for the visualization of tags in association with both geospace and time. In the next section, we will present our work concerning the spatialization of tags inside geographical contours to communicate their geo-references, before going to the latter section for the communication of temporal references through tags' appearances or additional visual cues added to the tags.

4.2   VISUALIZING TAGS WITH GEOSPACE

In the context of geospatial data, tags if combined with geospace can communicate meaningful information than the tags themselves, especially when geography is the very important information in everyday conversations (Jo and Ryu, 2010). In that regard, as a target of casual Infovis research, visualizing tags in association with geospace is a need for everyday usage scenarios. To this end, this section deals with a novel design for the visualization of tags with geospace (Nguyen and Schumann, 2010).

4.2.1   *Tag Clouds and Geospace*

Work on geo-referenced tag visualization is not new in tag clouds' research. Jaffe et al. (2006) suggest placing tags on general purpose maps for the exploration of geotagged photos. With that idea, Slingsby et al. (2007) and Wood et al. (2007) take advantage of mash-up tools such as Google Maps to present tags and tag clouds as labels separately brushed with maps or floated on them. And Dörk et al. (2008) develop tag clouds in the coordinated views of geo-referenced tags linking with geographical maps.

The development of those techniques provides first concepts for the exploration of geo-referenced data (such as photos) through tag clouds. But in those cases, tags are almost simply attached to the maps. This causes various problems: (1) the benefit of text-based visualization such as interactively grouping and linking words, and so on (Collins et al., 2009a) are hardly considered; (2) as discussed by Jo and Ryu (2010), navigating on geometric maps but keeping all maps features is not always the straight-forward solution dealing with large dataset (this is also right for tag clouds); (3) using geographical maps with a lot of unnecessary data is a waste of presentational space; and (4) user actions in zooming in and out on maps for overview and detailed exploration are not *toward the* always beneficial for browsing context.
approach...   Therefore, our approach is not to visualize tags in the forms of separated tag clouds brushed or floated on general purpose maps. Instead, we take advantage of the shapes of geographical areas to analyze and find out ways to arrange tags directly inside the areas, adapting to the visualization trend in trading off shape and area adjustments with other visual data (Keim et al., 2004).

4.2.2   *Approaches for Visualizing Tags with Geospace*

The motivation of our development bases on the ideas of "collective mental maps of Paris" (Milgram and Jodelet, 1976). To describe how landmarks in Paris were mentioned in a survey, Milgram and Jodelet draw words visually
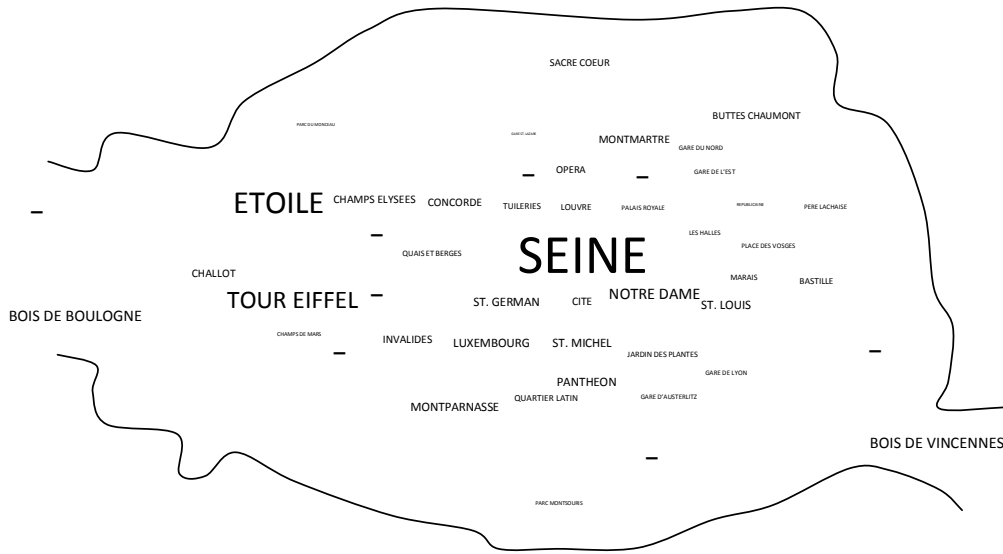
Figure 13: Collective mental maps of Paris: words' sizes express their frequencies in mentioning the landmarks in a survey (Milgram and Jodelet, 1976).

in the shape imitating Paris, where words' sizes express their frequencies in mentioning the landmarks (Figure 13). This visual illustration has the form of a tag cloud and expresses the message of geo-referencing – thus, when examined in the viewpoint of computational visualization, provides feasible solutions dealing with the issues mentioned in the previous subsection.

Different with a typical point-based cartographic labeling problem, where words are placed on maps at fixed positions (i.e., exact coordinates of the placemarks) and sizes (e.g., to differentiate the types of city names, river names, and so on), we provide the approaches where words are flexibly spatialized inside the geographical area. In details, we leverage only the shape of the geographical area to organize and represent collections of tags as follows:

proposed approach: tags are flexibly placed inside arbitrarily-shaped polygons

1. Areal contour is the referenced feature to express the geographical information of tags, as tags are spatialized inside the contour. In this way, we provide separated tag clouds in between different geographical areas.

2. Visual cues such as size, color, orientation, transparency, etc. of tags can be used for the communication of various information carried by the tags (such as their frequencies).

3. Large collection of tags are expressively browsable in the geographical areas.

Placing a set of words inside an arbitrary-shaped area is a *bin-packing* NP-hard problem[1], as presented in (Feinberg, 2010). There has been various work to cope with this bin-packing problem. Nevertheless, providing a large number of items (words) with different sizes into an area is impracticable without interaction.

Thus, *interactively* presenting words inside an arbitrarily-shaped area is our focus, especially in the case that we want to support the task of *browsing* tags in a large collection of tags. To this end, one can examine one of the two alternatives for the development of such a visualization technique: *(i) point-based* or *(ii) area-based* labeling approaches. Each can be carried out following the three main issues: (*a*) strategy in specifying places in the geographical area that the tags will be located, (*b*) mechanism in placing a tag at a specified place, and (*c*) solution in handling large number of tags.

three main important issues

a. Strategy in Specifying the Places for the Tags

Due to the fact that geographical areas are complex in shape (including not only convex but also concave and irregularly-shaped regions), spatializing algorithms such as those from Kaser and Lemire (2007) or Seifert et al. (2008) are not adequate. In those solutions, tags are typically placed inside rectangular or convex polygons, and they are not applicable for arbitrarily-shaped areas.

where to place the tags?

Given an arbitrarily-shaped area, the first issue to be considered is the design strategy in specifying the places that the tags will be placed:

i. According to Feinberg (2010), an easy way is to follow a *greedy* algorithm in identifying the places. It is greedy because a word finds its location in a local spatial area. From an anchor point in the area (typically the center of the area), it is followed a spiral path until an empty space for the tag to be placed is findable. Thus, it is a *point-based* labeling strategy. The challenge here is how to provide a suitable function in identifying the places, such as the just-mentioned spiral path, or a medial axis, or the skeleton of the geographical area, etc.

ii. The alternative is an *area-based* strategy, which means that the geographical area is first subdivided into subareas, where each subarea will be a place for a tag. When all subareas are already specified, the tags will be placed. For instance, the area contour, which is a polygon, can be subdivided into triangles in different sizes – such as through a *polygon triangulation* algorithm[2] – and the triangles are merged to form different subareas suitable for the tags. The challenge is how to subdivide the geographical area into how many subareas and in which sizes, so that the tags are placeable.

---

1 http://en.wikipedia.org/wiki/Bin_packing_problem

2 http://en.wikipedia.org/wiki/Polygon_triangulation

Another solution can be examining position for tags based on their coordinates, such as by estimating the positions (as in Li et al. (2013) for Twitter tweets or Flickr tags). The estimated positions and word frequencies can then Voronoi-tessellate a geographical area into subareas.

Choosing a strategy (*point-based* or *area-based*) influences the later steps in the spatializing algorithm. Depending on the purpose of the visualization, we will choose a suitable strategy. For instance, to emphasize biggest tags on the biggest places in the areas, subdividing the geographical area first can be a suitable solution. However, to support interactively *browsing* a large tags set, presenting them following the vertical media axis of the geographical area will be our option as presented in Section 4.2.3. By the way, now we will examine the two remaining issues.

but, how many and which tags are shown?

b. *Mechanism in Placing Tags at the Specified Places*

The second issue to be carried out is the mechanism for the placing of the tags at the positions or subareas mentioned in the previous step. Given a set of tags, which tag should be chosen to be associated at a specified place? The solution depends on the strategy in the previous step:

i. For *point-based* labeling approach, if we want to emphasize tags at the center of the region, that center must be chosen at the starting point for the spiral path, the medial axis, or the area's skeleton, etc. And, in order

Figure 14: The spiral path taken by the tag "Denmark", captured from (Feinberg, 2010). Noticing that the tags are not centralized by size, where many tags are resized and crammed into the gaps in other tags (e.g., at tag "lord").

for the biggest tags to be shown close to the area's center, they must be sorted by size. Then, starting from the center of area, we place the biggest tag, and finding new positions along e.g. the spiral path to place the next sorted tags step by step. Figure 14 illustrates the placing of a tag following a spiral path, but the tags are not sorted and centralized by size.

ii. For *area-based* labeling approach, a strategy is to sort tags by size and subareas by size, and then relate the biggest tag to the biggest subarea, and so on. For Voronoi tessellation, the tags are related to the subareas, but can be distorted if the subareas are not fit for the tags.

The challenge here is the adaptation of the tag. In order for a tag to be placed onto a specified place along e.g., the spiral path or a subarea, it has to be adjustable in height and width, since there might be tags with very long width while the shape of the arbitrarily-shaped area/subarea can be very strict (e.g., small in width or containing holes).

c. Solution in Handling Large Number of Tags

how to show the remaining tags?

The last but important issue in our approaches is the way that we handle large volume of tags: the number of tags to be presented can be much larger than the anticipated positions or subareas. How can we handle that? With the two provided approaches, there could be two relevant solutions:

i. For *point-based* labeling approach, one strategy is to show the most important tags (e.g., the tags with biggest sizes) following the mechanism provided in the previous issue: Rendering a tag, finding the next place for the next tag along e.g. the spiral path, and continuing the process until the whole geographical area is occupied, or when all tags are placed. If there are tags not yet placed, a post-processing step is carried out in terms of resizing the unshown tags and cramming them into the small gaps between the existing tags and characters, also following the spiral path (see again Figure 14).

ii. For *area-based* labeling approach, the strategy is also similar: rendering the most important tags for the estimated subareas, and then doing post-processing in terms of resizing and shifting the shown tags for the new space available for additional tags through interaction, such as using the particle-based labeling approach (Luboschik et al., 2008).

But the problem is that the remaining tags in the post-processing step can be too small to be comprehensible. Therefore, other solutions are needed.

In that regard, because a common design of tag clouds typically supports presenting less than 100 tags in a cloud (e.g. 30 tags (Seifert et al., 2008), 93 tags (Kaser and Lemire, 2007), 76 tags (Schrammel et al., 2009)), we suggest to

select just dozens of tags to be shown (even the tags set can be up to hundreds or thousands of tags), following the places specified in the previous issues. And then, following interaction, the visualization updates with new tags so that the remaining tags can be *browsed* on demand. This is acceptable in the context of a typical tag cloud visualization, because according to (Halvey and Keane, 2007) and (Bateman et al., 2008), people do often scan the cloud for the highlighted tags (mostly the biggest ones) rather than read all of them to find information - or we can say that just some tags are valuable in a snapshot of the visualization.

To this end, in order to keep a coherent view of the tag cloud for easily browsing, the center of the geographical area is always the emphasized place in our tag cloud visualization. In that way, tags are designed to be organized in the way that the updated ones (on new positions) preserve the form of the old ones in the cloud. Thus, we present the solution in handling large number of tags in terms of the *point-based* labeling approach as detailed in the next section.

4.2.3 *Taggram's Development*

Following the strategies just provided, this section presents the development of the technique Taggram in visualizing large tags set inside arbitrarily-shaped geographical area.

a. *Overview of the Technique*

As presented in Section 4.1.1, studies on user evaluation show that when exploring tag clouds, people often pay attention to tags with bigger font sizes where center of a cloud is the place where tags get most noticed (Bateman et al., 2008; Lohmann et al., 2009). Therefore, our approach is to place biggest tags close to the center of the area, and the other tags with reducing sizes further from that center. This forms a fisheye view, which – if preserving the view – supports the users in easily browsing tags when scrolling the large tags set (see the next Subsection *(d)*).

keep the fisheye view when scrolling

Following the considerations and strategies discussed in Section 4.2.2, the algorithm for Taggram's implementation is summarized in Table 2 in terms of a *point-based* labeling approach. The detailed algorithm will be described as follows: *(b)* finding the center and the vertical-medial axis of the geographical area (step 1), *(c)* enhancing tags to fit at the specified places (steps 2 – 4), and *(d)* handling the large number of tags on demand (step 5).

INPUT : An initial set of tags and a geographical area.

OUTPUT : Taggram inside the geographical contour.

---

1. Find the center and the vertical-medial axis of the area
2. Sort tags and identify the first tag to be placed
3. Place that first tag at the area's center
4. Follow the vertical-medial axis of the area

   while a new position can be found do

   4.1. Select the next tag to be shown
   4.2. Identify the new position following the medial axis and depending on the size of the tag
   4.3. Place the tag on the new position

   end while

5. Handle the remaining tags

Table 2: Overall algorithm of Taggram.

b. Finding Center and Medial Axis of the Area

In this design, the center (c_x, c_y) of a geographical area is computed based on its boundary's points, following Bourke's formulae (Bourke, 1988):

$$
\begin{aligned}
c_x &= \frac{1}{6A} \sum_{i=0}^{N-1} (x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \\
c_y &= \frac{1}{6A} \sum_{i=0}^{N-1} (y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i)
\end{aligned}
\tag{1}
$$

where (x_i, y_i) are the consequent points in a polygon of N points, and A is the area of that polygon:

$$
A = \frac{1}{2} \sum_{i=0}^{N-1} (x_i y_{i+1} - x_{i+1} y_i)
\tag{2}
$$

In the case there are many separated polygons (with area A_j and center c_j) in a geographic territory (e.g. the map of the U.S.), the center will be the weighted center of mass:

$$
C = \frac{\sum A_j c_j}{\sum A_j}
\tag{3}
$$

The center of the area will be the place that the first tag (which is the biggest tag – see *(c)* for step 2) is placed. Then, other tags with reducing sizes will be placed in increasing distance to form a fisheye view. In order for the fast interactively scrolling (see *(d)* for step 5), the tags are visualized leveraging the ideas of fisheye menu (Bederson, 2000). The difference here is that there are typically some tags on a horizontal scanline, where the middle one is normally the focus (bigger). Therefore, to support users in easily skimming and scrolling the tags (i.e., vertically from the top to the bottom of the area, or vice versa), the direction of our fisheye menu follows the *vertical-medial axis* of the area, which is connected by the mid-points of all horizontal scanlines in the area (see Figure 15b).

position of the first tag

c. Placing Tags at the Specified Places

The first tag to be placed at the center of the area is the biggest one. Because each tag has a weight (its frequency), one solution is to sort all tags by weight, and base on this weight, the size of each tag is computed when it is checked for placing (on the fly).

To provide a comprehensive view, as discussed, we visualize just a dozen of tags (e.g. maximum $n = 100$ tags as in common tag clouds). We select at most n highest frequency tags, estimate their sizes depending on the available space, and render on the screen.

In that case, the first tag to be placed at the area's center is the tag with index n, amongst n increasing-sorted tags. The next tags to be selected will be tags $n-1$ and $n-2$, which will be show before or above and after or below tag n, by greedy checking the next available space along the direction of the vertical media axis of the area. Further tags are iteratively selected (which are $n-3$, $n-4$, and so on) for the succeeding places, until no more tag or no more new position is determined. Figure 15b shows the visualization of the Flickr tags in Figure 15a on the geographical area of Germany.

positions of the next tags

To this end, it can lead to only a subset (the biggest tags) of the tags presented on the screen, but users might need to browse a larger number of tags. Thus, the additional step for handling the remaining tags is needed. As will be presented in *(d)*, the visualization of tags in terms of their frequencies doesn't suit for the browsing of large tags set. Instead, a visualization where tags are shown in alphabetical order is suggested. Thus, we will present here how to enhance tags' sizes and positions if they are visualized in alphabetical order:

The biggest and the expected smallest sizes (s_{max}, s_{min}) for tags in alphabetic Taggram are computed based on n, the expected number of tags to be placed and the region's area A.

$$s_{max} = \theta\sqrt{\frac{A}{n}}$$
$$s_{min} = \varphi\sqrt{\frac{A}{n}}$$

(4)

where θ and φ are pre-defined thresholds (e.g. 0.66 and 0.33 in our implementation) so that the scale ratio $scale$ between tags can be computed:

$$scale = \sqrt[n]{\frac{s_{max}}{s_{min}}} \tag{5}$$

In this manner, tag's sizes can be interpolated when a new tag is examined for the next placement (here we choose a linear scale, while logarithmic or other scales can also be examined):

$$s_{currentTag} = \frac{s_{previousTag}}{scale} \tag{6}$$

From the tag size, we compute its bounding box (in pixels) to be rendered on the screen. At this point, we need to specify the exact location of the tag in the area. For the first tag at the area's center, this area's center is also the center of the tag's bounding box. For the next tag, each will be computed based on the available space next to the just-rendered tag (i.e., its bounding box must not intersect with existing tags' bounding boxes or the polygonal contour of the area).

the positions are estimated in a greedy manner

At this point, if the tag is too long (containing many characters) to be fit into the area, we slice the tag if having more than e.g., 15 characters, and put the three-dots "..." at its end. In addition, sizes and positions of the tags can also be flexibly adapted within a predefined threshold (we allow a tag to be scaled up to ±30% of its original estimated size, and inside a wider bounding box) so that many tags can be crammed into the available space of the arbitrarily-shaped area. For this reason, size of the final smallest tags is not always identical to the estimated s_{min}, and the number of shown tags is not always identical to n.

the actual number of tags shown

Amongst the n alphabetically sorted tags, firstly tag $n/2$ will be chosen to be placed at the area's center, then tags $n/2 - 1$ and $n/2 + 1$, and so on are consecutively chosen to be rendered before and after the center tag.

d. Handling Large Number of Tags on Demand

Now, we are back at the discussion for the decision on visualizing tags in alphabetical order.

The solution which produces a static Taggram where the tags' sizes indicate their weights is straightforwardly developed in terms of common tag clouds. However, because just a limited number of tags are shown in comprehensible sizes, this solution is not adequate for the *browsing* of a large tags set – which is the focus of this chapter. As presented in Section 4.2.2c, if we want to show all the tags together on the view, there can be a lot of tags in pretty tiny sizes, which are unreadable. If we want to read them, we need to zoom the whole area much bigger, which is not the suitable solution in fast browsing the very large tags set.

(a) The tag cloud of Flickr tags retrieved for "Germany", visualized by http://tagcrowd.com/. Tag frequencies are indicated by size and darkness.

(b) Those tags are visualized in a frequency-based Taggram. The red dot and the brown line prompt the center and vertical medial axis of the area.

(c) The tags are visualized in Taggram in alphabetical order. As size is used to express the focus, only darkness of tags indicates their frequencies.

(d) The tags are scrolled-up on the alphabetical order Taggram to illustrate the browsing of tags in a large tags set.

Figure 15: Taggram presenting Flickr tags on the geographical area of Germany.

Therefore, we follow the alternative solution discussed in Section 4.2.2c: *Interactively* update the visualization with new tags (i.e., by adding new tags to the interface and removing some others). This strategy is perfectly carried out in terms of a fisheye-menu design: the tags are added and removed from the view, when they are scrolled up or down on the area. The center of the area will be updated with new biggest tag, which is always the focus of the browsing tags.

scroll to show tags in turn

But this solution is unadaptable if the sizes of the tags are strictly used to indicate their frequencies. We cannot move a tag to the center of the area in biggest size, if it is not at highest frequency. Therefore, we decide not to keep size to communicate the frequency, but just the focusing level, of a tag. To this point, because tags in a tag cloud are most easily comprehensive if organized in alphabetical order (Halvey and Keane, 2007), we modify Taggram to show tags in alphabetical order. And thus, the chosen solution is that tags are not sorted by frequencies but in alphabetical order for visualizing (recalling step 2).

price of the solution!

In this regard, in order to still communicate the frequencies of tags, we use color's brightness to encode the values, as illustrated in Figure 15c. Though the visualization looks different with common tag clouds, this solution satisfy all criteria requested in our development. Every solution has a price to pay.

Because tags are sorted and displayed alphabetically, interaction in Taggram can be straight-forward implemented. We support the task of browsing on Taggram with the supports of PC-equipped inputs: mouse-scrolling up or pressing up-arrow key removes tags at top of the displayed list out of the alphabet-list and adds new tags to the bottom, while mouse-scrolling down or pressing down-arrow key removes tags out of the bottom of the list and adds new tags to the top. In that manner, at a time, just a limited number of tags are displayed, but all tags will be shown-in-turn by mouse-scrolling or by arrow-key pressing. Figure 15d shows the scrolled-up Taggram of the one in Figure 15c.

Besides, in supporting users to see all tags while not explicitly interacting with the interface, we apply the mechanism that tags are dynamically updated (Spence, 2007). In that manner, the interface is unconsciously refreshed with new tags for every period of time (e.g. every second). A user can incidentally get the tags and is able to switch to the interaction mode whenever she wants.

So far, we have presented work for the visualization of tags in arbitrarily-shaped areas to communicate their geo-references. To achieve consistency, next section will present our work for the visualization of time which is combinable in Taggram development.

4.3 VISUALIZING TAGS WITH TIME

As presented in Section 4.1.2, our objectives here are to develop solutions for the visualization of tags in association with *both* geospace *and* time. In the previous section, we examined how tags are spatialized in geospace through the Taggram technique. Therefore, when supplementally visualizing with time, tags in Taggram communicate both spatial and temporal information, and thus fulfill the objectives. This section presents our development for the visual communication of tags with time (Nguyen et al., 2011).

4.3.1 *Tag Clouds and Time*

Because online communities are usually dynamic, there are a number of designs for the integration of one or other aspects of time into tag clouds.

The tool Twitscoop[3] uses the slideshow approach. It updates the visualization every second to reflect the currently most important keywords in Twitter. Yahoo! Taglines[4], for instance, uses animation to visualize changes of topics over time (Dubinko et al., 2006). Users can choose from two animation schemes (river or waterfall), where time goes from left to right and top to bottom, respectively. If a tag cloud spans only a small number of time steps or if just the latest snapshot of the tag cloud is relevant, a dynamic visual representation (slide show or animation) is suitable, because the temporal changes are usually easily comprehensible.

tags with temporal changes?

In order to facilitate more detailed visual analysis, additional visual cues can be used. Stefaner uses animation as well, but additionally encodes information about the "age" of tags (Stefaner, 2007). Cui et al. (2010) use color to differentiate newer and older tags in the cloud. But comparisons of different time steps or different tags are still difficult to conduct. In this case, combining tag clouds with additional views (e.g., a temporal bar chart as in Cui et al., 2010) is one option to solve this problem. A similar implementation is offered by Cloudalicious (Russell, 2006).

The above-mentioned techniques rely mostly on basic techniques and show only one snapshot of a tag cloud at a time, instead of visualizing data of multiple time steps concurrently or supporting analytical insights of temporal information such as frequency or rate of change. Recently some attempts have emerged to cope with complex time-referenced tags, such as SparkClouds (Lee et al., 2010), which combine spark lines with tags; while Lohmann et al. (2012) create colored histograms to highlight the time-varying co-occurrence of tags in the cloud. But still, visualizing time-varying tag clouds remains an interesting research topic.

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3 http://www.twitscoop.com/
4 http://research.yahoo.com/taglines/

4.3.2   *Design Strategies for Visualizing Tags with Time*

According to Aigner et al. (2011), time-oriented data can exhibit a number of different characteristics, which leads to a variety of potential visualization designs. So, there are various ways to visualize temporally referenced tags. In this work, we focus on adapting the visual representations of tags themselves to arrive at visual solutions for the representation of time-referenced tags.

In accordance with (MacEachren, 1995)'s time-related tasks, we aim at supporting users in answering the following set of questions:

Q1 - Does a specific tag exist at a particular time?

mostly,
elementary
tasks

Q2 - When in time does a tag occur?

Q3 - How old is a tag at a specific time point (if existing)?

Q4 - For how long does a tag exist?

Q5 - How often is a tag used?

Q6 - How frequent or strong does a tag change over time?

Q7 - Is there any special temporal relationship (e.g., co-occurrence) between some tags in the cloud?

Noticing the fact that tag appears alone in a tag cloud enables users to recognize the existence of a tag (Q1). Therefore in the following subsections, we will discuss design strategies for the visualization of time-referenced tags to deal with questions Q2 to Q7: (*a*) time is encoded through visual appearances of tags, and (*b*) time is represented by additional visual artifacts associated with tags.

a. Temporal Information Mapped to Tag Appearance

Basic visual attributes such as color, size, or orientation are normally employed to visually encode information associated with tags (see Section 4.1.1). Those visual attributes are therefore applicable for the encoding of temporal information of tags as well. For example, one can use hue, saturation, or brightness to differentiate tags that have appeared at various points in time. Figure 16a illustrates the encoding with brightness: more recent tags are darker and older tags are brighter. Similarly, text size can indicate how recent a word is (see Figure 16b). For both encodings, the assumption is that recent tags are more important.

Provided that appropriate legends are supported, such visual encodings allow users to discern a tag's age (Q3), and thus to estimate a tag's location in time (Q2). Conceptually, we are now able to visualize tags and a single data

(a) Brightness encodes tag age.

(b) Size encodes tag age.

(c) Distortion encodes tag frequency over time.

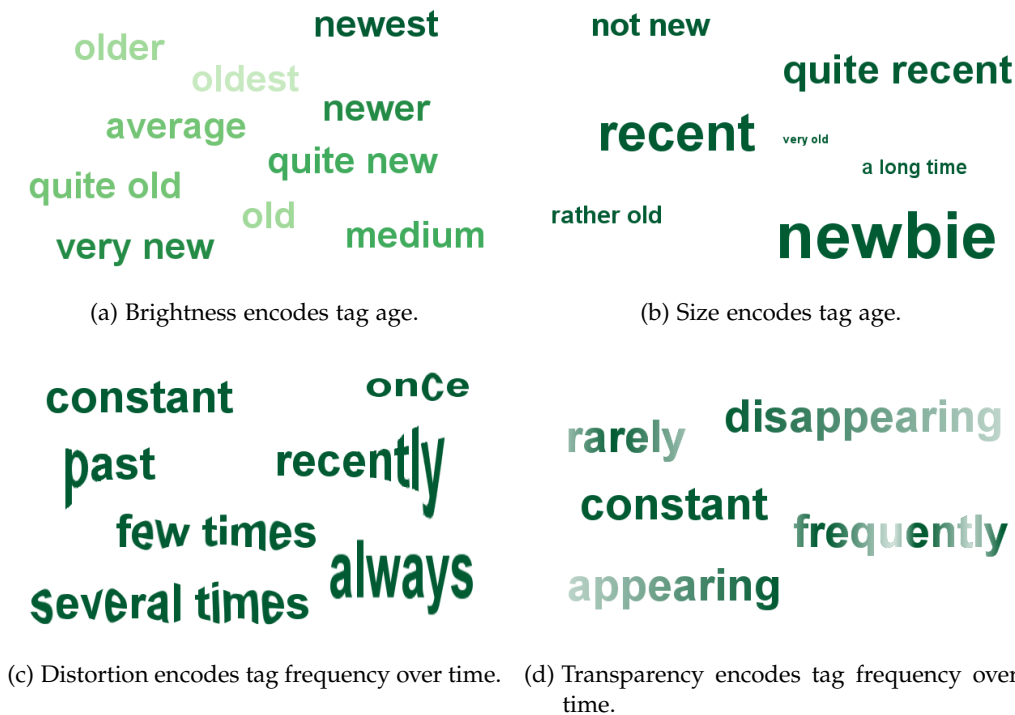(d) Transparency encodes tag frequency over time.

Figure 16: Examples in encoding temporal aspects with text appearance.

value per tag (e.g., age). But this is not enough for explicitly visualizing multiple time steps concurrently or for supporting the analysis of temporal aspects such as the frequency or rate of change. In order to arrive at conclusions for the questions Q4 to Q7, we need to consider other visual encodings.

One option is to modify the text rendering along the tag. The basic idea is to map individual time axes along the tags' horizontal orientation. That is, the beginning of a tag corresponds to the first time step and the end of a tag corresponds to the last time step. Given this mapping, we can vary the rendering along the tag. In Figure 16c, we show tags that have been distorted to visualize how frequent the tags appear over time. For example, the letters of "always" are larger throughout, indicating that the tag has been important at all points in time. On the other hand, the letters of "recently" increase in size towards the end of the tag, indicating a tag of growing importance. Similarly, one can vary other rendering parameters such as transparency as shown in Figure 16d.

Provided that there are no uncommonly short or long tags, these encodings along the tags' horizontal axes are suitable for indicating how tags have developed over time. For a more detailed information, however, varying basic visual attributes alone is not sufficient. Because tags are different in length, different scale of time line are implicitly applied. That could be misleading for some

visualization is powerful...

...but challenging

users. Or, by distorting the height of tags for frequency, it is problematic as the heights of characters are not the same, which also complicates the assessment and comparison operations. Therefore, other options using additional visual artifacts are needed as described next.

b. Temporal Information Mapped to Additional Visual Artifacts

By additional visual artifacts we mean enriching tags with additional graphical primitives. The main advantage of this solution, in comparison to the designs of the previous paragraphs, is its flexibility: By encoding temporal information with the visual attributes of the additional graphical primitives, we can visualize more complex temporal information. A positive side effect is that basic visual features of the tags (i.e., color, size, etc.) are kept for the traditional encoding of tag importance.

groups of tags communicate synoptic task

Figure 17a shows a first simple example where a background rectangle has been added to each tag. The rectangle's color is used to indicate three groups of tags with different temporal behavior: appearing tags are green, disappearing tags are orange, and constant tags are gray. An interesting point is that this visual solution not only communicates elementary tasks but also a synoptic task.

More complex encodings can communicate further information. Again, the basis is to construct an appropriate mapping of the time axis. For example, one can use color-coded segments along the horizontal extent of a tag to show the frequency of the tag over time. Figure 17b shows consecutive segments which are equal in size but different in orangish darkness to communicate tag frequency over time: darker segment indicates a time step with higher frequency. This strategy is suited to visualize time in a linear fashion. In the same manner, cyclic reoccurrence of tags can be made comprehensible with the help of table-based calendar (Figure 17c) or cyclic calendar glyphs (Figure 17d): each cell of the table-based or cyclic calendar glyphs with different color darkness shows a different frequency of tag at a different time (here seven columns indicate seven days in a week). In that regard, these visualizations can also help in identifying special temporal information (such as tag "weekends" is emphasized with the cells at the last two columns in Figure 17c).

With the aforementioned solutions, the remaining questions Q4 to Q7 can be clearly answered: The duration of tag existence, the frequency of tags, as well as the rate of change appear vividly in Figure 17b-17c, and temporal relations are recognizable in Figure 17c-17d.

Further options are to compose different design strategies to show different temporal information as hybrid visual representations. One can develop to visualize time points together with time intervals, show linear time together with cyclic structures, and switch to alternative perspectives, in order to explore complex temporal information of tags. However, care has to be taken to

(a) The color of background rectangles indicates three different classes of tags.

(b) Color-coded segments visualize tag frequency over time.

(c) Color-coded cells of calendar tables help in discerning reoccurring patterns.

(d) Color-coded circular calendar glyphs are useful to communicate cyclic patterns.

Figure 17: Examples in encoding temporal aspects with additional visual artifacts.

avoid cluttering the tags and to maintain the tag cloud's legibility. There, the very important demand is to support user interactions such as zooming into details, highlighting tags or time points of interest, or interactive adjustment of the visual encodings.

cares are always needed!

The next consequent step is to extend the above generic design strategies to address a specific design in visualizing tags regarding time points of interest.

4.3.3 *Visualizing Tags with Regard to Particular Time Points of Interest*

Following the generic design strategies just provided, we now address concrete visual solutions for time-referenced tags as provided by Flickr. Noticing the fact that when talking about time in reality, it is usually mentioned in terms of time points or periods specified by a time domain. Therefore, to visually communicate temporal information of tags, relevant concepts are to be specified. To this end, we take into account the concept of TOI (*time of interest*)

for our visualization development. For instance, giving a time domain communicating the period of Sun 8/15/2010 – Sun 8/22/2010, Thu 8/19/2010 can be selected as a TOI. This TOI divides the time domain into three parts: the time before the TOI, the TOI itself, and the time after the TOI. Note that the before and after parts might be empty, if the TOI is the beginning or the end of the time domain.

The problem here is how to visually communicate the TOI in terms of time-referenced tag clouds and to answer questions Q1 to Q7. To this end, in applying the above-introduced strategies, we develop dedicated visual encodings to illustrate temporal information of tags through (*a*) their visual appearances and (*b*) additional visual artifacts associated with tags.

a. Temporal Information Mapped to Tag Appearance

The two design solutions that we present next are based on masking the tags. They operate on two different semantic levels. For the first design solution, we focus on *qualitative* statements regarding the existence of tags in the time domain. In the second solution, we extend to *quantitative* assessments regarding the frequency of tags over time.

ENCODING FOR QUALITATIVE STATEMENTS   By qualitative statements, we support answering simple questions like Q1 and Q2. With regard to the TOI concept and the existence of tags, our solution are capable of communicating seven cases in which color gradient is our visualization strategy. In this manner, the seven cases can be represented with e.g. red standing for existence and gray indicating non-existence of a tag (Note that the combinatorial eighth case (i.e., the tag does not exist at all) must not be handled, because in that case the tag does not appear at all). The following list summarizes the seven cases of tag existence and the corresponding visual encoding: A tag exists

1. only at the TOI:

2. only before the TOI:

3. only after the TOI:

4. at the TOI and before:

5. at the TOI and after:

6. before and after the TOI:

7. before, after and at the TOI:

To establish a visual association of a tag with one of the seven cases, the tag in this solution is masked with the gradient fill. This way, each tag is rendered according to the case it belongs to.

Because we do not visualize any specific quantitative references in time, but just qualitative statements about tag existence, we smoothly interpolate the colors. This avoids hard color transitions, which could otherwise be misinterpreted. Figure 18a illustrates this with a sample data set extracted from Flickr (the number indicates the corresponding case): (1) tag "deutsch", (2) tag "flyeralarm", (3) tag "feierei", (4) tag "eisenbahnen", (5) tag "feuerwerk", (6) tag "duitsland", and (7) tag "eos".

From the encoding presented here, the user can derive only qualitative information about tag existence (Q1 and Q2). How quantitative values such as tag frequency can be encoded will be examined next.

ENCODING FOR QUANTITATIVE ASSESSMENT   Now our goal is to visualize data values associated with tags such as tag frequency (i.e., the number of occurrences of a tag over time), and then other questions (such as Q3, Q4, etc.) are to be tackled. What we need is a visual mapping of the time domain that is capable of showing quantitative values per time point.

To this end, we create series of visual segments (one for each time point) along the horizontal orientation of tags. We continue using the idea of the TOI and use different shapes for the segments. A diamond shape ◇ is used to represent the TOI, whereas time points before and after the TOI are represented as arrow shapes ≪ and ≫, respectively. We use colors from the ColorBrewer[5] to color-code each shape according to the tag's frequency at the corresponding time point. As tag frequencies might be distributed unevenly over time, additional color mapping concepts from (Tominski et al., 2008) are applied to redistribute colors for more effective perception. For those time points where the frequency is zero, we use a hueless color to clearly indicate the non-existence of that tag at that time point. These mapping steps result in visual representations like ≪≪≪≪◇≫≫≫ for each tag. Again, we mask the tags to integrate the visualization of the time-dependent frequency values with the visual appearance of tags. Figure 18b illustrates such masked tags for a part of Germany for a time range of 8 days in August 2010. This visual encoding is suited to additionally find answers to the questions Q3 to Q6. For instance, considering tag "eisenbahnen", one can recognize not only the existence of the tag at the TOI (answering questions Q1 and Q2), but also its duration of existence (which is 4-days, to answer questions Q3 and Q4), appearance times (Q5), as well as frequency changes (Q6). However, differentiating the individual time points may be difficult, especially when the time domain is large. In such cases, one could exploit the hierarchical structure of time and represent aggregated fre-

differentiating individual time points is difficult

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5 http://colorbrewer2.org/

(a) The tags are masked with gradient fills to communicate the *qualitative* existences: at, before, and after the TOI (time of interest).

(b) The tags are masked with color-coded shapes to communicate the *quantitative* frequencies at different time points.

Figure 18: Visualization of Flickr tags on maps with temporal aspects represented by text appearance.

quencies (such as of days through weeks), rather than those of individual time points. Another option is to associate additional visual artifacts with tags.

b. Temporal Information Mapped to Additional Visual Artifacts

As indicated earlier, using the visual appearance of tags alone might not be sufficient for more complex information or larger time domains. Therefore, we now consider adding visual artifacts to the tags (while size, hue, or tag appearances' encodings are kept as for traditional values of tag clouds). Some artifacts are developed for the communication of temporal information in detailed as follows:

complex information for time

BAR CHARTS REPRESENTING TEMPORAL DEVELOPMENTS   In this visual encoding, we use bar charts as additional visual artifacts to visualize the existence and frequency of tags over a period of time (regarding questions Q1 - Q6). We chose bar charts because they are an accepted means for visualizing time-dependent data and because they are easy to interpret.

The design of a bar chart per tag is straightforward: For each time point, we create a rectangular bar to show if the tag exists and how frequent it is. We add a small red dot to indicate the TOI. Color (globally for the whole cloud) and height of bars (locally within each tag) are used to show tag frequency at individual points in time. The color-coding is the same as described in the previous section. Using a dual encoding with color and height has the positive side effect that we do not have to deal with the special case of non-existence, because in that case the bar has zero height and is invisible anyway.

The bar chart artifact is illustrated in Figure 19a for a list of Flickr tags in the period of Mon 8/9/2010 to Sun 8/29/2010 in Germany, where Sat 8/28/2010 is selected as the TOI. From the bar charts in this visual representation, a user can easily see how tags appeared and if there are any linear temporal relations. All questions Q1 - Q6 are answerable: tags with selected TOI are highlighted (Q1), tag "ocean" appears immediately before the TOI and lasts only for 2 consecutive time points (Q2 - Q4), tag "munich" exists at almost all time points and is emphasized at some specific points (Q5, Q6). However, bar charts are almost not suited in finding more complex and possibly reoccurring temporal structures.

CALENDAR TABLES REPRESENTING COMPLEX TEMPORAL INFORMATION
Color-coded calendar tables, whose horizontal and vertical axes represent independent levels of time, are promising alternatives. For example, a possible solution is to show weeks as rows of a table, which implies that columns represent individual weekdays. Each table cell's color indicates tag frequency (or any other attribute users might be interested in). Figure 19b shows with each tag a table-based artifact containing 3 × 7 color-coded cells.
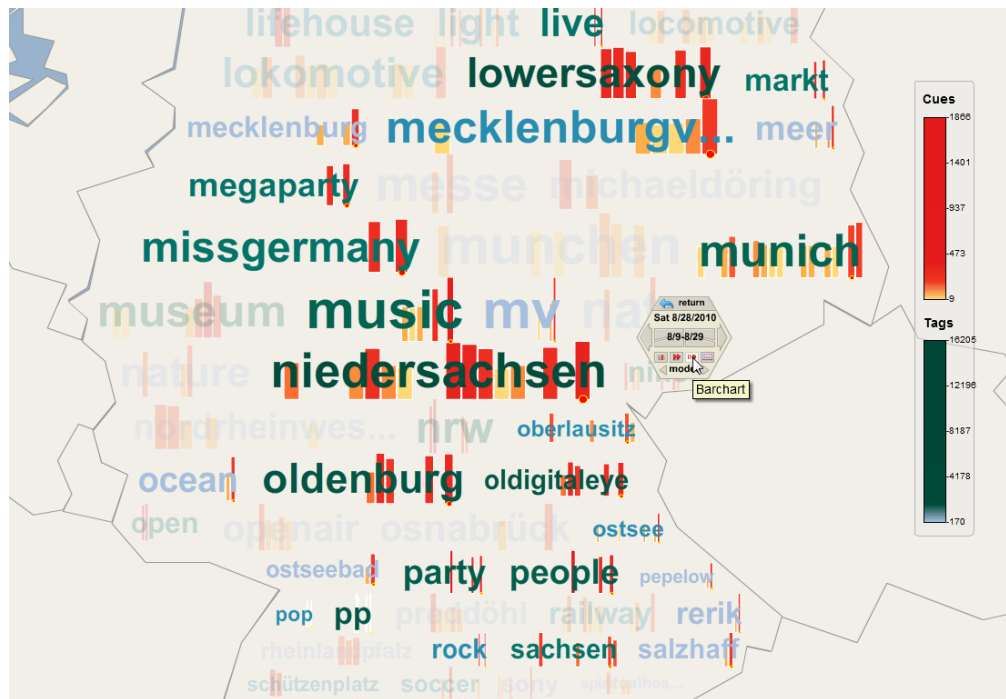
(a) Color (globally for the whole cloud) and height of bars (locally within each tag) visualize tag existence and tag frequency over time.
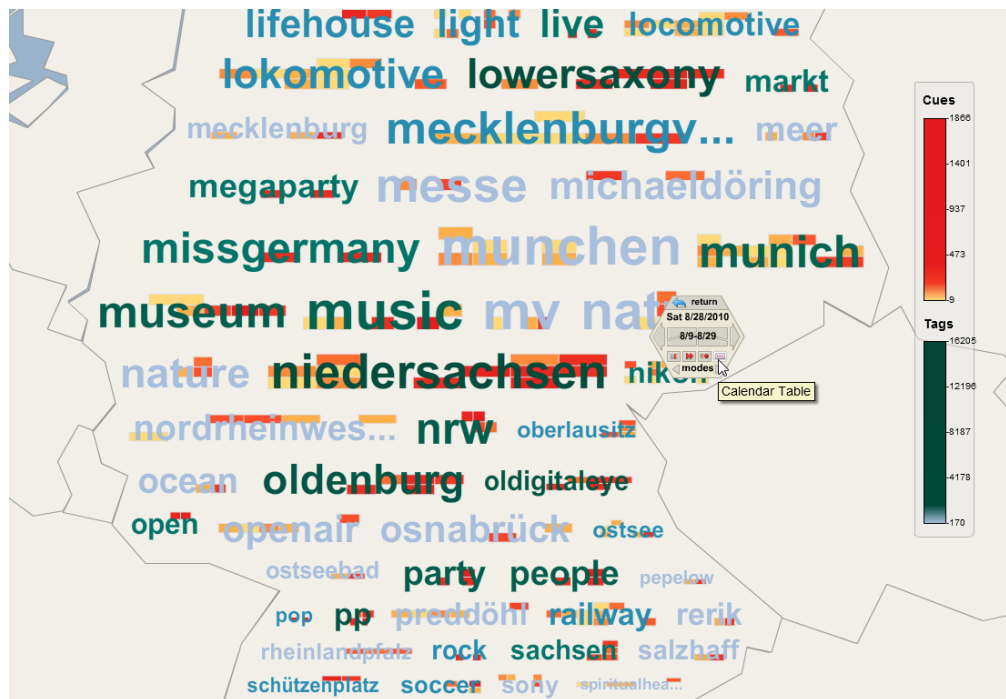
(b) Color of the cells of calendar tables visualize tag frequency.

Figure 19: Visualization of Flickr tags on maps with temporal aspects represented by additional visual artifacts.

Besides getting answers to the questions Q1 - Q6 similarly to the case of bar charts, a user can now spot more complex temporal information (Q7). Several interesting examples can be seen in the above demonstration with Flickr data: The tag "niedersachsen" is significant throughout all weeks, but almost not appear at mid-weeks. Quite nicely one can see that the event "museum" appears in the middle of the second week (second row of the table) and are emphasized toward the weekend. In other words, one can get not only simple visual values at cells, but also further insights with temporal information from the visualization.

4.3.4 *Discussion*

The two basic design strategies (i.e., visual appearance of tags vs. additional visual artifacts) that we provided for the visualization of temporal information of tags have advantages and disadvantages alike. For both strategies the aim is to visualize additional temporal aspects while maintaining tag legibility. By changing only the appearance of tags, our options for encoding temporal information are limited, and thus only simple questions are supported. Moreover, traditional encodings of tags (such as frequencies through size or color) are skipped. On the other hand, tag legibility is only marginally affected (provided that appropriate colors are used), and the encoding of a tag and its associated temporal aspects is overlap-free.

This is different when using additional visual artifacts. In this case, there can be significant overlap which could occlude possibly important temporal information, for example, when a letter occludes the cell with the highest frequency in a calendar table. This is the price to pay for the additional options that visual artifacts offer for the visualization. Solutions are needed, such as to provide mechanisms to interactively show/hide visual artifacts or to move artifacts onto top or underneath the tags.

When visually communicating temporal data, depending on the specific data, usage contexts, and tasks at hand that the developers should choose which strategy to follow. In that regard, to support the different tasks, interactive manipulation with visual encodings and their adjustment is expected.

interaction needed

In the next section, we will see examples for the visual combination of time-referenced tags with tag clouds using Taggram in interactively exploring spatiotemporal Flickr tags.

4.4 EXAMPLES FOR SPATIOTEMPORAL FLICKR TAGS

In the previous sections, we have presented generic design strategies and specific solutions for the visualization of tags in association with either geospace

or time. To illustrate our development, this section presents particular examples for the browsing of spatiotemporal tags provided by Flickr.

4.4.1 *Environment*

Flash application

We implemented a Web-based visualization application Tempo-Taggram to illustrate the concepts introduced in the previous sections based on the available Flickr tags data. While the visualization part in our implementation exploits the graphics and interaction capabilities of Flash and ActionScript, the data part is based on MySQL and Flickr web services APIs.

DATA – We store a database containing geographical borders for countries and administrative areas in the world based on ThematicMapping[6] and Global Administrative Areas[7] (GADM)'s datasets. The Flickr APIs[8] support queries for the relations of tags and geographical regions of the map using the services `flickr.places.tagsForPlace` and `flickr.places.placesForTags`. Both calls expect a range of time points as input and return lists of tags or places as output, respectively.

The spatiotemporal tags data are as follows. At a particular time point (e.g., specifying as of a date), a tag can be associated with various geo-coordinates inside a geographical region (i.e., geo-referenced). Because in Flickr a geographical position can be indicated through various administrative levels of territories (i.e., place types: locality, city, state, etc.), a tag listed for one place can be listed for other places at other administrative levels as well. For example, a tag listed for Berlin (level: city) may also be listed for Germany (level: country). We utilize this for semantic zooming as users zoom into particular regions of the map.

For a place (e.g. a city) and a given time point (i.e., a date), there exists a list of spatiotemporal tags. Consequently, for many time points, there are multiple lists of tags, one for each time point. Because our visualization client requires efficient access and iteration over multiple time points and geographical regions, we reorganize the retrieved query results in our database, which consists of multiple lists of tags indexed by dates and geographical regions.

INTERFACE – The data backend drives the efficient visualization of Flickr tags with spatial and temporal references in any Flash-enabled Web browser. The visual exploration of spatially and temporally referenced tags involves various aspects, and thus we need sufficient means for user interaction: On the one hand, users are supported to visit different places in geospace and to

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6 http://thematicmapping.org/downloads/world_borders.php

7 http://www.gadm.org/

8 http://www.flickr.com/services/api/

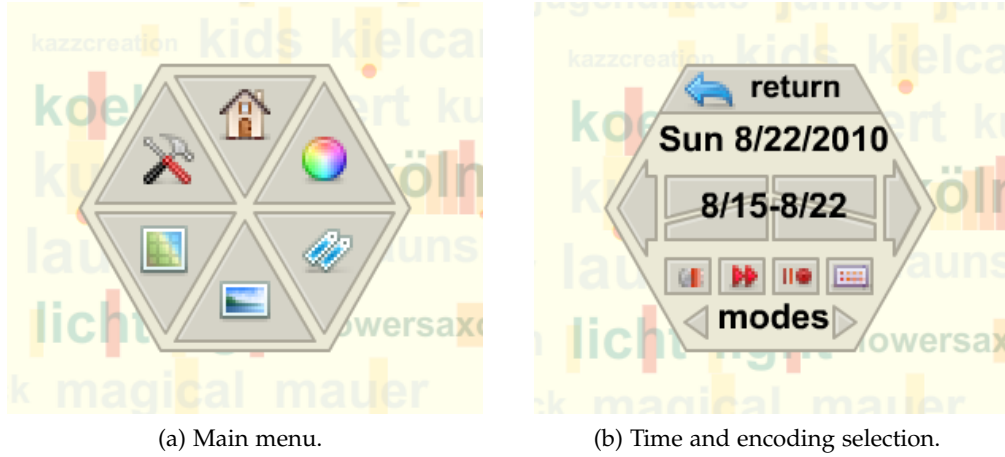(a) Main menu.   (b) Time and encoding selection.

Figure 20: Tempo-Taggram's controller interface.

browse different tag sets and their associated time ranges from the database. On the other hand, visual encodings are to be suitably provided regarding users' needs and preferences. We implemented the interface that supports users in accessing dataset for different places (by browsing on the maps of the Tempo-Taggram) and different time ranges (by using the query interface of a controller, as described later).

Users are supported to zoom and pan to any place on geographical maps as in conventional maps interfaces. In addition, they are supported to switch to various visualization modes where tags are handleable using mouse and keyboard inputs.

To provide easy access to the interface, we provide a custom-made user interface component, which borrows the idea of floating menus. Figure 20a shows the main menu with various options, including home, settings, color legends, map display, photos, and tag selection. When the user clicks an option, the component switches its interface accordingly. Figure 20b shows the interface component for "tag selection", which allows users to select the time range as well as ways that time is encoded with tags.

Tags are visualized with various temporal encodings. The "tag selection" interface shows a range of time which is adjustable: users can expand or shorten the time range by clicking on four buttons in the middle, and specify the time of interest (TOI) by clicking on the side buttons. On the top of the interface is the button for switching back to the main component interface, and at the bottom are four buttons indicating the four encoding strategies: qualitative and quantitative encodings through tag appearance, and bar charts and table-based calendar glyphs as additional visual artifacts.

4.4.2 *Use Cases*

Our development deals with flexibly visualizing tags inside geographical areas to communicate their area-based geo-references. But tags can be associated with precise coordinates in the areas as well. As a result, when using our tool, users are also provided with a functionality for the exploration of those positions. This can be seen as a useful task, because Flickr data aggregate spatial information of tags to larger regions with different degrees of uncertainty. Through visualization, users can establish the connection of tags to more specific locations.

As a tag could be linked by different geo-positions in an area at different time points, a user may interact with visual cues on each tag to explore the positions. The user hovers on a tag for a selected time point, and Tempo-Taggram updates the display in terms of showing all positions. Figure 21a shows an example where the user hovers on tag "eos" in Germany at the time point Sat 08/21/2010 (see the tooltip). To this end, by highlighting positions at various time points, the tool supports the user to experience the possible movement of tags over geospace in time. In addition, this might also reduce the problem of visual cluttering in the case there are so many positions linking with tag in a long time period where individual time points are specifiable (this visual solution is applicable for all design strategies implemented in the tool, which are segment-based appearance, bar charts, and calendar table).

Besides representing temporal development within each tag, it is also important to take advantage of inter-relation between different time points for
*...with
open topics*
tags to get other insights. For example, for some selected time points, there are some tags that exist at all of those time points (while other tags on the cloud are not). These tags are defined as co-occurrence at the selected time points. We therefore leverage that fact to support the users in getting high-level information from spatiotemporal tags rather than the tags themselves. This is an interesting synoptic task for tag data analysis and exploration.

In that regard, the user can select many time points in addition to the default TOI. And when she selects many time points, tag cloud is adapted by highlighting the co-occurrence tags, and dimming those which do not contain the co-occurrence. Figure 21b shows the example where Fri 08/20/2010 and Tue 08/24/2010 in the time period 08/15 - 08/27/2010 are selected, which reveals an interesting fact in the data: It appears that there was a "lasershow" in "lowersaxony" in August 2010.

4.4.3 *Feedback*

We conducted a small check to collect informal feedbacks for the tool Tempo-Taggram in terms of a casual Infovis development. Twelve Web users (ages

(a) Hovering on a TOI of a tag to highlight the precise associated geo-positions in terms of markers.
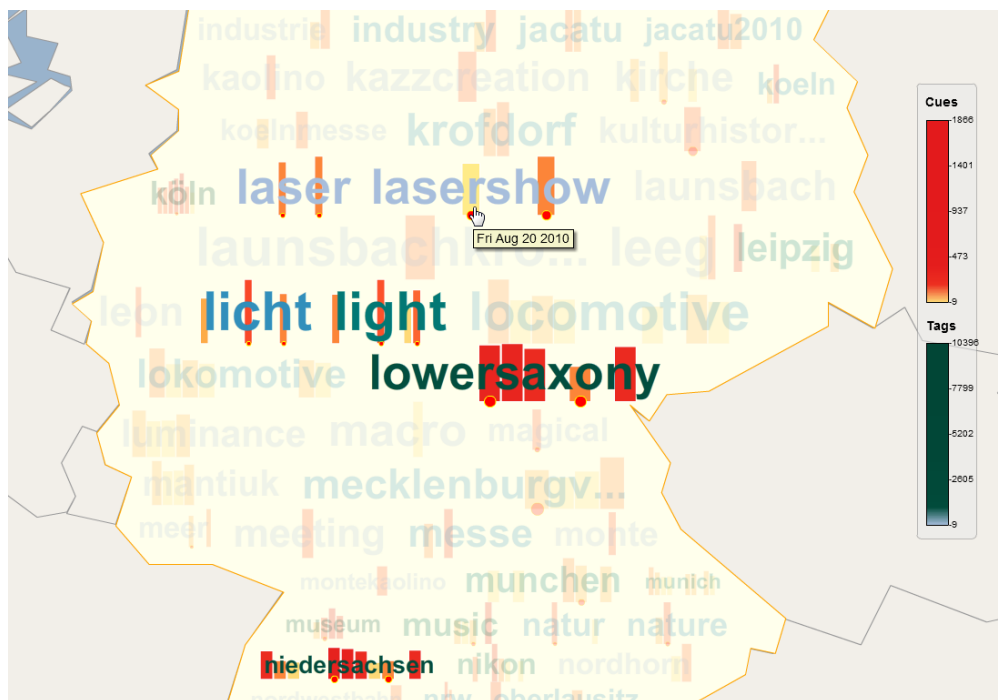
(b) Selecting multiple time points of interest to reveal the tags that are co-occurring in time.

Figure 21: Use case examples in interacting with time-referenced tags on the Tempo-Taggram.

16-28, 3 females, with different backgrounds, familiar with Tag Clouds and geographical maps, but none of them were visualization experts) were asked to use the tool. We did not perform evaluations in terms of a traditional Infovis technique (such as effectiveness or appropriateness, and so on); rather, we were interested in general and casual feedbacks with regard to how users think about the tool based on their wills and curiosity.

At the first glance, nine out of twelve participants liked the fact that they could handle the tag clouds concerning space and time (about which they haven't thought before). But there were also negative feedbacks. Though the visualizations were interesting, the users said that the visualizations show too much information, which makes them confused about the purposes of the visual means. Additional visual encodings to tags was experienced as interfering with the legibility of the tags, and tags on maps conflict with the traditional ways of using geographical maps.

interest vs. utility

However, with the aim in interacting into details, especially as zooming and panning with the maps – or selecting visual encodings on tags, we got their satisfactions. The users were strongly interested in the interactive visualization that highlights the co-occurrence of Flickr tags on the map for different selected time points. In addition, the exploration of temporal relations (e.g., weekdays in a calendar-based artifact) got special attention.

After five to ten minutes interacting with the tool, in conclusion, all of the users accept the utility that the tool Tempo-Taggram supports. However, two users still preferred to use tag clouds separately with geographical maps, while temporal information could be included with the tag clouds. In addition, the users also asked for additional functionalities: mechanisms for querying – in particular a textual search for specific tags of interest, and visual linking of tags with interrelated geographical regions or regions from various administrative levels.

4.5 SUMMARY

Research on personal and community integrated data on the Web challenged us to deal tag clouds in association with geospace and time. In this chapter, the three aspects of spatiotemporal tag data were considered for a visualization development: *what* - tags, *where* - geospace, and *when* - time. We presented solutions for the visualization to support the *browsing* of spatiotemporal tag clouds, where (i) tags are spatialized inside arbitrarily-shaped areas so that their geospatial information is conveyed, and (ii) tag appearances are modified or tags are embossed with additional visual cues to express temporal information.

In that regard, spatiotemporal tag clouds acts not just as a social signaler. They also support the exploring and discovering spatiotemporal data with

insights. With the use cases, we have seen examples for the exploration of tags where their data aspects are combinable, such as hovering on a time point of a tag to show related positions on geographical maps.

Now, tags are amongst the most simple type of contents compared to other data on the Web such as images or even videos. But the above informal user test showed that users were somehow confused about the diversity of information that was encoded by spatio-temporal tag clouds. Therefore, additional methods to support the *navigating* on the visualization to dig into further information are expected. As a result, in the next chapter we will study solutions for the communication of not only tags, but also photos (and videos), which are associated with geospace and time; and we will focus on dealing with the visual navigating for spatiotemporal data of interest in terms of the various Peuquet (1994)'s combinatory situations.

5

PHOTOS & VIDEOS WITH GEOSPACE AND TIME

*The meaning of mental image is not very definitely fixed by usage,
but with some the term characterizes that large group of images
whose location in space and time has been lost.*

— J. W. Slaughter, 1902

In the previous chapter we have seen work about tags visualization linking with geospace and time. In this chapter, we continue with another kind of Web data: pictorial contents such as photos or videos. Photos and videos, like tags, are nowadays very popular in connection with geospace and time. And thus, visually exploring them in connecting with their spatiotemporal references is another interesting research topic. This chapter presents our work for the visualization of pictorial data such as photos or videos in terms of the second direction proposed in Section 3.3: The three aspects of spatiotemporal pictorial data (*what* – photo/video contents, *where* – geo-references, and *when* – time-references) are represented at various granularity levels to make an integrated visualization approach. There, visualization solution to support the *navigating* to locate photos or videos of interest with regard to geospace and time is the focus (Nguyen and Schumann, 2012, 2013a).

*second type
of Web data
in consideration*

The chapter is organized as follows. In Section 5.1, basics about pictorial content visualization are introduced. In that concern, we present our objectives for the visual exploration of spatiotemporal photos or videos. With motivation and problems, Section 5.2 provides our design strategies in visually exploring photos with geospace and time. Following that, examples for the exploration of spatiotemporal Flickr photos are illustrated in Section 5.3. With the same approach, we continue with ideas for the visualization of spatiotemporal videos in Section 5.4. Finally, the chapter ends with a summary in Section 5.5.

5.1 GENERAL REMARKS

With the development of hi-tech cameras and camcorders, a large amount of photos and videos is nowadays provided on computers and on the Internet. Though their collections are increasingly huge, photos and video contents are commonly explored in linear sequences such as through slide-shows or list-based views. This is convenient, but it is not adequate for the analytical exploration of photos or videos through various data aspects. In this section, we present related work in photo and video visualizations, which motivates our

objectives in visually exploring photos or videos in terms of geospace and time.

5.1.1 *Photo and Video Visualization*

Showing images and pictorial contents has been considered from the first days of GUI design. Today, there are variety of techniques in presenting photos and videos on screens. Basically, photo and video visualizations are created in terms of supporting the tasks of navigating through photo/video representations to examine specific contents. In that manner, goal of a visual solution is to provide the users useful information from photo or video data sets. In our research context, such information can be specified from the *what* (pictorial contents), the *where* (geo-references), and the *when* (temporal references) of photo or video data.

A very popular photo or video visualization strategy is to show photos or videos in linear sequences, where users are assisted to easily find photos or videos from list-based views. Windows Photo Viewer, Google Picasa[1], or Youtube[2] are examples of this approach. Users scroll a view and navigate on the photo/video sequence to examine the contents of interest. The main goal of those tools is to straightforwardly locate pictorial contents (the *what*), while their geo-references (the *where*) and time-references (the *when*) are almost not taken into account. Users only get geospatial or temporal information if examining additional descriptions or detailed properties of each selected photo or video.

focusing on pictorial contents but not geospace or time

There are other specific designs. Porta in (Porta, 2006) develops some particular forms to arrange photos as "cylinder", "rotor", "tornado", or other views. Bederson creates a hierarchical visualization structure that highlights the relations of photos in collections (Bederson, 2001). In PhotoLand, Ryu et al. (2010) suggest another way to arrange photos on screen: the photos similar to each other (with pre-defined content criteria) are placed close together to form spatial clusters, and the clusters are in turn forming a land-based presentation. For videos, combined contents from frames can be examined in generating video narratives (Correa and Ma, 2010). By doing so, they show that users can better comprehend and navigate to photos or video of interest compared to traditional list-based views.

To interact with those visualizations, users can select a displayed area of interest, change a zooming level (typically for a subset of photos or video scenes), and interactively navigate through the dataset. Pictorial contents can be shown in a stand-alone view, highlighted with visual attributes (e.g., size, border, motion points and lines, etc.), magnified to be distinguishable (e.g.,

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1 http://picasa.google.com/
2 http://www.youtube.com/

fisheye lens is used to highlight the focused photos (Liu et al., 2004) and video scenes (Ramos and Balakrishnan, 2003)), or linked with other descriptive data (e.g., in (Kristensson et al., 2008), a tag cloud is used where each tag in the cloud can be connected with a slide-show collection of photos).

So far, we have seen techniques for the visual exploration of photos or videos focusing on the *what* aspect, while their associated temporal and geospatial information (i.e., *when* and *where*), which are the objectives of our research, get less noticed. In the next subsection, we will see how time and geospace can be combined for other situations for photo visualization (the state of the art of video visualizations with geospace and time will be added separately in Section 5.4).

5.1.2 *Photo Visualization with Time and Geospace*

We first consider the *time* aspect. Yahoo! Taglines (Dubinko et al., 2006) is an example for the visual exploration of time-referenced Flickr photos, where users are supported to select linear time points in a timeline slide-bar, and then associated photos are presented on screen. Huynh et al. (2005), in another way, use not only the timeline but also a set of graphical charts to represent the time connected to photo thumbnails. Photohelix (Hilliges et al., 2007), with spiral-based time visualization, is another example for visualizing photos linking with time. Those are techniques that present a general kind of visual navigating in terms of *when → what* or *what → when* visualizations.

with geospace or time but not all

To present photos with regard to *geospace*, geographical maps are popularly used. Commercial tools currently provided on the Internet such as Flickr Map[3], iMapFlickr[4], or Google Panoramio[5] are typical applications for the exploration of photos based on geographical maps. Those applications support showing photos as thumbnails (Google Panoramio, iMapFlickr) or placemarks (Flickr Map) on the maps. A list of photos is optionally connected with the map on a separated view for referencing. Those tools support the task of navigating with geospace for photos of interest, while temporal references of photos are almost neglected. In other words, those tools express only the situations of *what → where* and *where → what*.

WWMX (Toyama et al., 2003) is considered as one of the first known applications that support the visual exploration of photos connecting with both geospace and time. It is a multiple-views design, with a view representing geographical maps, a view supporting time selection (dots with weights on a timeline presentation), and a view that shows an explored photo linking with a list of thumbnails. Users select a dot which represents a set of photos
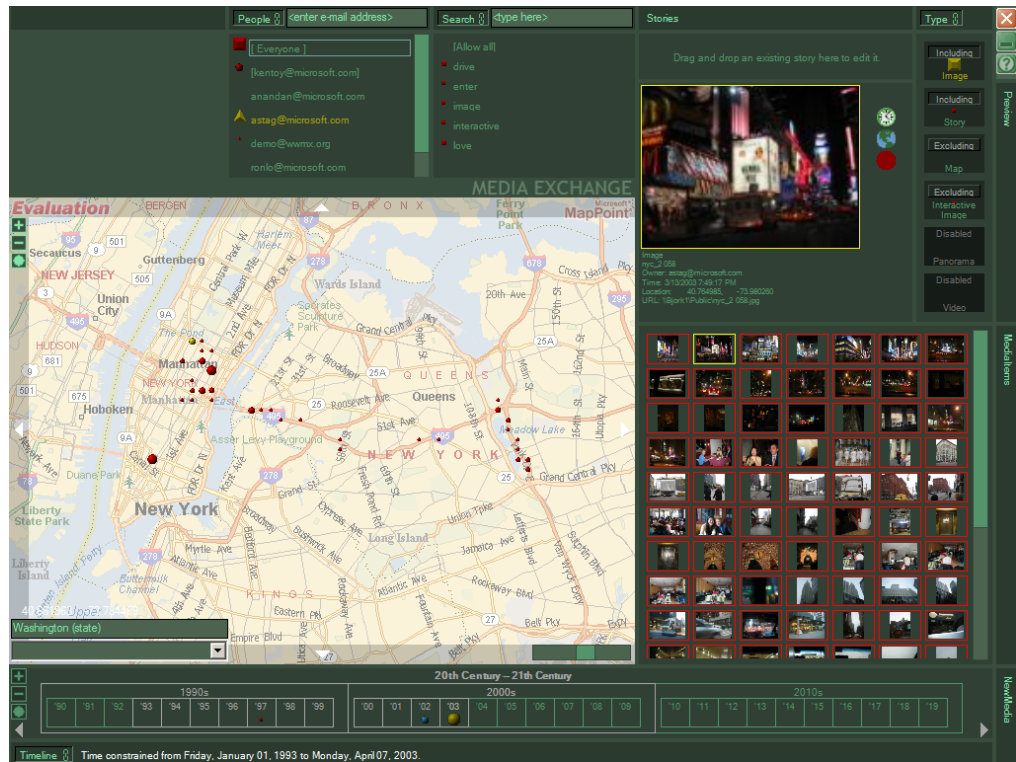
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3 http://www.flickr.com/map
4 http://imapflickr.com/
5 http://www.panoramio.com/

Figure 22: The tool WWMX for the exploration of photos linking with time and geospace, captured from (Toyama et al., 2003).

on the maps, and the list of thumbnails, each links with a timeline view, is relatively updated (see Figure 22). However, additional insights or analytical information from spatiotemporal photos are not provided. To deal with it, recent research in exploratory visual analysis of spatiotemporal photos, such as those in (Gomi and Itoh, 2010) or (Peca et al., 2011), emerges. However, none focuses on examining the whole relationships of the triplet of geospace, time, and photo contents.

all 3 aspects, but...

In conclusion, although there are useful and well-established techniques for the exploration of photos in association with time and geospace, many techniques focus only on one or two aspects rather than supporting the whole triplet of *space*, *time*, and *data contents* of photos; or they need further investigations for the visual exploration of photos in terms of Peuquet-based situations as motivated next.

5.1.3   *Objective*

In (Peuquet, 1994), Peuquet indicates that when examining spatiotemporal data, one can get not only thematic contents of the data, but also insights

with information and knowledge from their spatiotemporal combinations. She confirms that with the triplet of *what* (data contents), *where* (geo-references), and *when* (time-references), one can come up with three general combinatory situations: (1) *what + when → where*, (2) *what + where → when*, and (3) *when + where → what*. In visualization research, those situations are reviewed by Andrienko et al. (2003) for numerical spatiotemporal data. Here, questions can be raised concerning pictorial spatiotemporal data such as photos or videos. To this end, we need to cope with the following contextual situations:

s1 – *what + when → where*: Suppose that a user explores photos or videos of interest (*what*) regarding specific timestamps (*when*), and wants to know *where* on the earth those photos or videos refer to. It would be useful if there are visual hints so that photos or videos, when combined with time, effectively provide means for the navigating to their geospatial references.

s2 – *what + where → when*: Another situation, suppose that the user is interested in photos or videos with specific contents (*what*) on geographical areas (*where*). In other saying, the data contents exist and the places are given. Because those photos or videos were recorded and accessed in time, extensively exploring their history (*when*) is an interesting task.

s3 – *when + where → what*: And, suppose that the user is interested in some selected points of time (*when*) in association with some places (*where*), and she wants to know which photo or video contents or subjects (*what*) are relatively connected. In this case, it is necessary to provide means to support the navigating to the data contents of interest.

Though the three above situations are somewhat interrelated, developers can come up with very specific designs for specific purposes. However, most of current visualization techniques (as presented in Section 5.1.2 for photos or Section 5.4 for videos) do not explicitly support a comprehensive exploration of spatiotemporal data with regard to all situations S1 to S3.

Therefore, our objectives here are:

1. Develop visual solutions in which the three data aspects can be simultaneously addressed: *what* - specified with various levels of granularity in presenting photos or videos (such as the photos or videos themselves, the representative thumbnails, or the associated tags), *where* - geographical maps, and *when* - time-referenced plots and glyphs.

2. Examine the cases where all situations S1-S3 are answerable.

5.2   AN APPROACH FOR VISUALIZING PHOTOS WITH GEOSPACE AND TIME

approach?

This section presents our work for the visual exploration of spatiotemporal photos dealing with the above-mentioned situations S1-S3. In this concern, the general view of our novel design will be indicated in Section 5.2.1. Then the detailed design about the visual communication of time-referenced photo tags (through the *time-referenced tag plots* presented in Section 5.2.2) and geo-referenced photos (through *photo thumbnails* and *time glyphs* presented in Section 5.2.3) is included.

5.2.1   *A Novel Design*

To visually support situations S1-S3, the challenge to be dealt with here is that every of the three data aspects *what*, *where*, and *when* of spatiotemporal photos must be suitably communicated. In addition to that, they are to be represented in the ways that the aspects are combinable (such as *what + where* or *where + when*) and are meaningful so that all situations S1-S3 are reachable. To this end, this subsection presents ideas of our visualization development.

different granularities,

COMMUNICATING THE THREE ASPECTS OF PHOTO DATA   The visualization is to communicate every of the three photo aspects: (1) *what* – photo contents to be communicated through different levels of granularity (which are: photos, thumbnails, and tags), (2) *where* – geographical maps, and (3) *when* – time-referenced plots and time glyphs. The reason for such design is that photo data are complex as connecting to geospace and time, and thus it is impracticable to create a stand-alone view that includes all the three aspects.

1. *what* – To communicate photos, firstly the imagery contents should be exploited as provided in many photo viewer tools. Secondly, thumbnails can also be used to indicate the photos (as in Google Panoramio). Lastly, because photos on the Web are commonly linked with user-generated tags, tags are also another kind of data in conveying photo data.

2. *where* – To express geospace, geographical maps are used because they are effective means for geo-data communication (as commonly seen in cartography and geovisualization). Maps are employed here to show geospatial context of photos, where photo data can be visually represented on maps, linked with maps, and interactively explored as maps are zoomed and panned.

3. *when* – To communicate time, time-oriented photo data can be represented through time-referenced plots and time glyphs. This provides ways for users to discover temporal information as well as relations

amongst time referenced photos, such as the periodic cycles in the time glyphs presented on geographical maps.

VISUALLY COMBINING THE THREE ASPECTS   Each stand-alone view for each photo aspect is not appropriate to communicate all information of photo data in terms of situations S1-S3. Therefore, to support the tasks of navigating for spatiotemporal data, we need visualization strategies where visually combining the three photo aspects is the bottom line in the design.

simultaneously,

In our consideration, it is beneficial by the various granularity levels of abstractions of the data to communicate different aspects of the photos, where combinatory situations will emerge. For the communication of time-referenced photos (i.e., *when + what*), we show numerous tag sets, each associates with a specific time-referenced plot, to form a *time-referenced tag plots* (Section 5.2.2). To present the combination of *where + what* or *where + when*, we communicate them in terms of *photo thumbnails* and *time glyphs* on geographical maps (Section 5.2.3).

and,
novel designs

By doing so, instead of communicating photos, tags, geographical maps, and time independently as in most of photo visualization tools, our visualization solution provides the interlinking of photo aspects, and thus supports users to navigate and explore photo data with regard to Peuquet-based situations. To that end, the combination of every two aspects is linked with the third aspect as follows:

1. For situation S1 (*what + when → where*): Tags on the time-referenced tag plots (*what + when*) are explored in connection with geographical maps, and thus their spatial information (*where*) is relatively conducted from the maps view.

2. To deal with situation S2 (*what + where → when*): With selected tags (*what*) from the time-referenced tag plots, users zoom and pan on maps (*where*) to find out more temporal information of the associated photos over geospace in terms of time glyphs (*when*).

3. Finally, for situation S3 (*when + where → what*): With temporal information of photos on maps through the time glyphs (*when + where*), we support users to filter the time to arrive at specific photos of interest (*what*).

5.2.2   *Designing Time-Referenced Tag Plots*

It is aimed that navigating with the *what* and the *when* can be a starting point for the exploration of the *where* of photos (i.e., situation S1: *what + when →
where*). The strategy here is to take advantage of photo tags: In many photo sharing sites, such as Flickr or Google Picasa, photos can be coarsely explored

through a set of tags; thus, we combine tag clouds with time to provide a mechanism for the exploration of spatiotemporal photos at this level.

Examining photos over time, we have different sets of tags (linking with photos) for different time points. Therefore, visualizing all tag sets with all time points creates a visual combination of *what + when*.

Derived from the ideas of tag clouds and parallel coordinates plot, Parallel Tag Clouds (Collins et al., 2009b) is a suitable technique for the visualization of time-referenced photo tags: each coordinate in the parallel tag clouds presents a set of photo tags at a particular time point, and the whole tag clouds show all tags over all time points. However, we have to enhance the basic approach (i.e., the parallel tag clouds) to allow large volumes of tags and time points to be examined in our *time-referenced tag plots*.

granularity level of tags

Our solution is to apply a fisheye lens to focus on plots of interest and tags of interest. That means: (*a*) tag plots are visually represented in different ways to emphasize different selected time points, and (*b*) tags within each plot are displayed in different sizes and positions with regard to their levels of interest.

### a. Emphasizing Plots of Interest

We visualize every set of tags at a time point embossed on a vertical line (a plot), where all plots are parallelly shown in correspondence to a linear sequence of time points following the time development of all tag sets (Figure 23). Due to the large number of plots and tags, we cannot show all tags on all plots in readable sizes. Therefore, just some plots of interest are displayed in the size that their tags are easy to read, while for other plots, tags are re-sized much smaller to fit the display area. For example, on the typical desktop environment, we design the time-referenced tag plots with the width of 450pt, where the size of a plot on which tags are clearly shown is 150pt (we call the plots with width = 150pt as *full-width* plots). To that end, we support the user in selecting particular plots of interests, e.g., in order to compare tags over particular time points.

parallel plots for time

To support that mechanism, plots' widths and their tag sets are updated through user interactions. If no plot is selected, all plots are evenly positioned along the horizontal of the time-referenced tag plots, and tags are presented in a small size (all tags' height = 1pt) (see Figure 23a). When the user hovers on a plot, it is indicated as temporarily selected (with cyan outer ring on its top), and its tags are enlarged to be readable in big size (min tags' height = 10pt) (in Figure 23b, one plot is selected). If a plot is temporarily selected, when the user moves mouse out of the plot, it is deselected and its tags are minimized. The plot can be permanently selected or deselected with a mouse-click. In that case, it is indicated by a brown inner dot at its top (in Figure 23c, one of the two emphasized plots is permanently selected). If the user wants to permanently select more than three plots, just three most recent plots are emphasized, as

(a) All plots are evenly distributed on the horizontal, as none is emphasized.

(b) A plot is temporarily emphasized, indicated by its top's cyan outer ring.
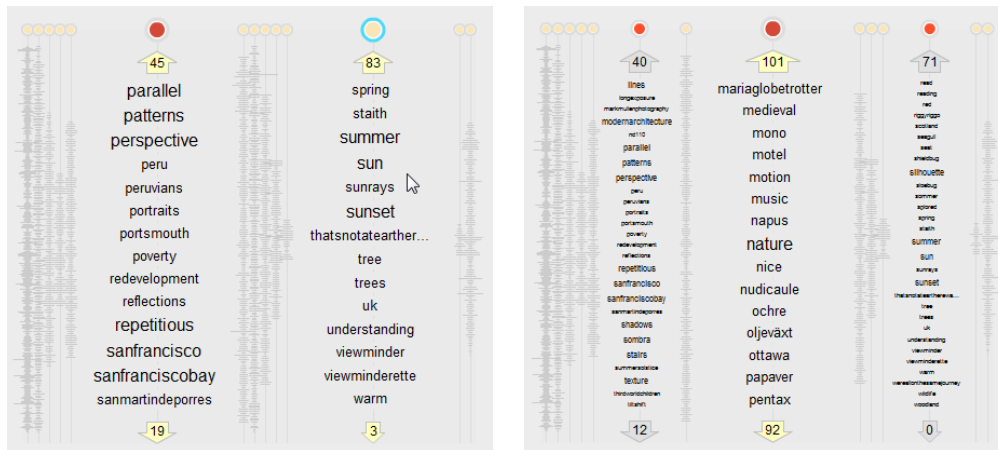
(c) Two plots are emphasized. One is permanently selected (the left-hand-side), indicated by its top brown dot.

(d) At most three plots are emphasized, with one in full-width (yellow arrows), and two in half width (grey arrows).

Figure 23: Time-referenced tag plots with selected plots of interest. When a plot is hovered or clicked, the dot and its outer ring at the top of the plot change colors. At most three plots can be emphasized, where two older selected ones are half-width comparing to the last-selected full-width plot.

shown in Figure 23d, with a *full-width* plot (i.e., 150pt, with yellow background for arrows at its top and bottom) and two others with width = 75pt (referred to as *half-width* plots, with gray background for the arrows).

b. Emphasizing Tags of Interest

Now, how do we show tags on the tag plots? The tags shown on each plot are displayed in alphabetical order for easy searching. For the non-emphasized

*sorting by frequency can be another option*

plots, all tags' heights are minimized to 1pt. For the *full-width* plots (150pt), tags' heights are in a pre-specified range for easy reading (with `MIN = 10pt` and `MAX = 24pt` for typical desktop environment). These heights proportionally increase in terms of the tags weights (which are the numbers of associated photos): tag's height = `MIN` + tag weight / max tag weight * (`MAX` - `MIN`). The tags in *half-width* plots (75pt) are relatively half in height comparing to those on *full-width* plots.

Because there could be much more tags than the available space that we can show, on each emphasized plot (both full-width and half-width) just a subset of tags is displayable. Again, the idea of fisheye menu (Bederson, 2000) is integrated. Only a sub set of tags in a range [i, j] ⊂ [1, n] (n is the number of tags) are displayed in the heights proportional to their weights, while those which are out of that range are removed from the plot's view (where digits shown on the arrows at the top and bottom of the plot indicate the numbers of unshown tags). The shown tags are updated through user interactions (i.e., by scrolling or paging up and down) on the plot.

Each tag can be highlighted when the user hovers or selects it through mouse interactions. Color and background of the tags indicate their selected or hovered states. We show the hovered tags in red with pink border, while the selected tags are colorized with orange background (In Figure 24a, tag "`nature`" is hovered and tags "`music`" and "`ottawa`" are selected).

horizontal alignment provides another highlight

We also visually link tags over plots. Because tags are only readable on emphasized plots; however, although we cannot read the tags on other plots, we want to show whether a particular tag is included there. Therefore, we
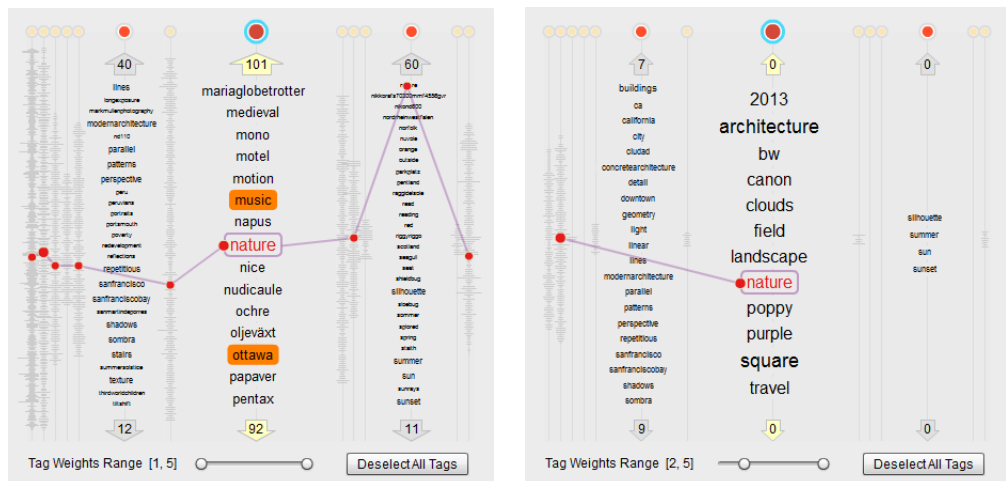
(a) Tags are selected (orange background), hovered (red text), and linked (pink lines).

(b) Only the tags with weights in the range of [2, 5] are displayed.

Figure 24: Presenting the hovered and selected tags of interest over tag plots.

provide a mechanism to highlight those associating tags. Through user inter-action (e.g., with Shift key), tags which are identical to the examined tag on the hovered plot (e.g., tag "nature") are highlighted with connected pink lines and red dots on other plots. The size of the dots are relative to the weights of the tags through plots (i.e., their heights in full-width plot). If a linked tag is out of range on another selected plot, its range is updated (in Figure 24a, tag "nature" was out of the displayed range, and it is shifted to the top of the right-hand-side emphasized plot). Users can select or deselect tags identical to the hovered one on all plots as well (selected tags on the minimized plots are encoded in orange color). Lastly, we support filtering tags in terms of their weights (i.e., the numbers of associated photos). Figure 24b shows just tags with weights in between [2, 5] associated photos.

In other words, tags which are linked with visual cues of colors, positions, and heights on time plots communicate temporal information of associated photos in terms of *what + when*. To this end, we connect this time-referenced tag plots with geographical maps to support exploring photo data in terms of situation S1 (*what + when → where*). Next, by selecting the photos filtered by selected tags on time plots, and following their geo-referenced coordinates, we display photo thumbnails and time glyphs on geographical maps. The design of photo thumbnails and time glyphs is presented in details in Section 5.2.3 where all examples are illustrated in Section 5.3.

5.2.3   *Designing Maps-Based Thumbnails and Time Glyphs*

Now, we aim at other possibilities where showing the *what* and the *where* can be a starting point for the exploration of the *when* (to support situation S2: *what + where → when*), and showing the *when* and the *where* can be a starting point for the exploration of the *what* aspect of photos (to support situation S3: *when + where → what*). In both cases, geographical maps are used to communicate the *where* aspect.

Combining the *what* (or the *when*) with the *where* aspect of photos are accomplished through other granularity levels of encoding photo contents on geospace:

PHOTO THUMBNAILS   Photo thumbnails are the reduced-size of photos typically used in organizing large amount of photos in collections (e.g., in the linear sequence view of Google Picasa). Thus, they are used to provide a glance view of photo distribution on geographical maps. Nevertheless, if we have so many photos, showing all thumbnails will cause perceptual problems. In Figure 25a, when thumbnails are shown in size of 40×40 pixels, they overlap each other. If they are shown in smaller sizes (e.g., by 14×14 pixels as in Figure 25b), the overlapping problem reduces, but the thumbnails are too

granularity level of thumbnails

small to comprehend. Therefore, similar to Google Panoramio, we decide to selectively show a subset of thumbnails in comprehensible sizes (i.e., 40×40 pixels). For this purpose, photos are clustered based on their geo-coordinates

clustering procedure

at each zooming level of the map. A cluster is composed of a list of photos within a local square region around a centroid photo. By checking every photo in the collection, each of them might fall into existing clusters (if close to the existing centroids, e.g., < 40 pixels). If not, the photo under checking forms a new centroid for a new cluster. The process ends when all photos are iteratively checked. In Figure 25c, photos from Figure 25a are clustered with square 80×80 pixels (the centroid is at position of pixel (40, 40)). The clusters will be located if the map changes its zooming level. With each cluster, we show the thumbnail for a photo of particular interest (e.g., the photo with specific tags). For clusters that contain more than one photo, a "stack"-background is added to the thumbnail. However, since photos are not evenly distributed on the maps (they are condensed at some places and sparser at other places), thumbnails with stack-background do not adequately differentiate such information. Therefore, numbers are added on the thumbnails to indicate the amount of

(a) Showing 100 photo thumbnails on maps in size of 40×40 pixels.

(b) Those thumbnails are shown smaller in size of 14×14 pixels.

(c) Thumbnails for clusters in the range of 80×80 pixels square.

(d) Time glyphs for clusters (80×80 pixels square).

Figure 25: Showing photos as thumbnails or time glyphs on geographical maps.

photos within the clusters. This strategy allows the communication of the *what + where* aspects.

To this end, we have two interesting options to be observed: It makes sense to communicate the *what* aspect based on the *what + where* combination, or it is the job to provide the referenced temporal information for cluster-based thumbnails. For the former case, we support users to switch to photos at another abstraction level: users can click on a thumbnail to see the photo in much bigger size with title and hyperlink to the source data (as presented in Figure 27c). For the latter case, it makes sense to communicate the *when* aspect in terms of time glyph as presented next.

TIME GLYPHS   We show temporal information of photos by *time glyphs* on maps (see Figure 25d) as follows: Within each geo-referenced cluster of photos, there could be interesting information about their temporal dependencies, such as the co-existence of photos at some specific time points (e.g. days in week). Therefore, for each cluster of photos, we create a time glyph with three main parts: (1) a center dot with a number indicating the number of photos in the cluster, (2) a ring with labels for temporal information (here, three cyclic structures are provided: hours-in-day (numbers for hours such as 0, 6, 12, 18 – Figure 26a), days-in-week (abbreviated as M, T, W, Th, F, S, Su for Monday to Sunday – Figure 26b), and months-in-year (abbreviated as J, F, M, A, M, J, J, A, S, O, N, D in consequence for consecutive months from January to December – Figure 26c)), and (3) arcs linked with the ring to indicate the numbers of photos falling into the associated time slots. The length and darkness of an arc represent the number of photos and their states under interactions.

To provide a comprehensive view, the length and darkness of the arcs vary depending on different photo sets (which are updated when a user loads the

temporal context of geo-referenced photos

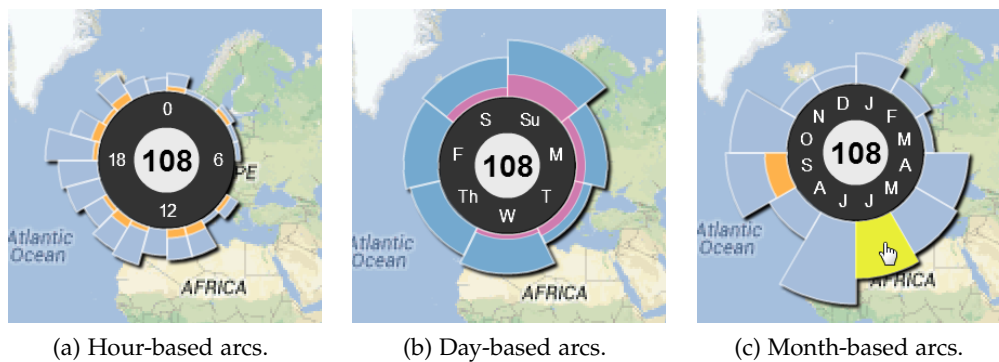| (a) Hour-based arcs. | (b) Day-based arcs. | (c) Month-based arcs. |

Figure 26: Time glyphs in different modes. The arcs are colorized in terms of interactive states: (a) orange portions for relative selected tags, (b) pink portions for relative hovered tags, and (c) yellow as directly hovered.

interactions...

Flickr data set – see examples in Section 5.3). The whole arc at a time slot represents the number of associated photos at the relevant time point. If the user hovers on the time-referenced tag plots or emphasizes some specific tags (recalling Section 5.2.2), the time glyphs' arcs are updated as well. For example, when the user selects tags (shown with orange background on the tag plots) part of the arcs are brushed in orange (Figure 26a); when she hovers on tags (pink borders and links), the arcs are relatively brushed in pink (Figure 26b). The remaining photos are indicated by the blue arcs. Finally, we allow the user to directly interact with the time glyphs' arcs to perform other tasks, such as hovering (indicated by yellow color - Figure 26c), or clicking on each arc to show the associated photos in more details.

To this end, the situations S2 (*what + where → when*) and S3 (*when + where → what*) can be answered. Photos which are clustered on maps are reachable in terms of time glyphs when the user navigates with the tag plots and the maps. While clicking on a time glyph will pop-up detailed photos at another granularity level: photos with bigger size hyperlinking with detailed descriptions.

The next section will realize the above design through the implementation of the tool PhotoTima to support the navigating on time-referenced tag plots, photo thumbnails, and time glyphs for the exploration of spatiotemporal photos in terms of all situations S1-S3.

5.3   EXAMPLES FOR SPATIOTEMPORAL FLICKR PHOTOS

So far, we have presented the design for photo tags linking with time on the so-called *time-referenced tag plots*, and photos linking with geospace or time as *photo thumbnails* and *time glyphs*. This section presents their realization through the tool PhotoTima, and provides use cases for the exploration of spatiotemporal Flickr photos with regard to all situations S1-S3.

5.3.1   *Environment*

Flash application

We implemented a Web-based visualization tool in Flash (built with Adobe Flash Builder[6]). The tool PhotoTima is developed for the visual exploration of Flickr photos which are retrieved directly from Flickr servers through its APIs[7], while Google Maps API[8] is employed for the manipulation of geographical maps.

The interface consists of three components: a main toolbar on the top, a view for geographical maps (*maps view*) on the left, and a view for time-referenced tag plots (*tag plots view*) on the right (see Figure 27). We allow users

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6 http://www.adobe.com/products/flash-builder.html

7 http://www.flickr.com/services/api/

8 https://developers.google.com/maps/documentation/flash/

to toggle the tag plots view, specify a period of time in that view, provide some initial tags (if needed), and then load Flickr data. Through Flickr API `flickr.photos.search`, PhotoTima loads a list of photos, each contains a set of tags, a taken time, and a latitude-longitude coordinate. As Flickr photos are extremely large (as of Jan 2012, millions of photos are uploaded to Flickr every hour[9]), by default PhotoTima iteratively loads 10 photos per a query and refresh the interface. The photos are loaded from the most interesting ones (criterion provided by Flickr). Then, tags are grouped in various ways: per day, week, month, or year (options are provided on the tag plots view, e.g., "months" is selected in Figure 27). Based on the selection, tags are accumulated for relevant time points (e.g., months) and then consequently visualized on the time-referenced plots of the tag plots view. *data directly from Flickr*

With options on the main toolbar, a user can choose whether to show photos as thumbnails or time glyphs on the maps view. Photo thumbnails and time glyphs are implemented as overlay objects added onto Google Maps. They represent photos distributed over geospace and time. In addition, for photo exploration, the user might need to see the photos in detail (a necessary task in any photo viewer tool). Thus, we do the same as Google Panoramio in showing detailed photos on demand. The user clicks on a cluster's thumbnail or choose an arc on a time glyph, and a window is popped-up with detailed information about relevant photos. We show in the pop-up window: (1) title of the photo under examination, (2) its pictorial content in size of max 240×240 pixels (Flickr photos' small size), (3) links to other photos (if existing) in the cluster or the examined arc, and (4) navigator link to the hyperlinked photo on Flickr website with full descriptions, comments, etc. *...and Google*

5.3.2   *Use Cases*

To explore Flickr photos in the context of situation S1 (*what + when → where*), supposing that a user navigates with photo tags and their associated time on the *time-referenced tag plots*, and she wants to get the geo-references on the maps view. To illustrate the procedure, we demonstrate to load 200 most interesting Flickr photos taken in the year 2010 (from Jan 01 to Dec 31) in terms of the tag "`poor`". The tool PhotoTima shows clusters with 51 photos (the most) in the area of Europe, then 40 in India, 37 around South East Asia, 30 in Central Africa, and 17 in Central America, while in other areas there are very few photos (15 photos in the US, and less than 5 photos on all other areas). However, when the user selects an additional tag "`homeless`" (which is semantically related to tag "`poor`" - a criterion provided by Flickr) just 6 of 51, 5/40, 1/37, 0/30, and 3/17 photos are counted for those "poorest" areas, respectively, but *first example*

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9 http://thesocialskinny.com/100-social-media-statistics-for-2012/
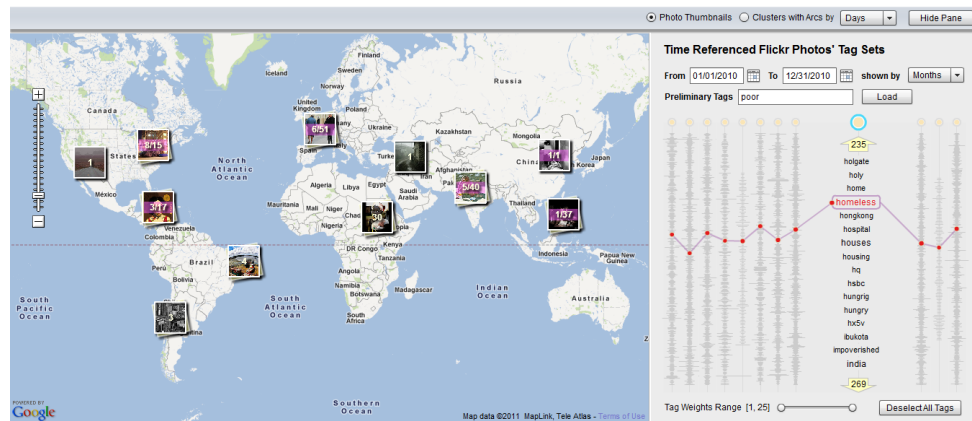
(a) Loading Flickr data with preliminary tag "poor" and showing the retrieved tags on the time-referenced tag plots. As the tag "homeless" is emphasized, numbers on thumbnails on the maps indicate the associated information.
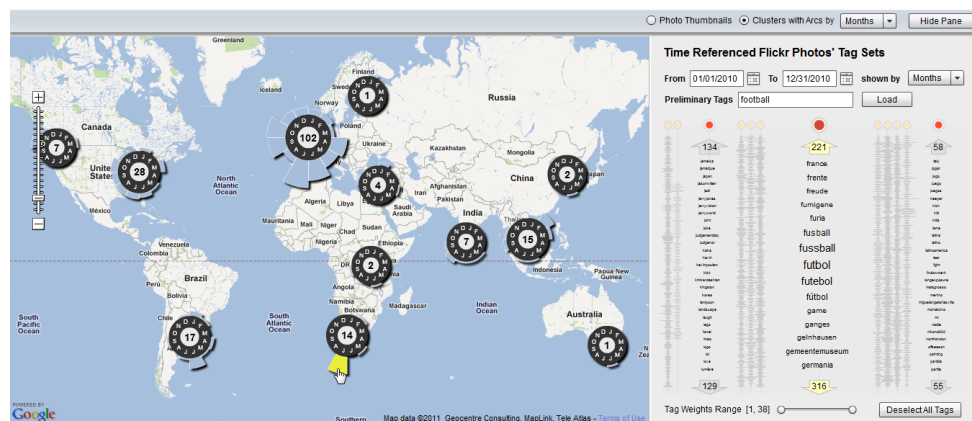
(b) Loading with preliminary tag "football" from 01/01/2010 to 12/31/2010, PhotoTima shows time glyphs with a prominent arc for "July" in South Africa. It is highlighted in yellow through a mouse-hovering.
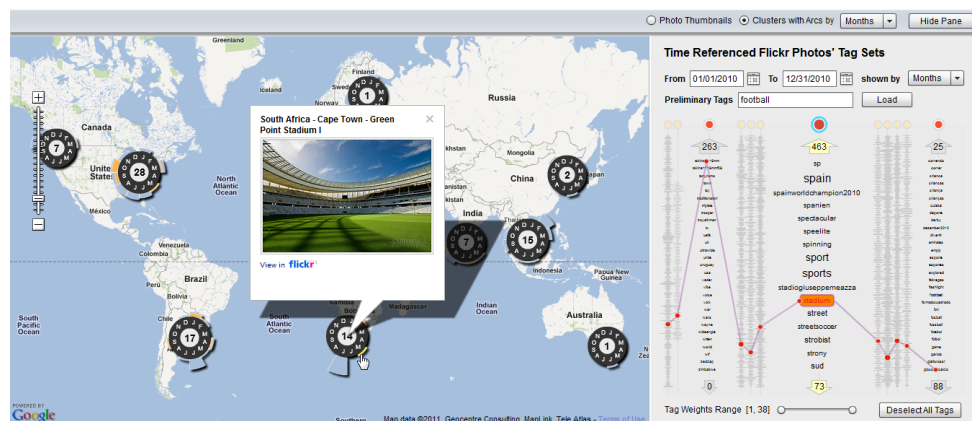
(c) Selecting tag "stadium" and then clicking on the arc for "May" in South Africa to pop-up a window with the detailed data of the photo.

Figure 27: Screenshots of the tool PhotoTima.

up to 8 of 15 photos were highlighted at the area of US (numbers in pink in Figure 27a).

Here, the user might wonder about the presented information. Thus, the tool PhotoTima provides an interlinking mechanism for further exploration. For example, the user explores the maps to see how photos are distributed in time over geospace through the *time glyphs*, or clicks on the *time glyphs* to see the more detailed photos.

We illustrate with another example for 200 most interesting photos taken in 2010 with initial tag "football". The visualization shows that there are 102 photos in Europe, 28 around North America, 17 in South America, 15 in South East Asia, and 14 in South Africa, and so on (Figure 27b).

In that regard, one would examine how the photos are specifically distributed in time (e.g., by months) over geospace. This can be accomplished in terms of situation S2 (*what + where → when*). With the photo data retrieved in terms of the preliminary tag "football", the visualization shows that photos are not evenly distributed in time through the time glyphs on the maps. As presented in Figure 27b, the numbers of interested photos in United States are not so different in different months. But for the photos in South Africa, there is a prominent arc for "July" on the time glyph. The "July" arc of South Africa is also a prominent arc in comparison to other places on the earth (except in Europe).

Now comes the question: Why do we get this distribution? What is the special information in July 2010 in South Africa? By clicking on the time glyph's arc indicating July in South Africa, the pop-up window shows photos with titles such as "World Cup 2010 South Africa: Spain v Netherlands" or "World Cup 2010 South Africa: Spain v Germany". The answer is now clear: the particular insight about "football" photos in July 2010 is about World Cup 2010 taken place in South Africa. In that regard, the user has explored the photos in terms of situation S3 (*when + where → what*).

Alternatively, the user can also examine how tags in the time-referenced tag plots could be used to help her to find out similar information. One of the related tags of the tag "football" is tag "stadium". It is interesting that tag "stadium" appears in all plots of the time-referenced tag plots. By selecting it on all plots (i.e., for all photos), the two remaining arcs indicating February and May in South Africa's time glyph are highlighted. Why those photos refer to "stadium"? Could we find any relation between those photos and the others in South Africa in July? By clicking on them, e.g., the photo in May, the user finds out that the description is about the Green Point Stadium I in Cape Town, and when she continues to click on it to jump to the Flickr website, she gets the descriptions and comments about the stadium in its preparation for World Cup 2010 (Figure 27c). From that, the user could imagine what the photos in July 2010 in South Africa are about.

5.3.3   *Feedback*

We conducted informal interviews to get a preliminary feedback for the tool PhotoTima. Eleven users (two visualization experts, and nine are novice users, ages 16-36) were invited to use PhotoTima to explore Flickr photos. We first introduced the tool and its functions (interface components, mouse options, and hot keys). Afterwards, the users applied PhotoTima to explore Flickr photos. After having used the tool, they were asked to give informal feedbacks.

In general, all users gave positive feedbacks. They particularly pointed out that PhotoTima presents useful hints about time for Flickr photos on maps in terms of time glyphs (nine of them used to explore photos on Google Maps, and one of those users used to expect to explore photos in connection to not only geographical maps but also to time). They said that the tool is easy to use because all of them are familiar with photo thumbnails, tag clouds, and geographical maps. In addition, they said that our tool is very comprehensible because it smoothly updates the interface.

different perspectives from experts and novice users!

However, although the visualization design was expressive, various matters were provided. At that point, what interesting to us is that visualization experts and novice users took different perspectives into account. That was what we really expected in terms of a casual Infovis development. The visualization experts mainly talked about design issues (e.g. "the way you design connected lines on the time-referenced tag plots would cause misinterpretation"), while the novice users were just interested in the utility of the tool (such as "How can I see the tags that belong to the same topic on the tag plots view?").

Besides, the users also expected the tool to be improved with additional supports: (1) providing hints so that users can select related tags of any tag, (2) showing all selected tags in a separated view as they are important information, (3) providing more hints for the photos from clusters without clicking on the icons, and (4) automatically updating photos and tags when the maps view is updated. They are nice requests for future development.

5.4   VISUALIZING VIDEOS WITH GEOSPACE AND TIME

At the 2012 International Conference on Web Information Systems and Technologies[10], questions emerged regarding the development of a technique similar to our PhotoTima for the exploration of spatiotemporal videos (e.g., from Youtube). In our opinion, it is another challenge to develop video visualizations in terms of Peuquet-based situations, because the data aspects in videos are not identical to those in photo collections. This section briefly presents our ideas as the first steps for the development of such a visualization technique.

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10 http://www.webist.org/?y=2012

We firstly consider the situation when examining current video visualization research. Since data contents in spatiotemporal videos are not the same with those in photos, we should take a loot on them considering the relationships in *video contents*, *geospace*, and *time*, and the ways they are dealt with in existing video visualization techniques.

In the recent state of the art survey about techniques dealing with videos as input data in computer graphics and visualization, Borgo et al. (2012) present that video visualization techniques have been developed to reveal important features and events in videos. By extracting meaningful information from a video and conveying the extracted information to users in abstract or summarized visual representations, video visualization aims at offering tools to assist users in their intelligent reasoning while removing the burden of viewing the original videos.

Most of existing video visualizations take advantage of the semantic relations amongst video scenes (including their spatiotemporal relations) to provide e.g., content summary, scenes narrative, and other kinds of features and events, instead of focusing on relations amongst different videos. Because of that, space and time - the very crucial information in highlighting feature events to enrich video experience - are *locally* emphasized in each stand-alone video, instead of *globally* examined among the collections of videos. Borgo et al. (2012) classify video visualizations with regard to their outputs: another video or an animation, a large collection of images, a single composite image, or additional information and actions; where geospace and time are considered as follows:

- If output is *another video or an animation*, time is importantly exploited: enhanced controls for playback speeds and positions are developed to provide faster access to video's frames or scenes. Twist Lens is an example where timeline is encoded through the fish eye view of frames (Ramos and Balakrishnan, 2003), and timeline slider is combined to aim end-users to see several abstractions of video contents (Schoeffmann and Boeszoermenyi, 2009). But spatial information is almost neglected or implicitly used, e.g. objects in geospace over many frames (Dragicevic et al., 2008).

- For output as a *a large collection of images* (typically in terms of selected video's frames) – where we expect techniques similar to those of photos with space and time – the survey by Borgo et al. (2012) shows that only contents (the *what*) are important, while geospace and time (*where* and *when*) have not been noticed, even in the case that geo-information constitutes the so-called "video collage" (which is also *a single composite image*) (Mei et al., 2008).

- Lastly, to generate outputs using *additional information and actions*, supplemental data are used. Accordingly, geospatial and temporal references are also included. Stroke and glyph annotations are created to indicate visual contents in geospace and time (Goldman et al., 2006; Nienhaus and Dollner, 2005), while volume visualization expresses well the concepts of space-time volume for video summarization (Daniel and Chen, 2003; Chen et al., 2006).

In summary, there exist many video visualization techniques dealing with spatial and temporal information for the exploration of video contents. However, such spatiotemporal information is *locally* examined in stand-alone video instead of being considered *globally* amongst different videos in collections. Video visualization techniques have been developed to support the task of exploring each video clip, rather than supporting the navigating and locating videos of interest in collections with regard to geospace and time. Therefore, research about video visualization in terms of Peuquet's situations is an open work.

IDEAS FOR VISUALIZING VIDEOS WITH GEOSPACE AND TIME   To visually exploring videos in terms of abstract and summarized representations, the above-mentioned video visualizations typically exploit image and video processing to acquire necessary preprocessing data. Those data are then represented in visual forms to provide comprehensive views more compact than original videos to the users. This is complicated but meaningful. Thus, if considering for collections of videos, the preprocessing data – which can be much more complicated than those in a separated video – are to be somehow combined. Therefore, base on the work about photo visualization with PhotoTima, we propose the visualization to communicate video contents in different granularity levels as follows:

base on, but must extend PhotoTima

- First, we simply consider videos in the same way as photos in collections. It means: complex information depicting visual contents from frames and scenes in videos are not taken into account at this granularity level. Only coarse information such as user-defined tags or thumbnails with key pictorial frames, together with geospace and time, are employed for the visualization of videos in collections. In doing so, Peuquet-based situations provided in PhotoTima are similarly applied: video tags and thumbnails (such as key frames) are presented simultaneously. Video tags are visualized with time in terms of a time-referenced tag plots. In addition, we may have some more options: for example, it could be interesting to design tag plots with regard not only to time points, but also to video genres. In that concern, each plot could be associated with a separate time point to show time dependencies or to a genre plot for

a specific genre. Video thumbnails are also spatializable on geographical maps, and time glyphs can be used for the communication of time-referenced videos. And then, through interactions, users are assisted to navigate through the tag plots, video thumbnails, and time glyphs to locate videos of interest.

• In addition, further representations can be taken into account to support the exploitation of other data in each video or amongst many videos. At this granularity level, videos can be examined with further information extracted from image and video processing steps: the preprocessing data such as content summaries, features, or events are other interesting data for visual communication. In that manner, it is supposed that users not only navigate with the tag plots, time glyphs, or click on a video thumbnail on geographical maps to watch a video. Instead, they are supported with visual means describing the abstract information processed from videos to perform additional exploration tasks. This is the challenge for future work.

5.5   SUMMARY

In this chapter, we developed solutions for the visual exploration of pictorial contents linking with geospace and time. We addressed the visual communication of photos/videos through various granularity levels of representing and integrating the triplet of *what*, *where*, and *when* aspects of photo/video data simultaneously. Through the design of time-referenced tag plots, thumbnails, and time glyphs on geographical maps, we supported the tasks of visually navigating and locating (seeking) photos or videos in terms of Peuquet-based situations: *what + when → where*, *what + where → when*, and *when + where → what*.

Together with Chapter 4, we have provided visualization solutions and techniques for the exploration of specific data contents on the Web: tags, photos, and videos. Anyway, alike most of visualization techniques existing so far, the developed-visualizations of those data contents on the Web take place in terms of stand-alone applications developed for the already-specified data only, but not for Web contents on any arbitrary webpage.

To this end, thinking about "contents first" (see Chapter 3), we should care about a general view where "contents" means any webpage. And, thinking about "overview first" means that we should develop visualizations to aim the navigating, locating, and linking information together with such any existing webpage on the WWW. Puzzling them all together, the next chapter will go on with the general study where visualization solutions are hybrid and the both tasks of browsing and navigating-locating diverse Web contents are to be carried out.

6

DIVERSE DATA CONTENTS WITH GEOSPACE AND TIME

We meet with the forms of space and time
with the whole manifold of spatial and temporal objects,
with their gradations, continuous transitions,
and combinations in various proportion,
all of which we cannot seize by our ordinary means of expression.

— Ludwig Wittgenstein, 1929

The two previous chapters dealt with specific visualization techniques for the exploration of some common data with spatiotemporal references such as tags, photos, or videos collected from the WWW. Visualization solutions have been developed with regard to the tasks to be supported: tags are browsable in interactive tag clouds linking with geospace and time, while photos or videos of interest are reachable when users navigate with the visual representations of spatiotemporal information. To support data browsing, raw contents (i.e., tags) are at highest priority in the visual communication, while for navigating and seeking for photos or videos of interest, the visual representation of spatiotemporal information is important. Because supplementing each others, visual presentations of raw contents and aggregated data can be seen as "the two sides of a coin" in our casual Infovis developments.

In this chapter, we go on with the general case where visual representations are hybrid and expected to be carried out for diverse Web contents linking with geospace and time. To support browsing, navigating, and locating contents of interest on existing webpages, there are various research problems to be considered, including contents analysis, information extraction, and visual communication. Within the scope of this thesis, we focus on dealing with the visual communication of data and tasks directly added onto webpages in terms of "augmented Web browsing". To that end, we present ideas where visual supports are carried out as (1) visual cues encoding additional information directly bound to a particular hypermedia item, and as (2) additional visual layers flexibly attached to any webpage – to intensify the different tasks in Web browsing (Nguyen and Schumann, 2013b).

not specific, but general Web data in consideration

This chapter is organized as follows. In Section 6.1, basics about data contents visualization are provided. In that concern, we present problems and objectives for the visual communication of diverse *data contents + geospace + time* on the Web. Section 6.2 introduces a generic approach for the design of visualizations and interactions to support augmented Web browsing. And then,

the design for a concrete augmented browsing scenario of Web snippets with spatial and temporal references is included in Section 6.3. The Firefox add-on VizMe with demonstrations is realized in Section 6.4. Finally, the chapter ends with a summary in Section 6.5.

6.1 GENERAL REMARKS

Today, 2.5 quintillion bytes of data are created everyday (IBM, 2013). A large amount of them is shared on the WWW through the forms of text, audio, videos, click streams, log files and other contents. People browse webpages everyday to access those Web contents. With the advancement of nowadays hi-tech devices, computational intelligence, and Web services, it is requested to investigate and develop forward-looking visual interfaces and techniques that can support end-users in effectively browsing and performing different tasks with those contents on the webpages. This section presents related work leading to our objectives in visualizing Web contents with spatiotemporal references.

6.1.1 *Data Content Visualization*

We firstly recall the general view about data visualization. As indicated in Chapter 2, visualizations have been being studied with considerations in terms of the two perspectives of *visual data analysis* vs. *browsing*. For visual data analysis, data contents in raw forms are seldom kept in the visualizations, while for visual data browsing, the raw contents are seriously preserved. Depending on development goals, *what* data and *how* the data are selected, transformed, represented, and presented are to be taken into account. Under the umbrella of casual Infovis, we are more or less focusing on visualizations in which raw contents are preferably included. To this end, we want to take a look on related work about content visualizations, and with specific notice about content visualizations on the Web.

Data content visualization in this context means that raw contents are somehow included in the visualizations. So far many media contents can be listed such as text, static images, videos, audios, log files, and the others. However, among them almost just text gets much concentration in visualization research due to the integrability of textual data. Various visualization techniques have been developed to aim the exploration of document contents (e.g., Collins et al., 2009a), common words (Viegas et al., 2009), emails (Viégas et al., 2006), news (Weskamp, 2013), words in contexts (Wattenberg and Viégas, 2009), and so on. There, many concepts for Infovis are discussed and applied.

In our opinions, deploying Infovis for other raw contents can also be similarly studied with challenges. As presented in Chapter 5, there has been work considering the arrangement or placement of photos or videos in various de-

signs to support the exploration of photos or videos of interest in collections. To support exploring media contents, additional visual cues can be supplied. For instance, timeline is combined in locating photos (Dubinko et al., 2006) or video portions in time sequences (Viaud et al., 2010). To this end, it raises challenges for the development of visualizations dealing with the diverse data contents on the Web. So, what are the problems to be dealt with here?

VISUALIZATION ON THE WEB   We have just listed some visualization techniques for data contents exploration. Many of them are developed as non-online applications. With the advancement of nowadays Web developments, we can say that now is the time that all visualization techniques are to be developed and deployed online. Viégas et al. (2007) develop IBM ManyEyes to provide a platform for end-users in creating or uploading pre-formatted data sets to get visualizations in forms of scatterplots, bar charts, treemaps, tag clouds, and so on. Andrews and Lessacher (2010) implement various gadgets integrated onto Google Doc Spreadsheets with the support of Google Visualization API. Tableau Software is another useful public tool for data visualization on the Web. Ho et al. (2012) develop a Web-based toolkit to represent data visualized in mutiple-views linked by various graphical components. And many more visualizations can be now deployed online thanks to the frameworks such as D3 (Bostock et al., 2011). However, visualizations for data available on the Web are still not at such desire.

non-online vs. online

The above-mentioned visualizations get attractions from Web users. But the visual communication of data is strict in terms that the visualization components typically stand alone and deal with the already-specified data. The visualizations represent data which may be collected from webpages and can be embedded back into webpages, but the visualizations and the existing Web contents are not forced to strictly connect together. In other words, visualizations have not been created or provided on existing webpages with the focus on browsing the existing Web contents. To support augmentedly browsing existing webpages (see *Augmented Web Browsing* in Section 6.2.1), more studies are needed. Fisher et al. (2010) develop a framework where visualizations are embeddable into any compatible application. And thus their ideas could be examined and extended here so that to adapt into the context of Web-based developments.

visualizations augmented to any webpage?

6.1.2 *Content Visualization with Geospace and Time*

Because data are created and used in space and over time, a variety of contents provided on the Web contain geospatial and temporal information. Normally, temporal information can be extracted through timestamps or events accompanying with Web snippets such as a news summary, a comment, a tweet,

a hyperlink, a photo, and so on; while geospatial information is still rarely found in the metadata of a few media such as a geotagged photo or indicated implicitly by location names in textual contents.

When users are accessing and interacting with Web contents, some Web applications generate and visually provide the data that the users are manipulating in time-referenced manners. Facebook uses a timeline, while a zoomable time-based list layout is employed to aim the users in fast accessing news snippets (Stefaner, 2007). Or temporal information from large news collections is extracted and visually combined with common words in form of sparklines (Yang et al., 2010). Those techniques contribute to temporal visualization (see Chapter 2) in terms of content-oriented visualization techniques.

visualization for Web data with geospace and time is a broad topic

For data contents containing geospatial information, almost geographical maps are used for geo-communication. Google Maps at the time this thesis is writing show on their maps the geo-referenced photos, videos, webcams, weather information, and wikipedia links. In addition to that, recently users can also take 3D photo tours of landmarks by experiencing the related 2D photos from the maps. Relevant ideas can be found in the work of Snavely et al. (2010).

The above visualization techniques and applications can be extensively discussed in connection with visual solutions provided in Chapter 4 and Chapter 5. Data contents, geospatial, and temporal information are selectively represented in terms of the browsing or navigating tasks. There, data contents are browsable and explorable in connection with the visualization of geospatial and temporal information. However, they are more or less created as standalone applications. The visualizations are not created and embedded as a part of webpages in terms of augmented Web browsing. As a result, we aim at further work as motivated next.

6.1.3   *Objective*

Let us consider an activity commonly taken place on the Web. Jane is surfing CNN online[1] and paying attention to an interesting information stuff from a Web snippet. She wonders whether or not there are other data relating to that information somewhere on the WWW. It would be helpful if she can get hints about related news or other Web resources concerning that information while she is still surfing the CNN website.

further data added while surfing...

Retrieving and displaying additional data – especially those with spatiotemporal information – to aim end-users in better browsing Web contents on a current browsed webpage is the target that we want to reach in this chapter. This would be more problematic than visualizing independent data on a standalone application, where the visualizations are not necessarily linked with any

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1 http://www.cnn.com

existing webpage. Visualizations for Web browsing in this case require to deal with the two following problems:

1. Identify, analyze, and extract suitable data from the browsed webpage or other Web resources to further visually communicate on a current browsed webpage.

2. Decide how the additional data should be visually communicated.

Within the scope of this research, we focus on the second problem: the visual integration of additional data onto a current browsed webpage. To this end, we provide a 2-step-approach development. With the first step, we introduce a general procedure about which visual supports can be provided in terms of: (1) visual cues encoding additional information directly bound to particular hypermedia items, and (2) additional visual layers flexibly attached to the existing webpages (see Section 6.2). And then, with the second step, we adjust the settings with regard to a given Web browsing scenario (presented in Section 6.3). *2-step-approach*

6.2 VISUALIZATION TO SUPPORT AUGMENTED WEB BROWSING

Visualizing data additionally added onto existing webpages to support Web browsing will be taken place leveraging recent achievements in Web and visualization and interaction research. This section present our discussions in terms of augmented Web browsing and a general approach for visualization and interaction design.

6.2.1 *Augmented Web Browsing*

Today, to browse and manipulate Web contents, users are supported with a lot of tools and services provided online. Unfortunately, existing tools and services are typically provided on specific stand-alone applications or websites (such as searching the WWW on Google site[2]). That means, if a user wants to google further contents of interest while browsing a webpage, she has to switch to the Google site to get the needed data. In various cases, this is not always sufficient for the user to switch in between different webpages, as she might loose the context or connections due to the matters of cross-memorizing, locating, and relating the tasks in between the many windows. Therefore, we need interfaces to support end-users in reducing the switching of webpages and performing useful browsing tasks. *avoid switching between webpages and applications?*
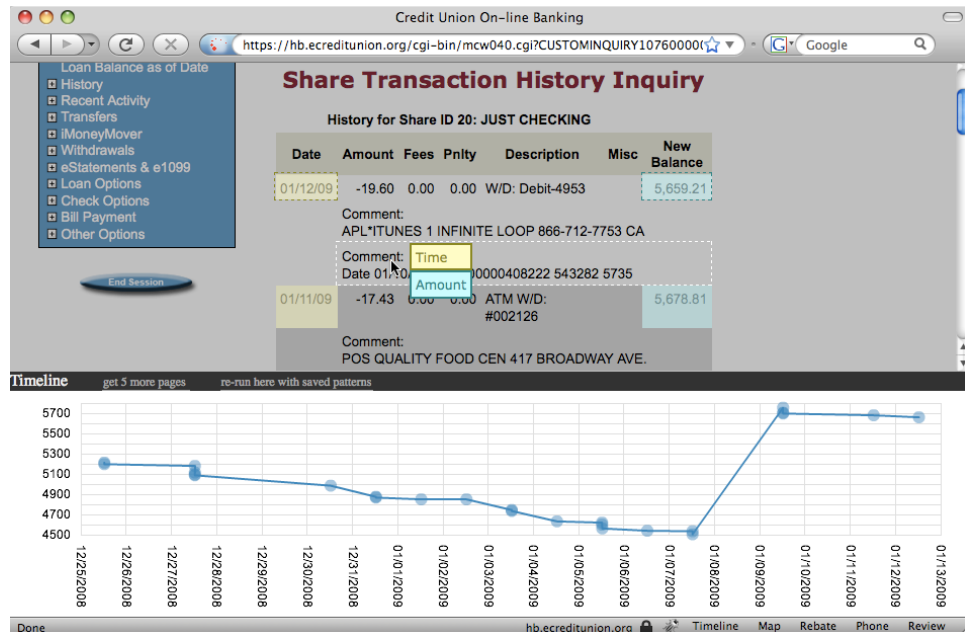
Augmented browsing is a recently emerged research topic for Web developments (Díaz, 2012). Because no webmaster can afford to support all the re-

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2 http://www.google.com
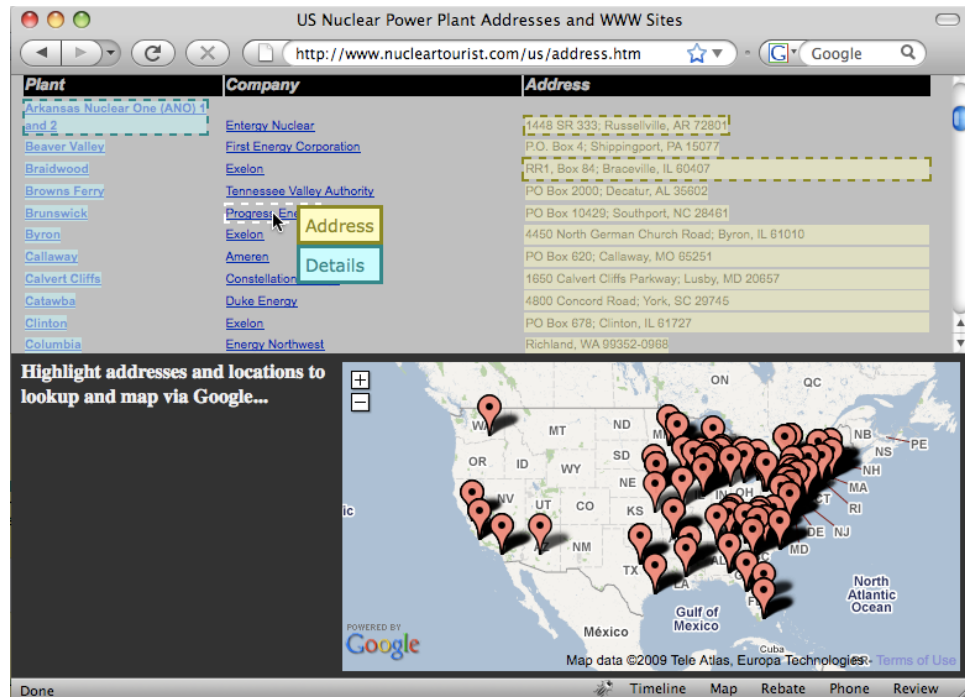
(a) Identifying and visualizing extracted addresses as markers on the geographical maps.

(b) Identifying and visualizing extracted bank amounts over time on a timeplot.

Figure 28: Screenshots of the Firefox add-on reform (Toomim et al., 2009). Users mark text with formats such as addresses, timestamps, and numbers. The tool then detects (a) all addresses, or (b) bank amounts associating with timestamps on the browsed webpages, and visualizes them on the add-on. The visualizations on the add-on do not explicitly brush with the webpages.

quirements of diverse end-users, it is expected that a webpage provided online should be designed with facilities to be able to self-modify its content-structure and page-layout on purpose. Popular sites such as Google, Yahoo!, or Facebook today allow end-users to slightly customize their client-side presentation of the pages, typically concerning user interests and experiences. It is useful because a person can remove unnecessary parts of contents from her personalized pages or to re-allocate and re-order contents for better navigating and browsing. However, it is not enough as the user might want to flexibly add and manipulate further data or tasks which might be missed on the existing webpages. To deal with it, personalizing the webpages with further hypermedia items and providing more interactions from the client-side is the amendment solution. Webpages are not only to be rearranged or self-modified, they are to be added with additional items and manipulatable with embedded scripts. For instance, with GreaseMonkey on Firefox or IE7Pro on Internet Explorer, programmers and end-users have been creating scripts to decorate and control their personalized webpages (Bigham and Ladner, 2007; Pafilis et al., 2009).

Web personalization

Anyway, Web content modifications and scripting manipulations are strict in terms that developers and end-users must know well the structure of the webpages before modifying. Additionally, it is also problematic that the added data would cause changes in original contents and purposes of the webmasters. An effort to reduce those matters is to provide data and interactions on additional browser extension's components, and use them on demand. To this end, because browser extensions are separately developed from the webpages, visual supports and interactions in between the added data and the existing Web contents are important. In Toomim et al. (2009), the authors present first ideas for the exploration of specific spatial and temporal data extracted from pre-formatted addresses, timestamps, and numbers on selected websites and visually presented on a Firefox add-on (see Figure 28). The visual components with geographical maps and temporal charts can be seen as the first work about visualizations for augmented Web browsing. However, they do not provide ideas for the interactions to support augmented Web browsing in general. Thus, further work is needed.

...and limitations

6.2.2 *A General Approach*

In this work, we introduce a general approach to enrich webpages by visualizations and interactions in the sense of augmented Web browsing.

Generally speaking, when browsing Web contents, users access content elements in terms of selecting and performing different tasks. Selections can be done through mouse or other events (keyboard, touch, etc.) which typically mark and highlight contents of interest on the webpages. Then, other tasks can be accomplished through requests or other manipulations associated with se-
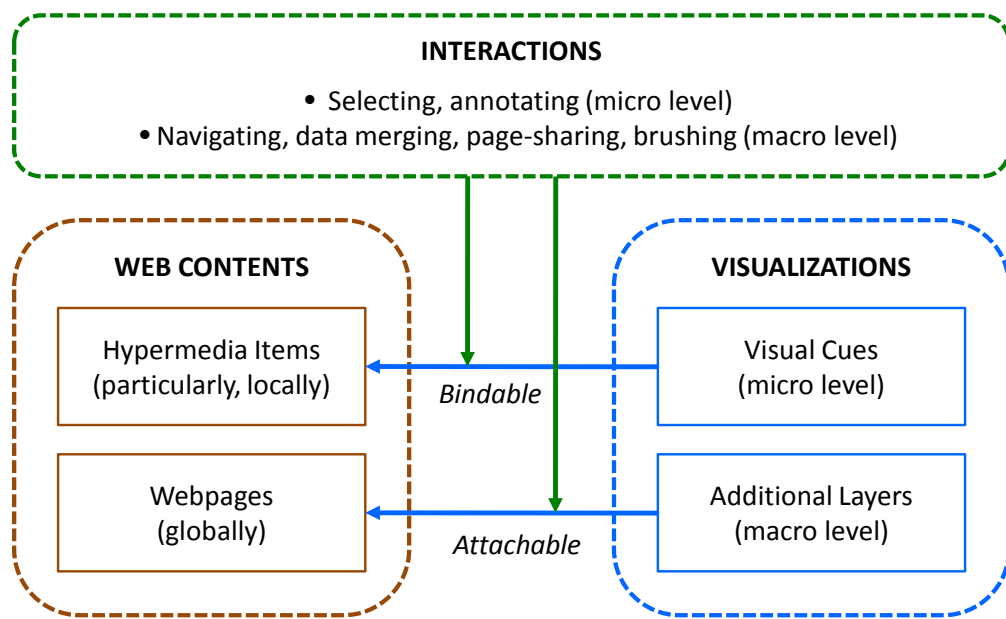
Figure 29: Visualizations and interactions provided onto existing webpages for augmented Web browsing. At *micro* level, visual cues are bound with particular hypermedia items in terms of selecting and annotating. And at the *macro* level, additional layers are attached on the webpages to support the navigating, data merging, page-sharing, or brushing and linking things on webpages.

lected Web contents – so that to receive responses with data and tasks updated from servers or within the client by using client-side scripts. In this regard, visual supports must be developed and provided for all of those activities.

In visualization to support browsing media contents, various design issues are to be considered – including the development of visual encodings, relationships in between the visualizations and existing data contents, and interaction strategies. There, relationship in between the visualizations and the existing data contents is important because visual comparison (Andrienko and Andrienko, 2005) decides how users interact, combine, and complete tasks. Thus, in the context of visualization for augmented Web browsing, we need to examine ways to provide visualizations and then interactions to communicate the additional data and tasks directly added onto the existing webpages.

additional data at micro vs. macro levels

We define two levels of visualizations and interactions provided onto existing webpages (see Figure 29). On the one hand, at the so-called *micro* level, visual cues and interactions are developed for the particular hypermedia items of interest in terms of the two tasks: selection and annotation. On the other hand, at the so-called *macro* level, visualizations and interactions are provided

to support the navigating for data, merging data, sharing data on different webpages, and brushing and linking things on the webpages.

Now, because the additional data are provided onto the webpages to become a new part of the webpages, details about the design of visual supports is needed. In the next two subsections, we describe all options in terms of designing visualizations and interactions for the both proposed levels.

6.2.3 *Micro Level Visual Supports at Particular Hypermedia Items*

We firstly indicate visualizations and interactions at *micro* level. We call them as *micro* level visual supports because the visualizations are designed for and will be bound only to a particular hypermedia item which position is locally determined on a browsed webpage (and not relating to any other contents, i.e. the global context, of that webpage). The additional data are visually encoded considering the basic HTML and CSS styles of the hypermedia item or through additional visual cues bound with the item. Interactions refer to that particular hypermedia item only.

"micro" regarding single items

VISUALIZATION DESIGN   The visualization design to communicate information linked with existing hypermedia items is constrained with the characteristics of the hypermedia and the supports of Web browsers. In other words, the specifics of the selected hypermedia items (types, styles, available spaces, and their visual integrability) have to be considered:

- For hypermedia such as text, images, and other standard W3C HTML[3] in basic forms: Visualization can be taken place in terms of text font styles, color, background, border, and other visual styles of objects using CSS directly assigned to them.

- If basic CSS are not appropriate to communicate the additional data (such as dynamic information associating with a text, or suitable CSS are already used to encode other data), we need visual cues carrying the information and bind with the HTML items. For example, additional visual cues (Nguyen et al., 2011) can be mixed to text to show the time-references.

- For non-HTML-standard objects (e.g., complex graphical objects embedded on the webpages): Because the objects could be complexly created, mixing additional visual cues together with them is not straightforward. The additional visualization might change the original designs of the objects. Therefore, visual cues are suggested to be created and separately and closely bound with the objects.

...flexible designs

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3 http://www.w3.org/html/

INTERACTION   Although the additional visualizations provide further information, it would not be easy for all Web users to accept them. The visual cues may be sometimes and to somebody appropriate, and not for the others. Thus, visual cues are expected to be supported at run-time as needed. The items to be enriched with additional visual cues should be handled interactively:

- Selecting: Hypermedia content selection is the very common task on Web browsing, thus visualizations to support content selection are obviously needed at this *micro* level. When contents are selected, they should be emphasized with additional marking and highlighting.

- Annotating: After selecting specific items, additional data can be added on demand. Typically, annotations provide information concerning the selected hypermedia items. And thus, annotations can be provided in terms of CSS styles or additional visual cues bound with the items. This can be accomplished through the requests sent by (e.g., Javascript) events. The visualizations are generated and shown at runtime, while the hypermedia items are changeless.

Visual supports at this *micro* level is beneficial for interacting and augmenting the browsing directly at particular hypermedia items. It provides run-time and instant information for hypermedia items under selection or examination. Visual hints with the support of CSS or simple additional visual cues are to be straightforwardly created, but creating complex visual cues for the non-HTML-standard objects can be challenging. The visual encodings are to be settled locally. However, they can extensively link with other data at the *macro* level as well, as discussed next.

6.2.4 *Macro Level Visual Supports for the Whole Webpages*

To aim end-users in exploring contents arbitrarily and globally (i.e., somewhere) on a browsed webpage, or to reduce switching in between different webpages, visual supports are needed at *macro* level.

VISUALIZATION DESIGN   Communicating additional data in connection to the whole webpage means that the developed visualizations should be flexibly created and provided on that webpage. How should we do that?

As discussed above, additional data must not change the existing page-layouts. Therefore, we suggest not to create visualizations as wrapped objects inline existing webpages, but as extra components on additional layers which are attachable and floatable anywhere on any browsed webpage. The hereafter-mentioned layer can be a typical HTML layer or other browser-integrable ones (such as an Adobe Flash[4] canvas). The concrete designs (number of layers,

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4 http://www.adobe.com/flashplatform/

which visualization components are developed on layers, which information do they communicate, and so on) depend on real scenarios (such as those presented in Section 6.3). To this end, two typical types of layers can be built:

- HTML-panel: A layer can be designed in the same manner as common HTML panels. But its visual components should be displayed and interacted with existing Web contents in specific ways. We suggest that HTML panels and components are adjustable with values indicated by the many CSS of the HTML.

  ...flexible designs

- Graphical components: For more complex visualizations, we suggest to create layer components carrying visualizations implemented in HTML5 canvas or SVG that are well-supported by many Web browsers (other libraries such as Adobe Flash or Microsoft Silverlight[5] are considerable as well).

INTERACTION   By providing additional visual components at *macro* level, the visualizations are expected to provide visual hints and insights flexibly so that end-users have further means to browse and explore the diverse Web contents. To achieve suitable visual supports, interactions are needed for specific tasks at hand. At this point, interaction design might follow the *visual seeking mantra* of Shneiderman (1996), while to position layers, magic lenses (Bier et al., 1993) or folding visualizations (Tominski et al., 2012a) could be interesting choices.

- Navigating: By default, additional visual layers provide hints for the navigation to locate the Web contents of interest. Whenever the layers are created, positioned, or changed, the visualizations on components are interactively updated.

- Data merging: The additional data on the layer might refer to contents somewhere on a browsed webpage. Therefore, they are to be merged from diverse parts of the webpage. This is special because the merged data provide abstract and aggregated information for the data of interest.

  ...suggested tasks

- Page sharing: Because additional data can be from any webpage, sharing them in between webpages are necessary so that users do not need to switch in between the opened windows. The data are to be updated and shared amongst the browsed webpages so that to provide the cross-referencing of information on the Web.

- Brushing: Macro level visualizations support the navigating for Web contents. But to aim the navigation, in some cases, brushing and linking the

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5 http://www.microsoft.com/silverlight/

data forth and back and explicitly in between the additional layers and the Web contents is a need.

Macro level visual supports on additional layer components provide flexible ways in displaying additional data and interacting with Web contents on existing webpages. In reality, they might be designed not separately, but in combination, or even blurred with visualizations at *micro* level when appropriate to completely support the different tasks of augmented Web browsing.

6.3   AUGMENTED BROWSING WEB SNIPPETS WITH GEOSPACE AND TIME

specific designs

The above discussions refer to the first step, the generic design. Now, we want to consider the second step, the specific design of visualizations and interactions with regard to a concrete augmented browsing scenario – especially the case of Web snippets linking with geospace and time.

Recalling the example situation presented in Section 6.1.3. Jane is surfing CNN website and notices an information stuff. Besides the existing contents on that webpage, she expects to see further data additionally presented onto the webpage to aim her in comprehending and better browsing the interested information stuff. The portion of Web content carrying the information stuff is here referred to as a *Web snippet* (in general, a Web snippet can be a selected portion of text, a hyperlink, an image, or other Web selections).

Now, supposing that Jane selects a portion of text, and with that text she wants to google for further data from the WWW. Through Google Search API[6], we can retrieve data in forms of a set of related records with timestamps (e.g., for a news record, Google returns the title of the related article, the URL, the publisher, a short descriptive text, and the timestamp in UTC time format, and other data – as seen in the use cases in Section 6.4.2). To this end, we provide in this design visual supports to show those googled data linking with time in forms of annotations – binding with the selected text at *micro* level (Section 6.3.1). In addition, we also design to support other tasks at *macro* level. In detail, we develop to support the navigating on additional layers, merging of data from webpages, sharing data amongst webpages, and brushing the additional layers with the existing Web contents (Section 6.3.2). Amongst them, placenames extracted from Web contents are geo-referenced data. And thus, both geospatial and temporal information are included in our visualization design.

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6 https://developers.google.com/web-search/

6.3.1 *Visual Supports at Micro Level*

When *selecting* hypermedia contents on an existing webpage, we need to indicate the selections on screen, e.g. by marking and highlighting them (such as the selected text "Tommy Robredo" in Figure 30a or the highlighted words "Tsonga" in Figure 30b). Based on the selection, further data can be combined such as the additional googled news with temporal information in forms of *annotations* so that to augment the browsing task.

In that regard, we create visual cues to be shown at *micro* level binding with the selected hypermedia items as follows. To visually communicate the time-referenced googled data, because the records are associated with different timestamps, we build a time plot (size 210×90 pixels) to present an overview of records distributed over time on the fly (Figure 30c). The horizontal direction indicates the timeline where the records' timestamps are normalized as time points in terms of dates; and the vertical one relatively expresses the number of googled records at each time point (noticing that the axes of the time plot can be adjusted or exchanged, depending on the designer's viewpoint). To avoid the cluttering of a complex encoding, by default we simply show only two labels to indicate the time period that the records appear on the timeline – at the beginning and at the end of the horizontal direction (such as "today", "five days ago", "a week ago", "a month ago", etc., depending on the googled data). If there is only one time point for all records, we show only one tick at the middle of the timeline. In addition to not showing many ticks (if there are) on the timeline, we also exclude the explicit axes on the visualization. However, through the blue line chart, users can still recognize the trend of records distributed over time.

visualization with time

Now, the user might want to see in more detailed which googled records are retrieved for the selected Web snippet. Thus, we support the user to interact with the timeplot to see the more data. When the user hovers on the timeplot, we calculate the mouse position for a relative time point, then show a vertical line with dots to indicate the relevant amount of googled records. Figure 30d shows a gray vertical line with no dot to indicate no record at that time point, while Figure 30e shows an orange line with three dots for three records. To this end, it could be hard for the user to distinguish the dots (especially in the case of having many dots). In addition, the user might also want to know the detailed record at the dot. Thus, we support the user in continuing hovering on the dot, which will be magnified, and then the associated record of interest is prompted as a pop-up annotation – which includes the detailed data returned by Google (Figure 30f). In that way, through interactions, the visualization supports showing additional googled data from the time-referenced overview to details on demand.

interaction for more information

(a) Showing the selection of the text "Tommy Robredo".

(b) Showing the highlightings of the words "Tsonga".

(c) Annotating for "Tommy Robredo" with a time plot showing the overview of the time-oriented googled data.

(d) Hovering on the timeplot to see the amount of googled records at a time point. The gray line indicates there is no associated record.

(e) Hovering on another time point to see the existence of some records, which are indicated by orange dots on the orange line.

(f) Annotating with an additional popup showing the detailed googled record of interest. The related orange dot is enlarged.

Figure 30: The specific design of visual supports at micro level.

6.3.2 *Visual Supports at Macro Level*

At the *macro* level, we provide visual supports for the *navigating* with additional layers, *merging* of data from webpages, *sharing* data amongst webpages, and *brushing* the additional layers with the existing contents on a current browsed webpage. There, the special consideration is that geo-referenced data, which are placenames from Web contents, are extracted and visualized on additional geographical maps.

For navigating with additional visualizations, the additional layers and visual components are created and attached onto any browsed webpage with regard to the tasks at hand. In particular, when browsing on a webpage and the user wants to google further data of interest, we provide a HTML layer attached directly to the webpage that carries the googled data. In that regard, the user doesn't need to switch to the Google site for the data of interest. We also support sharing the googled data amongst all opened windows on the Web browser. Therefore, similar HTML layers are created and attached onto all other open windows. The googled data are automatically synchronized if one of the open webpages updates its googled contents.

tasks...

We similarly provide another HTML layer component containing a rich text editor on the browsed webpage, and allow the user to select, drag and drop, and edit contents that she wants to gather (merge) from the webpages. The gathered contents are shared amongst the open Web windows.

Another important design is that we merge and show the abstract summary of Web contents on the additional layer. Through interactions, important words or placenames from text selections on a webpage are analyzed and extracted, and then visualized in terms of tag clouds (sizes of the words indicate their frequencies). To this end, the beautiful Wordle (Viegas et al., 2009) is employed as a graphical component in our design (through it is not a useful tag cloud as evaluated in Section 6.4.3).

visualization with geospace

The wordle of placenames gives hints for the geographical places mentioned in the webpage (i.e., the set of places and their different sizes – while colors are just for aesthetics). But for geographical information, it is more intuitive to be shown on geographical maps. Therefore, for each placename indicating a geographical location, it should be shown as a marker on the maps. Taking in mind that a placename might appear many times in the associated Web contents, we need to include that information on the maps as well. To this end, the visual solution proposed by Mahe and Broadfoot (2010) is employed. For each placename, we look-up its lat-lng coordinate, and present a marker with number (for the occurrences) and color at the relevant position on the maps (the default color setting is #6ECC39 for 1–9, #F0C20C for 10–99, and #F18017 for above 99). This solution also solves the matter that many markers for different placenames are too close together on the maps: within a square

maps and tag clouds

area (60×60 pixels) the markers with numbers are aggregated. The bounding area of the markers can be optionally shown (in blue) when the user hovers on the representative marker. Figure 31 illustrates the placenames in terms of map markers and their wordle.

So far we have provided supports for visual navigating, data merging, and page-sharing. Now the remaining task for brushing-and-linking is considered. With the just-mentioned design, visual components should communicate the relational information in between the maps, placenames wordle, and the existing Web contents. Therefore, they should be brushed-and-linked. We employ the mechanism affecting the associated data when the user moves and pans the maps. As an icon on the map is hover, besides the blue bounding area, related words on the wordle are kept for highlighting (other words are dimmed). When the user clicks on an icon marker or pan the maps, the maps views are refreshed, and the new marker icons and new wordle are updated. Besides, as the user hovers on a word of the wordle, associated words on Web contents are highlighted or visually linked through yellow straight lines. At that point, the visualizations provide hints about the places of the words in the contents so that the user is able to navigate to, e.g., by mouse scrolling the webpage.
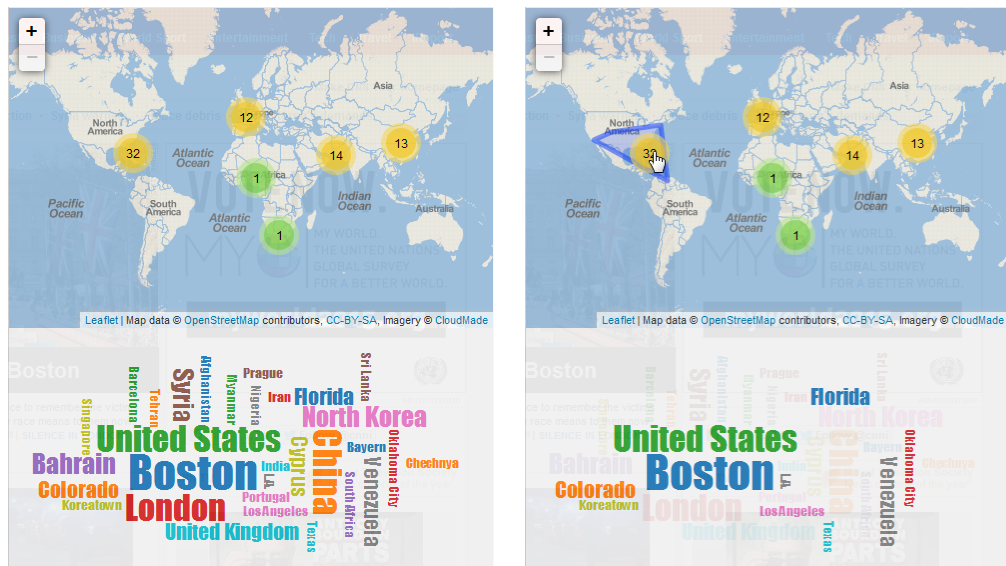
(a) Placenames wordle in association with map markers.

(b) As a marker is hovered, its bounding area is displayed (if having), and associated placenames are kept for highlighting.

Figure 31: The specific design of visual supports at macro level. The sizes of the words indicate the relative amount of placenames' occurrences, while their colors are just for aesthetics. The colors of map markers are: ■ for 1–9, ■ for 10–99, and ■ for above 99.

With the just-provided visual supports, we have presented the 2-step approach in designing visualizations and interactions to support augmented Web browsing. In the next section, we will realize the design with use cases on a real browser's add-on.

6.4 THE FIREFOX ADD-ON VIZME

VizMe is a Firefox add-on which provides visual supports for data and tasks added onto any browsed webpage in terms of augmented Web browsing. This section presents the implementation of VizMe with demonstrated examples.

6.4.1 *Environment*

VizMe is implemented as a Firefox extension on Firefox add-on builder[7]. It leverages standard Web technologies (including JavaScript, HTML, CSS, and SVG) and employs many open-source libraries and Web services to handle data at the client-side and visually communicates them on the screen.

Firefox add-on

INTERFACE   The interface and functionalities on VizMe are designed with common tools to broadly support diverse end-users. Thus, at *macro* level we provide with VizMe a main HTML panel togglable and shown with transparencies (Figure 32b). The panel is toggled through a button on Firefox's main toolbar (Figure 32a) or through hot-keys or context-menus (Figure 32e). Depending on the tasks, we show on the panel different visual components (Figure 32d), which are also selectable through the menus at the top of the panel (Figure 32b). The menus include: "Google" with "Web", "News", "Images", and "Videos" for googled data, "Edit" with a rich text editor, and "Visualize" with "Wordle" for tag clouds and "Places" for geographical maps. Through the panel, users can navigate with visual components, merge and share data, and interact to brush them with existing Web contents. And at *micro* level, VizMe supports showing timeplot and pop-up annotations close to specific Web snippets when they are selected and examined.

incorporating all designs discussed above

Now, everything can be accomplished with the supports of events managed by Firefox chrome, as illustrated in the following use cases.

6.4.2 *Use Cases*

Supposing that Jane is surfing CNN online. We support her to browse, google, and gather Web contents, as well as to interact with additional visualization

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7 https://builder.addons.mozilla.org/
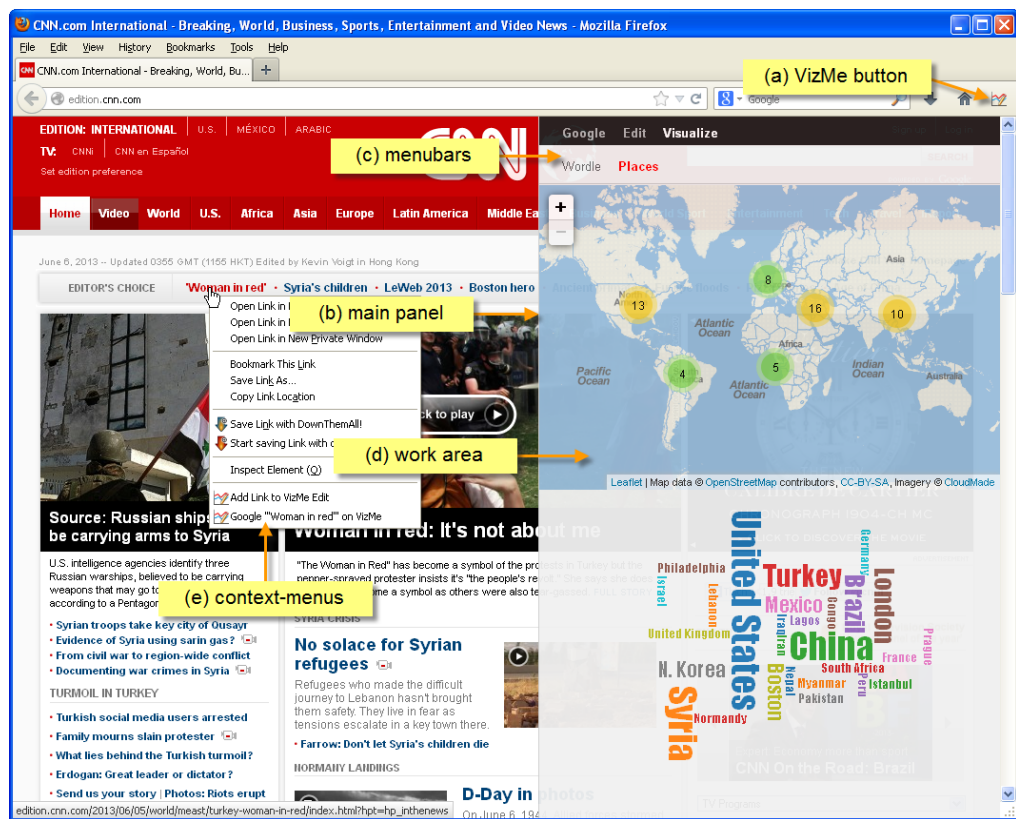
Figure 32: Interface components of the Firefox add-on VizMe. (a) VizMe button on Firefox's main toolbar, which is clickable to toggle on/off the main panel. (b) The main panel of VizMe contains (c) menubars on its top, and (d) work-area for visual components. (e) Context-menus (as right-clicking on Web snippets), provided for specific tasks.

components to explore data of interest – using the above-developed *micro* and *macro* level visual supports.

a. Mimicking Google Integrated as a Browser Extension

According to Pew Internet Research (2012), searching the WWW is the most common everyday activity on the Internet. People access Google, Microsoft Bing, Yahoo! or other search sites to find out their necessary data. Searching the WWW and the many other tasks supported by Google, in our opinion, if provided as browser's extensions, facilitate Web users in better *augmentedly* browsing the webpages as follows.

NAVIGATING WITH SUMMARY   Firstly, when Jane is surfing CNN home-page, it is expected that Jane has to skim all tips and headlines on the page to know what CNN presents at that time. It would be interesting if there is
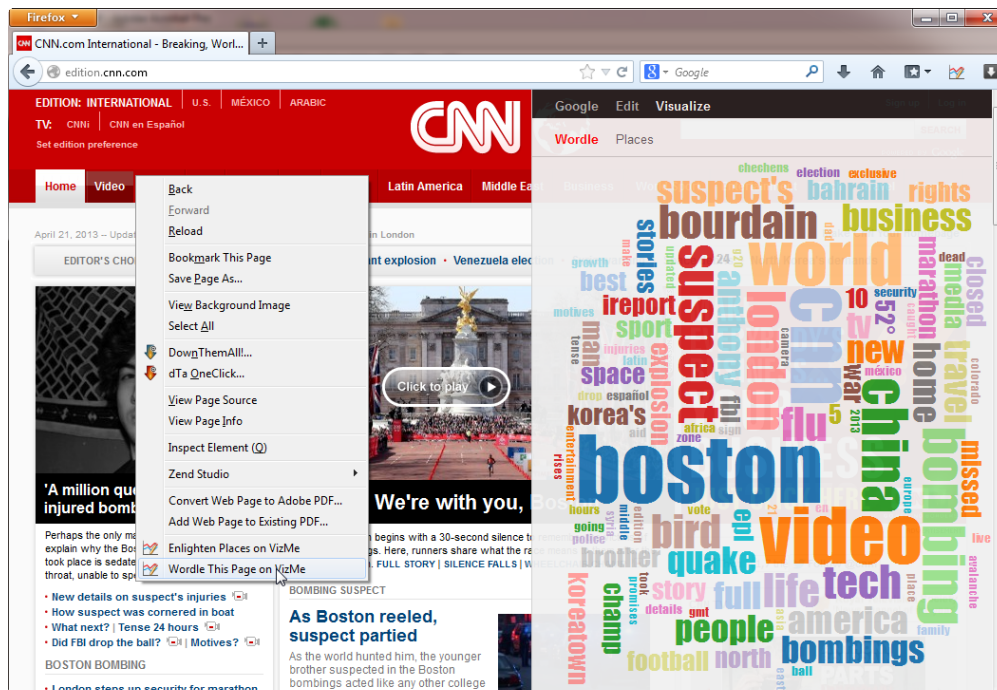
(a) Wordling CNN homepage through a context-menu.
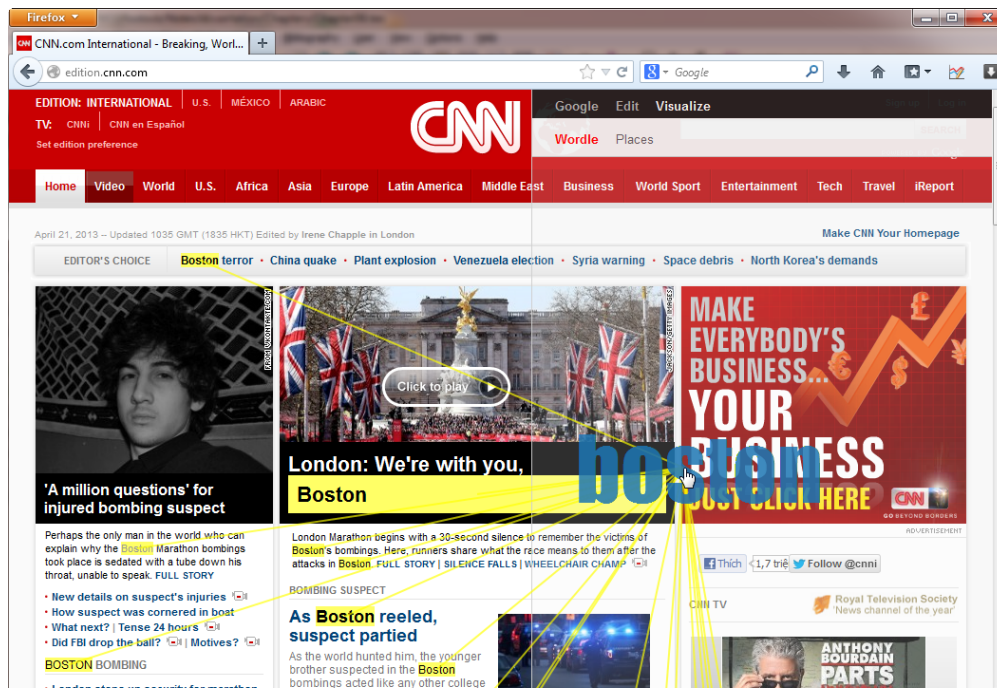
(b) Clicking word "boston" to see where on the webpage it refers to. Users can keep scrolling to any part of the webpage to link the word with the associated contents.

Figure 33: Wordling and showing the tag cloud with prominent words from CNN homepage on VizMe (accessed on April 21 2013).

a summary of all news in terms of a wordle as shown in Figure 33a to help her to have an overview about the contents of that page. In other words, as browsing any webpage, instead of reading the many words for necessary data, one might skim just prominent words in a wordle representation for useful information. At this point, we employ D3-Cloud library[8] for the implementation of the visualization component (*macro* level). Now, with the wordle created on the webpage, Jane can hover on each word to brush the associated highlight words on the webpage (*micro* level), and explicitly link to them on the webpage or navigationally scroll to relevant places on the webpage to access the detailed contents (*macro* level) (Figure 33b). The wordle is shown only on the associated webpage.

BROWSING GOOGLED DATA   One of the word on the wordle that Jane notices is "`flu`". By brushing and scrolling to the bottom of CNN homepage, Jane finds out an article entitled "`China bird flu case count rises`". Now, instead of reading the article, Jane wants to know more about "China bird flu". Thus, she `googles` "`China bird flu ...`" on VizMe through a context-menu.

various online Web services are integrated Figure 34a shows on the add-on panel (*macro* level) recent results responded by Google Search API. To this end, Jane can browse those related websites, google for more results, or skim the googled results for the information that she actually needs.

In the current implementation, we show on VizMe's main layer the Web, news, images, and videos Google search results. However, according to the available Google services, various facilities provided on official Google website can be missed in the tool.

The contents to be googled can be text selections, hyperlink texts, or image filenames selected from any webpage. For hyperlinks, the text string inside the `<a href>` is used, while for images, their file names are temporarily used. Different with the wordle that is strictly linked only to the associated webpage, the googled results are shared (*macro* level) in between the many browsed tabs. This will help users to keep the googled results for more explorations when accessing many webpages. In addition to that, users can also amend more text (e.g. from other selections or other webpages) to an existing search text.

MERGING CONTENTS TO EDITOR   As reading a webpage, Jane might want to collect contents of interest for further usages. Of course, she can copy and paste to Google Docs[9] or other document-editors. But, it would be more convenient if she collects them directly onto a VizMe interface layer, where she can later access them, e.g., visualizing with Wordle, or share on other opened webpages (*macro* level). Figure 34b demonstrates the contents from two differ-

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8 http://www.jasondavies.com/wordcloud/
9 https://docs.google.com/
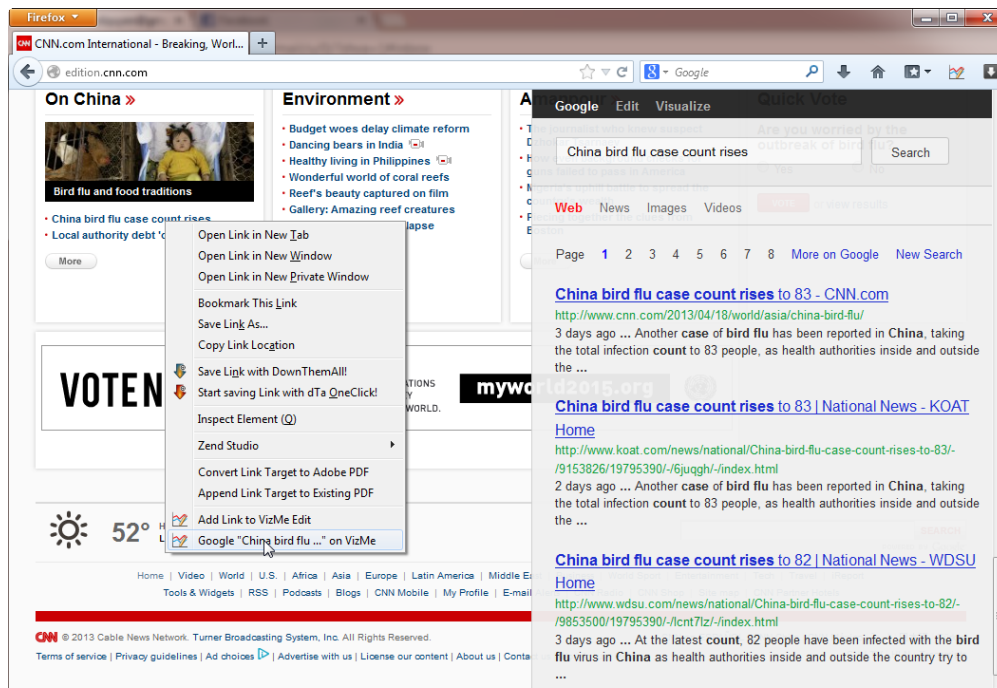
(a) Googling "China bird flu..." through a context-menu on VizMe.
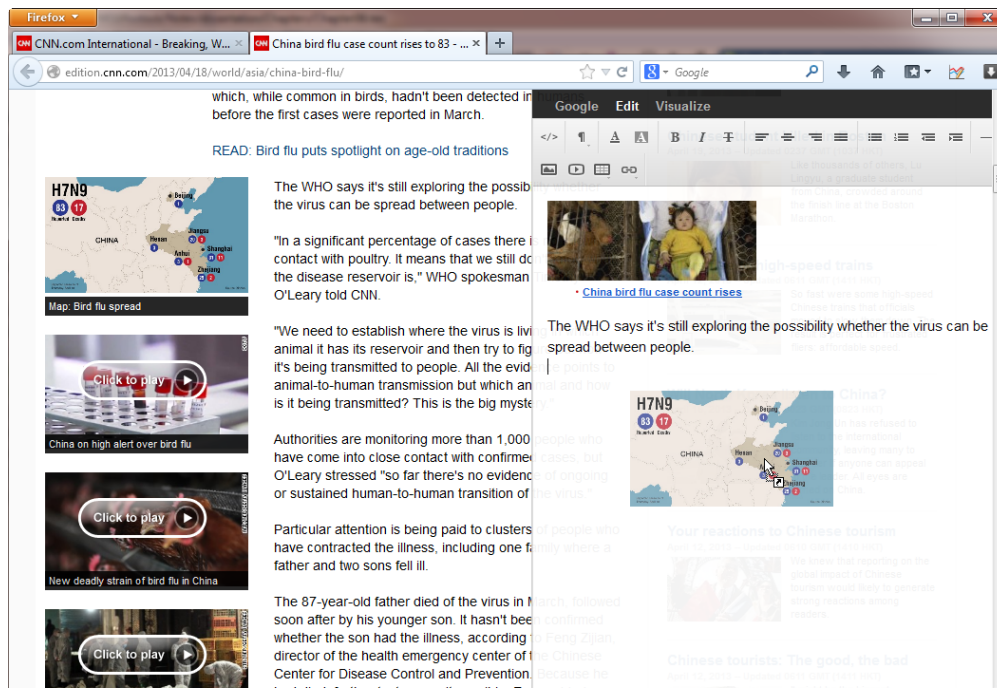
(b) Gathering various Web contents onto the rich text editor on VizMe. Here, the image "Map: Bird flu spread" is dragging and dropping.

Figure 34: Googling and gathering contents on browsed webpages with the supports of VizMe.

ent webpages that were selected and drag-dropped onto the rich text editor Redactor[10] on VizMe main panel.

b. Exploring Spatial and Temporal Web Snippets with Visual Supports

So far we have presented the demonstration examples where the mimic Google facilities are developed as Firefox extensions. Now we will go on with the examples concerning the visual exploration of Web snippets with geospatial and temporal references on webpages.

ANNOTATING WITH TIME-REFERENCED NEWS   Following the *micro* level visual supports designed in Section 6.3.1, we implement to show time-referenced googled news relating to a selected Web snippet under examination. Activating through hot key (default is the Shift key) and when Jane is selecting a Web snippet or hovering on a hyperlink, we retrieve Google search results and visually communicate them as annotations close to the Web snippet or hyperlink.

special consideration: geospace & time

Currently Google API v1.0 returns at most 64 records for each search. Most of them are recent Web resources (commonly within around one month) posted on popular news websites. Each of the record contains a title of the related article, its URL, the publisher, a short descriptive text, the timestamp (in UTC time format), and other data. In that way, we can easily compute the distribution of news records over time. We accumulate the records in terms of days, and show them as an overview time plot annotation.

Through interaction, Jane can explore for more details on demand, such as hovering over the time plot to see the number of records for each time point (day) in forms of dots on orange (if having) or gray (if not having) vertical line. She can also able to read the detailed googled data as hovering on each dot in terms of a pop-up annotation (Figure 35a), and click on the dot to open the full article on another Web browser tab (or window) following the URL.

NAVIGATING WITH GEOGRAPHICAL MAPS   Another interesting task in surfing webpages is exploring name entities from the Web contents. With current advancements on semantic Web, it is expected that important contents could be analyzed, extracted, and somehow displayed to the users. In this implementation, we employ Thomson Reuters Calais[11] to extract the name entities from Web contents, then get the placenames and visualize them on VizMe at *macro* level. Following the design provided in Section 6.3.2, we visualize the placenames as marker icons on Leaflet maps[12] together with a wordle visualization for the names of the places.

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10 http://imperavi.com/redactor/
11 http://www.opencalais.com/APICalls
12 http://leafletjs.com/
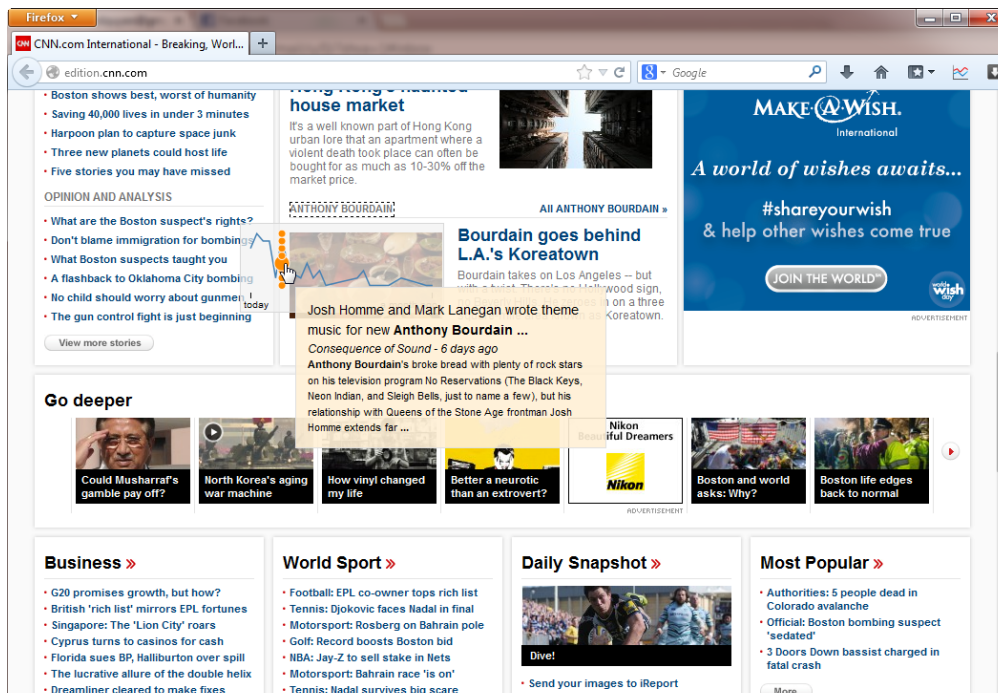
(a) Showing time-referenced news annotation for "ANTHONY BOURDAIN".
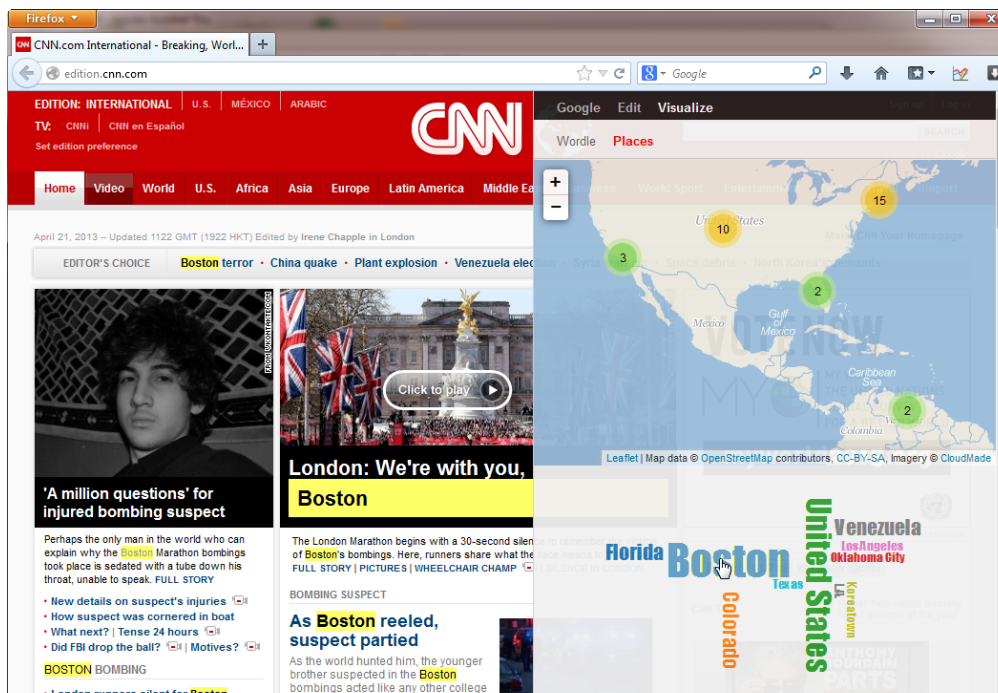
(b) Updating markers and placenames as the maps in Figure 30 change view.

Figure 35: Browsing time-referenced googled news and geographical placenames on CNN homepage (April 21 2013) with the supports of VizMe.

When surfing CNN homepage, Jane is interested in knowing which locations CNN is talking about. She uses VizMe to show the placenames on geographical maps and wordle. Recalling Figure 31, she easily know that most of the news on 04/21/2013 relate to America. By zooming and panning, Jane can explore details on demand the markers and placenames. For instance, she hovers and clicks on the marker numbered 32 to update the wordle of placenames and update the markers as map changes its view. Also, similarly to the functionality presented in the previous examples, any placename on the wordle can be hovered or clicked to link to the contents on the webpage (Figure 35b).

6.4.3 *Evaluation*

We conducted a user experience study to collect feedbacks for VizMe in terms of casual Infovis. Eighteen users (four females, ages 19–34 with mean of 24.7, familiar with surfing the WWW on a Web browser) were invited to test the add-on. We first introduced the add-on's interface and its functionalities (through the main panel, menus, and hot keys). Then the users freely and independently explored their webpages of interest with the support of VizMe.

The purpose of this user study was to evaluate user reactions so that to provide suitable clues for the realization of browser add-ons in terms of additional visual supports. Therefore, user's backgrounds and their responses were collected for the examination. After having browsed webpages with the support of VizMe, users were requested to rate the tool and to give subjective feedbacks. Based on them, we analyze and provide conclusions.

a. *Evaluation Criteria*

To evaluate VizMe, users' prior backgrounds were collected before the users tested the tool, as summarized in Table 3. In general, all of the users were familiar with browsing the Web, reading news, and searching the WWW (e.g., with Google), many of them sometimes gathered contents of interest from webpages (e.g., to Microsoft Word), most of them knew a Web-based geographical map (e.g., Google Maps); but many did not have good knowledge about tag clouds, and nearly all of them were novice in visualization design. Based on their informatics (IT) background, we divide the users into three main groups: U1 – six casual users (non-IT users), U2 – seven IT students (first year undergraduate students), and U3 – five workers with IT background or know simple visualizations (but none of them are visualization experts). Then, the users were invited to test all the tasks that VizMe supports:

T1 - Googling contents of interest on the main panel of VizMe.

T2 - Gathering and editing contents of interest on the rich text editor.

Background	Users (18 users)	Often (Familiar)	Sometimes (Basic)	Never (Unknown)
browsing the Web	U1 (6/18)	100 (%)	0	0
	U2 (7/18)	100	0	0
	U3 (5/18)	100	0	0
reading news	U1	83	17	0
	U2	50	50	0
	U3	80	20	0
searching the WWW	U1	100	0	0
	U2	100	0	0
	U3	100	0	0
gathering Web contents	U1	17	50	33
	U2	57	29	14
	U3	20	60	20
using a geographical map	U1	50	33	17
	U2	57	43	0
	U3	60	40	0
familiar with tag clouds	U1	17	50	33
	U2	0	71	29
	U3	40	40	20
know visualization	U1	0	17	83
	U2	0	0	100
	U3	20	60	20

Table 3: Prior backgrounds of VizMe testers (values are in percentage).

T3 - Exploring text summary in terms of wordle (a kind of tag clouds).

T4 - Navigating with geographical maps for placenames from Web contents.

T5 - And, interacting with the overview timeplot or pop-up annotations with regard to the googled data.

The tool was examined in terms of common user study criteria. Thus, each of the above T1–T5 tasks were rated (from 1 to 5 for very negative, negative, neutral, positive, and very positive, respectively) in terms of the five criteria:

C1 - Comprehensibility: Does the user feel that the tool is easy to comprehend?

C2 - Usability: Does the user feel that it is easy and efficient to get things done with the tool?

C3 - Utility: Is the tool important or necessary to the user?

C4 - Satisfaction: Does the user perceive the functions in the tool fit for the purpose?

C5 - Interest: Does the user see the tool attractive? Or wow experiences?

Noticing that to the users the tasks T1 and T2 are familiar as existing on common websites and applications, while tasks T3–T5 are quite unfamiliar or even strange, where information visualizations were included as designer's intention (tasks T3 and T4 were designed in terms of casual Infovis with geospace and time). If supposing G1 (common Web tools such as T1 and T2 and others) and G2 (novel abstract visualizations such as T3–T5 and others) as two main groups of expected tasks to be included in further development, we also asked the users which of the two (G1 and G2) must be the focus (i.e., higher priority). The answers were collected in terms of users' subjective responses. In addition, their responses regarding the impressiveness of the tool, its pros and cons, and other requirements were surveyed as well.

checking UX for both casual vs. expert users on both casual vs. pro visualizations

b. Results

The rating results are summarized in Table 4; and depending on users' subjective feedbacks, we come up with the following six conclusions:

R1 – VISUAL SUPPORTS IN BROWSER EXTENSION ARE EXTREMELY NEEDED
All users expected to have our add-on as a tool to support augmented Web browsing. Though the means of utility (criterion C3) of the different tasks (T1–T5) are not the same, all the tasks are important or necessary (above neutral (3.5–4.8)) to all the users (except the wordle visualization (task T3) for non-IT users (group U1) with the mean 2.5 and big standard deviation 1.64) (see also Figure 36a).

R2 – THE UTILITY OF THE TOOL IS MOST IMPORTANT   Because the add-on was developed in terms of casual Infovis, utility (C3), satisfaction (C4), and aesthetics (within C5) (recalling Section 2.2) were the criteria that we wanted to examine. The users told us that utility is the most important criterion which decides their ratings. In fact, when considering the evaluation criteria, we found from the results that the satisfaction (C4) and interest (C5) of the tool depend on the utility (C3) that the tool supports (while comprehensibility (C1) and usability (C2) differ a little bit with respect to the friendliness of the design). The more important or necessary a task that the tool supports is, the higher

Tasks	Users	Compreh.	Usability	Utility	Satisfaction	Interest
(5 tasks)	(18 users)	(means of ratings | standard deviations, ratings are from 1 to 5)				
	U1 (6/18)	4.67|0.52	4.33|0.52	4.17|0.75	4.17|0.75	4.67|0.52
T1	U2 (7/18)	5|0	4.57|0.53	4|0.82	4.14|0.38	4.43|0.53
	U3 (5/18)	4.6|0.55	4.6|0.55	4|0.71	3.8|0.84	4|0.71
	U1	4.83|0.41	4.67|0.52	4|0.89	3.33|1.21	4.17|0.98
T2	U2	4.86|0.38	4.71|0.76	4|0.82	3.71|0.95	4.29|0.76
	U3	4.8|0.45	4.8|0.45	4.8|0.45	3.6|0.89	4.8|0.45
	U1	2.5|1.05	2.83|1.47	2.5|1.64	2.17|1.17	2.17|1.17
T3	U2	4.57|0.53	3.57|1.4	3.57|0.98	3.29|0.95	4|1
	U3	4|1	4|1	3.6|0.89	3.6|0.89	4|1
	U1	4|0.63	3.83|0.75	3.5|1.05	3.5|1.05	3.5|1.05
T4	U2	4.71|0.49	4.14|0.9	4.14|0.9	3.71|0.76	4.43|0.53
	U3	4.4|0.89	4.6|0.55	4.2|0.84	4.2|0.84	4.4|0.89
	U1	4|0.63	4|0.89	4|1.26	3.5|1.05	3.83|1.17
T5	U2	4.43|0.53	4|1	4|0.82	4|0.58	4.43|0.79
	U3	4.6|0.89	4.6|0.55	4.4|0.89	4.2|0.84	4.4|0.89
overall rating		4.41|0.83	4.2|0.95	3.91|1	3.66|0.96	4.1|0.99

Table 4: Means and standard deviations of evaluation results for the add-on VizMe (1: very negative, 2: negative, 3: neutral, 4: positive, and 5: very positive).

satisfaction and interest the users gave (regardless their prior backgrounds) (e.g., taking a look on Figure 36b in comparison to Figure 36a).

utility of tools and tasks are important

R3 – THE UTILITY OF THE TOOL DEPENDS ON USER BACKGROUND   However, there are differences in rating the utility of the tasks (and their relative satisfactions and interests) in between the groups of users. Considering the statistics on user backgrounds (Table 3), we noticed that all users gave high rates ($\geqslant$4) for the tasks T1 and T2 since those tasks were familiar to them, but the tasks T3–T5 got lower rates especially from non-IT users (U1) who did not have much knowledge about visualizations.

This was more confirmative when we got users' subjective expectations for future developments. For the two groups of tasks to be supported (G1 - common functions and G2 - advanced functions with abstract visualizations), there were two trends of expectations. Most of users from group U2 and U3 (IT students or workers) told us that they expect both of the groups, and group G2

(a) Evaluation results in terms of *Utility*.

(b) Evaluation results in terms of *Interest*.

(c) Priorities for development in terms of G1: common tasks, and G2: new visualizations.

(d) Distribution of users' ratings in terms of *Impression*.
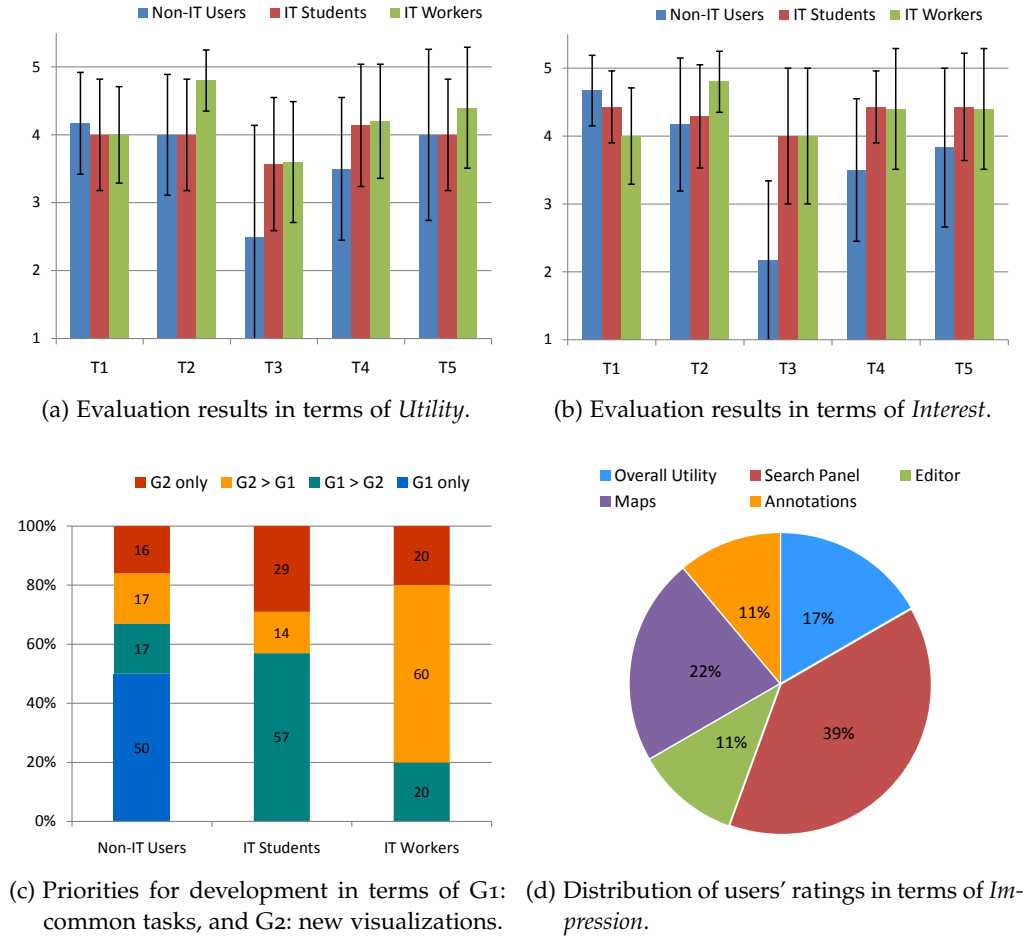
Figure 36: Visualizing the feedbacks of the Firefox add-on VizMe.

got high priority because they did not find them anywhere else; while to the users from group U1 (non-IT users), they mainly preferred to be supported with tasks from G1, and tasks from G2 are just options if available (see Figure 36c).

R4 – ABSTRACT VISUALIZATIONS MUST BE INFORMATIVE   When being asked what of the tool impressed them (no impression was also acceptable), all the users responded that the tool was impressive by the utility of the tasks that it supports. In details, three users were impressed by the overall utility, seven were impressed by the search panel (T1), two by the editors with drag-and-drop capability (T2), four by the maps (T4), and the remaining by the annotations (T5). In other words, the support for a common task (Google panel) got most impressive. Figure 36d shows the distribution of the impressiveness.

Wordle (T3) which is an abstract visualization got no impression (and with low utility as already discussed) though it looks aesthetics. This was especially indicated by the non-IT users. But for IT users, they said that the visualization of abstract textual contents must be valuable if it provides more useful information, such as those provided by the geographical maps (T4) or annotations (T5) (which already got good impressions).

R5 – CASUAL INFOVIS WORKS WELL FOR DATA + GEOSPACE + TIME   At this point, the special conclusion is that our work in visualizing *data contents + geospace + time* has been successfully accepted by diverse end-users. The tasks T4 and T5 were designed in terms of the thesis goal. Through the rating results (all means $\geqslant$ 3.5) and the total impression of 33 percent, we can say that many users – even they are novice – need, understand, and work well with casual Infovis techniques for geospatial and temporal data.

casual Infovis for spatiotemporal Web data

R6 – IMPROVEMENT   Though the add-on VizMe was impressive (100%), comprehensive (C1 with overall mean of 4.41/5), and usable (C2 with overall mean of 4.2/5), it was still not really satisfactory (C4 with overall mean of just 3.66/5 – the lowest mean amongst the five criteria). Various issues need to be fixed and improved with the following expectations:

- The main panel should be more flexible in auto-hiding, resizing, and rearranging. It is expected that the tool can auto detect user actions to intelligently show the panel, such as automatically toggling on the editor as the user begins to drag selected Web contents, and automatically toggling off the panel if there is no action.

- Displaying additional full webpage in association with a googled result under examination on a current browsed webpage for comparison.

- Improving the editor with auto-save (extremely useful if saved similar to Google Docs for logged-in users), while the gathered contents should be linked (bookmarked) with the related webpages for future access.

- Visualizing textual contents (such as text summary) with advanced computational linguistic functions (e.g., text searching, phrase visualizations, and so on).

- Annotating contents under examination automatically (i.e., without using hotkey), annotating with bigger and clearer visualizations. And multiple annotations for comparison is also a need.

- Finally, because many other tasks can be integrated, there should be options for the users to choose the tasks, personalize the functionalities, and support multiple languages.

6.5   SUMMARY

Work to support exploring diverse Web contents is a wide topic, with regard to the research on data analysis, information extraction, and visual communication. In this chapter, within the scope of a thesis, we provided solutions dealing with the visual communication of additional data with spatiotemporal references for augmented Web browsing.

By analyzing the working domain of existing webpages and the tasks to be supported, we discussed and presented a general approach on how visualizations and interactions should be built and provided onto any browsed webpage. We presented two levels of visual supports. At the *micro* level, additional data are communicated through the CSS styles or additional visual cues locally bound with particular hypermedia items. The visualizations communicates information and interactions only at the hypermedia, and are not necessarily affecting the context of the whole webpage or many webpages. At the *macro* level, we provided visual supports to communicate the data merged from webpages, shared amongst opened webpages, navigated, or brushed in between the additional data and the existing Web contents. The visualizations are flexibly attached and floated as HTML layers or graphical components.

We presented use cases mimicking Google facilities as Firefox extensions in searching the WWW or gathering contents on a rich text editor, and showing visualizations for the browsing of Web snippets with geospatial and temporal references. To represent time-referenced googled data close to the Web snippets at the *micro* level, we showed time plot with prompted dots and annotation popups. To communicate geospatial information at the *macro* level, we presented on geographical maps icon markers linking with wordle of placenames and brushing with contents on the webpage.

To this end, we have examined and developed techniques for the visual exploration of Web contents linking with geospace and time. They are successfully developed in terms of the motivation presented in Chapter 1 as well as the challenges mentioned in Chapter 3. In the next chapter, we will summarize the dissertation, present final discussion remarks, and propose open problems for future work.

7

CONCLUSIONS

> *The world is changing and the way we understand these changes*
> *is itself making new worlds.*
>
> — Dodge, Kitchin, and Perkins, 2009

The goal of this thesis, as motivated in Chapter 1, was to develop visualizations for the exploration of Web data in different types linking with geospace and time in terms of casual Infovis. Studying the features of various data contents and the tasks to be supported, we have developed several visualization techniques presented in Chapter 4 to Chapter 6. This chapter summarizes the contributions, lists the positive results as well as the limitations not yet tackled. Then, discussion remarks and future work are given.

7.1 THESIS SUMMARY

Chapter 2 presented that visualization is considered in terms of producing visual means and insights for interactively communicating with the data. Giving an input dataset, it is expected that visualization research is tailored for the selection, transformation, representation, and presentation of the data to get the useful *show-me*. In that regard, there has been being a lot of research topics. In the context of working with Web data (big data, with ca. 2.5 exabytes of new data per day), visualizations are expected to support *everyday users* – many of them are novice and non-experts – in better browsing and comprehending Web contents. And with that consideration, we identified the goal of this thesis: developing visualization techniques in terms of *Casual Information Visualization*.

visualization for everyone

Besides the existing research problems in casual Infovis such as aesthetics and usage contexts, casual Infovis in this thesis took the matters about *data contents + geospace + time* into account, where contents in raw forms are preferably included in the expected visualizations. The development of a technique relies on *what* and *why* we need the new visualization: which *data contents* are to be visualized and which *tasks* the visualization supports. The matters of data contents + geospace + time are the matters in terms that they are diverse, while the matters about the tasks concern the expected activities in supporting novice and non-expert users to *browse* the available data contents or *navigate* with visual means and *locate* the data on the Web.

to explore everyday Web data

In examining the availability and the integrability of Web data contents and geospace and time following the tasks at hand, we developed visualization solutions following the two generic directions: to support browsing, data contents are at highest priorities in the visual communication, while for navigating, overview of information has to be considered first.

Following the specification of those two directions in Chapter 3, we actualized them through the development of visualization techniques in the later chapters – from the specific ones as stand-alone techniques, to the general solutions for augmented Web browsing on existing webpages – as follows:

depending on data & tasks

TAGS + GEOSPACE + TIME   Chapter 4 dealt with user-generated tags, a simple type of textual data commonly found on the Web, such as collected from Flickr. We realized that, for browsing with a set of tags, that task if carried out in connection to geospace and time communicates meaningful information. Therefore, we developed to spatialize tags inside geographical areas to communicate their geo-references (Nguyen and Schumann, 2010), and added visual cues together with tags to communicate their temporal references (Nguyen et al., 2011).

The tool Tempo-Taggram was developed for the exploration of spatiotemporal Flickr tags. While tag clouds and geographical maps were straightforwardly accepted in a certain degree, additional visual encodings of time were still curiously questioned by casual users.

PHOTOS/VIDEOS + GEOSPACE + TIME   Chapter 5 dealt with another kind of Web data: pictorial contents, and the task about navigating on visualization of geospace and time to locate photos or videos of interest. Pictorial contents such as photos or videos were visually communicated at different granularity levels of abstraction, and they were combined so that to adapt the three Peuquet's situations: *what + when → where*, *what + where → when*, and *when + where → what* (Nguyen and Schumann, 2012, 2013a).

The tool PhotoTima was developed for the exploration of spatiotemporal Flickr photos. It was strongly accepted by casual users; and expectations for similar tools to explore video contents such as from Youtube emerged.

DIVERSE DATA CONTENTS + GEOSPACE + TIME   Lastly, instead of creating visualizations in stand-alone applications, Chapter 6 provided an approach for visualizations added onto any existing webpage in term of *augmented Web browsing*. We developed visual supports additionally added to particular hypermedia items or as flexible layer components attached onto existing webpages – where the both tasks of browsing and navigating with visualizations were supported (Nguyen and Schumann, 2013b).

The Firefox add-on VizMe was developed to support end-users in selecting and annotating Web snippets, googling Web contents, gathering and sharing contents of interest on the rich text editor, and brushing the visualizations with the exiting webpages. Similar to the previous techniques, we got positive feedbacks from the users. However, extra discussion remarks with regard to all above developments are to be included in this conclusion chapter to clarify the work in the research area of casual Infovis.

still problems not yet solved...

7.2 DISCUSSIONS AND FUTURE WORK

Following the just summarized solutions and techniques, this section presents the discussions to deal with the not-yet-solved problems and to open the challenges for future work.

ISSUES IN CASUAL INFOVIS   The thesis was carried out in terms of casual Infovis research. To develop the techniques, we followed the recommendations of Sprague and Tory (2012): to reduce costs at initial use, the relevance of data is important, while additional visual encodings are employed to achieve some goals of the techniques (even if they are just for curiosity). Then, depending on the tasks (such as browsing and navigating), the data are visualized in various ways. However, the tasks were specifically developed and used on demand. In a general view, we need to broadly study many tasks (browsing, navigating, searching, brushing, and so on) for a taxonomy of tasks carried out for Web contents.

In addition, the fact that casual Infovis regarding the issues of limited computing power, restricted bandwidth, small screens, etc. has not been taken into account. The issue of Web data with different levels of uncertainty (especially in connection with geospace and time) is also another problem. Therefore, further works for ideas and approaches in selecting, processing, and visualizing Web data in those conditions are also worth to focus.

tasks, usage contexts, and utilities

Another matter, we have conducted user studies which showed that the importance of our techniques concerns the utility that the tools support. However, our user evaluation studies have not been deeply performed (especially for the techniques Tempo-Taggram and PhotoTima). Those led to some suboptimal designs. Therefore, further user studies are expected, especially in a close connection to HCI issues for the diverse Web data + geospace + time. In that regard, the relations in between utility and aesthetics, data, and interactions (Lau and Vande Moere, 2007) should be particularly noticed, so that to arrive at further useful design guidelines and useful tools.

TYPES OF DATA CONTENTS   We have developed techniques for different data contents in different contexts. But there are many requests for further developments.

improvements needed

Regarding textual data, it can be said that tag cloud is a simple visual presentation. But for aggregated textual data, many relations between words, phrases, and other linguistic information can be considered for other types of visualization design. Further visualization techniques are expected to be developed, such as those similar to Collins (2010). Also, synoptic tasks for tags over geospace and time is also a challenging issue. In that regard, intelligent data analysis and other computational processing are to be applied, for documents and other spatiotemporal textual data on the Web.

For video data, the prominent type of multimedia. Due to the fact that dealing with video data is very complex with regard to the analysis and processing of pictorial, speech, and textual components. Visualizations for video data with geospace and time are therefore not limited to the design like in PhotoTima. Visualizations for videos need considerations in terms of not only their metadata, but also the results of computational analysis and intelligence for information in and between videos in collections. In that regard, casual visualization for video contents is another research challenge.

Additional, the huge amount of real-world data are available from diverse sources on the Web, such as from Yahoo!, Bing, TripAdvisor, and so on. They not only contain tags, photos, but also many other structural outputs such as stocks, weather forecasts, travelling tips, hotel bookings, and so forth. They are demanded objects for casual Infovis developments.

Finally, visualizations are challenged to be deployed in terms of augmented Web browsing so that everyone can easily use the tools and techniques. To provide a more general view on the concepts provided in Chapter 6, we need to tackle the problems not yet well-discussed (such as which types of information to be visualized at micro and macro levels, how to avoid the problems in providing (many) additional data, and so on). To arrive at that target, not only the research on visual supports and visualizations are needed, but also the advancement in Software Engineering concerning the development of browsers, data managements, and so on, is carried out, which is a wide topic for research as well as for industry.

BROADER VIEW FOR VISUALIZATION RESEARCH   In addition to the challenges about Software Engineering, visualization research for diverse Web data + space + time needs to be carried out in the interdisciplinary research manner. We need future work to be considered with regard to casual Visual Analytics, Ubiquitous Computing, and Web Science.

casual Visual Analytics

To deal with large amount of data, Visual Analytics is an on-going research trend in visualization. So, for casual visualization development, casual Visual

Analytics can be considered as a parallel promising research direction. In this case, user tasks in terms of Keim et al. (2008)'s *visual analytics mantra* are to be examined for casual usage contexts, data perspectives, and user communities.

"The commitment to pervasive or ubiquitous access for users as they travel reflects more than just technological challenges; it generates opportunities for novel services with temporal and geospatial requirements." (Shneiderman, 2007). In that regard, Web Intelligent and Casual Infovis in terms of pervasive or ubiquitous access for geospace and time usage scenarios is another interesting research direction.

To this point, future work should focus more and contribute to the research area of Web Science as well, because Web Science is considered as a recent interdisciplinary research field which shares many similarities to Human Computer Interaction (Hooper and Dix, 2013) (where visualization plays an important role). This means, further studies in casual Infovis are expected to be dealt with other problems in the scope of Web Science. For instance, to support Web users in exploiting the additional data (*what*) in terms of augmented Web browsing, further study for the interactions and linking (*how*) of Web contents and the visualizations can be considered such as following the work of Streit et al. (2012).

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THESIS STATEMENTS

1. Everyday, people work, study, and play with a lot of data. Visualization research has been being taken place to support people in better visually exploiting the data. In the context of everyday usage, where many people are novice and non-expert users, visualization research follows the direction of *Casual Information Visualization* (casual Infovis). This thesis aims at developing casual Infovis techniques for the exploration of data contents on the Web with a specific consideration: the data are diverse and are associated with spatiotemporal references.

2. Existing casual Infovis research mainly focuses on aesthetics, design, and usage contexts for visualization developments, whereas the issues about types and perspectives of data have not been seriously considered. Therefore, when taking Web data with *different types of contents* (tags, photos, videos, and so on) + *geospace* + *time* into account, we contribute to this research area in terms of data perspectives as a supplemental work.

3. Conventional Infovis typically focuses on visualizing aggregated data to support the analysis and discovery of insights. Casual Infovis, on the other hand, takes care about the visual communication of data in popular forms (such as presenting raw contents) so that the diverse everyday users can easily comprehend. However, when presenting data in raw forms, other visual cues and abstract representations are needed to foster users' tasks. To this end, there need solutions in compromising the raw data and abstract representations.

4. To support everyday users to explore everyday Web data, we are interested in two main tasks to be supported: *browsing* vs. *navigating*. Thus, two generic directions are proposed for the development of our casual Infovis techniques: to support browsing, raw forms of data contents get highest priorities in the visual communication, while for visual navigating (and locating the data contents), abstract and overview of information should be considered first.

   To this end, various techniques are developed in terms of the different *spatio-temporal data contents* and *tasks* at hand.

5. To support the *browsing* of user-contributed *tags* linking with *geospace*: Because tag cloud is the common visualization in presenting tags on the Web, visualizing tag clouds inside geographical areas communicates

their geo-references. The technique Taggram is developed for the interactive browsing of large set of tags (i.e., in raw forms) inside the arbitrarily-shaped areas in terms of a point-based labeling technique.

6. Additionally, visualizing time together with tags in a Taggram results the time-referenced Taggram. We provide design strategies in visualizing tags with time: visual cues are developed to encode time in terms of tag's appearance or additional artifacts bound with the tags. In that way, users can *browse* for tags linking with *both* geospace *and* time in the Tempo-Taggram technique.

7. Pictorial data such as *photos* or *videos* are other common data on the Web. To support the *navigating* and *locating* photos or videos of interest in collections, representing the aggregated data is a need. We develop the visualization technique PhotoTima for the exploration of photos linking with geospace and time: photo contents, geospace, and time are visualized at different granularity levels of abstraction. They are visually combinable to support the task of navigating with the overview of information in terms of the three combinatory situations: *what + when → where*, *what + where → when*, and *when + where → what*.

8. Webpages, where data contents are diverse, are interesting everyday data. Many visualization techniques on the Web are created as stand-alone applications and deal with the already-specified data. We, on the other hand, provide visual supports additionally added onto *any existing webpage* in terms of *augmented Web browsing*. In that regard, two levels of visual supports are developed: (1) visual cues and interactions are bound to particular hypermedia items to supports the tasks of *selecting* and *annotating*, and (2) visualizations and interactions are provided to support the *navigating* for data, *merging* data, *sharing* data on different webpages, and *brushing* data on the webpage. The tasks are accomplishable on demand. The Firefox add-on VizMe is developed in realizing the concepts with demonstrated examples for the interactions with Web contents, especially Web snippets with spatiotemporal references.

9. With user studies, it is shown that in order for everyday users to employ casual visualizations to explore common data contents on the Web, the techniques should provide good utility, while aesthetics can be the option in attracting the users.

DECLARATION

I hereby declare and confirm that this thesis was entirely the result of my own work except where otherwise marked and cited.

Rostock, June 2013

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RÉSUMÉ

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