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Design of Interactive Visualizations of Movies in Space and Time

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Abstract

Considered an important art form, a source of entertainment and a powerful method for educating, movies have the great power to affect us perceptually, cognitively and emotionally. By integrating various symbol systems like image, audio, and text over time, they are very rich. Moreover, technological advances are making a large amount of movies and related information available over the years, and these media are increasingly being created, shared and accessed from different platforms and devices, supporting georeferencing as a form to further enrich their context, in time and space. However, the richness that makes these movies so interesting and accessible comes with a challenging complexity, highlighting the need for new and powerful ways to access, browse, and view them.

Current navigation, search and access to movies happen mostly based on limited types of information, the applications that explore movies and videos do not fully exploit this potential due to the few dimensions they handle. Therefore, more and richer criteria of search, along with interesting and ludic visual aids are needed in order to help the user to manage and access this large amount of complex information. Interactive visualizations can help to handle this challenge.

Through a Practice-Based Research, and by following a set of systematic fundamentals of design, we provide new and easy ways to explore, navigate and access movies through spatiotemporal interactive visualizations that allow for both professional and ludic uses. Accordingly, we focus on the exploration of information about movies released over time, in a certain location (e.g., movies of the Drama genre that were released in 2011, in France), and the information that is waived in the contents by criteria such as those related with image, audio, speech, with a focus on emotions (e.g., colors, music mood, spoken words and the emotions felt by the viewer). We validate the design through an evaluation that had positive and encouraging results, and showed the strengths and weaknesses of the visualizations and, above all, contributes to the refining towards improved proposals.

Keywords: Design, Visualization, Interaction, Time, Space, Design-Based Research.

Resumo

Considerados como uma forma de arte importante, os filmes desempenham um papel fundamental no entretenimento e na educação, exercendo um grande impacto ao nível da percepção, da cognição e da emoção. Ao integrarem vários meios como a imagem, o áudio e o texto, ao longo do tempo, são muito ricos. Além disso, os avanços tecnológicos estão a tornar disponível uma enorme quantidade de filmes, e informação relacionada, ao longo dos anos, incentivando e permitindo que cada vez mais sejam criados, partilhados e acedidos a partir de diferentes plataformas e dispositivos, e que suportem georeferenciação como forma de enriquecerem ainda mais a sua contextualização, no espaço e no tempo. No entanto, a riqueza que torna estes filmes tão interessantes e acessíveis, tem uma complexidade desafiante, o que aumenta a necessidade de encontrar formas novas e eficazes de aceder, procurar e explorar este tipo de informação.

Actualmente, a navegação, procura e acesso a filmes baseia-se em tipos limitados de informação, e acima de tudo considera poucas dimensões. Assim, critérios de procura mais ricos e ajudas visuais interessantes são necessários para facilitar e enriquecer o acesso a este tipo de informação, e dado o campo considerado, de uma forma lúdica. A visualização interactiva pode ajudar.

Fundamentando a tese na prática do design, a partir de uma série sistemática de fundamentos que documentam todo o processo investigativo, desenvolvemos visualizações interactivas espacio-temporais para navegar e aceder a filmes, permitindo usos nos campos do entretenimento e profissional. Neste sentido, representamos informação sobre filmes localizados no tempo e no espaço (e.g., quantidades de filmes do género Romance que sairam para o mercado em 2011, em França) e a informação dos conteúdos por critérios relacionados com a imagem, o áudio, e o discurso, com um foco nas emoções (e.g., estado de espírito da música). Validámos o design através de uma avaliação que teve resultados positivos e encorajadores e mostra os pontos fortes e fracos das visualizações e, sobretudo, contribui para melhorar as propostas apresentadas.

Palavras-chave: Design, Visualização, Interacção, Tempo, Espaço, ‘Design-Based Research’

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1 Introduction

Movies play important roles in the arts, entertainment, and education. They have an immense power to affect us perceptually, cognitively and emotionally by combining diverse symbol systems such as image, audio, and speech.

The movie industry is very active, and advances in video technology are enabling the access to movies over the Internet, interactive TV and video on demand making accessible large amounts of movies and related information. Moreover, users generate, share and access these media from different platforms and devices and increasingly, video can be geo-referenced, allowing the enriching of its contextualization.

But all the richness that makes these movie collections so interesting comes with a challenging complexity to handle, movies are not structured and change over time, so perceiving and searching all the content of a movie is often not an easy task, and even more complex in the presence of large amounts of these media being published over time.

Current navigation, search, and access to movies are mostly done by linear displays of information. In the same way, applications that explore content properties are somewhat simplistic due to the few variables they handle when considering the richness of the movie contents. Therefore, more and richer criteria of search, along with visual aids are needed in order to help the user to manage and access this amount of complex information through interesting and ludic uses.

Having its roots in scientific reasoning, visualization has traditionally been viewed as an analytical tool for sense making (Viégas & Wattemberg, 2007) being its inherent aesthetic qualities associated with efficient performances.

The role of design in the HCI field and in particular in interactive visualization is undisputed. Personal logic and intuition are needed in the finding of the best strategies to represent information, and these activities are constituents of the design process (Bertin, 2010). Interactive visualization implies the communication of data visually while providing active experiences that involve reasoning and thus, by influencing perception, design shapes the user responses affecting their ability to perform the task.

Users commonly like to be aware of the evolution of data over time, and in discovering trends and patterns (Aigner et al., 2007; Silva & Catarci, 2000), even when precise and formal information is not needed. Spatiotemporal relations enable people to get insights about the data and moreover, visual experiences are “embedded in a context of space and time” (Arnheim, 1974, p.48).

The following projects served as initial inspiration for the interactive visualizations we present: *MovieClouds* (Martins et al., 2011), an interactive web application based on the *Tag Cloud* paradigm, that allows to explore and access movies through the information conveyed in their contents, mainly audio and subtitles with a focus on emotions; and *SightSurfers* (Noronha et al., 2012), an interactive web application to share, navigate and visualize geo-referenced 360° user-generated videos. Both applications were designed and developed in the context of research projects where our own work was developed: VIRUS and ImTV.

We follow a Practice-Based Research that intends to present, document, and apply the process to the design studies of spatiotemporal interactive visualizations.

In Chapter 1, we frame and contextualize the study throughout the issues that motivated the research, the goals, and the contributions to be achieved. In Chapter 2, we try to understand the way the user perceives images and the way they seek information in order to be able to better shape interactive visualizations toward efficiency. The representation of information through *Tag Clouds* and the way emotions are managed and represented are also in focus due to their presence in our own visualizations. We apply those concepts to design, and present a set of fundamentals that aim in shaping the spatiotemporal interactive visualizations that stand for the core of the resulting work of the thesis. In Chapter 3, we review the work done in the areas we also explored, related to time and space representations, the retrieval of information about movies, and the showing of movie contents. In Chapter 4, we present and discuss the design studies of the interactive visualizations in space and time that allow the navigation and access to movies, both collections, and contents, through accurate or casual uses. Chapter 5 focuses the principles applied in the design of the visualizations, going from the elements that constitute the interface, to the structure that organizes them, to interaction that allows the user to disclosure the various levels of information. In Chapter 6, we validate the visualizations through an evaluation that aims at testing the design in showing meaning, as an aid in guiding the user throughout the interaction and as navigations in user scenarios by casual and professional target audience. Finally, we reflect on the work done towards future developments.

1.1 Research Questions

It is our goal to ease, enrich, and make more ludic the access and navigation of movies, while taking the most of the richness waived by their contents through interactive visualizations.

- RQ 1: How can design be fostered towards efficient interactive visualizations of movies that consider the time and space components?

- RQ 2: How can the movie contents be explored, filtered and retrieved in order to be used either for professional and ludic purposes?

Throughout this research, guidelines that can help fostering the design towards the building of efficient interactive visualizations were provided, and interactive visualizations were presented. Collections and individualized items were contemplated, and among the properties waived in movies' contents (image, audio and speech) we explored geo-referenced information through location and trajectories.

1.2 Research Framework

Interaction design concerns a holistic view of the relationship between the composition artefacts, the user, and the context in which those appear (Fallman, 2008) being considered as a multidisciplinary field. This section provides the framework for our research options.

We follow Candy (2006) in her Practice-Based Research grounded on both practice as process, and the practice embodied in an outcome that is the design object. On the one hand, we intend to communicate the results through the empirical work that is the design studies, and on the other hand to contribute to knowledge, i.e., to demonstrate while discussing the fundamentals that inform our visualizations. As a model to guide interaction design research, we follow Fallman (2008) proposals. His model intersects three activities that are taken together and through which the focus of the work is positioned, throughout movements and tensions among activities. We consider the three activities as constituents of our research (Figure.1.1) and explain them next.

- **Design Studies**: the area of interaction design research that most resembles traditional academic disciplines, consisting in analytical work that goes from theory, methodology, history and philosophy of design, and that "seeks the general rather than the particular, it aims to describe and understand rather than to create and change (…) a cumulative body of knowledge" (Fallman, 2008).

Within this activity, it is our aim to deepen the main matters to have in mind in the design process, and they are: i) the processes of perception and cognition, in order to shed some light on the process of reading visualizations; ii) the design principles that concretely inform visualization and that result from the acquired knowledge.

- **Design Exploration**: involves the seeking for graphic solutions while trying to break existent paradigms. It embodies the question: "What if?" in an attempt to wide open possible courses for the empirical research. Aesthetics is the area of main importance in this activity allowing for discovering and asking questions.

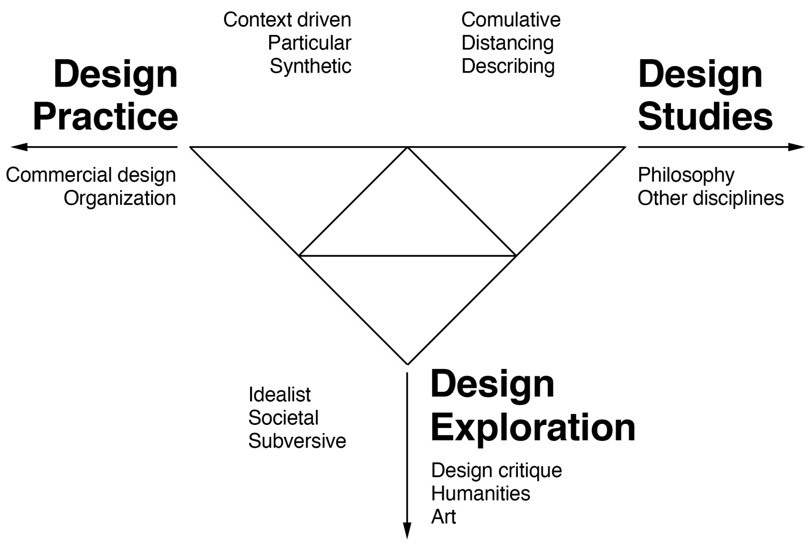


Figure 1.1. *Model of Interaction Design Research* (Fallman, 2008)

Relating to our own work, we aim to explore visuals in a way that it is possible to change ways of searching for information, from the commonly used word query through list, to richer, more interesting and ludic image-based representations. This step includes the arts in three ways: i) as an intuitive gear for visual innovation; ii) as a sum of theoretical considerations that follow perception-based psychology studies; and iii) through the info-aesthetics concept (Giannetti, 2005; Manovich, 2008; Quaranta, 2006) that influences the shape of visualization, as an artefact that embodies aesthetics with digital systems in the information-age the user is part of;

- **Design Practice**: intrinsically related with the market, i.e., constrained by its rules (e.g., budget), this activity concerns the shaping of the empirical artifact.

Basing the doing on the "competence, intuition, experience, and taste, in a complex conversation with the material" (Fallman, 2008) this activity relates to the outcome that are the visualizations of video collections and contents, in spatiotemporal dimensions.

The Model proposed by Fallman (2008) allows a more complex use through *loops*, *trajectories* and *dimensions* toward and among activities. We focus our approach on the strengths to stress in the activities that constitute the research process. It is our aim to enhance the *practice* as the activity that mostly reflects the functionality, usability and satisfaction of the user when interacting with the final outcome.

As a final step to the design process we trust on evaluation methods for a clear awareness of the efficiency of the visualizations (Carpendale, 2008; Frohlich, 2004; Giannetti, 2005; Kosara, 2007; Lam et al., 2011; Sack, 2011). The tests were conducted in a real context of use and based on specific tasks. A preliminary user study was conducted first, to evaluate some of the presented visualizations in terms of their usability, efficacy and strength as representation concepts.

1.3 Research Context

This project was developed with the support of Fundação para a Ciência e a Tecnologia (SFRH/-BD/51798/2011) through the UT Austin | Portugal Program; LASIGE, Faculdade de Ciências da Universidade de Lisboa; and NOVA LINCS, Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa.

The research has been developed at the LASIGE Lab, in the context and follow-up of two research projects: i) VIRUS, "Video Information Retrieval Using Subtitles", FCT project, with participation of research teams from LASIGEHCIM and XLDB Groups at FCUL, between 2010 and 2012; and ii) ImTV, "On-Demand Immersive-TV for Communities of Media Producers and Consumers", FCT UTAustin | Portugal project, with participation of research teams from NOVALINKS at FCT/UNL, INESC Porto, FCUL/LaSIGE/HCIM, UTAustin/USA, RTP, Zon, FCCN, Duvideo and MOG, 2010-2014.

1.4 Contributions

This section summarizes the main contributions of the research that are also reflected in the publications, demos, posters and presentations that took place during the PhD work.

1.4.1 Main Contributions

The research that was conducted has produced the following contributions:

- The development of the conceptual context that supports interactive visualization, from perception-based matters to those related with the way people seek for information.
- A set of design principles that may help peers in future work with interactive visualization.
- The conceptual and representational characterization of spatiotemporal visualization.

- A survey of the work that relates to the representation of data in interactive grounds, both related with the access of movies and videos by rich criteria, and with navigation through the properties that are waived in their contents.
- A set of design studies of spatiotemporal interactive visualizations for movie collections and contents, that allow the user to, i) relate and compare amounts of movies released over time, by genre and rating; ii) zoom in and detail the information toward the individualized movies; iii) compare various movies' contents by image, audio, speech, genre, title, and plot; iv) obtain details and complement information of each movie's contents by image, colors, motion, audio, speech and emotions; in the space dimension, v) relate and compare amounts of movies by genre and location; vi) detail the information considering one genre only; vii) compare amounts of movie trajectories by location; viii) zoom in and detail one area of interest by duration and date of the shooting; ix) navigate to one trajectory's contents showing its images, audio, speech and other videos that were shot in the neighboring area.

The following publications, posters and demo presentations were made in the context of this work:

1.4.2 Publications

- Ana Jorge, Nuno Correia, Teresa Chambel, "Designing Interactive Spatiotemporal Visualizations to Enhance Movie Browsing", in Proceedings of Interact2017, pp.352-355, Mumbai, India, 23-29 September, 2017. (CORE A)
- Ana Jorge, Sérgio Serra, Teresa Chambel, "Interactive Visualizations of Movies and Video Tours in Space and Time", in Proceedings of SciTecIN'15, Sciences and Technologies of Interaction Conference, pp.163-170, Poster, Coimbra 12-13 November, 2015.
- Sérgio Serra, Ana Jorge, Teresa Chambel, "Acesso Multimodal em Dispositivos Móveis a Vídeo Georeferenciado através da Forma, Velocidade e Tempo", in Proceedings of SciTecIN'15, Sciences and Technologies of Interaction Conference, pp.24-30, Coimbra 12-13 November, 2015.
- Ana Jorge and Teresa Chambel, "Visualizations in Time for a New Look at the Movies", Special Issue on Advances in Creative Interfaces and Digital Arts, International Journal of Creative Interfaces and Computer Graphics, 5(2), ISSN: 1947-3117, pp. 42-64, July-December, 2014.

- Ana Jorge, Sérgio Serra, and Teresa Chambel, ”Interactive Visualizations of Video Tours in Space and Time". In Proceedings of British HCI'2014, The 28th International British Computer Soiety Human Computer Interaction Conference: Sand, Sea and Sky Holyday HCI, pp. 329-334, Southport, UK, 9-12 September, 2014. (CORE A)
- Sérgio Serra, Ana Jorge, Teresa Chambel, "Multimodal Access to Geo-referenced Mobile Video through Shape, Speed and Time", In Proceedings of British HCI'2014, The 28th International British Computer Society Human Computer Interaction Conference: Sand, Sea and Sky Holyday HCI, pp. 347-352, Southport, UK, 9-12 September, 2014. (CORE A)
- Ana Jorge e Teresa Chambel, "Visualização Interactiva de Propriedades Temporais de Filmes". Interacção'2013, 5ª Conferência Nacional de Interação Pessoa-Máquina, pp.152-159, Vila Real, Portugal, 7-8 November, 2013.
- Ana Jorge and Teresa Chambel, "Exploring Movies through Interactive Visualizations". In Proceedings of BCS-HCI'2013, The 27th International British Computer Society Human Computer Interaction Conference: The Internet of things, pp. 1-6, London, UK, 9-13 September, 2013. (CORE A)
- Ana Jorge, Nuno Gil, and Teresa Chambel, "Time for a New Look at the Movies through Visualization". In Proceedings of Artech'2012 Crossing Digital Boundaries, the 6th International Conference on Digital Arts, pp.269-278, Faro, Portugal, 7-9 November, 2012.

1.4.3 Demos and Posters

- Ana Jorge, Teresa Chambel, “Interactive Visualizations of Movies’ Collections and Contents in Time and Space”, Poster, Ciência 2016, Lisbon Congress Centre, July 04-06, 2016.
- Ana Jorge, Teresa Chambel, “Interactive Visualizations of Movies and Videos Tours in Time and Space”, Demo and Poster, Program Achievements and Future Opportunities, Rectorate Building of New University of Lisbon Lisbon, Portugal, May 23-24, 2016.
- Ana Jorge, Teresa Chambel, “Interactive Visualizations of Movies and Videos in Time and Space”, Poster, presented at:
- Workshop Lasige-FCUL, Lisbon, Portugal, November 7, 2015 (Best PhD Poster Award).

- ICT 2015 Innovate, Connect, Transform, organized by the European Commission, together with Fundação para a Ciência e a Tecnologia, Lisbon, Portugal, 20-22 October, 2015.
- Ana Jorge, Teresa Chambel, "Interactive Visualizations of Movies and Videos in Time and Space", Demo, Fostering Science & Innovation Ecosystems: 1st Joint Conference and Exhibition, Poster, Portugal-USA Partnerships, Lisbon, Portugal, 28-29 May, 2015.
- Ana Jorge e Teresa Chambel, "Visualização de Filmes e Vídeos no Espaço e no Tempo", Demo, Open Day, Faculty of Science, University of Lisbon, Portugal, 23 April, 2014.
- Ana Jorge, Teresa Chambel, "Classificação e Visualização Interactiva de Filmes", Demo, Open Day, Faculty of Science, University of Lisbon, Portugal, 29 April, 2015.
- This demo was also presented to groups of students and teachers from high schools visiting the Informatics Department at FCUL, 3-4 times in 2015-16.

1.4.4 Presentations

- "O Design na Visualização de Informação", Ciclo de Conversas Design+Multimédia, University of Coimbra, April, 2016.
- "Interactive Visualizations of movies and videos over Time", Workshop UT Austin Portugal-M-ITI, Madeira, Portugal, June, 2015.
- "Visualização de Filmes no Tempo e no Espaço", Cultural Week in Superior Institute of Education and Sciences, Lisbon, Portugal, April, 2015.
- "Time for a New Look of the Movies through Visualization", SmallTalk, Faculty of Science, University of Lisbon, Portugal, October 13, 2013.

The publications on Interactive Visualization (listed in 1.4.2) at Interact 2017, SciTecIN 2015, British HCI'2014, Interacção'2013, BCS-HCI'2013, and Artech'2012, were also presented by the author.

1.5 Structure

The structure of this thesis presents seven main chapters. In the first one, we contextualize the work, framing the contributions we aim to provide. With the goal of establishing guidelines for the design of interactive visualizations, we position our work in terms of the research methodology, reflect on the research questions and report the work over time. In the second Chapter, we go through the fundamentals for the designing of visualizations. We focus on perception and cognition in an attempt for a consistent shaping of the design fundamentals, and narrow them toward spatiotemporal representations, approaching the specifics of *Tag Clouds* and emotions. In the third Chapter, we present work that mostly relates to ours, firstly addressing the presentation of information in time and space, and secondly, through work that allows both the watching and retrieval of movies, and their contents. In the fourth chapter, we present the design studies of the interactive visualizations that go from movie collections to contents, with temporal and spatial dimensions. In Chapter 5, we characterize and discuss the proposed visualizations in the light of the presented set of design principles and in Chapter 6, we present the evaluation of the interactive visualizations. Finally, we reflect, and conclude about the work done, and discuss next directions for future work.

2 Visualization and Information Understanding

Simple tasks are many times difficult to perform because users do not have the right tools to do them (Deacon, 1997, p.47). Graphic aids are needed in order to ease those tasks, and computers can help creating “new methods for amplifying cognition, new means for coming to knowledge and insight about the world" (Card et al., 1999, p.1).

Visualization started to mean the construction of an image in the mind but it is now commonly related with graphical representation of data and concepts maintaining though, a close relation to the mind due to its roots in research on visual perception and cognition (Few, 2009). It is stated that visualization makes information clear and eases the classification of large amounts of data, allows the discovery of properties, enables the immediate acknowledgement of problems, allows the identification of patterns, and facilitates the formation of hypothesis, thoughts and concerns related to the represented information (Ware, 2012, p.4). Therefore, the mind is compelled by visualization not only in the process of understanding information but when managing it towards a goal.

We aim in shedding light in the essential features that make interactive visualization an efficient way to communicate data, through the mind’s ability to capture and translate images (Damásio, 2010), and the way people browse and access information (Marchionini, 2006).

Design is disclosed in its main principles as ground for the presentation, understanding, and managing of the information. Time and space dimensions are in focus due to their specificities in the representation of information about movies. Aesthetics is inseparable from design, and therefore the collaboration from the arts is stated as contributing to visualization (Few, 2010; Lau & Moere, 2007; Mackinlay & Winslow, 2009; Paul, 2003; Viégas et al., 2004; Yang & Marchionini, 2005).

2.1 The Role of the Human Mind

> *I am not sure we are ever quite sufficiently surprised at our capacity to read images, that is, to decipher the cryptograms of art (Gombrich, 2000, p. 34)*

The most distinctive property of the brain is its ability to create maps (Damásio, 2010, p.55). The human brain maps all the things, actions and relations among objects outside itself, and in the body that holds it (p.55). Interactive visualizations are to be designed with this in mind. By focusing in perception and cognition we aim to understand the way the user perceives, and navigates through the information.

2.1.1 Perception and Reasoning

An analogy for a better understanding of the way the brain creates visual maps is in the electronic billboard constituted by a pattern, that is drawn by the active or inactive highlighted elements which state is easily and rapidly changed through the simple redistribution of those elements (Damásio, 2010, p.58). The reception of visual information is done by the retina, "an elaborate outpost of the brain" (p.58) composed by a grid, ready to receive those maps. According to Damásio, the particles of light (fotons) reach the retina with a specific distribution, making a pattern that activates the neurons that constitute a temporary neural map. Afterwards, additional maps will form from the original one built by the retina in the nervous system (p.58), going from simple to complex perceptive patterns (Arnheim, 1974) in a progressive disclosure of information.

The process of the mind is a flux of images corresponding some of them to the outside world that is being observed, while other are mental maintaining though a correspondence among each other (Damásio 2010, p.60). Both external and internal images are equivalent (Gombrich, 2000, p.84; Burnett, 2005) since they all start inside the brain and are constructed either when we are intending to act, or when we are acting already by the “mind’s theoretical eye” (Flusser, 1999, p.24). Mental images are schematic representations that we create and that enable us to make visual concepts in order to recognize patterns of information (Gombrich, 2000).

Schemas represent the shape of an object by its fundamental characteristics (Arnheim 1974, p.40). Humans have the ability to interpret and test the clues gathered through experience from the outside world, and recognize these configurations (Gombrich, 2000, p.276). We understand and are able to identify integrated patterns only, e.g., we apprehend a human face as a whole pattern composed by components as the nose or the mouth. If we decide to focus on someone's eye, we are again confronted with another total pattern composed by the circular iris surrounded by ciliated eyelids, and so forth. If we lose the context of each part in the whole, all parts will lose their meaning (Arnheim, 1974, p.78) since we expect to be presented with a specific sign situation, and prepare to cope with it (Gombrich, 2000, p.53). If a result deviates from what we consider possible, we revise our hypotheses and test it against a more accurate observation (p.272).

After the capturing of the structural shape of the object by sight, perceptive concepts are built in the mind through the maps that constitute memories. This mapping, - functional and useful for the managing of everyday life -, can detect the presence of an object in space as well as locating it, or give its trajectory direction, being these situations useful when assessing opportunities and risks (Damásio, 2010, p.55). These perceptive concepts, or mental models, have the power to provide predictive and explanatory understanding of the interaction between us and the world (Norman, 1986, p.46).

Susan Weinschenk (2011) refers Susan Carey (1986) and states that mental models are "incomplete facts, past experiences, and even intuitive perceptions" that help shaping actions and behavior, influencing what people pay attention to, and how people approach and solve problems. Toward design, they refer to the representation of something that a person has in mind, e.g., a device, and they appear from past experience with the device, or assumptions made about it, predicting what it is going to do relating to their expectations (p.73).

In order to achieve an appropriate concept model for the user to interact with the device, Norman (2013, p.31) suggests to gather as much information as possible, e.g., the shape of the device, the knowledge about the using of similar devices in the past, the sales literature, and all that can be read about it, information the author named as "system image". "A conceptual model is an explanation, usually highly simplified, of how something works" (p.25), and when built with consistency, systems are able to let the user explore them in a predictable way through past knowledge with similar systems (p.149).

After being aware of the mental model of the user, the designer can build the conceptual model to apply in the design of the system, in a way that its use is more natural and easy. A good conceptual model allows people to figure out errors and to correct them, being key to understandable and enjoyable products (p.32). "If there is a mismatch between the person's mental model and the product's conceptual model, then the product or Web site will be hard to learn" (Weinschenk, 2011, p.73). Built from conceptual models, metaphors are extended to motion, since people expect objects to move and behave in a certain way (Apple, 2015). It is thus preferable to go according to the user's expectations than going against them, being the latter case cause for confusion and disorientation from the user (Apple, 2015). And this is the reason why the way the user understands the world must be taken into account.

Mental models are not either accurate or complete, and evolve naturally depending on the past interactions of the user. Memory plays here a crucial role.

It is known our ability to see and hear what is no longer there by memory, by projection (Gombrich, 2000, p.172). Damásio (2010, p.224) states that we were born already with certain connection patterns arranged according to the instructions of our genes. According to him, after we are born our personal experiences act on those connection patterns. Thus, earlier phases overlap in the mind and are recalled when needed (Benzon & Hays, 2006; Gombrich, 2000, p.87). "The greater the biological relevance an object has to us, the more will we be attuned to its recognition" (Gornbrich, 2000, p.51).

In order to characterize memory, Norman (2013, pp.92–97) adapts Baddeley (2002) model and separates it in two major types:

- **Short-Term** or **Working Memory**: retains little amounts of information that are automatically retrieved without effort. Very useful when performing everyday tasks;
- **Long-Term Memory**: retained from past experiences, it takes time for information to be memorized.

When relating memory with cognition, i.e., in order to retrieve knowledge, people use (p.98):

- **Memory for Arbitrary Things**: with no structure, it allows people to retain items with no relation among each other, and no previous knowledge;
- **Memory for Meaningful Things**: relates items among each other, and among acknowledged things.

From here, cognitive and emotional processes work together in the brain in three different levels providing an idea about the way users behave (pp.49–54):

- **Visceral Level**: related with the immediate perception, it is associated to the subconscious being “all about attraction or repulsion”;
- **Behavioural Level**: connected with learned skills and thus subconscious, it is the most important level to assign positive results toward the expectations of the user;
- **Reflective Level**: belonging to the conscious level of cognition, it is where the user makes decisions through reasoning, and the level that drives them to recommend a product to use, or to avoid.

The designer should have in mind that the *three levels of perception* work in synchrony, shaping the response of the user in future performances. “Reflective memories are often more important than reality” (p.53), i.e., the user might start by having a great experience in the *visceral level of perception* and end up having problems when performing the task. The first emotional impact might override the latter though since “Attractive things work better”. On the other hand, the difficulties can also influence the final judgement from the user, although the first impression is the one that designers hope wins.

The images that compose the interface are the core elements in the design of visualizations by playing the ultimate role in the making of aids toward the execution of tasks by the user. They are tools, and function as the code that enables the user to discover information by embodying meaning.

2.1.2 Image as Code for Information

> *"All human communication is through symbols, through the medium of a language, and the more articulated is the language the greater the chance for the message to get through." (Gombrich, 2000, p.326)*

The science of signs originated in the 1920s, led to the idea of being possible to create visual communication according to scientific principles. The aim was to understand communication between humans and machines. Gombrich (2000) relates the act of reading pictures with the deciphering of a code through the *send-receive* message process. He highlights the pertinence on the beholder in interpreting the message, i.e., in 'supplementing' the partial information given the fact that all representative images are 'incomplete'.

The study of symbols evolved in two perspectives and although there is not a distinct border separating them, they can be described as follows:

- **Sensory symbols**: they are designed to stimulate visual sensory system and therefore they are naturally perceived. They are effective because they match neural processing (e.g., it is common sense to consider a circle as representing a bounded region) (Ware, 2012, p.12).
- **Arbitrary symbols**: they obey to conventions created by culture, and are therefore dependent of the user awareness about the 'imagetic' context (p.7), (e.g., a written word or a flag imply the memorization of those specific codes without which they cannot be understood). As learned, these associations "will tend to get weaker and weaker if some significant degree of co-occurrence of stimuli is not maintained" (Deacon, 1997, p.68).

Ware (p.15) highlights the importance of the latter, often created by designers through "perceptually valid forms". Principles such as those relating the 'concept' are of great importance since they help the viewer to understand the visuals, e.g., signs for airport procedures concern shapes and colors that serve as aid for their use, and thus, although built from conventions, they are based on perceptual skills, and therefore, "most visualizations are hybrids." (p.12).

Whether referring to *sensory* or *arbitrary* symbols, they function as metaphors by standing for something other than themselves. Unlike classical theories that refer metaphor as relating to language only, contemporary assertions consider it as a matter of thought (George, 1998, p.202). Lakoff and Johnson (1980) conceptualize metaphor as an embodied phenomenon belonging to the physical realm, i.e., grounded in bodily experience. They relate it with *gestalt* in the way that it is understood through the perception of the world (e.g., 'more' is 'up'). "Such metaphors are good candidates for universal concepts since they have such a strong physical basis" (p.201). People do not think in terms of logic but instead in terms of context and metaphors (Lakoff, 2013).

Metaphors must not be taken as a mental model, though. The latter represents the process through which a person thinks about how something works, and "A good way to take advantage of people's knowledge is to use metaphors" representing ideas that can help them understand new experiences (Apple, 2015).

2.1.3 Gestalt Fundamentals

Many assumptions related with the way we perceive objects in a composition were retrieved from Gestalt Theory (Arnheim, 1974; Gombrich, 2000), a body of scientific principles built by the founders of the Berlin School in the beginning of the 20th century that derived mainly from experiments in sensory perception (Arnheim, 1974, p.4). Max Wertheimer, Wolfgang Köhler, and Kurt Köffka explored relations, interactions, organization and structure among the elements of a composition, i.e., the way viewers "experience and organize their perceptions" (Sabar, 2013).

> *"In the essay that gave Gestalt theory its name, Christian von Ehrenfels pointed out that if each of twelve observers listened to one of the twelve tones of a melody, the sum of their experiences would not correspond to the experience of someone listening to the whole melody" (Arnheim, 1974, p.4).*

Most *Gestalt* principles are under a more general principle, the *Prãgnanz* law that stands for the tendency of human's perception to interpret a display by choosing the organization "that yields the simplest and most stable shape or form. Thus, simple and symmetric forms are seen more easily than more complicated and asymmetric forms" (Galotti, 2013, p.43). According to the theory, the visual system organizes visual information by grouping the elements in a way that they constitute a whole. Relations and interactions among parts "form and are formed by the organization and structure of the whole, i.e., the Gestalt" (Sabar, 2013).

We describe the most relevant Gestalt laws to consider in the design of visualization, being the first six specifically related with the grouping of elements.

- **Proximity**: the observer relates and understand as a group the items that are near from each other (Smith-Gratto & Fisher, 1999),
- **Similarity**: the observer relates, and understands as a group the items that are similar from each other (Smith-Gratto & Fisher, 1999),
- **Good Continuation**: perception tends to group objects with contours that form either a

straight or curve line (Galotti, 2013, p.43),

- **Closure**: an incomplete shape of a well-structured pattern is closed by the eye (Arnheim, 1974),
- **Common Fate**: elements that are moving together are perceived as being together (Galotti, 2013, p.43),

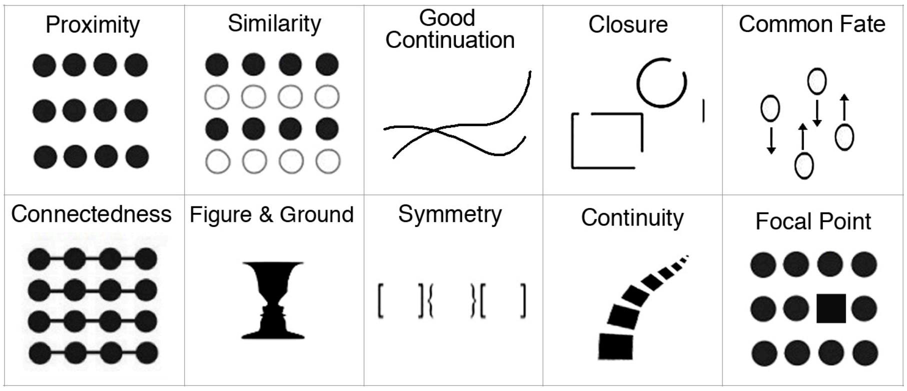


Figure 2.1. *Gestalt laws*

- **Connectedness**: considered as the most fundamental grouping principle by Smith (2007) refers the tendency of vision to perceive uniform and connected regions as singular units;
- **Figure-ground**: foreground and background recognition is a perceptive tendency. Flat two-dimensional pictures do not exist (Arnheim, 1974),
- **Symmetry**: the mind perceives visual elements as being symmetrical and around a center point. Perceptually, to divide objects into an even number of elements that are symmetrical is pleasant for the eye (Soegaard, 2010), and light for memory (Karlsen et al, 2010),
- **Continuity**: human eye instinctively follows a direction from its visual field (Chang et al., 2002).
- **Focal Point**: this place in the composition is automatically focused by perception as being the main “point of emphasis” (Chang et al., 2002).

Another model of perception is the *featural analysis model*, proposed by Irving Biederman in 1987 that is consistent with some of the Gestalt principles of perceptual organization. It relies on the segmentation of objects “into simple geometric components, called *geons*.” This theory seems more suited for perception of 3D objects though, which is not our focus.

Complex interactive visualizations gather large amounts of information and most of the time more than one level of information is presented. Effectiveness in the understanding of information is fostered by design that relies on the way the user perceives information, i.e., Gestalt principles.

2.1.4 The Seeking for Information

> *"Imagine a predator, such as a bird of prey, that faces the recurrent problem of deciding what to eat, and we assume that its fitness, in terms of reproductive success, is dependent on energy intake. (..) For the bird of prey, this means that the different habitats or prey will have different access or navigation costs" (Pirolli & Card, 1999).*

Pirolli and Card (1999) consider the seeking, gathering, sharing, and consuming of information by humans as a cultural task, which takes Hantula (2010) to characterize us as species as "informavores". From here and according to the authors, humans need "increasingly sophisticated information-gathering, sense-making, decision-making, and problem-solving strategies". Grounding their theory in the *Optimal Foraging Theory*, they developed a concept through which organisms adapt their structure and behaviour to the environment in order to maximise the foraging for food.

In accordance to this concept, people alter their procedures by modifying either the strategy, or the structure of the interface in order to enhance the finding of information. Pirolli and Card (1999) assume that people choose designs that improve returns on information foraging. Due to the amounts of information available, they see as a core problem of both information gathering and sense making, the allocation of attention. This theory highlights the layout structure as an important player in the role of enhancing the process of retrieving information, e.g., through "patches" of information, "clusters of task-related information" that reduce the effort of accessing the items of interest.

Grounded in the basic mental model categorized as vertical and lateral thinking by Bono (1990), the three-stage model from Marchionini (2006) (Figure. 2.2) characterizes the various ways of finding information:

- Lookup: relates to vertical thinking as a logical, goal-oriented, selective, and utilitarian establishing of the simplest path towards the problem solving. The user is seeking for specific information.
- Learn Search: enhanced by lateral thinking, happens in a search by neighbourhood of

interest, by comparison, comprehension and interpretation.

- Investigate: enhanced by lateral thinking, it aims in the evaluation of the results, and accuracy.

The latter two - *Learn* and *Investigate* -, constitute the *Exploratory Search*, considered an enhancer for insights, i.e., *serendipity* discoveries. It is a more generative and indirect way of finding information that promotes i) diverse thinking as opposed to the obvious one; ii) jump from reference to reference gathering the information in the final; iii) follow ways that look misleading at the beginning; and iv) alteration of the theme while searching (Bono, 1990).

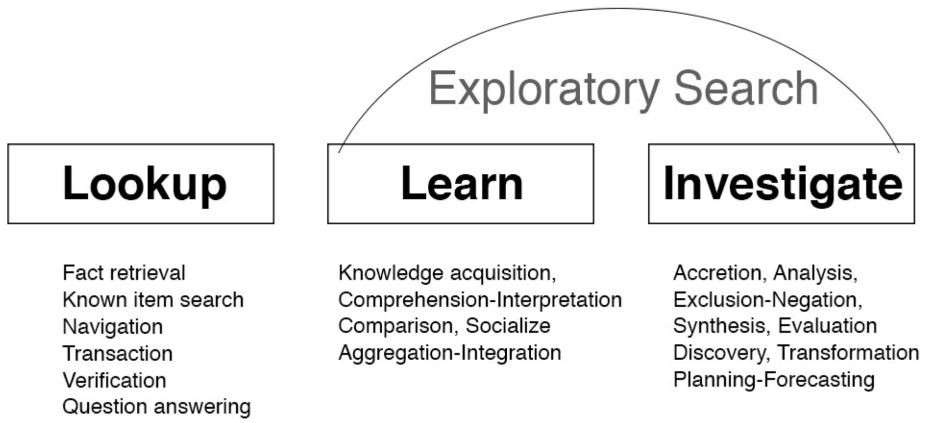


Figure 2.2. *Browsing Activities* (Marchionini, 2006)

When considering interactive systems, Marchionini (2006) considers *Lookup* as a “turn-taking” where the user seeks for information through a query and the system returns results, implying a process in which “human and system take turns in retrieving the best result.” *Learn* and *Investigate* search, imply more time spent in the search requiring more participation from the user toward exploration. The author emphasizes interactive information retrieval as a field that regards the search problem “from the vantage of an active human with information needs, information skills, powerful digital library resources situated in global, and locally connected communities.”

2.2 Shaping Visualization by Design

Design is the construction of artefacts by humans as the making of aids, as the creation of artificial substitutes (Gombrich, 2000; Flusser, 1999; Deacon, 1997) as an addition of art plus technology, i.e., holding both aesthetic properties and the code as the process of doing it (Flusser, 1999). Designers are planners with an aesthetic sense (Munari, 2008, p.29). Design and aesthetics are thus intrinsically related being their role considered as key to the success of an efficient interaction between the user and the system, in the way things work and can be controlled (Norman, 2013).

2.2.1 The Role of Design

Design is intrinsically related with technology and art (Flusser, 1999, p.17) as a "a kind of mediator between action and man" (Barthes, 1994, p.181).

Alberto Cairo (2013) sees visualization as a tool for its role in communicating with the readers, and by allowing them to analyze what is presented to them (p.73). It shapes information in number and in complexity, by reducing large amounts of 'data' to the smaller number of categories of information possible (Bertin, 2010, p.xiii). Being a tool that amplifies cognition through abstract and generalization concepts (Thomas & Cook, 2006), reasoning is the idea of visualization (Tufte, 2015).

Although interactive visualization had been considered within the HCI field for a long time, the role of design in visualization is now undisputed. According to Bertin (2010), both personal logic and intuition are needed in order to manage the best strategies to represent information, and these subjective characterization belongs to the design realm. One might think that the use of a computer is enough to simplify information but "the most important stages are not those that can be automated, but in fact those preceding and following automated processing" (p.xiii). Accordingly, Manovich (2010) characterizes visualization "as a mapping between discrete data and visual representation", and states that not only the core idea of visualization has not been changed by the appearance of computers, also the basic visual language given by points, lines, rectangles, and other graphic primitives remains unaltered.

The role of design in shaping visual representation is two-folded:

- communicate and persuade through data visuals (Mackinlay & Winslow, 2009) by presenting information "in a comprehensive, usable, and effective manner" (Zimmermann, 1997), and to express structures visually (e.g., the underground map), being the latter defined as "Information Design" by Manovich (2010),
- allow the user to think in an active experience that involves the answering of questions (Mackinlay & Winslow, 2009) and a provider of awareness of structures defined by Manovich (2010) as "Information Visualization".

Both roles overlap, when "Information is the interface" (Tufte, 2015).

The experience of the user when performing the tasks must be taken into account by the designer since although users might be taught how to interpret a display as well as how to use an interactive device, it is the latter that has to "ensure that the techniques given to the users can prompt insights and foster reasoning" (Andrienko et al., 2011). When referring to movies, Daniel and Chen (2003) and Hauptmann (2005) have stressed the importance to develop methods to extract and highlight interesting and meaningful features of these media.

2.2.2 The Role of Aesthetics

> *"[D]esign choices influence perceptions, elicit different responses, and affect a person's ability to complete a task. When we talk about a button or a typeface, the focus should be on the effect of these objects, not the objects themselves. This is the domain of aesthetics" (Anderson, 2011, p.18).*

It is common sense to define aesthetics as to something beautiful and pleasant for the eyes, and to relate it with art. We take Gaviria (2008) statement in order to clarify the distinction between them: "While the concepts have some commonalities, Aesthetics is concerned with the theories of sensual perception, while art is a social practice involved in certain forms of research and investigation processes, and in the construction of particular types of artefacts". And thus, aesthetics might be found in a work of art while the inverse does not apply.

Aesthetics is central to the design of artefacts and therefore it is imprinted in the information culture in which we live. Manovich (2008) denominates *info-aesthetics* as the reflection of the way we live on the objects we use, as the way we communicate and interact with, in visual conventions (e.g., icons and folders), in the particulars of the media (e.g., shape, material, and texture of a mobile phone), and in the fact that these devices are part of people's lives.

Thought about and related with information (Domingues, 1997; Giannetti, 2005; Manovich, 2008; Sack, 2011; Salem & Rauterberg, 2005; Tufte, 2006), aesthetics reflects the "informationalization" that puts pressure on society "to invent new ways to interact with information, new ways to make sense of it, and new ways to represent it" (Manovich, 2008).

More and more attention is being given to aesthetics in the creation of interactive visualizations. Even if it is still considered by some as a distraction during the performance, it is mostly viewed as able to captivate users' attention (Gaviria, 2008) and foster the engagement of the user. The way they feel influences the use toward the accomplishment of a goal (Norman, 2005) in the idea that "Effective is often affective" (Mackinlay & Winslow, 2009). On the one hand, aesthetics makes the product appealing for the user to have the intention to start using it (Kurosu & Kashimura, 1995) and on the other hand, it motivates people to spend more time using the system, while more forgiving when errors occur (Moere & Purchase, 2011).

The look and feel when using a, e.g., web site is much more influential in its credibility than structure, usefulness of the information, tone of the content, and name recognition (Anderson, 2011, p.24). Several studies give aesthetics the merit of being the most cited factor for the evaluation of the credibility of a web site, through the appeal of the overall visual design including layout, typography, font size, and color schemes (Fogg, et al., 2002). In another study from Sauer and Sonderegger (2009), in which teenagers were presented with two different mobile phones regarding their attractiveness, the visual appearance of the most attractive mobile phone had a positive effect of the performance. Kurosu and kashimura (1995) and Tractinsky (2004) complement the findings, stating that not only the time users take to finish their tasks but also the actual performance are fostered by the visual characteristics the device.

Arnheim (1974, p.2) states, “The particular qualities of the experience created by a Rembrandt painting are only partly reducible to description and explanation. This limitation, however, applies not only to art, but to any object of experience”. Grounding his knowledge in Gestalt theory, the author discusses perception by paralleling the artist and the “common activity of the eyes in everyday life (p.5). “All seeing is in the realm of the psychologist, and no one has ever discussed the processes of creating or experiencing art without talking psychology” (p.3). Aesthetics directly influences the user’s performance toward an interactive visualization.

The whiteness and lack of decoration of Apple design is the paradigm that characterizes the current *simplicity* trend that shapes the design of today. Subjective as it is, *simplicity* allows the observer to feel “no difficulty in understanding what is presented to him” (p.55). It must not imply minimalist style though, since the aim of design is to achieve rich and understandable data despite its complexity, as a balance (Maeda, 2006), by concentrating on the essential aspects while letting out the non-essential elements (Lovell et al., 2011). Also Nielsen (1999) refers in *Aesthetic and Minimalist Design* the exclusion of irrelevant or not needed information in order to not diminish the visibility of relevant units of information. Tufte (2001, p.96) goes accordingly, defending that unuseful graphic elements can misguide the awareness of information by the user, and (Mackinlay & Winslow, 2009) argues that the layout must be the ’whiter’ as possible, as an aid for understanding.

The designer must have in mind though, that *complexity* is a value (Maeda, 2006) and that the omission of an element in the composition might turn a shape into a more complicated element (Arnheim, 1974, p.145). Information must be preserved (Maeda, 2006), and the real challenge is to tame complexity (Norman, 2005) by dealing with its subjectiveness, e.g., the cockpit of a plane is not complex for the pilot but it is very complex for the average person, therefore, he argues "Forget the complaints against complexity; instead, complain about confusion" (p.4). People prefer a little amount of complexity since things that are too simple are viewed as dull and uneventful and moreover, continues Norman, subjectiveness is also in the fact that complexity gradually diminishes throughout the use.

Maeda (2006) explores the idea of improvement through simplification by establishing ten laws:

1) Reduce: Shrink, Hide and Embody elements in the composition (see Interaction in this section).

2) Organize: when well organized many elements appear fewer.

3) Time: saving in time feels simpler.

4) Learn: knowledge of the system simplifies tasks.

5) Differences: duality between simplicity and complexity is needed.

6) Context: periphery is not to be neglected.

7) Emotion: the more emotions the user can feel, the best.

8) Trust; simplicity reflects trust.

9) Failure: some things are not to be made simple.

10) The one: take out the obvious and add the meaningful.

Simplicity is related with memory for it prevents the short-term memory load. The number of items that can be memorized by the user is subjective although its limitation in number should be achieved, allowing for recognition rather than recall (Nielsen, 1999; Shneiderman et al., 2009). After conducting a series of studies on human memory and information processing, Baddeley (1994) suggests that the magical number is four, and Weinschenk (2011, p.48) goes in the same direction and states "people can hold three to four things in working memory as they aren't distracted and their processing of the information is not interfered with".

Weinschenk (2011, p.65) segments memory load on a user in three basic types: *cognitive* (including memory), *visual*, and *motor*. The first two are the loads that the designer aims more in reducing although there is always a trade-off, i.e., added functionalities imply more complexity in the use of the system, but it might be worth the cost if they are functions that the user is willing to try. For *Motor*, the author states that by using Fitt's law, the design, e.g., to either gather or separate two buttons in the composition, their relation in terms of use has to be to considered. Although designers aim in reducing memory loads in the user, especially cognitive and visual, sometimes it is the contrary that is intended, e.g., for the product to catch the attention of the user it is necessary to add visual information to the composition, which will increase the visual load.

It is interesting to note that people understand and remember depending on their past experience (p.36), and towards simplicity, the user chooses strategies that help memory, e.g., “chunking” information together into groups according to *gestalt* principles of perception. “Instead of having to remember 10 separate numerals, a phone number has three chunks with four or less items in each chunk” (p.48). On the other hand, *words and images* are processed through different systems and when gathered in the same composition, the two code systems ease the retention of the information by the user (Mayer, 2009). It is therefore an advantage to consider the distribution of information through both words and images.

2.2.3 Designing for Function, Usability and User Experience

Tufte (1990, p.10) states that principles of information design are “universal like mathematics”, but setting guidance for the design of interactive visualization is not an easy task. Cited by Maeda (2015), the designer Paul Rand (1914-96) relates the design activity with intuition, concluding that it cannot be taught, and accordingly, Krug (2006, p.7) states design “is a complicated process and the real answer to most of the questions that people ask me is “It depends””. Design reasoning happens unconsciously (Moere & Purchase, 2011), resulting from years of training and practical experience, being difficult to describe or quantify (Agrawala et al., 2011; Moere & Purchase, 2011).

Nevertheless, design principles are argued to be powerful tools for good design to be achieved (Krug, 2006, p.7; Norman, 1986) as visual designers manipulate perception and cognition by applying principles of good design (Agrawala et al., 2011). They can “explain” how to use visual techniques in order to emphasize or otherwise lower information details, e.g., in a subway map, the most important information and thus the information to be emphasized is the sequence of stops over each line, whereas the true geographic path of the lines is to be disregarded by the designer (Agrawala et al., 2011). These principles are generalized abstractions that orient designers (Rogers et al,. 2011, p.25), being “derived from a mix of theory-based knowledge, experience, and common sense” that provide the “dos and dont's of interaction design” (p.26).

It is important to note that there are no final solutions for the design, as design principles are instead ‘triggers’ that provide features to be used in the design of the interface, being the most known design principles related to “what users should see and do when carrying out their tasks using an interactive product” (p.26). Moreover, while design principles can improve the design process, they also explain the chosen options towards the resulting outcome. According to

Moere and Purchase (2011), “Although the number of sophisticated and novel information visualization techniques is increasing, little is known about the design reasoning behind the best practice exemplars, that is the mindful rationale that drove their design decisions.” and they conclude stating “Sharing such integrated approaches to design can benefit future visualization designers, who can be guided by understanding how good visualizations are best created, from conceptual decisions such as why a specific visual structure was chosen to apparent trivial choices regarding fonts or Colors.”

And this is our goal: to present a set of guidelines that can be of help to peers. Firstly, we address the grounds under which principles must lay by discussing function, usability, and user experience. From here, we name and characterize the design principles that inform and enhance the contents that compose the interface, the structure that supports them, and interactivity as the way for the user to navigate throughout the system.

Graphic design shapes interactive visualization through the graphical elements that compose the layout, the structure that frames them and the colors that enhance communication, attractiveness and engagement. Reasoning and decision-making are demanding challenges for the designer to handle when building interactive visualization.

The proposed principles aim in enhancing design toward function, usability and user experience, three main purposes to have in mind when creating interactive visualizations. On the one hand, “usability is fundamental to the quality of the user experience and, conversely, aspects of the user experience, such as how it feels and looks, are inextricably linked with how usable the product is” (Preece et al., 2015, p. 19). Not only function is to be taken into account, joy, excitement, pleasure and fun, combined with beauty, are central for the use of a product (Norman, 2004).

The field of Human-Computer Interaction used to stress interaction primarily through effectiveness measured by usability, understanding, the number of errors, and the amount of time required to complete a task, but this focus is now changing toward emotion and aesthetics (Norman, 2004). According to the author, “usability and understandability are never goals – they are means toward the goal. Pleasure, happiness, fun, on the other hand, can be goals”.

Good usability optimizes the interaction people have with products by ensuring that the product is effective to use (effectiveness); efficient to use (efficiency); safe to use (safety); having good utility (utility); easy to learn (learnability); and easy to remember how to use (memorability) (Preece et al., 2015, p.19).

The user experience is the way people feel about a product and their pleasure and satisfaction when using it. The authors point out, though, that it is not possible to design *a* user experience, but only design *for* a user experience, i.e., "one cannot design a sensual experience, but only create the design features that can evoke it" (p.12). The "great experience" demands that the user care" (p.11).

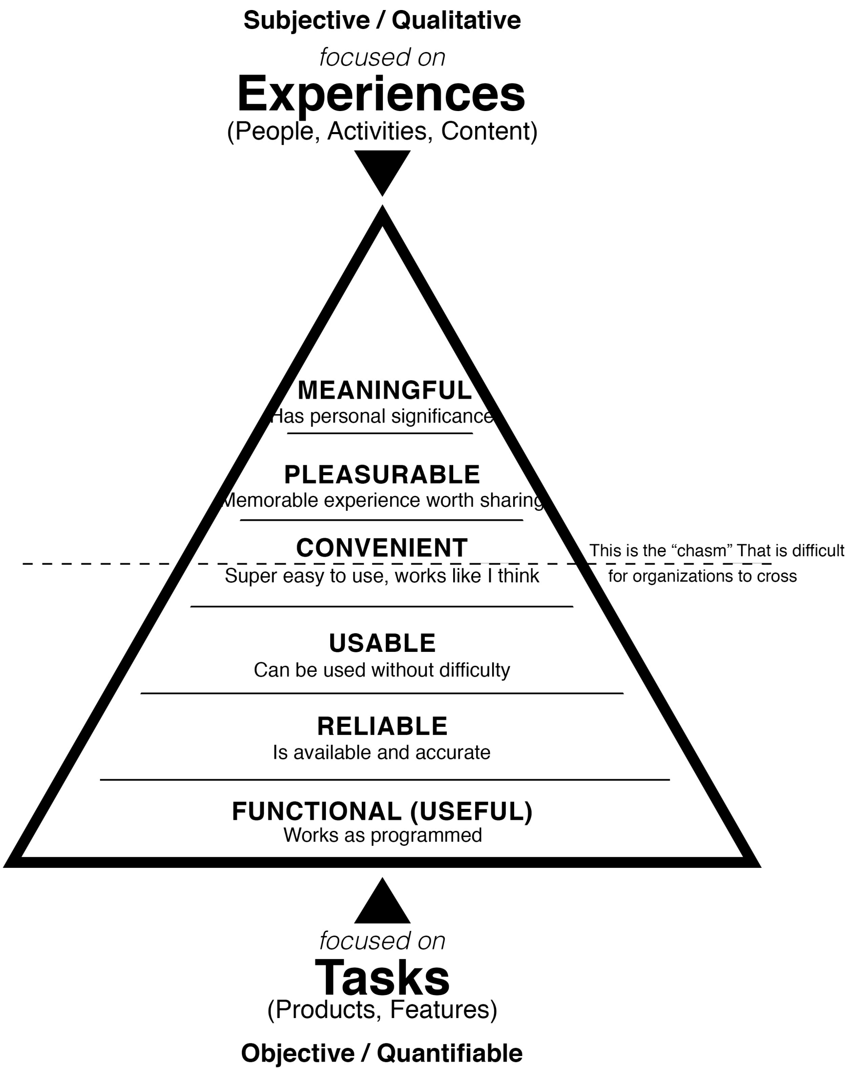


Figure 2.3. *User Experience Hierarchy of Needs Model* (Anderson, 2011)

Anderson, 2011 (pp.11-13) presents a six level process of maturity of a technology product or service experience (Figure 2.3), from "hey, this thing actually works!" to "This is meaningful in my life." The author's statement is that to create a revolutionary product one must start with the experience the designer wants people to have rather than the its function, i.e., focus on experience rather than in tasks. According to the author, the approach from this perspective allows to see new ways of designing the artefact. With experiential things they mean emotions, clever language, and aesthetics.

“The total experience of a product covers much more than its usability: aesthetics, pleasure, and fun play critically important roles” (Norman, 2013, p. xiii). The emotional response from the user helps the communication and engaging (Mackinlay & Winslow, 2009).

Focusing on the user experience implies that the approach to concept goes in the direction of making the experience of the user during the interaction with a product pleasurable, fun, exciting and contains flow properties. *Flow* is a concept from Csikszentmihalyi (1996), and stands for the design of interactive user experiences involving intense emotional states that causes the user to loose the sense of time. Accordingly, web interfaces can be designed for users who know what they want, and on the other hand to induce such a state of flow that leads the user to ‘unexpected places’.

Content

We now address the roles and uses of the elements that constitute visualizations.

Metaphor

Metaphors function as cognitive models of the interactive system (Ware, 2012, p.327). The consideration of HCI as a design discipline allowed *metaphor* to function as a creative tool for the designer (Blackwell, 2006). Both Apple and Microsoft built their *metaphors* for the GUI upon people’s knowledge of the world in order to provide the most direct and intuitive interfaces to users, in a way that allows them to understand them in a natural way.

Effective *metaphors* depend “on the talent and insight of designers to see new analogies, perhaps drawing on theoretical research findings in order to choose the right set of correspondences” (Blackwell, 2006, p.494). They are abstract ideas that play the role of a design tool.

Metaphors are *signifiers* and can be found within a wider concept named *Discoverability* by Norman (2013, p.14), and obbey to the user’s need to figure out how to work with a system, i.e., “discovering what it does, how it works, and what operations are possible”. Designers should present visual clues that permit the user to easily figure out the information they can, and cannot disclose, i.e., the design must foster the understanding of the user toward interaction. One possible example of a visual clue,

- is the use of color in order to indicate alert or danger and the green to communicate ‘go’,

Metaphors must be used with care since when badly chosen, a *metaphor* plays a worse role than no *metaphor* at all (Blackwell, 2006). Marcus (1998) argue the use of metaphors is not recommended when:

- taking metaphor as a mental model, because they are different in meaning,

- culture, and the passage of time, when not well studied.

Text Legibility

Some assertions about the way people read are interesting to note. Firstly, people anticipate what they are reading and the understanding of what they read depends on past experience, point of view, and instructions that might have been given to them before the reading. Thus, designers are encouraged to,

- give special attention to titles and headlines through simple words and few syllables (Weinschenk, 2011, p.33).

"We don't read pages. We scan them" (Krug, 2006, p.22). Reading in screens is tiring for the eyes due to the emission of light and constant refreshing, therefore,

- the line length of the text is supposed to be read calmly, and should not be longer than 45 to 72 characters (Weinschenk, 2011, pp.42–44),
- the font is to be large enough with enough contrast between foreground and background (pp.42–44).

It is not possible to concretely suggest *font size* since it totally depends on its role in the layout, e.g., block text, headline, legends, and text that is visible on demand. The resolution of the screen is also to take into account, although this problem is gradually loosing pertinence due to technological developments. As stated by Weinschenk (p.40),

- The font size is to be large enough for users to read the text without difficulty.

Relating to capitals,

- capital letters are more likely to be used in order to claim for attention, and in warning messages (p.32).

Fonts that are too decorated, i.e., that have their original shape altered, might decrease the ability of the user to recognize patterns, and thus,

- the decoration of fonts should be done with reason (p.38).

Colors

"Above all, color exercises an undeniable psychological attraction" (Bertin, 2010, p.91). Tying color to information is elementary and straightforward since it allows the addressing of multi-dimensionality, and when used consistently, color speeds recognition in many tasks performed by the user as a way to relate items (Shneiderman et al., 2009). As a basic element of visual perception, color is processed automatically not requiring many cognitive abilities (Treisman, 1987).

Colors might be used in order to (Tufte, 1990):

- label (color as a noun),
- measure (color as quantity),
- represent or imitate reality (color as representation),
- enliven or decorate (color as beauty).

Color use is very complex, but there are some rules to have in mind:

- keep the same color code throughout the system (shneiderman et al., 2009),
- beware of the common expectations from the users about color coding (Shneiderman et al., 2009),
- limit their use to when they are able of showing meaningful relationships (Shneiderman et al., 2009),
- customize color palette and let the user decide if codes are active or not (Shneiderman et al., 2009),
- beware of the effect of colors on the users' vision (Shneiderman et al., 2009), and among other colors;
- constrain the use of colors depending on their dimension and role in the layout (Shneiderman et al., 2009),
- design for monochrome and be aware of color-deficient users' needs (Shneiderman et al., 2009). One way to substitute the coding by color is to graphically show the meaning of that color, e.g., for a green item that stands for a button we can use large contour for the user to understand that the item is clickable (Weinschenk, 2011, p. 26).

Structure

The guidelines presented next refer to the organization of the composition, i.e., the way the elements are to be disposed in the layout.

Organizing Information

“Every visual mass is a constellation of forces” (Arnheim, 1983, p.155). It is the relationship among elements in a composition that determines the way the viewer perceives them, and this is the core of the grouping principles of *gestalt* (see section 2.1.3):

- Proximity, Similarity, Good Continuation, Closure, Common Fate, and Connectedness should be followed when the intention is to group items, while,
- Figure-ground, Symmetry, Continuity, and Focal Point are to be applied in order to organize information in the layout.

It is also important to consider,

- Alignment, that helps guiding the viewer's eyes through information and gives a sense of perceived order of the whole.

In order to be better understood by the user, information should be organized through (Wurman, 1989):

- Category (e.g., similar, or related),
- Time (e.g., chronological),
- Location (geographic),
- Alphabet (by alphabet order),
- Continuum (e.g., bigger versus smaller).

Hierarchy of Information

The overall organization of the layout obeys to conventions, codes, and rules (Burnett, 2005, p.15). The way people see and understand data is conditioned by it. Each part of the layout generates visual expectations about the other parts, and often determines where the eyes move to in the following moment (Tufte, 2001, p.60). *Hierarchy of information* relates images and/or text serving as guide for the viewer to disclose information.

Perceptiveness related with hierarchic relationships among elements in a composition is related with,

- left-right and top-down positions, and is influenced by proximity, size, and connecting lines among them.

Iconic Representation

The power of schema stated by Arnheim (1974) and Gombrich (2000) has here its relevance. Simple and geometric representations are easier to be recognized by the viewer and accordingly, (Weinschenk, 2011, p.8) favours two dimensions against three dimension representations, since "the eyes communicate what they see to the brain as a 2D object. 3D representations on the screen may actually slow down recognition and comprehension” (p.8), and thus,

- prefer the 2D representations and apply the three dimensions with reason.

Either *sensory* or *arbitrary* symbols (see section 2.1.2) are perceived by the user as simple information to retain. Through the use of simple charts, (Haroz et al., 2015) tested the impact of pictographic representations in visualization and concluded that

- charts foster low loads of memory even with the adding of data, speed the finding of information and help the engaging throughout navigation, although, when superfluous, the effect is negative in the meaning that they distract the viewer.

Layers of Information

The designer should separate the different levels of information in order to maintain the detail and coherence of the layout, and moreover, to allow the co-existence of complementary data without losing meaning (Horton, 1996; Tufte, 1990).

Possible techniques for the enhancement of information are,

- data-ink, i.e., the changing in value of the ink according to the changing of data (Tufte, 2001, p.93),
- mapped pictures that combine “representational images with scales, diagrams, overlays, numbers, words, images” (p.13),
- color, that can foster the distinguishing of information by attributing low-level indications, or on the contrary, by emphasizing first level information.

Relate and Compare Side by Side

Humans apprehend through comparison (Gombrich, 2000) and therefore, the differences of the visually related elements are magnified when they are compared side by side. Bertin (2010) categorizes six “retinal variables” as graphical ways to represent information that can be compared to one another, by,

- shape, orientation, color, texture, value, and size.

One used technique that goes in accordance with this principle is *Tag Clouds*, that have been used as a tool for aggregation in analytical tasks. They are considered fun, engaging, aesthetic and creative (Viégas & Wattenberg, 2008).

Interaction

The way the user experiments interactive systems is of crucial importance ”for it determines how fondly people remember their interactions. Was the overall experience positive, or was it frustrating and confusing?” (Norman, 2013, p.10). *Progressive disclosure* is a wider concept that ought to allow the user of interactive systems to navigate from simple to more complex information, according to the basic perceptual principles from Arnheim (1974), Gombrich (2000), and Damásio (2010).

Weinschenk (2011, p.62) refers Keller (1987) to suggest that especially when dealing with interactive systems, but not only in that case,

- providing little amounts of information at a time permits the user to go deeper into inner levels of information gradually towards detail in their own time, and not be confused.

Users need to interact with large amounts of information that cannot be displayed “at one time on a single screen” (Cockburn & Bederson, 2008), and due to complexity, diagrams are not to be understood in a glance (Tufte, 2015). Bertin (2010, pp.140-148) establishes three *reading processes* as stages for the disclosure of information by the viewer that should be taken into account:

1) External Identification: the reader starts by identifying the components that are involved in the information. This stage relies on acquired habits from the viewer in recognizing words, shapes or colors, allowing them to isolate the information**,**

2) Internal Identification: the viewer is able to recognize the visual represented variables,

3) Perception of Correspondences: relates to the perceptiveness of correspondences in the graphic that are pertinent to the viewer.

Tufte (1990, p.37) statement “to clarify, add detail”, goes accordingly,

- ‘micro-readings’ and individual stories are possible to be disclosed by zooming out to larger structures of information (p.37).

Although people want to be presented with many choices, when confronted with them the thought process is paralyzed and thus, the solution is to give them information that they can control (Weinschenk, 2011, p.206).

Shneiderman et al. (2009, pp.550–552) set as basic principles in *Visual Information Seeking Mantra* those that specifically relates to interaction. We go through each step:

- *Overview: g*ives the user the sense of context and permits the identification of the functionalities, allowing the user to manage and control the interactive visualization

(Cohen et al., 1993; Mackinlay & Winslow, 2009; Norman & Draper, 1987). It allows the user to understand the concept model of the system at a glance, the alternative actions and their results (Norman & Draper, 1987).

- Zoom: when users are interested in some specific portion of the collection, being particularly important for small displays since it allows the magnification of the view of interest (Cockburn et al., 2008).
- Filter, the user chooses the data to explore, filtering out the information that is not important to them.
- Details-on-Demand, the user obtains information of interest by request. When gathered in the same screen in distinct spaces, detail helps the user not to loose context.
- Focus+context, allows the displaying of the focus of interest within the context area by, e.g., selectively highlighting items.

Regarding a wider *overview* concept, techniques such as paging, scrolling, and panning allow the information to be shown in order to fit the user needs. These mechanisms introduce a discontinuity among the information that is being displayed, though, forcing the user to mentally understand the overview plus its context among the displayed information, which can cause cognitive overload (Cockburn et al., 2008). When combined in the screen, *overview*, *zoom*, *details* and *cues* allow separate and blend views, permitting the user to understand the global relationship of information in the same display.

- Shrink + Hide + Embody, belongs to the first law of simplicity (Reduce) from Maeda (2006) and identifies:
    - Shrink, by decreasing the elements in size, the layout gains free space (Mackinlay & Winslow, 2009),
    - Hide, all the elements that are not necessary to be visible, are visible on demand,
    - Embody, different displays of information ready to be navigated according to the user's interest are in inside levels of information (e.g., the red icon standing for the stop representation).

As last, the widest principle to have in mind,

- accessibility. Systems should be designed for as many users as possible, despite their disabilities. Lidwell et al. (2003, p.14) highlight the following characteristics of accessible designs:

- perceptibility: every user is able to perceive the design (e.g., by redundancy);
- operability: every user is able to use the system (e.g., through affordance and constraints);
- simplicity: everyone is able to understand the system regardless their experience, literacy or concentration ability;
- forgiveness: error is minimized by the design (e.g., through constraints).

The named design principles aim in fostering interactive visualizations' efficiency in what relates, both, to the understanding of first-glance information and the information to be navigated by the user toward a requested goal. However, they are not to be considered mandatory as a whole, since each situation demands a new reflection towards the type and number of information to be disclosed. Other principles might be presented, these are the ones we consider of most importance to take into account in the building of interactive visualization, though.

2.3 Time and Space Oriented Visualizations

Time is a concept that we use in many ways in our daily lives (Peuquet, 1994). All visual experiences are "embedded in a context of space and time" (Arnheim, 1974, p.48) since nearly all of our daily tasks relate to where we are. Things in the world change due to the passage of time and if the universe did not change, there would be no time. Every event or happening that can be referred to, or thought about, has time attached (Allen & Hayes, 1985) and it is these changes that make us have conscience of the passage of time, through transformation and movement (Peuquet, 1994).

Several frameworks about time and space are conceivable since both concepts are subjective. In this section, we explore ways to represent them.

2.3.1 Time and Space Concepts

In our perception of the time dimension everything progresses forward in time whereas space can go either in forward or backward direction. Time is linear and irreversible following the course of nature, and only when considering space alone, both directions are possible (Peuquet, 1994).

There are various types of time and space, i.e., they can be observed in various ways, depending on the need and the community within they are being used (e.g., apparent solar time is important to historians due to their care about the moment that the event happened, either in daylight or in darkness) (Snodgrass, 1992).

Due to the steadiness of time-space models it is often necessary to change them in order to fit the intended situation, e.g., the duration of a game might be different, either including or excluding the time in which the referee stops the game, since this gap of time is both considered as part of the game, or not, in soccer or in ice hockey, respectively (Frank, 1998). In the same way it is not practical to consider seconds when measuring time, unless we are, e.g., narrating a running race. Due to this subjectiveness, questions about the way the measure of events should happen often arise. “A single model of time does not fit all situations and the differences between the models must be dealt with" (Frank, 1998), and thus the better measurement units must be chosen according to the questions needed to be answered (Peuquet, 1994).

Issues might occur throughout these considerations, such as the time concept to take into account when dealing with stored movies (Snodgrass, 1992), i.e., the moment in time the movie was filmed (valid time), the time it was stored in some database (transaction time), or the overlapping of both. Moreover, the time of a movie narrative is also of complexity to handle, e.g., movies in which time might be considered in the past, in the future, repeating in a loop, or jumping from past to future and vice versa, or movies located in a non-existent world, among many other possibilities. We do not narrow these perspectives, though, since the focus of this thesis is the movie structure, not semantics.

Although time is generally perceived as being continuous, we usually prefer to use discrete time models due to the inherent imprecision of measures (Snodgrass, 1992) due to i) clocking instruments (e.g., “It’s three o’clock”), ii) natural language (e.g., “We’ll meet around seven”), iii) the concept of point of time itself that allows the existence of a duration (“We’ll have tea at 3 o’clock”). The measuring of space is simpler due to the commonly accepted measure by meters or inches and also because distance is frequently measured through time (Snodgrass, 1992), e.g., “The cinema is a half an hour distance from here”. Both time and space are continuous and segmented into discrete units of uniform or variable length (Peuquet, 1994), which we present next.

2.3.2 Time and Space Characteristics

We characterize time and space according to its granularity and the purpose of the analysis.

Primitives and Structure

Time is considered through:

- time points: primitives that describe the moment in time an event happened, being assumed to have no duration (Frank, 1998),
- time intervals: time points with an extent are considered as the duration of an event that can be specified by two time points, as the limit range between the beginning and the end of the event, or by a time point plus a duration (Frank, 1998).

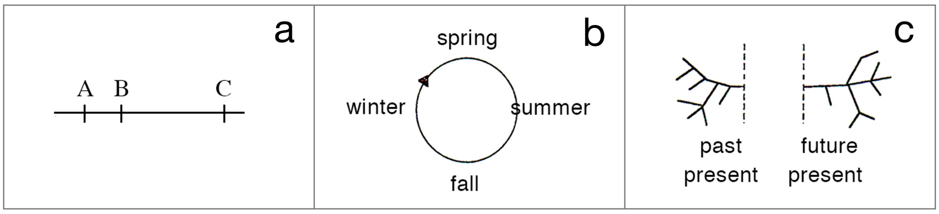


Figure 2.4. Structure of time: Linear (a), Cyclic (b) and Branching (c) (Frank, 1998)

Intervals of time may have different ways of progressing. Frank (1998) distinguishes three different structures (Figure. 2.4):

- Linear time (a): extends from the past to the future in an ordered manner.
- Cyclic time (b): events happen in a linear way but they repeat periodically in time. In practical applications it is often useful to unroll a cyclic time axis to a linear time axis.
- Branching time (c): the structure shows several events happening simultaneously, or in alternative scenarios.

Whether linear or non-linear, structures of time can be characterized either as *discrete* (limited in time) or *dense* (within an infinite set of values) (Bettini et al., 1998). Time can be *absolute* or *relative* if it is or it is not attached to a specific moment, respectively. To the former, an interval of time starts at a specific point in time (*anchored*), the later does not (*unanchored*) (Snodgrass, 1992). Temporal *determinacy* is related to the duration of an event that one can, or cannot, be aware of, while *indeterminacy* happens when there is no information about the time or the duration of an event (Goralwalla et al., 1995). If attached to a specific moment in time, the information is *anchored*, and if it is not, it is *unanchored*. The distinction is not sharp though, due to the inaccurateness of the reported information about events (Snodgrass 1992).

Space dimension is considered as being constituted by *points with no area or volume*, or as an *areal cell* in a data structure (Peuquet, 1994).

Time concepts are used for space dimension and thus, space structures are possible to be characterized as *discrete* or *dense* by considering Stephen Hawking's theory, "an open universe implies unbound space" (Snodgrass, 1992). Concepts such as "don't know exactly when" referring time, and "don't know exactly where" referring space are *indeterminate* information related with the awareness or not of the beginning, end, and duration of an event (Goralwalla et al., 1995).

Data

While suggesting the reading of Shneiderman (1996), Aigner et al. (2007) names the following categorization:

- frame of reference, when Abstract Data is not per se connected to any spatial layout, while Spatial Data contains an inherent spatial layout;
- variables, concerns the number of time-dependent components;
- level of abstraction, when data is represented accurately or through abstractions, being the latter more suited to foster the analysis of large data sets.

Ware follows Bertin (1977) in his *data values* and *data structure* concept and consider *entities*, as the objects intended to be visualized, and *relationships*, as the structures and patterns that relate entities among each other, and that can be provided, or discovered, through the visualization.

Representation

The achievement of an efficient representation of information implies a good integration of the visual methods, analytics and those that have the user as central focus. It must be taken into account, then, the data type (meaning and application) and the user (tasks and needs). Aigner et al. (2007) concentrate on two sub-criteria:

- time dependency: stablish that static representations visualize time-oriented data in still images, while dynamic representations automatically change over time, e.g., animations;
- dimensionality**:** distinguishes between 2D and 3D presentation spaces. The need for 3D is heavily discussed, some researchers argue that 2D is sufficient for effective data analysis, while others defend that 3D allows to add visual information, in an additional dimension and perspective, to the representation (Card et al., 1999; Tominski et al., 2005).

When space is considered alone, objects and location are the only entities that serve as basis for the representation (Peuquet, 1994) whereas when time is also required, information is stored relating *where* (location-based view), *what* (object-based view), and *when* (time-based view) by separating space (where), time (when), and objects (what), concept that is disentangled by the following three questions (Figure. 2.5):

- when + where = what**,** describes the objects or set of objects (what) that are present at a given location or set of locations (where) at a given time or set of times (when);
- when + what = where, describes the location or set of locations (where) occupied by a given object or set of objects (what) at a given time or set of times (when);
- where + what = when, describes the times or set of times (when) that a given object or set of objects (what) occupy in a given location or set of locations (where).

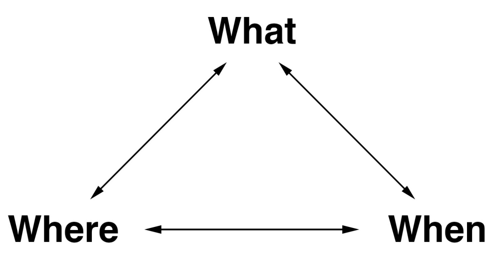


Figure 2.5. *Triad Framework* (Peuquet, 1994)

Spatiotemporal data blends location, time, and the objects that exist in space, and their multidimensional attributes that change over time. This information allows the study of the location properties, allowing understand temporal dynamics such as the development, and ageing of a location throughout time.

2.4 Representation through *Tag Clouds*

Tag Clouds ground their visuals in tag words which are represented by differences of font size, color, or weight, where larger tags correspond to higher frequencies.

Also known as *Word Clouds*, this concept was originated in Soviet Constructivism (Viégas & Wattenberg, 2008) (Figure. 2.6). Although from outside the visualization community, It evolved “as a core technique of information visualization that is applied in many different contexts” (Burch et al., 2013).

Figure 2.6. Alexander Rodchenko, Advertisement Poster, 1924 (Zurakhinsky, 2016)

Research on *Word Clouds* is two-folded: it investigates its effectiveness and perceptiveness by viewers while presenting works that improve, and extend the technique. A third path of research is argued to be added by Heimerl et al (2014) through the use of this concept for text analysis systems as one of its components.

According to Viégas and Wattenberg (2008), the first example of a visual overview of a collection of text might have been presented by the social psychologist Stanley Milgram (1976) in their *Psychological Maps of Paris* (Figure. 2.7). This experiment consisted in a query in which the authors asked people to name landmarks in Paris, information from which they built a "collective 'mental map' of that city" through a *Tag Cloud* that presented the frequencies of the times each landmark was mentioned. It was only twenty years later that *Tag Clouds* diagrams were created by a computer in "Search Referral Zeitgeist", a *Word Cloud* that showed the search terms that had led people to that website. In 2001 the use of this technique spread into mainstream media through the "cloud aesthetic", used in the finance section of Fortune Magazine that represented the 500 largest corporations of the world, being each corporation depicted by a cloud.

Flickr showed the popularity of image tags and coined the term *Tag Cloud*. Web sites using the Web 2.0 design feature spread being *Tag Clouds* considered by Maeda "The Greatest Diagram of 2004" (Viégas & Wattenberg, 2008). *Tag Clouds* became popular in websites such as *Flickr*, *Delicious*, or *Technorati* that used tagging as an indexing method (Smith, 2007).

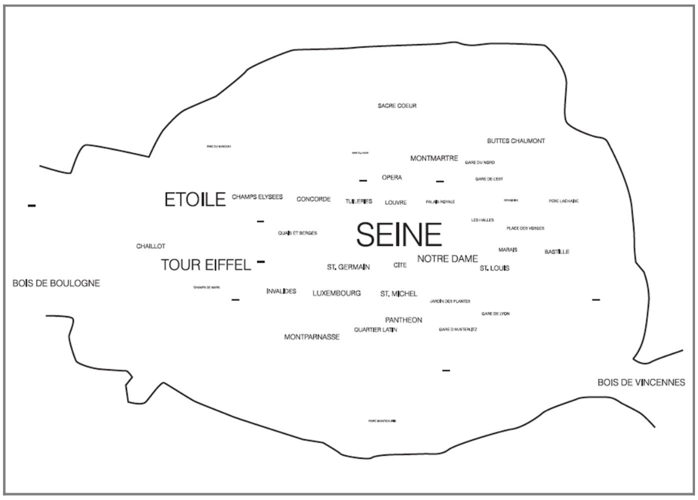


Figure 2.7. *Tag Cloud* that represents the psychological map of Paris (Stanley et al., 1976)

Later, the popularity of *Tag Clouds* spread towards different fields such as psychological experiments, fiction writing, and political analysis (Viégas & Wattenberg, 2008). Four tasks to perform using *Tag Clouds* can be stated (Rivadeneira et al., 2007):

- search, locating (or be aware of its absence) specific terms or one term that represents a concept, often in order to navigate to underlying content;
- browsing, often with no precise term in mind;
- impression formation, overview of the tag cloud in order to obtain an idea of the underlying data that give awareness of both higher and lower frequencies;
- recognition/matching, recognizing what the *Tag Cloud* aims in presenting, e.g., determining who a person is through their *Word Cloud*.

While considered as a design technique for visualization, *Tag Clouds* pose several problems: i) long words being emphasized over the short ones with no reason; ii) difficulty in finding a specific word due to their number (Viégas & Wattenberg, 2008); iii) difficulty in comparing words with little differences in size; iv) presentation of different forms from the same word as individual tags (e.g., singular and plural, and gerund "-ing"); v) not optimized space in the screen causing white holes among words (Burch et al., 2013); vi) the terms in the middle of the cloud receiving more attention on average than those near the borders (Bateman et al., 2008; Gross et al., 2009); vii) the greater ability from users to spot a specific item more effectively through an alphabetic order list that maintains sizes among words (Bateman et al., 2008; Gross et al., 2009; Heimerl et al., 2014).

Despite all disadvantages, this technique have become a chosen tool for analysis, providing an intuitive and visually appealing overview of most frequently used words (Heimerl et al., 2014).

Viégas et al. (2007) defend it as a starting point for a deeper analysis, intended to be design tools that result aesthetically. Its popularity seems to prove its applicability, if not theoretically, in the practical realm (Viégas & Wattenberg, 2008). *Word Clouds* is a good visualization technique to "communicate an "overall picture" of the text contents" (Sinclair & Cardew-Hall, 2007). As far as we know, its use does not include information about movies, though.

2.5 Representation of Emotions

Although it is difficult to define emotions (Damásio, 2003; Kleinginna & Kleinginna, 1981), it is usually agreed that they relate with people's psychological, affective, behavioral and cognitive aspects, resulting from a reaction toward events or concernes throughout people's lives. Emotions can be categorized as *objective*, if they are being shown (e.g., an image of a happy child playing), or *subjective*, if felt by the user when they are watching the image (e.g., the viewer feels happy by the image of a happy child).

Ekman (1999) characterizes emotions as discrete states of behavior and experience by the viewer. He based his study on human facial expressions beyond matters of culture, and identified: *Happy*, *Sad*, *Fear*, *Anger*, *Surprise* and *Disgust* (Figure. 2.8).

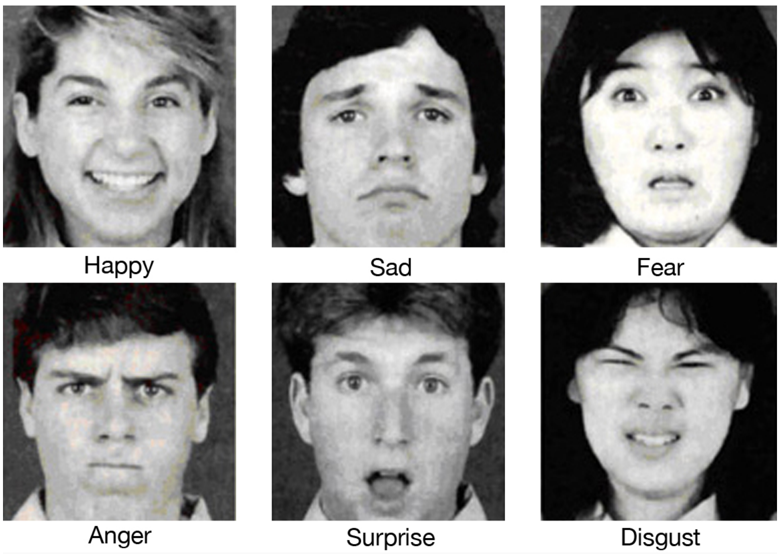


Figure 2.8. *Six Basic Expressions* (Ekman, 1999)

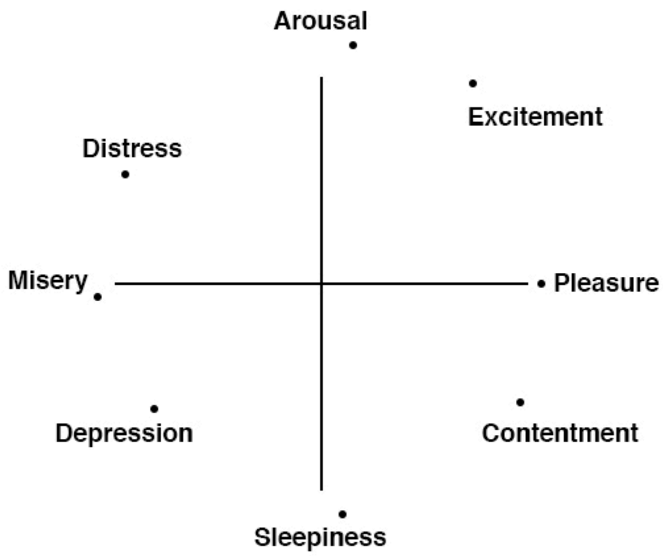


Figure 2.9. *Emotions Model* (Russell, 1980)

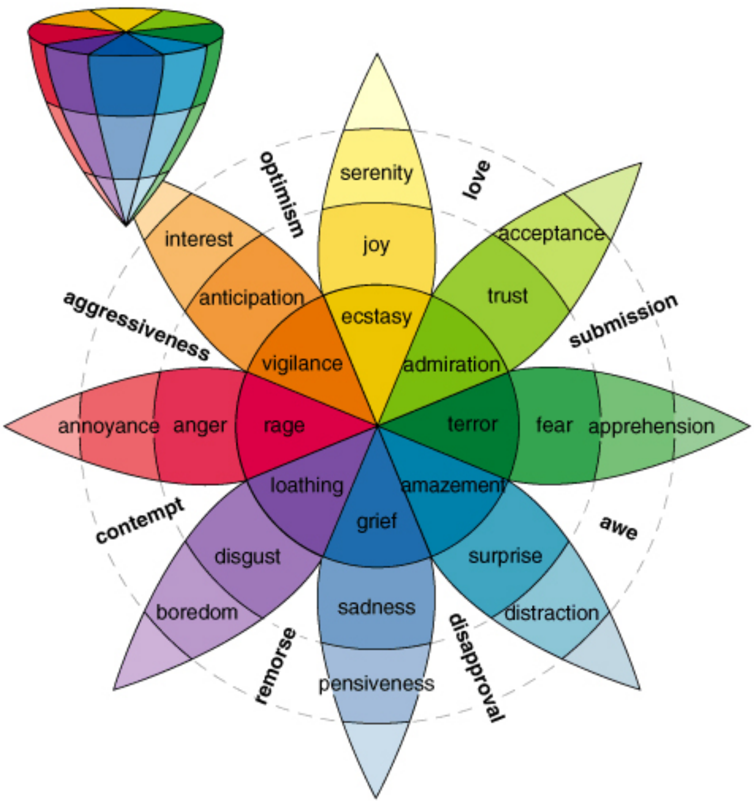


Figure 2.10. *Emotion Color Wheel* (Plutchik, 1980)

Itten (1974), Kandinsky (1977) and Klee (2002), among other theorists and artists, grounded their color theories on the emotional impact of color on people, and actually, it is known that colors are used as a way to induce emotional states on the movie viewer, through techniques such as the use of environmental colors of the scenes.

Accordingly, Robert Plutchik (Kamińska & Pelikant, 2012) established a 3D categorical and dimensional model that intersects polarity, similarity, and intensity (Figure 2.10). He assigns as basic emotions *Surprise*, *Fear*, *Trust*, *Joy*, *Anticipation*, *Anger*, *Disgust* and *Sadness*, and relates bright colors with positive emotions (e.g., yellow for *Joy*), and dark colors with negative emotions (e.g., blue for *Sadness*). In his model, the strongest color stands for the strongest emotion, e.g., *Ecstasy* stands for the stronger gradient of a family of emotions and has *Serenity* as the opposed emotional state.

In this chapter, graphical representation of data and concepts were related with visual perception and cognition. The aim was to enable Colin Ware's statement, according to which visualization clears, eases, and allows the gaining of insights in the understanding of large amounts of data. The mind is compelled by visualization both in the process of understanding information and when a task is performed, but only if the visualization proves to be efficient. We address the processes of seeing and understanding, and the browsing and accessing information.

We disclosed the main design principles that inform visualization, and focus also on aesthetics as a collaborative field of design that enhances its power of engaging the user when performing a task while easing, and enriching interaction. Since our visualizations are time and space oriented, the specifics of those dimensions were also matter of attention, conceptually, and in the way to represent them. The representation of frequencies with words and emotions were the topics that ended the chapter.

3 Related Work

Most relevant work that relates to our visualizations is presented with special focus on time and space representations. Firstly, we focus on visual ways to represent information; secondly, we present interactive interfaces that allow the exploration of information about movies, and their access; and thirdly, contents are addressed.

3.1 Visual Representations in Time and Space

Graphical solutions for the representation of information are presented in this section. The brief characterizations are intended only to highlight the features that served as starting points toward our visualizations.

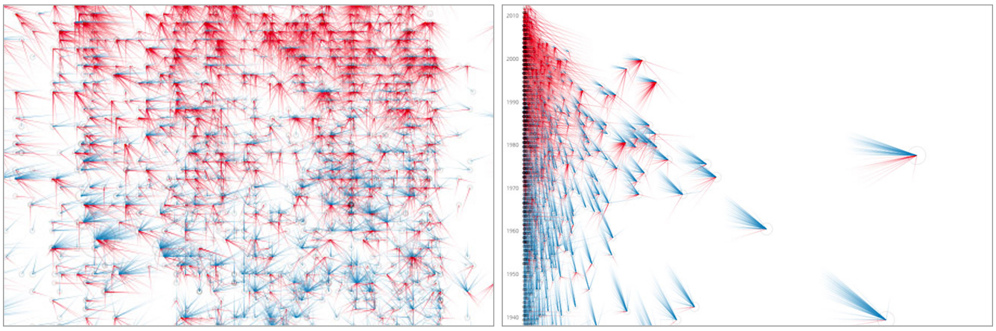


Figure 3.1. *Culturegraphy* (Albrecht, 2014)

Culturegraphy (Figure 3.1) relates movies over time through the influence they share among each other. Movies are presented as nodes and the influence they have in other movies is represented by the direction of the shades. The red-blue gradient aims in establishing a border in 1980, that separates the 'pre' and 'post' eras of cinema, being the latter the 'postmodern', thought as the moment in time when movies started adapting and combining references from other movies.

Of most interest to note are the *simplicity of this* vertical timeline, and both the strength of the shades, and the use of the *proximity* principle that make the information so perceptively clear.

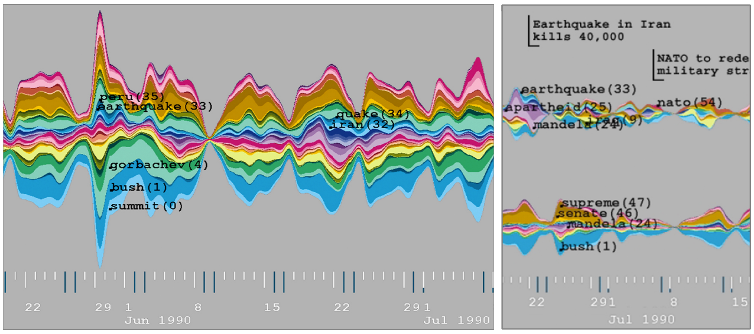


Figure 3.2. *ThemeRiver* (Havre et al., 2000)

ThemeRiver (Figure 3.2) represents thematic occurrences in a collection of topics that are depicted by colors. The timeline below provides awareness of the temporal context, and the text in black, above, allows to link occurring themes to external events. In the image on the right, parallel visualizations allow the user to compare data from two different cities, in the same period of time.

This river metaphor represents information in a fluid timeline in which accuracy gave way to aesthetics, although the former can be achieved by user's request through detail.

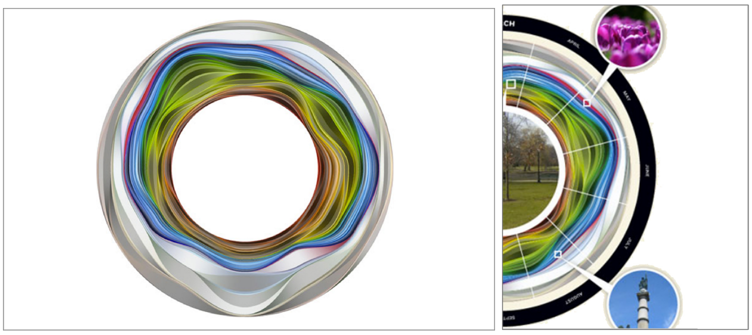


Figure 3.3. *Flickr Flow* (Viégas & Wattenberg, 2009)

Flickr Flow (Figure 3.3) presents the dominant colors in pictures taken around a year, giving an idea of the flow of seasonal colors. The relative proportions of the colors in the photos taken in each month are plotted in a wheel, being clear the identification of the seasons, e.g., it is possible to recognize the winter below, due to its white predominance as the color of snow.

Through a circular representation of time, this simple visualization presents the metaphor of the way we conceive the passage of time while representing the changing colors throughout seasons.

Figure 3.4. *Post History* (Viégas, Boyd, et al., 2004)

Post History (Figure 3.4) shows the evolution of email activity. Each square represents the emails changed during a day, and the rows depict weeks. Emails appear on the right, by title. Color is used to represent the more (red) or less (yellow) directedness to the user.

This visualization presents the black as background color in order to make colors to stand out. The red-yellow duality is very appropriate in showing information for the former is the warmest and emotional color, which strengthens the visualization metaphor.

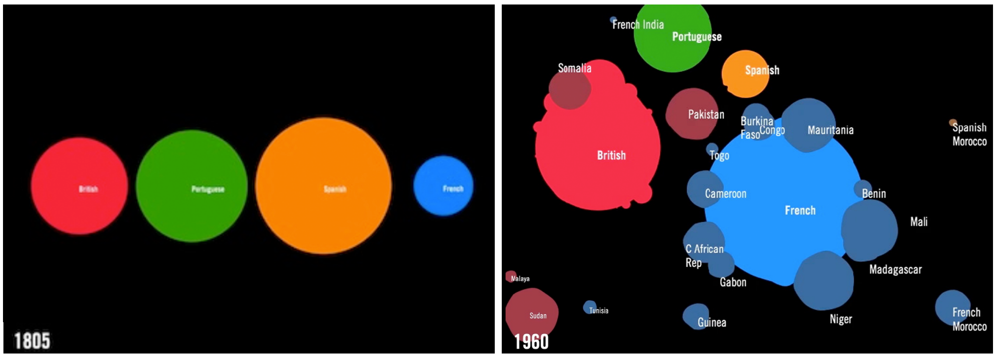


Figure 3.5. *Portuguese Empire Expansion and Decline* (Cruz & Machado, 2010)

Portuguese Empire Expansion and Decline (Figure 3.5) is an animated visualization that shows the evolution of the British, French, Spanish and Portuguese empires during the 19th and 20th centuries.

A major strength of this visualization is the color choices. As they are balanced in tone, none of the empires stands out from the others. The importance of the empires is represented through the size of the shapes, which although conceptually simple, presents information very clearly.

Figure 3.6. *Panoramio* (.com)
(unavailable since November, 2016)

Panoramio (Figure 3.6) is a space dimension catalogue of photos that allows selecting images of places in the world by tag (e.g., popular, recent, indoor). The user might be aware of the amounts of photos available by the thumbnails and when zooming in the location area, each image gets more accuracy. Larger images induce the user to click while giving dynamism to the composition, as they are not aligned among each other.

This visualization is simple and easy to use while inviting and inducing the user to explore places through the larger images. On the other hand, it allows the user to have an idea about the most photographed area by the overlapping images.

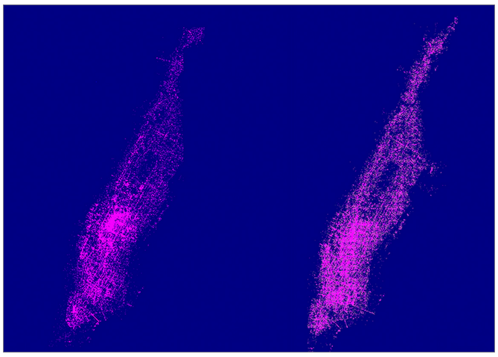


Figure 3.7. *Urban Social Media Inequality*
(Indaco & Manovich, 2016)

Urban Social Media Inequality (Figure 3.7) visualizes the contrast between "social media rich" and "social media poor" in Manhattan through the images people share. This visualization shows inequalities in income, wealth, education, social well-being and access to services. In some parts of the city people share more experiences than in other areas.

This visualization highlights the socially richer locations through brightness against the black background.

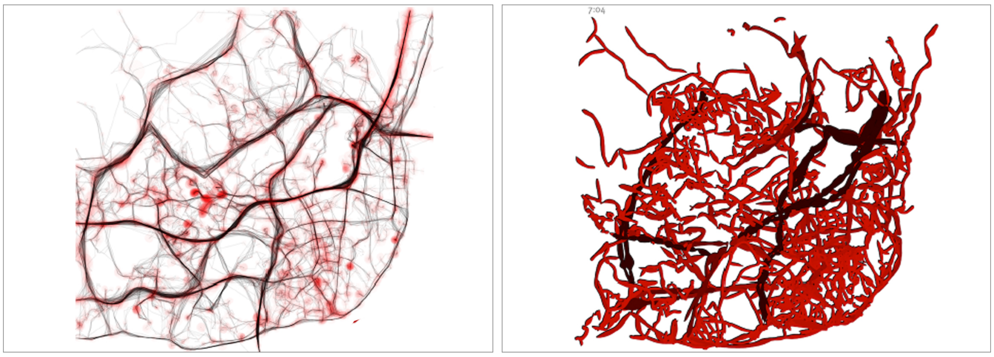


Figure 3.8. *Visualizing the Circulatory Problems of Lisbon*
(Cruz & Machado, 2011)

Visualizing the Circulatory Problems of Lisbon (Figure 3.8) presents a dynamic visualization of geo-referenced data of the traffic that runs throughout the roads in Lisbon. The thickness, color and length of the lines are functions of the number of vehicles and their average velocity. The visualization represents the beginning (image on the left) and the end (image of the right) of the day being the latter the moment when more vehicles circulate.

By depicting reality and being highly metaphorical, this spatiotemporal visualization reflects a message of alarm since it compares human health with fluidity of traffic.

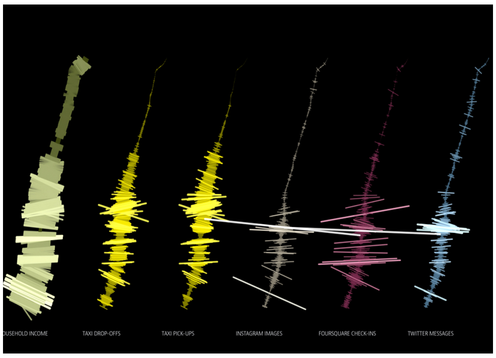


Figure 3.9. Detail on
On Broadway (Manovich et al., 2015)

This detail of the project *On Broadway* (Figure 3.9) represents geo-referenced occurrences over Broadway. Each color depicts information about household income, taxi drop-offs, taxi pick-ups, *instagram* images, foursquare check-ins and twitter messages, where the longer lines correspond to higher frequencies.

The metaphor is the spine of a human body by adopting its shape and position in the middle of Manhattan. Information is clear, even more for brighter colors.

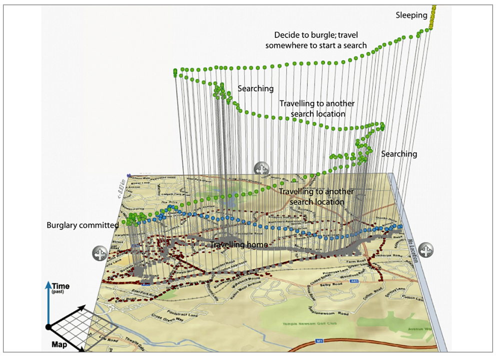


Figure 3.10. *3D Cube* (Hägerstraand, 1970)

This cube shaped visualization presents trajectories through time and space vertical (z), and horizontal (x,y) axes, respectively. The green sequential spots represent the path and duration. The higher the green spots the more recent the time.

Proximity, *similarity*, *good continuation*, *common fate*, *figure and ground* are in use in this visualization. The three dimensions seem to have great value in this multi-level visualization, and although representing many trajectories might bring confusion to the understanding of information, the combination of time and space, although difficult, is well managed in this case.

3.2 Video: from Collections to Items

The most relevant applications that allow the user to navigate and access information about movies and/or to access them, are presented next. The focus is the type of information that is available and the way to navigate through it.

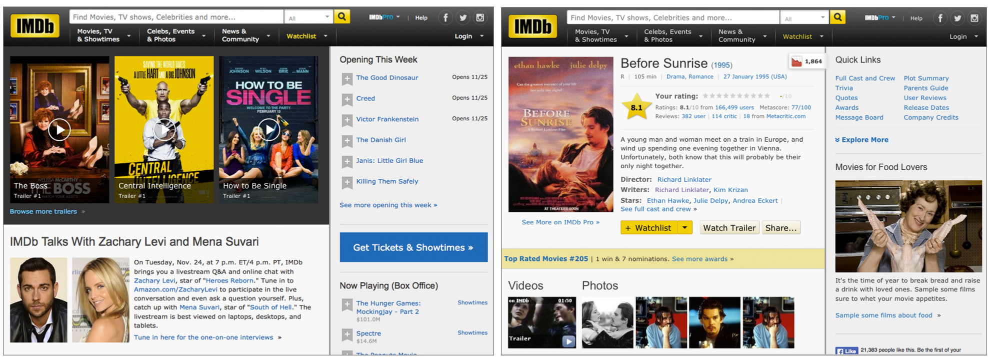


Figure 3.11. *IMDb* (.com)

IMDb (Figure 3.11) provides all sort of information about movies (e.g., directors, celebrities, later news, release dates) but it does not allow the access to watch them. It permits the user to filter the search for a movie (e.g., the location of shooting, ‘Oscar-Winning’, red car).

The most accessed website relating to movies allows for the exploration of diversified information, from metadata, e.g., the genre and rating, to the information waived throughout the contents being possible to find, e.g., a movie that contains in its length a ‘red car’ and that was shot in Canada. It does not allow the user to be aware of the specific scenes where criteria happen, though.

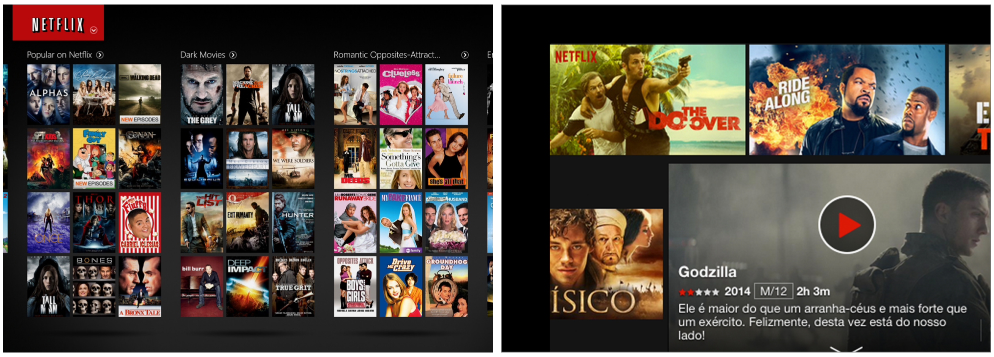


Figure 3.12. *Netflix* (.com)

Netflix (Figure 3.12) allows the access of movies through an on-demand service. The filtering is difficult due to the amounts of movies available and is done mostly by cover. When selected, information about one chosen movie is presented and after asking for details the user can read the main information such as the plot, and watch the trailer.

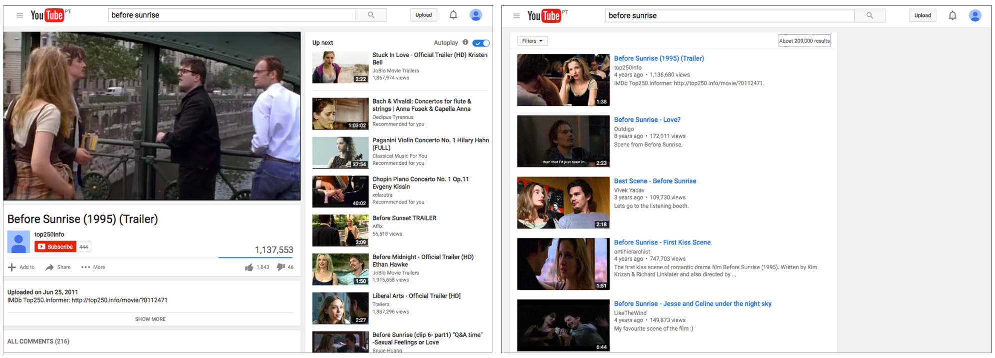


Figure 3.13. *YouTube* (.com)

YouTube (Figure 3.13), the most used website for accessing movies and videos, allows to play, navigate, search, comment, share and get recommendations. The filtering is through text, and movies are displayed by title, number of views, and the image of the first frame.

YouTube supports the retrieval of information though list only, which is a limited way of showing this type of information. The possibility for the user to upload high quality videos, and moreover the number of the videos that can be accessed due to the popularity of this application, seem to be its great value.

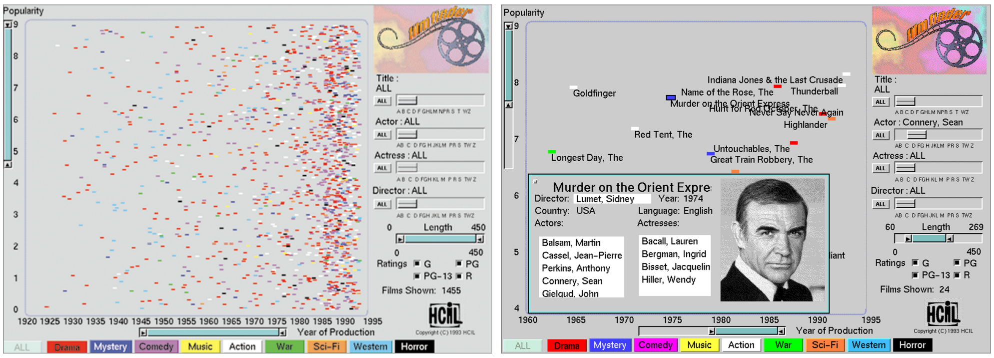


Figure 3.14. *FilmFinder* (Ahlberg & Shneiderman, 1994)

This interface (Figure 3.14) allows for multiple functionalities in the navigation and access to movies. The overview in the image on the left shows the movies released over time. Each spot depicts a movie by color genre throughout time (x axis) and rate (y axis). When zoomed, the screen shows titles (image on the right), and when asking for details the user can be aware of more information about the movie, e.g., director or actor/actress. We do not find meaningful relations between colors and genres (e.g. white for 'action').

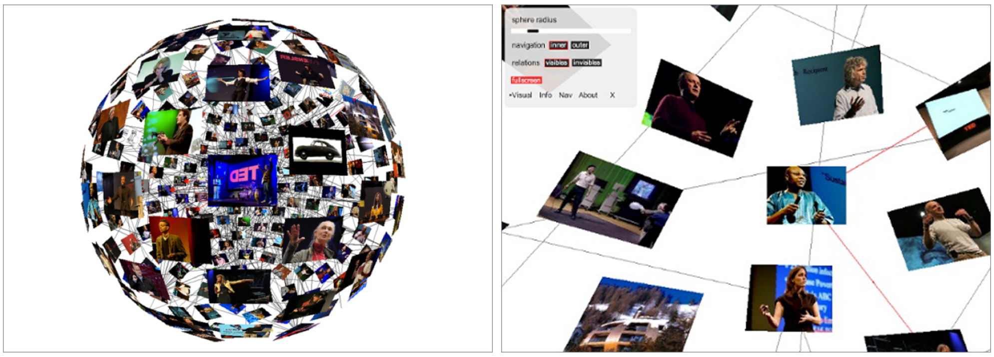


Figure 3.15. *Videosphere* (www.bestiario.org)

Videosphere (Figure 3.15) represents TED's conferences and adops the world metaphor. It is a 3D sphere video space with videos that are linked according to their semantics, allowing the user to navigate either from outside (image on the left) or from inside (image on the right) the sphere.

Grounded in the world metaphor, this 3D interactive visualization allows the user to navigate through information by dragging, with the videos connected by their semantics. Although the interaction is somewhat confusing, even more in the inside perspective, the information is presented in an unusual and appealing way.

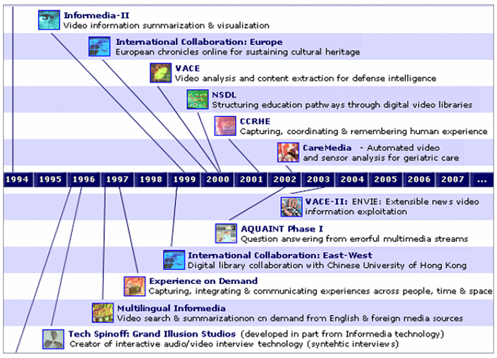


Figure 3.16. *Informedia Project* (Hauptmann, 2005)

Informedia Project (Figure 3.16) addresses digital video libraries management and access based on automatic video-content analysis, using metadata to index, search, navigate and retrieve video contents. It allows the search by speech and image, and provides the visual summarization of the scenes (mainly thumbnails representing scenes) for the search and image retrieval.

The interest of this visualization is the possibility to retrieve summarized videos, i.e., visually simplified video summaries, by words and image.

Figure 3.17. *Sensor-rich Video Exploration*
(Seo et al, 2011)

The overview in Figure 3.17 presents frames of geo-referenced user-generated videos over a map (inside the yellow circle), which depicts the videos shot in that place. They are automatically selected by the system based on popularity (regions and objects) in a geo-referenced area, allowing the user to choose places that are more visited, and moreover by marking the spot from which the video was shot.

This interactive space-oriented visualization allows the user to be aware of the most popular places to visit, and the location to go to get those images.

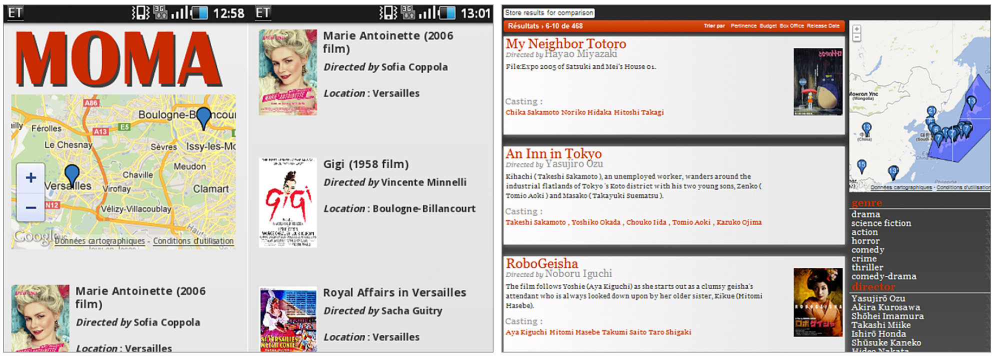


Figure 3.18. *MoMa* (Finsterwald et al., 2012)

The *Movie Mashup Application MoMa* (Figure 3.18) allows the user to be aware of related information about movies, and access them by location filtering through, e.g., director. In order to deal with the problem of multiple interpretations tagged to the same location (e.g., Washington as a city and a name of a person) Finsterwald et al. (2012) combine disambiguation processes (e.g., use the textual content around the toponym) narrowing the finding toward a more reliable result.

Interesting to note in this visualization is the possibility to choose a movie by location, in a map. The inverse is also possible, i.e., to know where movies were shot.

3.3 Video: from Items to Contents

Representation of movie content is addressed in this section. Attention is given both to visual solutions that show an overview of the whole movie in a glance, and the way to navigate and access them by criteria. All visualizations consider time and/or space dimensions.

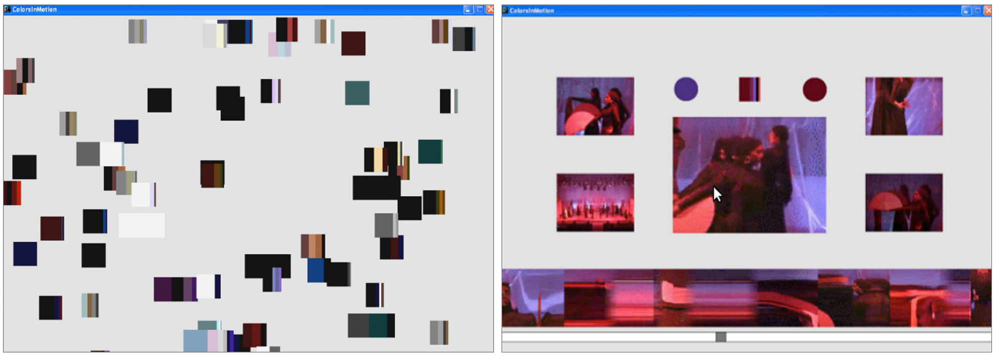


Figure 3.19. *Colors in Motion* (Martinho & Chambel, 2009)

Colors in Motion (Figure 3.19), allows to explore and visualize movie content based on color, movement and rhythm. It presents video loops both summarized by colors (the image on the left) and by the movie contents (image on the right). On the right, the video is playing in the center and on both sides loops are also playing. Through the scrollable slit scan image below, the total length of the video is presented allowing the selection of a specific frame, by clicking.

It is possible to compare movies by their colors, and be aware of colors and level of brightness throughout the length of the movie content.

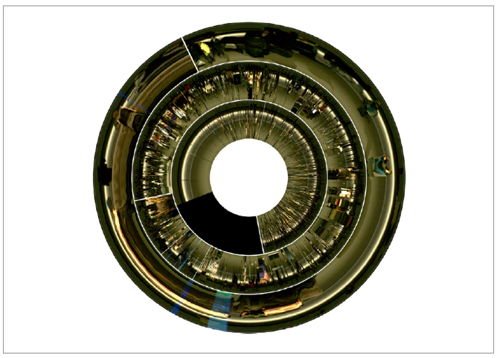


Figure 3.20. *Last Clock* (Angesleva & Cooper, 2005)

Last Clock uses summarization to represent video histories showing three levels of detail in the same overview. In Figure 3.20, a video storage depicts a visitor interacting with a display while showing the rhythm. The record of the event provides a reflexion about present and past history through round images that show one hour, one minute and one second (from the centre outwards).

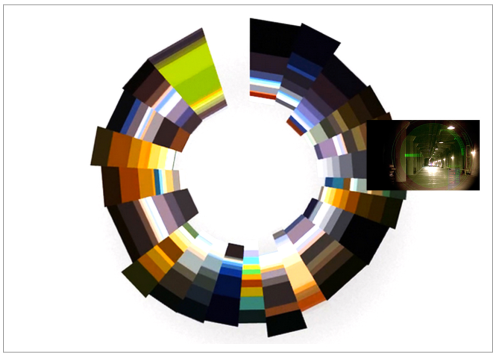


Figure 3.21. *Cinemetrics* (Brodbeck, 2011)

Cinemetrics (Figure 3.21) explores movement and colors in movies. Each scene is represented by its dominant colors in a shape that moves in and out towards the centre at different speeds according to the detected movement.

This simple interactive visualization presents information that is clearly understood in a glance. It represents two variables (movement and colors), and it allows for details (the frames of the movie) by request of the user. When compared side by side, the mood of the movies can be related and compared in a playful, while accurate way. We believe this is a good way of choosing a movie to watch.

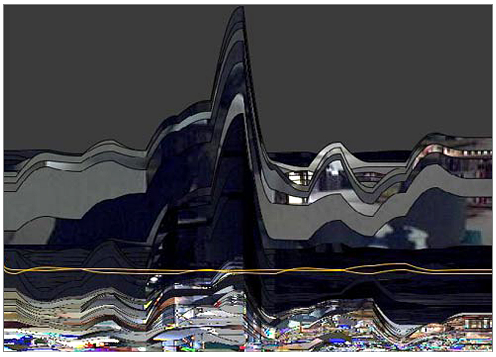


Figure 3.22. *Artifacts of the Presence Era* (Viégas et al., 2004)

Artefacts of the Presence Era (Figure 3.22), is conceptually based on the geological layers in sedimentary rocks, and it visualizes events in the physical space of a museum over time. The layers of the recorded video are changed in its height by the sound of the environment, i.e., the louder the audio, the higher the stripes.

This visualization reflects the levels of noise throughout time, allowing for a visual calendar of the activity in the museum.

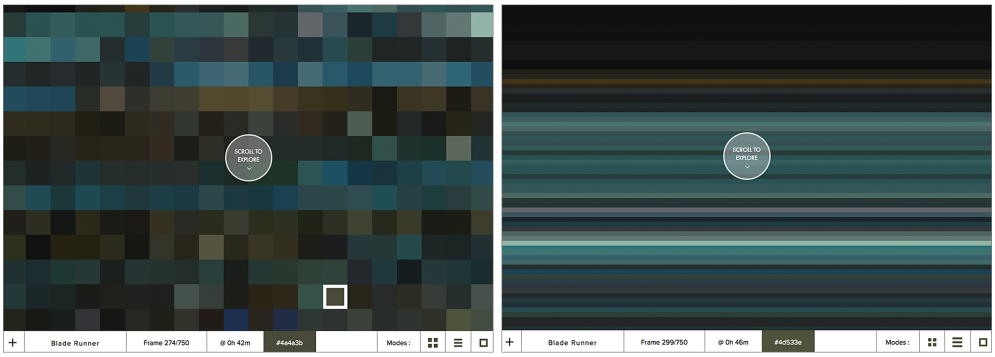


Figure 3.23. *Colors of Motion* (Clark, n.d.)

In the interactive visualization *Colors of Motion* (Figure 3.23) each square (image on the left), or stripe (image on the right) depicts a scene of the movie *Blade Runner* by its dominant colors. The system analyzes the frames and gets an average of their colors, allowing the user to be aware of dominant colors throughout the movie. By clicking on one colored square or stripe, the user navigates to the respective scene, and more accurate information about the selected color is available by click. Of interest to note in this visualization is the possibility for the user to be aware of the moves' mood through colors, and when located side by side, the viewer can relate and compare movies in order to watch them.

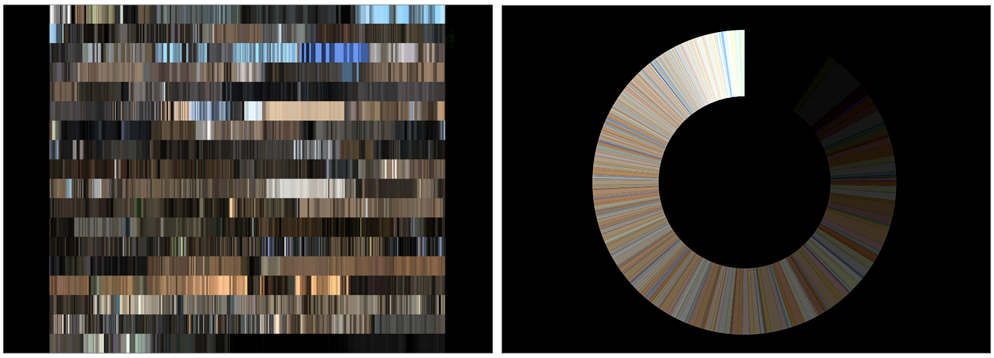


Figure 3.24. *Batman Begins* (Dirksen, 2013)

Adding to the previous visualization (Figure 3.23), Figure 3.24 presents a circular representation of colors throughout the length of the movie.

The circular representation of colors' progression is more accurate than the horizontal one since it prevents colors that are not immediately after or before to be mixed. The horizontal one is more detailed though, due to its wider range.

Figure 3.25. *Video Storylines* (Chen et al., 2012)

Video Storylines (Figure 3.25) automatically extracts and visualizes movies' narrative in a static image composition. Through a storyboard-like overview, images are organized left to right and top to bottom. The mood, the concept and context of the narrative are represented allowing the viewer to be aware of the content in a glance, without the need of watching the movie playing.

Figure 3.26. *Video Tapestries* (Barnes et al., 2010)

Video Tapestries (Figure 3.26) adopts the same goal of the previous visualization by gathering key frames in a sequence that ought to give an overview of the *Elephants Dream*'s narrative.

Similar to the previous visualization and following a linear timeline shape, the narrative is also perceived in a glance, although occupying a larger area in the layout.

3.4 Design Principles and Related Work

The sections above present work that relates to our visualizations. We believe they reflect interesting characteristics that helped us in the design of our own visualizations. We end by summarizing out how the design principles were used in these visualizations, as a foundation for our own proposals.

3.4.1 Function, Usability and User Experience

We now relate the way content, structure and interaction were represented having in mind the aim to foster function, usability and user experience. Content is addressed through the identification of the elements of the interface that convey meaning; structure relates to the organization that allows for the elements to be understood; and interaction as the way to be aware of other levels of information.

Content

We encountered interesting and surprising conceptual *metaphors* such as the clock (Figure 3.3, 3.20, 3.21 and 3.24); the river (Figure 3.2); the heart (Figure 3.8); the spine of a human body (Figure 3.9); walking steps (Figure 3.10), the world (Figure 3.15); and geological layers in sedimentary rocks (Figure 3.22); and physical *metaphors* as conceived by Lakoff and Johnson (1980), such as those that show amounts through size, in Figure 3.1 to 3.9, and 3.14.

Text legibility is questioned in Figure 3.2 where some tags are difficult to be read. Color serves to *label* in Figure 3.1, 3.2, 3.4, 3.5, 3.9, 3.10, 3.11 to 3.14 and 3.18; to *measure* in Figure 3.1-3.3, 3.5-3.9, and 3.14; and to represent reality in Figure 3.8. Design through color enlivens all the visualizations.

Structure

Gestalt principles are found through *proximity* and *similarity* (all visualizations); *good continuation*, (Figure 3.1-3.4, 3.8-3.10, 3.14, 3.16, 3.19, 3.20-3.24 and 3.26); *common fate* (Figure 3.1 and 3.5); *connectedness* (Figure 3.9, 3.10, and 3.15 to 3.17); *continuity* (Figure 3.2 to 3.4, 3.8 to 3.10, and 3.19 to 3.26): *figure and ground* and *focal point* (all visualizations excluding in Figure 3.23, 3.25 and 3.26).

Information is organized by *category* in all the presented projects, by *time* (Figure 3.1-3.5, 3.10, 3.14, 3.16, 3.19-3.24, and 3.26; and by location (Figure 3.6-3.10, 3.17, 3.18)

Interaction

Hierarchy of information is present in all visualizations, excluding the ones that consider one layer of information only (Figure 3.3, 3.20-3.22, 3.24-3.26).

Iconic representation is used in Figure 3.2, 3.8 and 3.15. Figure 3.20, 3.22, 3.24 and 3.26 hold one *layer of information* only, while others consider several layers.

In all visualizations information is related and compared side by side; and *micro and macro readings* is allowed in all since more detailed information can be disclosed by looking more attentively to the information; overview, zoom, filter, and details is allowed in the interactive visualizations and applications (Figure 3.1, 3.2, 3.4, 3.6, 3.11-3.21, and 3.23); focus and context is more visible in Figure 3.17 although, as in shrink, hide and embody principles, it is present in all the presented interactive representations.

3.4.2 Time and Space Dimensions

The specifics of time and space representations are addressed next.

Structure

All visualizations excluding those in Figure 2.27 to 2.32 may consider both points and intervals. Linear time is represented in Figures 4.2, 4.3, 4.13 and 4.14 and 4.19, while cyclic time is presented in Figure 4.4 to 4.10 and 4.16. Figure 4.21, 4.44 and 4.51 include both, and 4.12 is linear and cyclic, if it zooms in Figure 4.2, or 4.4, respectively. Only the visualizations that represent space consider points and area variables (Figure 4.27 to 4.51).

Information is discrete, absolute and with determinacy in all visualizations.

Data

Representations are abstract when they are based on time (Figure 4.2-4.21), they are spatial when maps are used (Figure 4.27-4.42), and they hold both in Figure 4.44 to 4.51. All visualizations have several variables and thus they are multivariate, and they all allow the user to access concrete data, in the first or second level information.

Representation

Visualizations are static by default, although those in Figure 4.21 and 4.44 might be dynamic, i.e., circular tracks can be moving in synchrony with the movie playing by the user request. They all allow interaction in the disclose of information. Visualizations in Figure 4.7 to 4.10 are represented in 3D.

4 Visualizations of Movies in Time and Space

Movies, with their rich contents conveyed in images, text, music and narration throughout time, tell us stories of different places and have great emotional impact on us. Moreover, technological advances are making available huge amounts of movies over the years, on the Internet and interactive TV. However, the richness that makes these movies so interesting and accessible, comes with a challenging complexity, highlighting the need for new and powerful ways to access, browse, and view them. Interactive visualization can play, here, an important role.

The works that served as inspiration and starting point for the visualizations we present in this chapter are *MovieClouds* (Gil et al. 2012), an interactive web application based on the *Tag Cloud* paradigm that allows to explore and access movies through the information conveyed in their contents mainly audio and speech with focus on emotions, and *SightSurfers* (Noronha et al, 2012) (Ramalho & Chambel, 2013), an interactive web application for sharing, visualizing and navigating geo-referenced 360º interactive user-generated videos as hypervideos, through which events can be synchronized with a map while happening on the video.

In order to present the design of the interactive visualizations, firstly, we address colors as codifiers of information used in most visualizations; secondly, we address the time dimension going from the collection level by genre and rating to the individual movies, and their contents, through image, audio, speech and emotions. Thirdly, the space dimension is explored by locations, from collections to the individual movies. Fourthly, spatiotemporal visualizations are narrowed through trajectories by speed and date of the shootings, to the content by image, audio amplitude and speech. Fifthly, we present the integration of spatiotemporal information in a single overview, and finally, we present the navigation with the main visualizations in order to provide richer and complementary information about the presented work.

The sketches have been done with *Photoshop* and *Illustrator*. *Processing* and *HTML5* were used in the building of the demo that was presented in several events and used for evaluation.

4.1 Colors

Colors, in addition to their role to label, measure and enliven information, induce and reflect emotions. As movies do. *Genre* is a motion picture category based on similarities in either the emotional response to the film (e.g., Romantic, Comedy) or the narrative elements (cowboys, aliens) (Wikipedia, 2017). Thus, we used colors in the design of the interactive visualizations in order to enhance, and ease the navigation through information in an appealing way, while reflecting the movies' mood, and the narrative qualities reflected in genres.

Although conceptually entangled, in the visualizations, genres and emotions are separate features, since they both represent genres assigned to a movie (e.g., Romance-pink), and the dominant emotions expressed on the movie (e.g., Love-pink). When the movie refers to its narrative elements, they do not so closely match emotions (e.g., Western-brown).

The meaning of colors is very personal, and thus our match relies in our preferences and literature (Figure 4.1). We use the Ekman (1999) basic emotions and the emotion coding colors by Plutchik (Kamińska & Pelikant, 2012) (both in section 2.5) to guide us. Regarding the Ekman's set of emotions, we added Love, due to the relevance of Romance in the cataloguing of movies. In order to harmonize all the colors, we adapted the rainbow palette.

Figure 4.1. Color code a) emotions; b) genres

We are aware of the influence colors have on perception, alone and near each other, e.g., brighter colors are perceived as closer to the viewer than darker ones. We aim at using colors with that in mind and thus, e.g., yellow represents *Comedy* (Happiness) since it is perceived as standing out in the same way a happy person feels, whereas dark blue represents Drama (Sadness) since it retracts among other colors. The emotion-color-genre match (Figure 4.1) is presented next:

- Purple-Thriller: The color of blood but in a darker and mysterious version;
- Energetic-red-Action: The emotions associated with red are rage (Plutchik, 1980), action, excitement (Kandinsky, 1977; Kaya & Epps, 2004);
- Orange-Musical: This is the second most lightened color of the spectrum, next to yellow, the happiest color.
- Hapiness-yellow-Comedy: Yellow induces joy, happiness, ecstasy (Hemphill, 1996; Kaya & Epps, 2004; Plutchik, 1980) and stimulation (Kaya & Epps, 2004);
- Surprise-bright blue-Sci-fi: From the over cleaned up and metal like environment of sci-

ence fiction and sci fi laboratories;

- Bright green-Fantasy: We find this color happy due to its closeness to yellow, the happiest color;
- Green-Adventure: Along with the bright green this medium green induces, we believe, the “Indiana Jones” adventurous feeling;
- Sadness-dark-blue-Drama: This color is sad (Plutchik, 1980), restful, quiet (Kaya & Epps, 2004) and timid (Kandinsky, 1977);
- Disgust-violet-Horror: Violet represents the illness and disgust (Kandinsky, 1977; Plutchik, 1980);
- Love-pink-Romance: The rose flower brought to this color the passion connotation;
- Brown-Western: Traditionally an US genre, these movies are geographically located in environments with this dominant color, e.g., the Grand Canyon;
- History-sepia: Color in old photos instantly induces an emotion related to ancient times;
- Fear-gray-War: This is the color of uniforms and vehicles of the military people and is related with lack of joy and fear.

The emotion-color-genre match aims in helping to associate these related properties in the navigation throughout visualizations, since, e.g., starting in a visualization that represents Comedy movies released in 2016, which are coded by yellow (e.g., Figure 4.2), the user can choose a movie and navigate to its content to be aware of which scenes are the happiest, also coded by yellow (e.g., Figure 4.39).

4.2 Movie Collections in Time

We present the design studies of time-oriented interactive visualizations of movies as aggregated information by genre and time of release, in two and three dimensions, by *Region of Colors* and *Tag Clouds*. Information is narrowed toward the contents by individualizing the movies either through abstract representations in overviews or more detailed and concrete properties in lists, being the abstract ones more suited to find movies by chance and the lists more suited to accurately access them. Visualizations support both casual and more analytical uses.

4.2.1 Rationale and Concepts

It is undisputed the power movies have to influence the viewers' mood, and the same applies to colors in their ability to induce states of mood in people. We take this assertion and attach colors to movies aiming in matching the emotional correspondence among them (e.g., both Drama movies and the color dark blue transmit Sadness, therefore Drama movies are coded by dark blue). Moreover, we are aware of the influence colors have among each other, e.g., that brighter colors are perceived as nearer to the viewer than the darker ones. This effect on perception enhances their power in reflecting emotions, e.g., yellow is a color that tends to show off whereas dark blue seems to retract, and thus yellow depicts Comedy (Enjoyment) while dark blue represents Drama (Sadness). We adapt the rainbow palette due to being perceived as natural by people, and for aesthetic reasons.

Along with colors, we rely on the *Tag Cloud* paradigm when expressing genre frequencies, following the storytelling concept that movies and videos intrinsically embody.

In the narrowing of information toward the individualization of movies, the star metaphor is taken from the movies' world, and accordingly, more or less rated movies are represented either brighter or dimmed, respectively.

Potential users are interested in exploring tendencies and trends in movie genres releases throughout time. They might be sociologists, filmmakers or interested people who want to access movies, while being aware of information about them, and these visualizations are meant to be very easy and simple to use by this target audience.

4.2.2 Design Studies

We present the design of interactive visualizations of movies released over time by genre, down to more detailed information in the individual movies. One year of releases is represented by genre through *Region of Colors*, and *Tag Clouds*. The color-genre matching (Figure 4.1) can be turned visible by request, or kept hidden.

Flowing colors in a timeline bring awareness about the genres released over time. In Figure 4.2, the year of 2011 is in focus, October appearing as the month of more releases, and Drama the most common genre, followed by Comedy. The *Tag Clouds* representation (Figure 4.3) shows the same information while allowing the reading with no need for the color-genre matching information, since genres are explicitly presented with text.

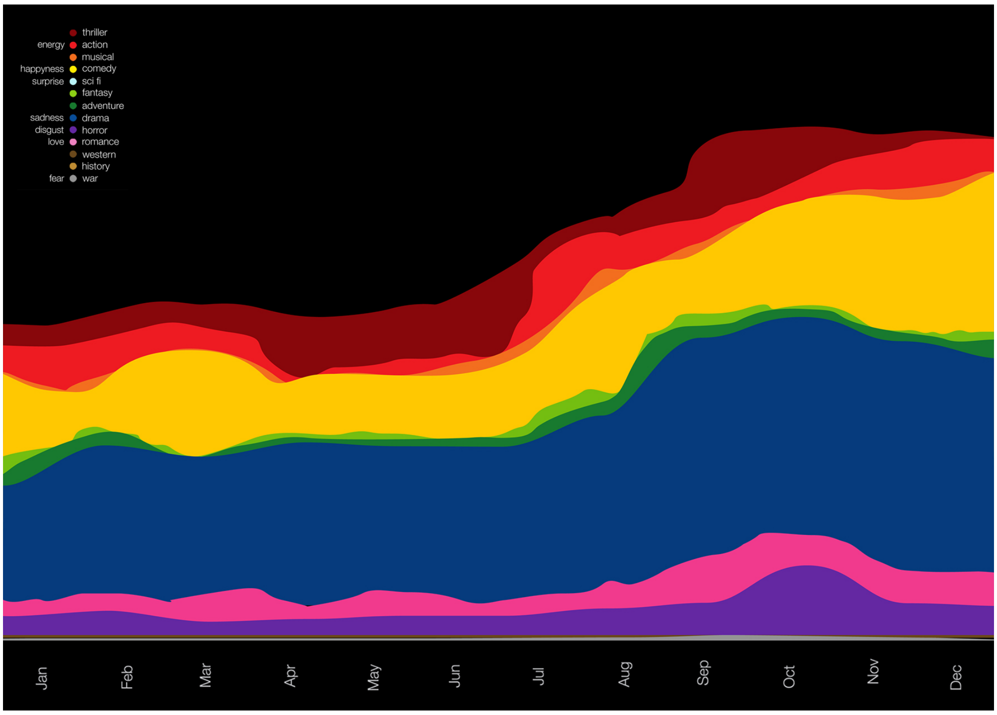


Figure 4.2. Movies in linear time over the year of 2011, by genre, through *Region of Colors*.

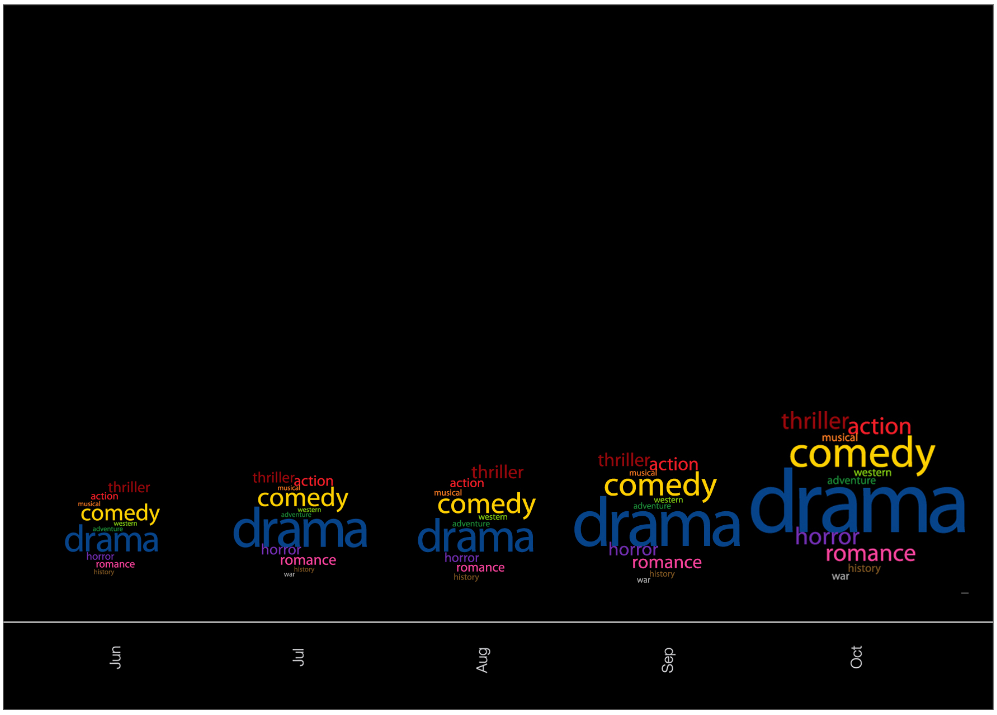


Figure 4.3. Movies in linear time (Jun-Oct, 2011), by genre, through Tag Clouds.

By comparing and relating the information represented throughout the years, it might be possible to infer if the preference from the movie industry to release Drama movies is a trend of all times or instead, if they belong to some particular moment in history, and furthermore, to relate preferences to their historical context. The underlying information that relates genres and emotions might bring awareness about the mood of the viewers over time, e.g., after a terrorist attack, knowing the preferred genre of people might disclose their state of mind.

Although visualizations based in *Colors* (Figure 4.2) and in *Tag Clouds* (Figure 4.3) differ in strength, in both, information that corresponds to higher frequencies is understood in a glance (e.g., Drama is clearly the most released movie genre), whereas the lower frequencies need the user to zoom in, in order for information to gain visibility. *Region of Colors* can be clearer in showing information, even more when represented with bright colors, nevertheless, visualizations based on *Tag Clouds* do not imply the mapping of genres' code since each tag explicitly present the genre.

In Figure 4.4, time is represented circularly, reflecting the way people consider the passage of time. When looking for patterns, these visualizations allow for a clearer comparing of several years side by side, and therefore visualizations in Figure 4.4 and 4.5 may be more efficient than linear (Figure 4.2 and 4.3) at showing this kind of information.

When comparing both *Region of Colors* (Figure 4.4) and *Tag Clouds* (Figure 4.5), the former presents a problem showing the information that is closer to the center and in distinguishing months. Regarding this problem, radial guides separating months can appear, along with the changing of the colors' order on demand, not to decrease the appealing value of the visualization, e.g. the Thriller genre that is the first from inside out might change place with the last one, War, and thus increase its visibility.

Issues related with the *Tag Clouds* representations are the difficulty of reading the information that is represented with dark colors, and the lower frequencies due to the diminished size and contrast caused by the black background. In order to solve these problems, these visualizations can be detailed by request. The quantities of movies in each genre released during a year might be related and compared in a clearer way by highlighting the color of the requested genre to white (Figure 4.6), preventing the distraction caused by the other colors while enhancing the level of the contrast against the black background.

Region of Colors and *Tag Clouds* were applied in Cyclic as a 3D helix (Figure 4.7) and helicoids (Figure 4.9) that go around every year and up to the next one, matching a synesthetic spatial representation of time that reflects the cyclic nature of the years and allows to compare and find patterns around and along the years.

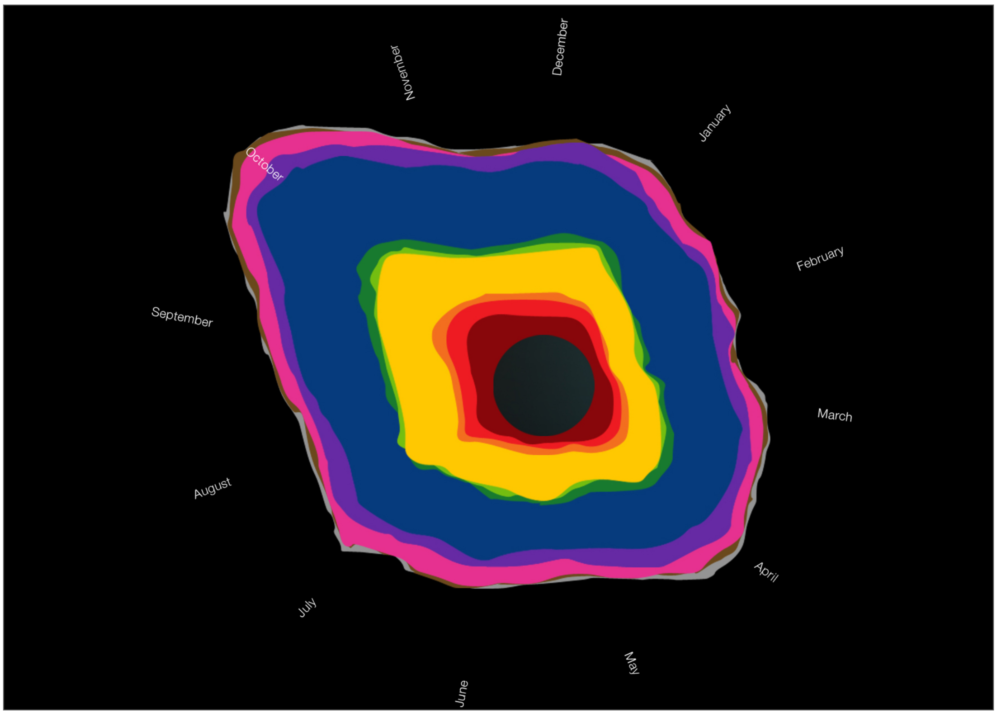


Figure 4.4. Movies in cyclic time over the year of 2011, by genre, through *Region of Colors.*

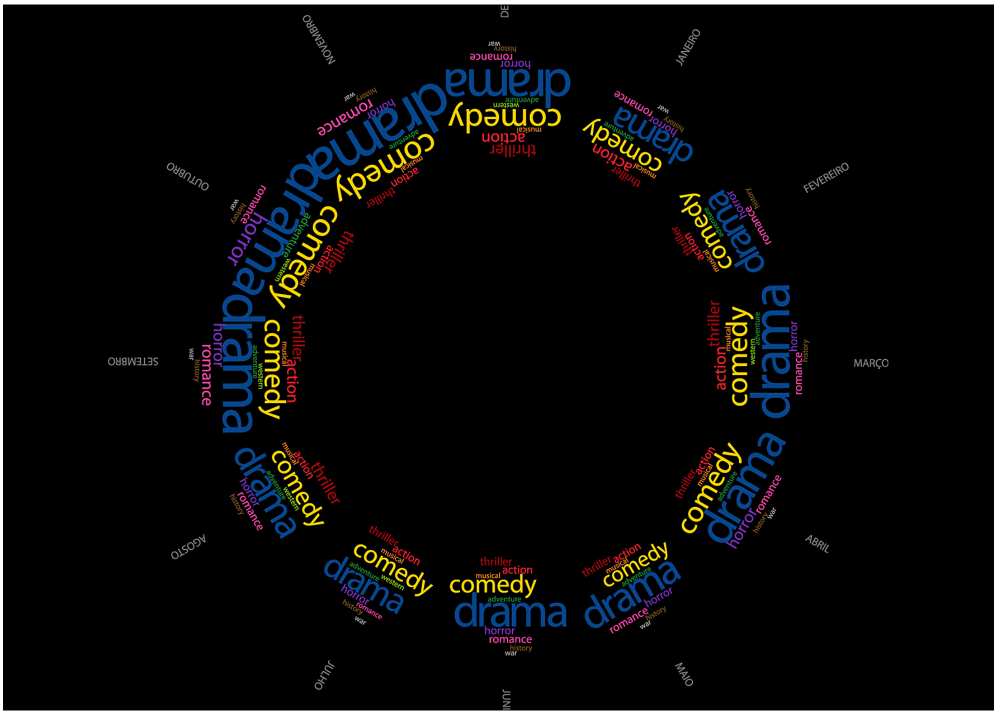


Figure 4.5. Movies in cyclic time over the year of 2011, by genre, through *Tag Clouds*.

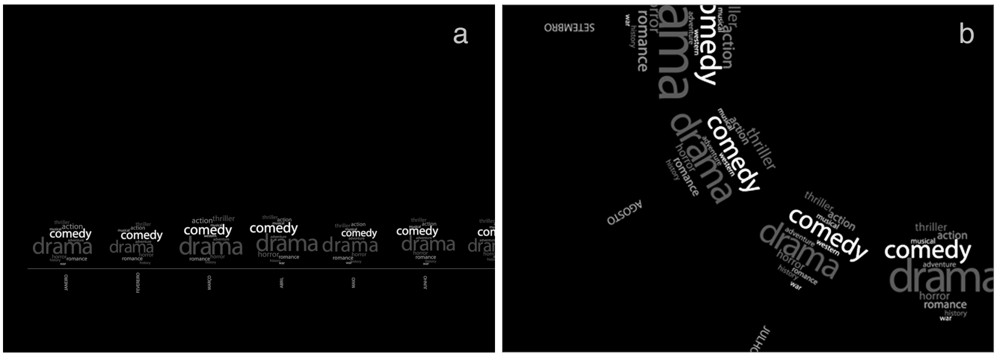


Figure 4.6. Details on movies in linear (a) and cyclic (b) time over the year of 2011 through monochrome *Tag Clouds*, with one genre selected.

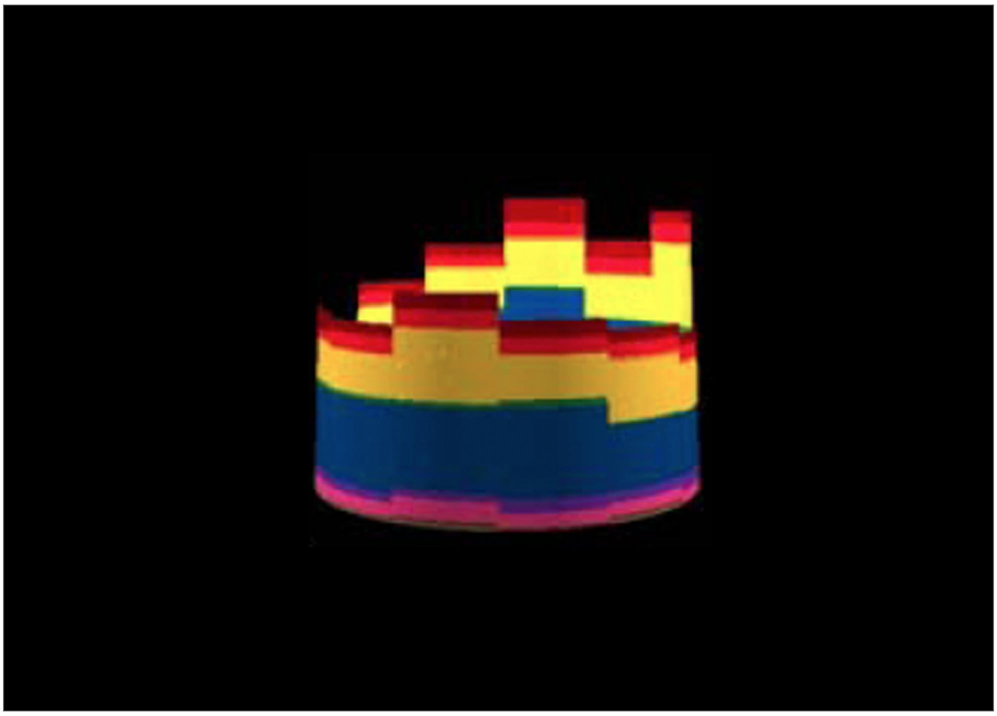


Figure 4.7. Movies released over one year (2011) in 3D cyclic time, by genre, through *Region of Colors*.

By dragging, the user chooses the better perspective for navigating information of movie releases from one year (Figure 4.7 and 4.8), two years (Figure 4.9) or several years (Figure 4.10). In the 3D representation of *Region of Colors*, frequencies throughout months were designed in hard transitions instead of *flowing* representations as presented in the Region of Colors in Figures 4.2 and 4.4 as a way to make more evident the different months and possibly ease the understanding of information during the interactive manipulation, since 3D might demand for more effort from the user in order to identify the months.

Figure 4.8. Movies released over one year (2011) in 3D cyclic time,
by genre, through *Tag Clouds*.

In Figure 4.9, several years of releases are presented and by dragging, it is possible to clearly compare the same month of more than one year. 3D visualizations ease the comparison of neighbouring months and the same month from different years, although hiding information from months that are on the other side of the year (on the back). These views might fold and unfold between linear and cyclic perspectives, and allow for the information to be explored in a more clear and ludic way.

We are aware of the challenge that *flowing* representations (Figure 4.2 and 4.4) present in showing information, i.e., frequencies are shown by the average value per month and smoothed in its shape in order to appear as flowing, what causes accuracy to fail. For this reason, visual efficiency of both *flowing* and *hard transition* visualizations (Figure 4.11) were designed in order to balance the aesthetic role of the visualizations versus the clearness in showing information.

From the representation of movies released over time, the user navigates to the individual movies (Figure 4.12). This visualization represents the zooming in of the initial overview (Figure 4.2 or 4.4). *Spots* depict movies by their genre and the more the associated genres the more spots attached to one movie. In this Figure, the selected movie has Drama and Romantic genres attached, so, the spots' dimension is half size when compared with the spot that depicts a movie with only one genre. A movie spot with three genres has one third of the main dimension, and so on. Each column represents one day of movies released.

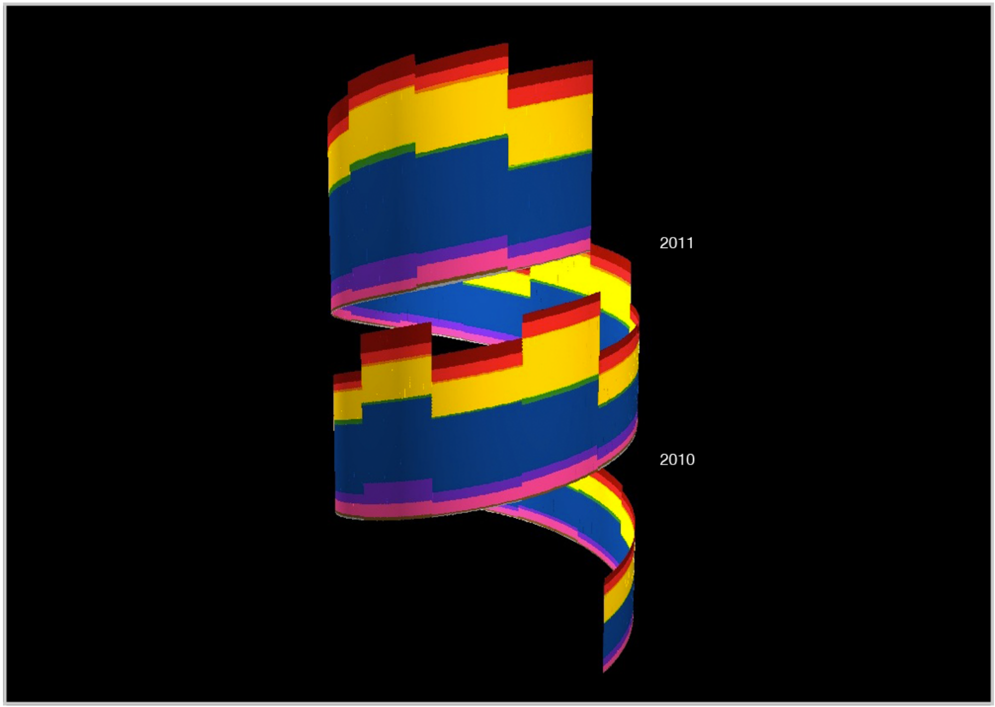


Figure 4.9. Movies released over two years in 3D cyclic time,
by genre, through *Region of Colors*.

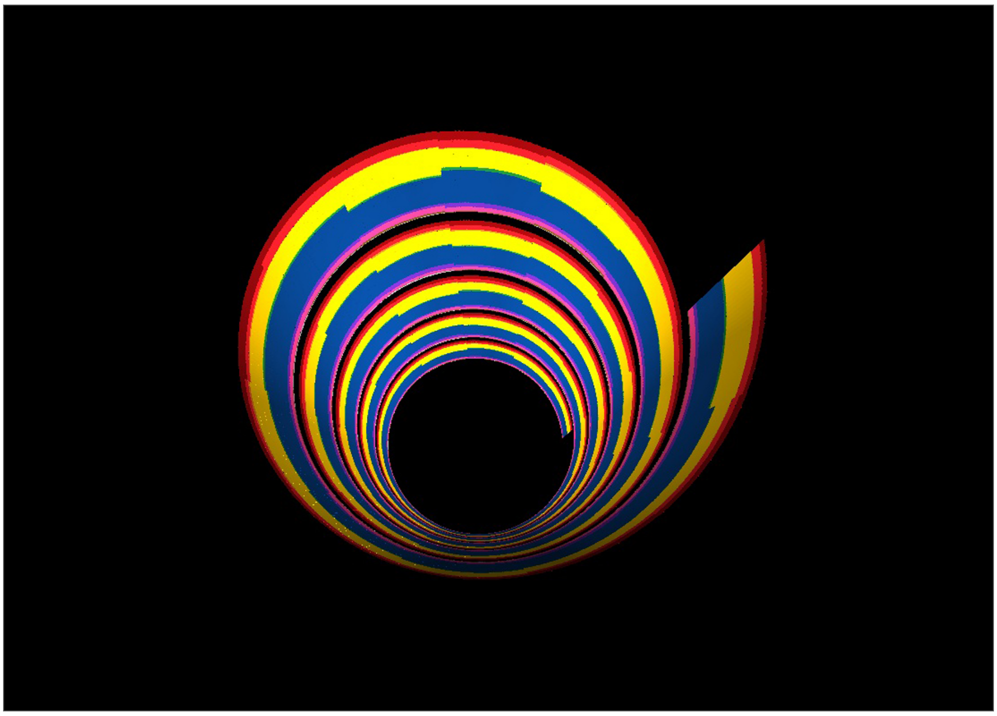


Figure 4.10. Movies released over several years in 3D cyclic time,
by genre, through *Region of Colors*.

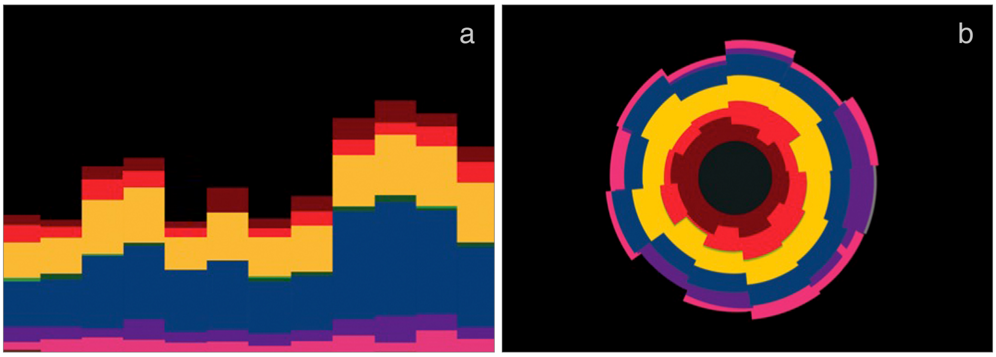


Figure 4.11. Movies by *Region of Colors* in hard transitions in 2011.

On mouse over one spot, in Figure 4.12, other spots from the same movie are highlighted allowing the user to be aware of all the genres tagged to that movie. After clicking on one spot, related information about the selected movie turns visible (title, genres, rating, date of release, and location of the shooting), and on double click, the movie can be watched (Figure 4.15). If clicking on *contents* in the tag, it is possible to navigate to the visualization that shows the content of the entire movie (Figure 4.16, 4.19, 4.21 and 4.44).

The main goal of this visualization is to show an overview of the movies released over time, while also allowing to find movies by chance, and by knowing when they were released. For this reason, other levels of information about the movies are disclosed only by user's request.

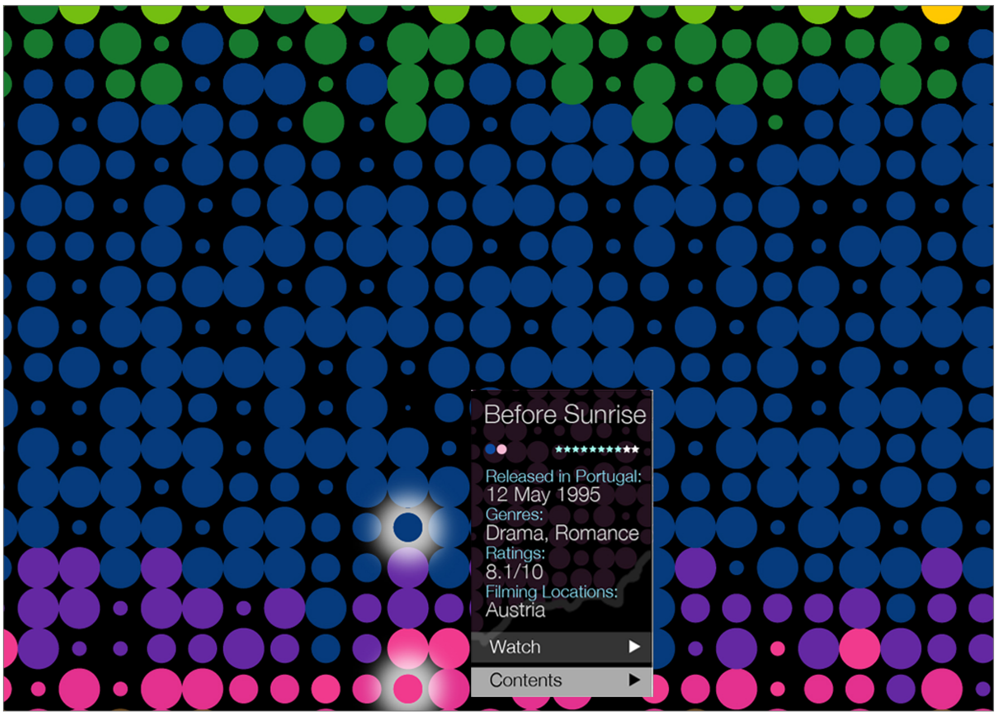


Figure 4.12. Zoom in and Details by genre, through Spots.

Figure 4.13. *List* view over one month (March, 2011), by genres and rating, in alphabetic order.

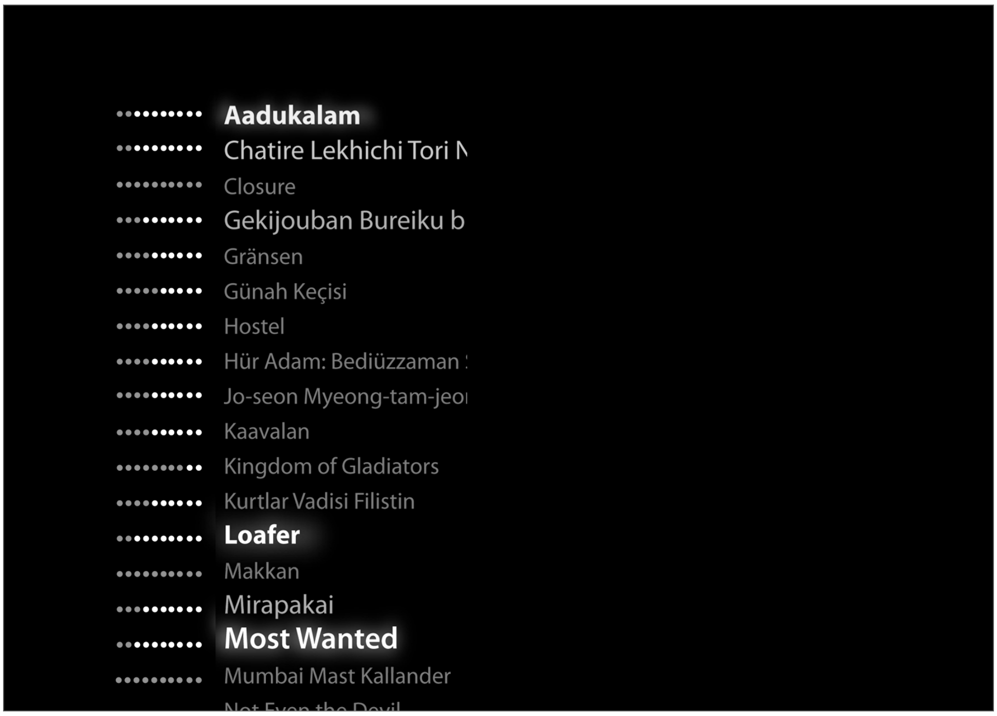


Figure 4.14. *List* view over one month (April, 2011), by rating, in alphabetic order.

Another possibility of seeing the movies released and choosing one to watch is by *List*, either by genre and rating (Figure 4.13) or by rating only (Figure 4.14). It is also possible to choose the alphabetic or the rating order. Higher rating is represented through progressive brightness, i.e., the brighter the title, the highly rated the movie. By using one of these visualizations, the user might be aware of all the movies that were released in one specific month of the year by the requested genre, and all the other genres of those movies are highlighted. The user can choose one movie to watch, or go to its contents.

4.2.3 Interaction Example

A possible navigation is presented in Figure 4.15. Users might start on the overview of movie genres released in 2011 in order to be aware of which genres were the released in that year, e.g., on Christmas (a); zoom in and either choose a movie to watch by chance (b), or accurately by *List* (c); and eventually access a movie to watch (d).

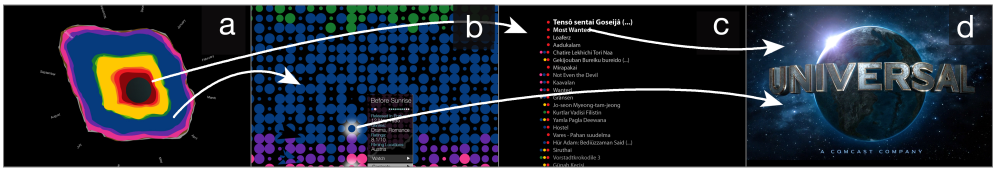


Figure 4.15. Navigation: One movie is selected either by *Spots* or more accurately (title *List*).

4.3 Movie Contents in Time

Visualizations presented in this section narrow the information about collections of movies toward individual movie's contents. After the individualization of movies (Figure 4.12-4.14) the user selects one or more movies to explore.

4.3.1 Rationale and Concepts

Choosing a movie to watch can be a hard task due to the large number of movies available, and therefore, ways to assist the viewer in the browsing of movies are wellcome. On the other hand, the awareness of the properties waived in the movies' contents can be interesting and fun, while useful. But browsing movie contents is also a challenging task due to their complexity, richness and the amount of properties gathered throughout their length in time.

It is our intention to allow the interactive exploration and access to movies in different perspectives related with image, audio, and speech, with a focus on emotions. We present visualizations that show the contents of movies and allow for zoom in and details for more accurate views. They provide the means to index and browse movie contents by the request of the user.

Concentric circular shapes are based on the clock metaphor according to the way people conceive the passage of time, while holding the role of rotating and steering to influence the progress onwards and backwards. In addition, they allow presenting the whole movie fitting a thinner space, making better use of the screen when compared with horizontal straight timelines. Traditional linear stripe shapes are also adopted, following the same concept, as the direction left right is usually used to represent the progression in time while allowing to present more detailed information to view in a glance.

Movies influence the viewers' emotions and this may be taken into account when selecting a movie to watch. It is our aim that visualizations are able to reflect the emotions associated with the movies, both expressed in the movies or felt by the users, to raise awareness about emotional impact, and help to choose the movies to watch.

The potential user is interested in movies relating their formal and semantic properties. They might be professionals that work directly with movie creation in the doing, e.g., of movie trailers; casual users that want to choose a movie to watch, or just curious viewers interested in different perspectives of movies. These visualizations imply easy uses although they might be of major usefulness for specialized tasks due to the types and the complexity of available information.

4.3.2 Design Studies

The proposed interactive visualizations show the contents of entire movies. Firstly, we present representations that allow to compare movies side by side. Secondly, we narrow and complement information toward one movie. All visualizations allow for increased details on demand, and to index and browse the contents to access the movies in a specific moment of their duration.

Movie content by Image, Audio, Speech and Genre

Visualization in Figure 4.16 allows to relate and compare the circular elements that represent the movies' contents through images, audio amplitude, most spoken words and genres, which reflect an overview of the movie context at first glance, e.g., a bright representation with loud audio and slang language suggests an energetic and teen-like movie. By interaction, the user can be aware of the title and the plot, see frames, and watch the movie playing.

The following features are represented:

- **images**: playing the most important role in the visualization, the images of the movie reflect an overview of their context at first sight, being the level of summarization customizable. If the user chooses to be aware of the contrast of light and colors throughout the movie, the summarization shows more scenes, and thus less detailed images (Figure 4.18 on the left). A more concrete overview of the movie context implies less, but more detailed scenes (Figure 4.18 on the right). In order to narrow that information, on hover on the images, the user can see the frames of the movie;

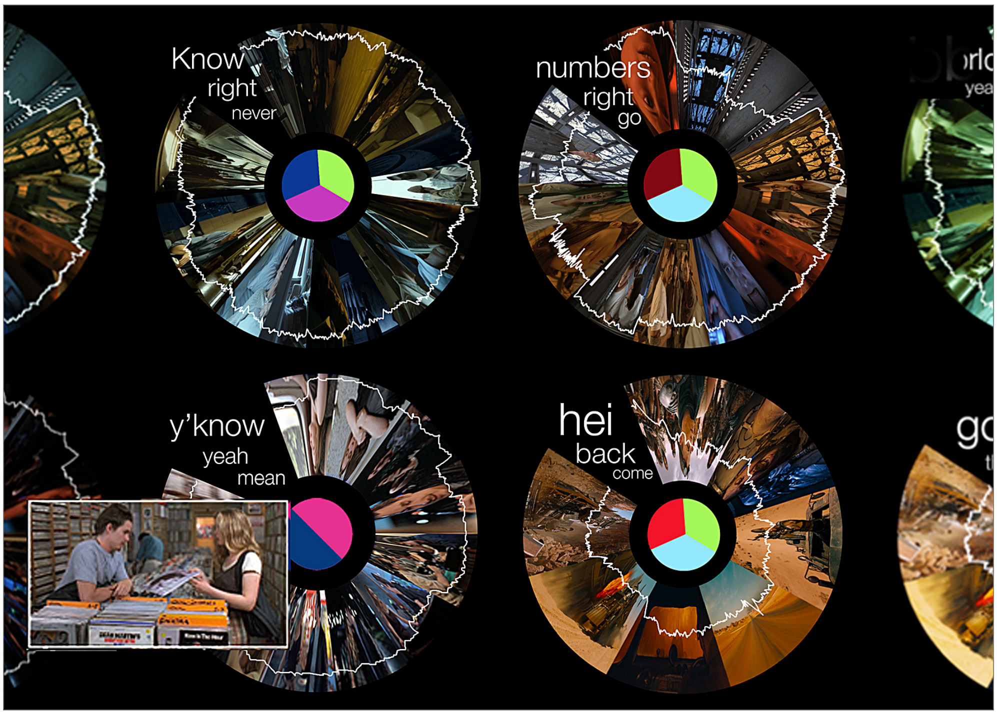


Figure 4.16. Comparing different movie contents by image, audio, speech and genre.

- **colors**: the movie can be represented by its dominant colors, which might reflect more traditional, nature-like, or more provocative films (Figure 4.17);
- **audio amplitude**: represented by a white stripe, variations in audio reflect rhythm and the dynamics of the movie. On hover on the stripe, audio plays in the selected moment of the movie;

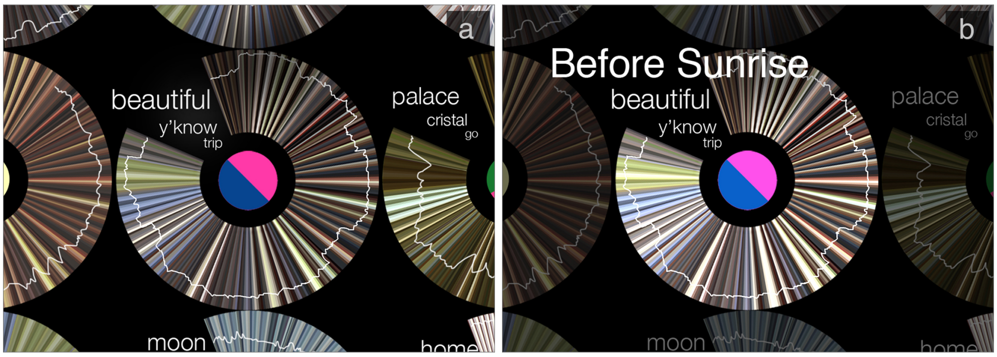


Figure 4.17. Details on movie content by dominant colors.

- **speech**: spoken words are represented by a white *Tag Cloud* that shows the kind of language used. It might bring awareness about the suited target for the movie, either a teen and rebel-like viewer (e.g., 'gonna', 'man' and 'bullshittin' retrieved from the movie 'Gone in 60 Seconds', from 2000), or otherwise a more traditional, or older people (e.g., 'Mr', 'well', 'Oh', and 'Mrs' in the Downton Abbey series, from 2010), giving and idea of the context;

Figure 4.18. Details on movie content by the number of the represented scenes.

- **genres**: presented in the center of the representations according to the color matching established in Figure 4.1, they complement the information about the movie. On hover, genres are named in words. The color-genre matching might be visible on the upper left corners of the screen by request, as in Figure 4.2.

- **movie paying**: by clicking one image that stands for one of the movie scenes, the movie plays that scene (Figure 4.16);
- **plot** and **title**: depending on the intention of the user, title and plot are visible or hidden. Although accuracy is promoted by text, the ultimate goal of this visualization is the representation to be able to prompt emotional sensations on the user, which might help them to choose a movie to watch in a more intuitive, and innovative way.

This visualization aims to reflect emotional effects perceived by the represented properties in movies, in a way that the user is able to explore and compare them side-by-side in order to choose one to watch, in an emotional way. Moreover, the user can also explore and navigate movies in more accurate ways taking advantage of their characterization.

Movie Content by Image, Audio and Title

Also based on the summarization technique and presenting similar goals as the previous visualization, the representation in Figure 4.19 aims to emphasize the rhythm. The dynamics of the movies is shown in their duration, information that is reflected by the audio amplitude. Each bar represents a movie that alters its height depending on audio frequency. By zooming in, the images of the movie are clearer (Figure 4.20), and different levels of summarization are customizable by the user, similar to what is shown in Figure 4.18.

This visualization allows to compare different movies in a chosen combined perspective over the timeline, and on mouse over, the respective frame of the movie is shown (upper left in Figure 4.19). The movies' duration is also easy to be aware of and to compare. Given the higher accuracy of this visualization when compared with the previous visualization (Figure 4.16), titles are visible in the first level information.

Although holding less variables than the visualization in Figure 4.16, this representation shows duration and rhythm in a clearer way. In the Figure 4.19, it is easy to perceive that the movie *SkyFall* is much more dynamic while shorter in duration, than *Cube*'s. Moreover, other variables could be assigned to this visualization (e.g., image-duration-motion instead of image-duration-audio amplitude) in order to complement information.

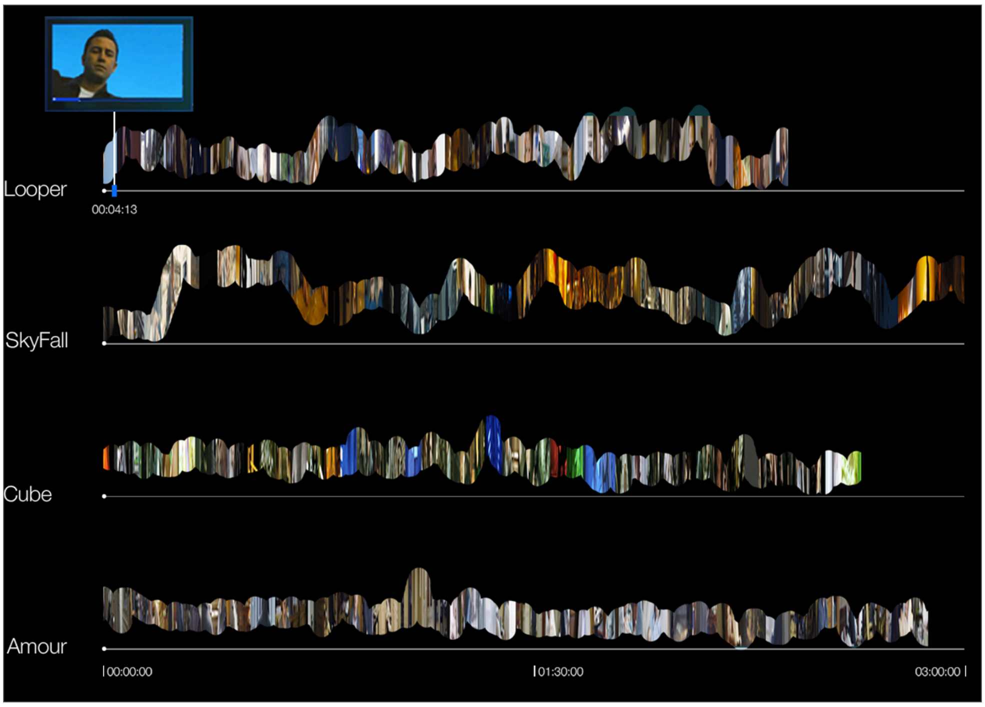


Figure 4.19. Comparing movie contents by rhythm, showing title, image, and audio amplitude.

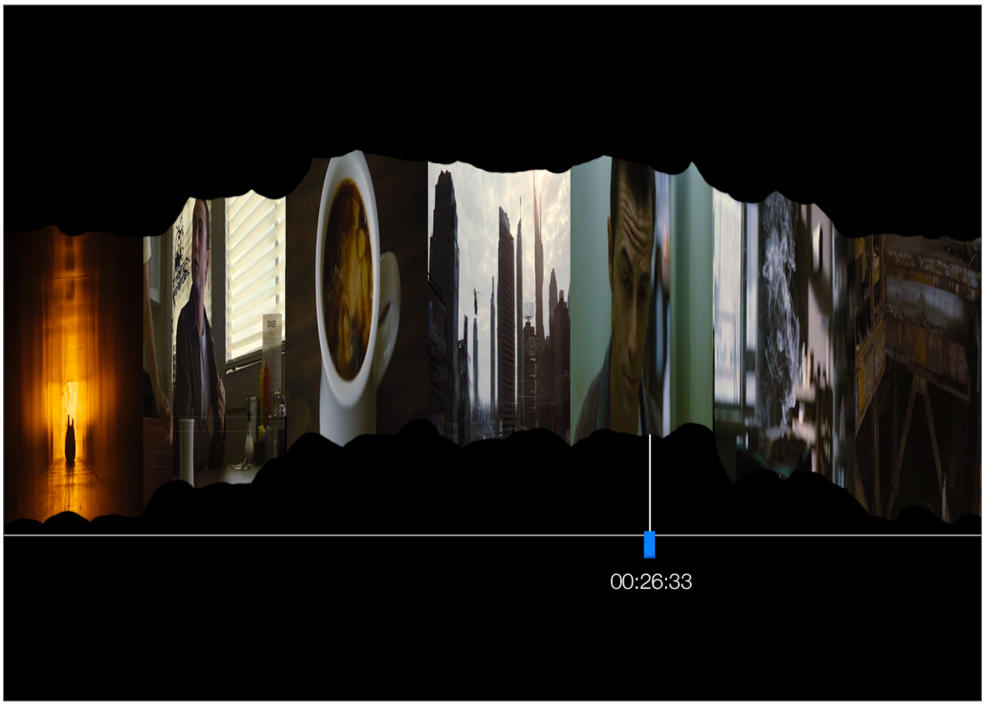


Figure 4.20. Zoom in of 4.19 by level of detail.

Movie content through image, color, audio, and emotions

We now address the content of one movie according to the same visual concept of the visualization in Figure 4.16, while complementing information by providing new features.

The visualization presented in Figure 4.21 stands for an entire movie. It is composed by circular elements synchronized with a timeline that depict the movie content properties by segmented scenes (thumbnails of the first frames of the scenes, motion, color, spoken words and emotions), typical information about the movie (title, genre, date of release and rating), and the movie playing in a selected scene. By default, the circular tracks are visible and those that relate with the timeline hidden, being their appearance in the visualization chosen by the user. Colors depict both emotions and genres according to the emotion-color matching established in Figure 4.1. The emotions that are located inside the circular tracks change over time, reflecting the emotions associated with the different scenes, and the genres in a second layer of information, on the upper right of the screen.

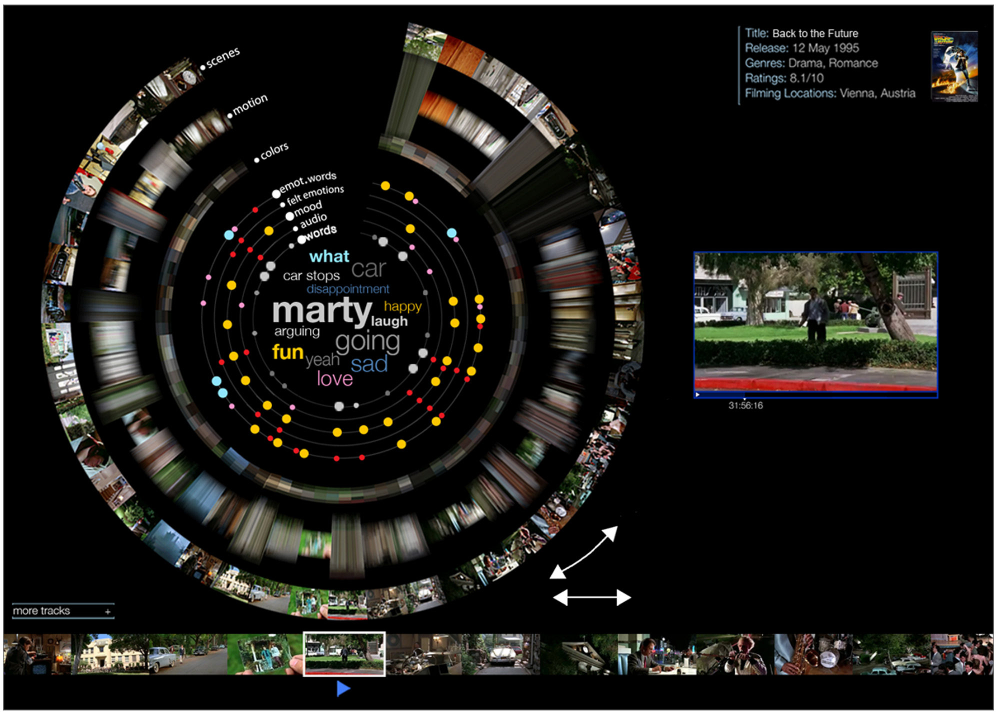


Figure 4.21. Movie contents by image, motion, colors, audio, speech, emotions, related information and the movie playing.

In Figure 4.21, the user might have an overview of the movie at first sight through the colors and motion variations, with the dominance of yellow suggesting a happy movie.

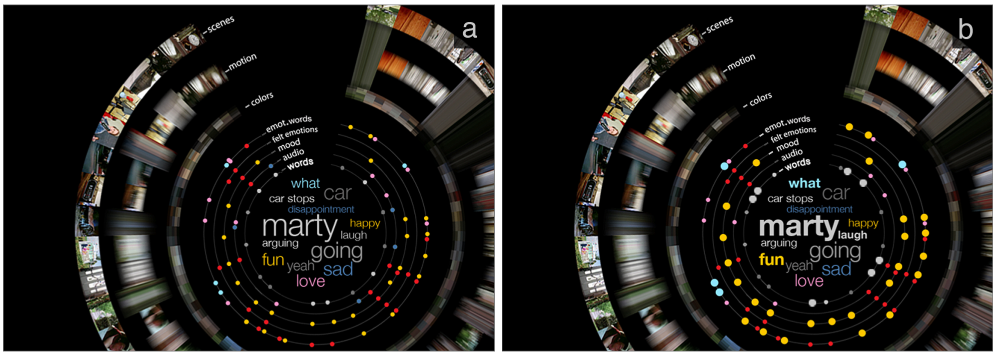


Figure 4.22. Details on content tracks: *Tag Cloud* and *Spots* selected on b).

We name and explain the tracks of information from inside out:

- ***Tag Cloud***: represents an overview of the content of the movie in a chosen perspective that we exemplify for spoken words and emotions:
    - **most spoken words**: these tags reflect the kind of language used, as explained in Figure 4.16. They are coded by shades of gray and correspond to the spots with the same color in the respective circular track. Shades of gray are randomly assigned in every click, for flexibility. On click, each word lights up the spots that relate to that word for the user to be aware of the exact scene when it occurs. As an example, the figure on the right in Figure 4.22 shows the word 'Marty' highlighted and the correspondent white larger spots in the respective circular track, depicting the scenes in the movie when they are mentioned;
    - **emotions**: represented according to the color match of Figure 4.1, and similarly to the spoken word frequency use, the emotions retrieved throughout the movie's length are observed by clicking on the colored words in the *Tag Cloud*, which highlights the respective spots in the circular track. The user becomes aware of the exact scenes that reflect that emotion, and they can watch the scenes. Emotions might standout according to our concept, e.g., a large word 'fun' in yellow (Happiness) reflects a good mood film by showing off, whereas a large word 'sad' in dark blue in the visualization reflects the opposite mood;
- **spots**: color spots have correspondence with the *Tag Cloud*. By clicking one spot, the respective word stands out in the *Tag Cloud*, and on double-click that scene is selected (Figure 4.22);
    - **spoken words**: marks the time location in the movie's length when the words in the tag are spoken;
    - **audio events**: spots are highlighted when some particular audio event happens (e.g.,

laugh, claps);

- **mood in audio**: represent audio or music mood (e.g., calm) throughout the movie duration following the color match code;
- **felt emotions**: measured on users while they were watching the movie, felt emotions are represented following the color match code;
- **emotions in speech**: representation of emotions expressed in the movie, retrieved from words, and obeying to the established color code set;

- **colors**: dominant colors throughout the movie;
- **motion**: amount of movement in the scenes represented by growing blur of the thumbnail images, i.e., the more dynamic the scenes, the more blurred the respective track;
- **scene thumbnails**: images that correspond to the first frame of each scene;
- **movie playing**: on the right of the screen, the scene that is selected in the white frame below the circular elements is playing, providing context;
- **traditional movie information**: text is provided up right in the visualization for a quick overview about the title, date of release, genre, and rating.

Figure 4.23 shows overviews with two different selected scenes. By dragging, either the circular tracks or the timeline, forward or backwards, the user can choose the scene of interest (e.g., the most dynamic). They might also double click in any scene in order to select it, causing it to match with the white frame in the timeline, and watch the scene playing. All the properties of that scene align vertically towards the middle of the circular tracks. In order to clear the layout, the user might see all the tracks or otherwise choose to hide those that are not of interest. Either way, the tags that stand for the properties maintain their visibility and might be clicked at any moment.

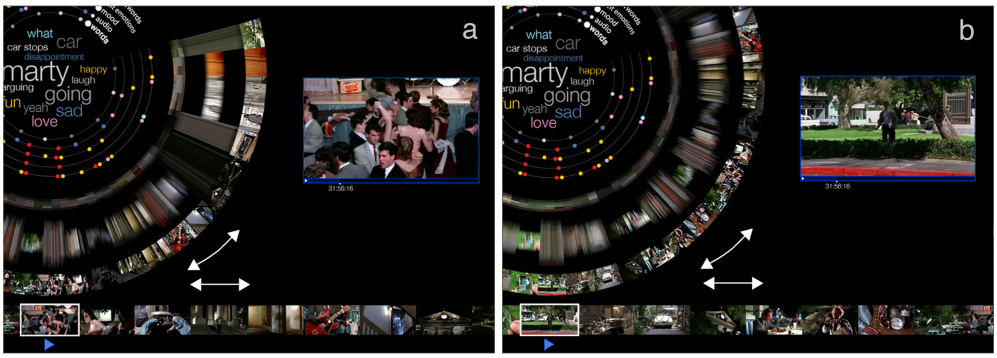


Figure 4.23. Details on two different scenes selected.

The intended scene can be observed with more detail on the timeline, where circular tracks and timeline scenes match. This synchrony of circular tracks and timeline can be automatic (user choice) matching in the current moment, as the video plays.

Since there are many content tracks available, along with the referred possibility to turn information visible or hidden, the user can change the displaying place of the movie depending on the their goals, e.g., if they are interested in visible tracks below the timeline (Figure 4.24), the floating display can be placed on the right (Figure 4.23), whereas if only the circular tracks are on interest, the floating display can be placed below the timeline.

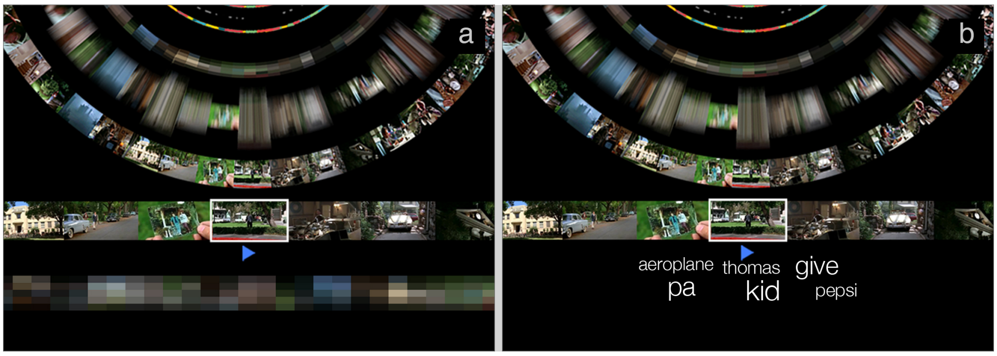


Figure 4.24. Details on two different tracks selected in the timeline: a) colors; b) *Tag Clouds*.

The user can either change the color palette according to their culture and taste, or turn it to monochromatic. In the latter case the maximum contrast will be assigned to the words and the correspondent spots, while keeping their matching, e.g., to a white colored word retrieved from speech will correspond a white colored spot in the circular track. Also as optional, along with the possibility of both the circular tracks and the timeline moving in synchrony while the movie is playing, an animated *Tag Cloud* might change as the scenes go by, as an alternative to the default static cloud that represents the entire movie. Visualization maintains itself static unless the user chooses it to be dynamic.

Comparing contents of movies

Through the thumbnail images of the scenes in the timeline, this visualization allows to relate and compare movies regarding image, movement and audio amplitude (Figure 4.25).

At first glance, only images and colors stand out letting the user have an idea about the brightest and darkest scenes of the movies. The scene that is playing on the right corresponds to the selected thumbnail in the white frame of the upper timeline. As in the previous visualization (Figure 4.21), both circular tracks and timelines move in synchrony. On click on one thumbnail of other movie, both the circular track and the timeline of that movie rotate and change places in order for the selected scene, - both in the circular track and the timeline – to lean against each other, as the reddish thumbnails in Figure 4.25. Related information about that scene is highlighted on the right and the scene of that movie plays.

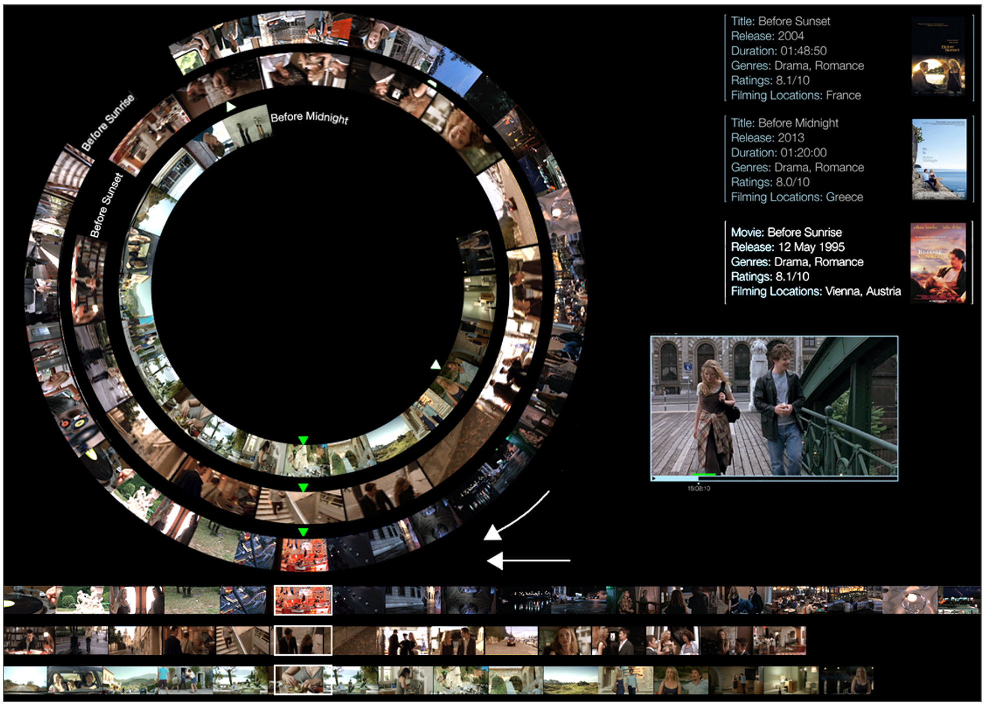


Figure 4.25. Comparing movie scenes by image and movement, or audio amplitude.

The user might ask for the most dynamic scene of the compared movies and they align vertically marked with an arrow in white, matching the scene both in the circular tracks and on the timelines in the white frames below. A second frequency might be requested, e.g., the louder scene, and they also align, with the arrow in bright green. The first requested scenes maintain the first mark that depicts the most dynamic scene, in white (Figure 4.25).

Other variables are possible to be considered in this visualization, e.g., the louder scene of the movies against the brighter ones. The user might be taken to previous visualizations in order to obtain more diverse information about each movie (Figure 4.19 or 4.21).

4.3.3 Interaction Example

A possible path is represented in the navigation shown in Figure 4.25. After comparing four movies by image, colors, audio amplitude and the most spoken words (a), the user narrows that information toward rhythm (b). They choose the most dynamic movie in order to explore the emotions that reflect its narrative in the, e.g., spoken words or audio events (c), and eventually watch the movie (d).

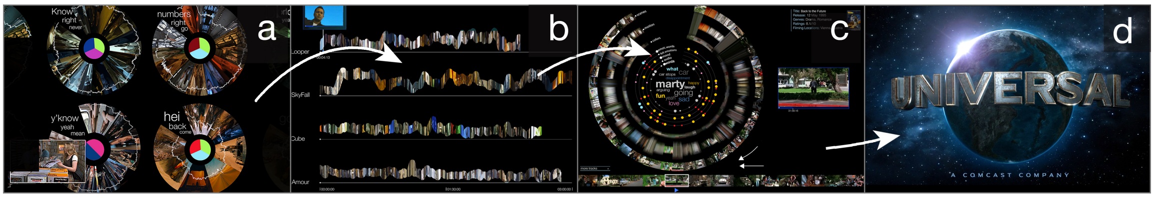


Figure 4.26. Navigation: The user selects one movie to watch after knowing about its images, audio, words and genre, and narrow information toward rhythm, exploring its contents in different perspectives.

These visualizations show different levels of information being the first two (Figure 4.26a and b) at the level of collections of movies and the last two for individual movies.

4.4 Collections of Movies in Space

In this section, we address locations by presenting visualizations that allow to explore and compare both amounts of movies released by various genres, and by one genre only, while allowing to access them.

4.4.1 Rationale and Concepts

Maps can help to ease the understanding of the spatial dimension, and as models of reality, when linked with movies, offer the viewer a new view of reality (Peuquet, 2001) amplifying the power of movies in affecting perception. By considering the spatial dimension in visualizations of movies, we aim at enhancing and enriching the user awareness when accessing and viewing them, and help choosing movies to watch by places of interest.

Conceptually, when representing amounts of movies shot, we maintain the use of color on the coding of genres, and the star metaphor through brightness, for frequencies.

Regarding a casual use of these visualizations, choosing a movie to watch by location and genre seems to be the most suited goal, but also researchers that study trends about the movie industry, along with the underlying information about emotional factors that can lead to those releases might be interested to figure out these trends.

4.4.2 Design Studies

The following visualizations allow the user to be aware of movies released by genre in a specific location, in a limited period of time.

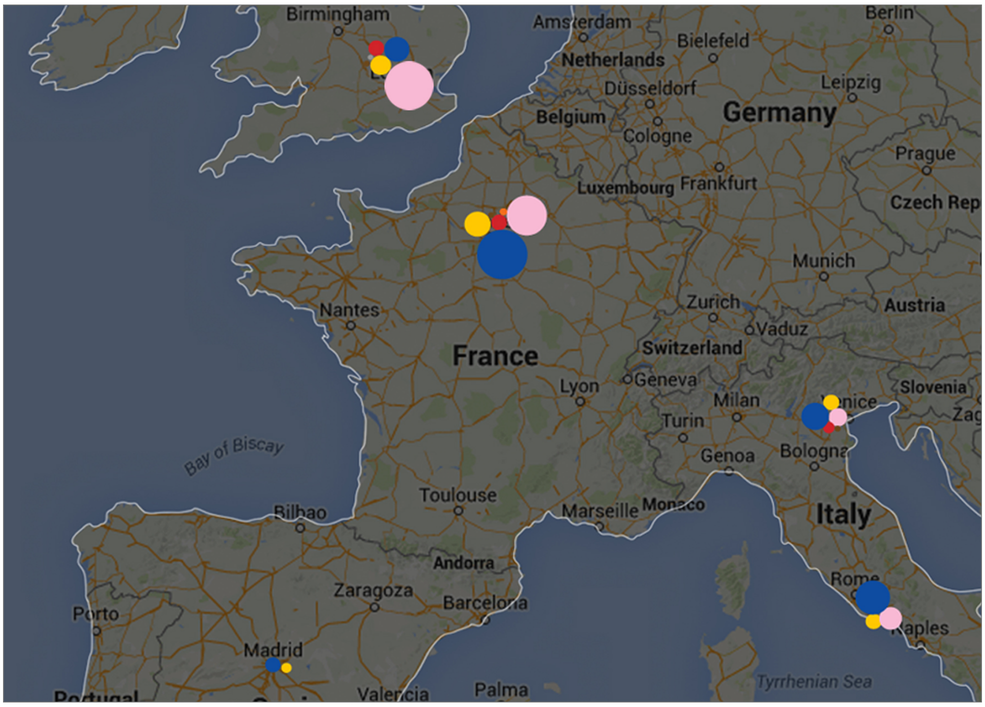


Figure 4.27. Movies released by location and genre.

Through the sizing of the circular shapes, visualization in Figure 4.27 allows to compare the numbers of movies released by location and genre. It is clear in this view, that Paris is the city with more movies released, and that the preferred genre is Drama (in dark blue). It is also possible to observe that Romantic movies have more releases in London than in Paris, the ‘city of love’. This information is clearer in Figure 4.28, where Drama genre releases can be compared among countries through pink strength. Since this visualization relies on colors to show information, issues regarding color blind people might appear, and thus the user can customize the color genre codes changing them to textures.

The user can select one country of interest, e.g., Austria, along with their preferred genre, e.g., Romance, in order to revisit it in the movies (Figure 4.29). They can individualize the Romance movies released in Austria (Figure 4.30) and click to watch one, by chance, or after turning visible the title, rating, and the other genres of that movie.

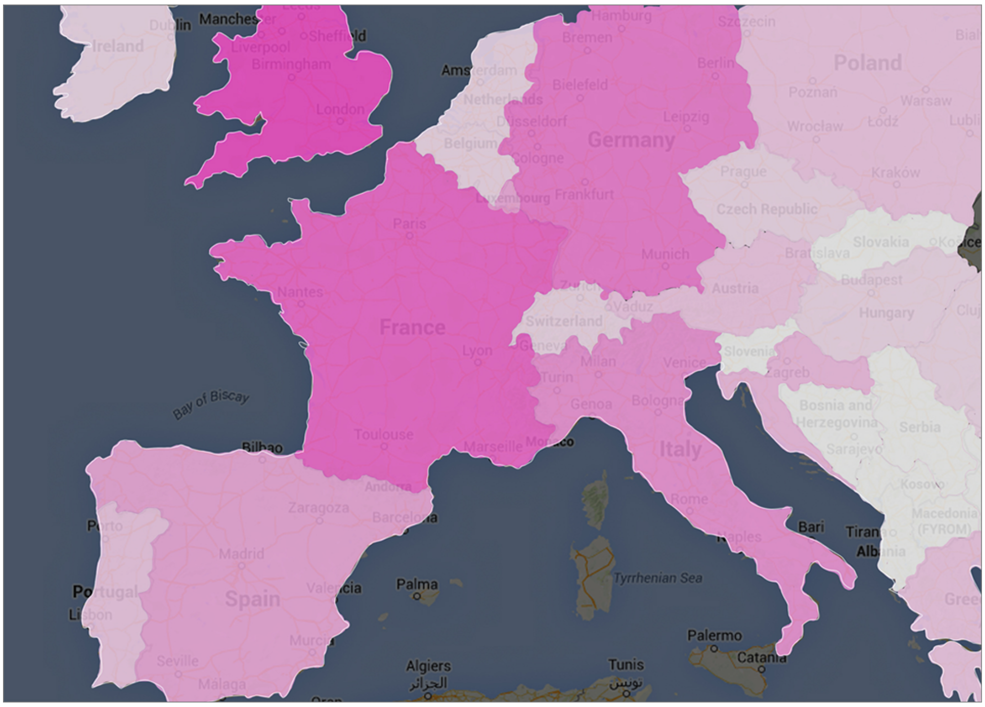


Figure 4.28. Details on *Romance* movies released by location.

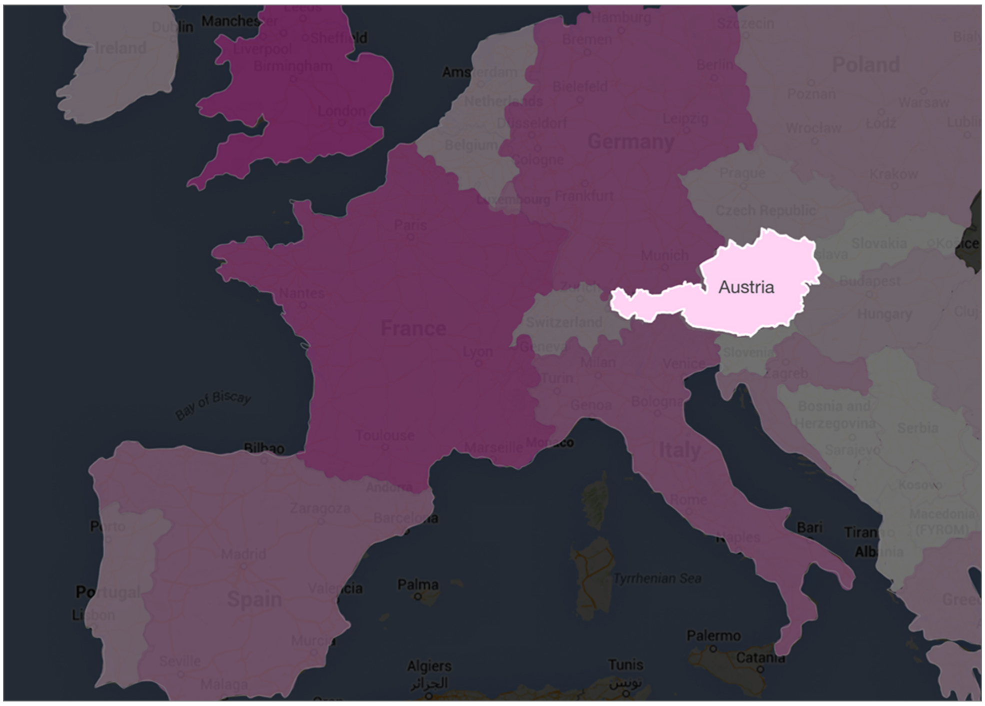


Figure 4.29. Austria is selected.

Similarly to the visualization in Figure 4.12, each large spot represents one movie with one associated genre, and the smaller ones depict movies with more than one genre attached, e.g., a movie spot with 2 genres has half of the main dimension, and so on, when compared with the larger spots that stand for movies with one genre. On hover on one spot, a tag with information about that movie appears, allowing the user to both watch the movie, and be aware of the properties waived in its contents (e.g., Figure 4.21). Moreover, the user can select more than one movie to relate and compare (e.g., Figure 4.16).

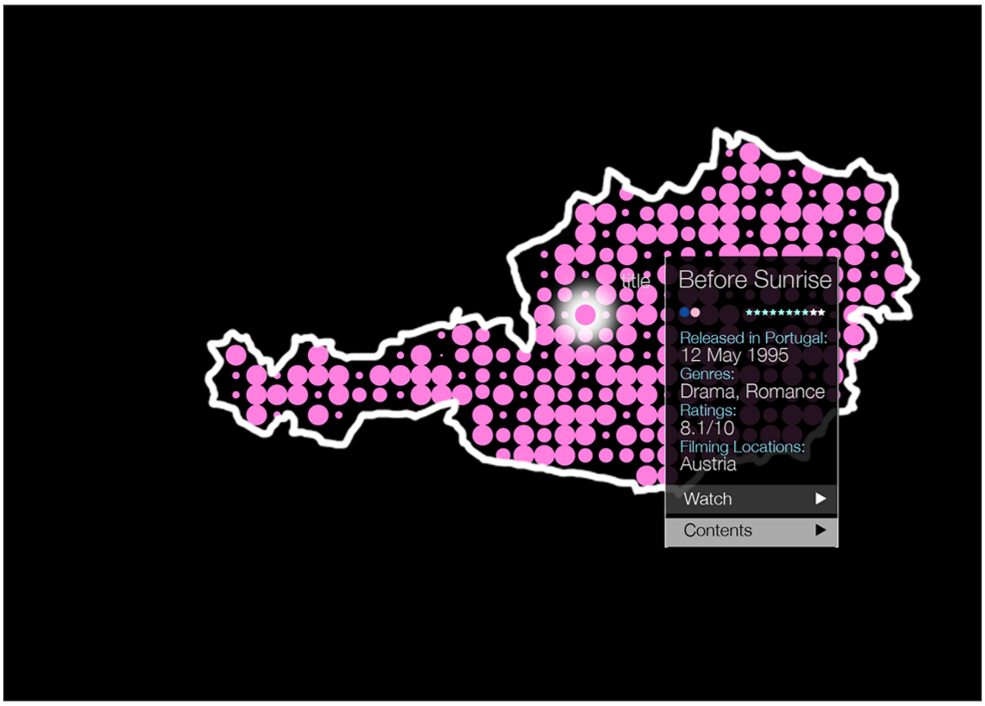


Figure 4.30. Movies released by genre and location.

Movies might be part of sequels, as in the case of *Before Sunrise*, *Before Sunset* and *Before Midnight*. The shooting places of these sequels are represented in Figure 4.31. Detailed information about each movie turns visible by click.

All the locations filmed in each movie might be explored (Figure 4.32). On the upper right part, a larger window with a zoomed map is presented, showing the spots of the filming locations, and below, the locations that correspond to the spots. The user can select one area by clicking in order to know more about that geographic location.

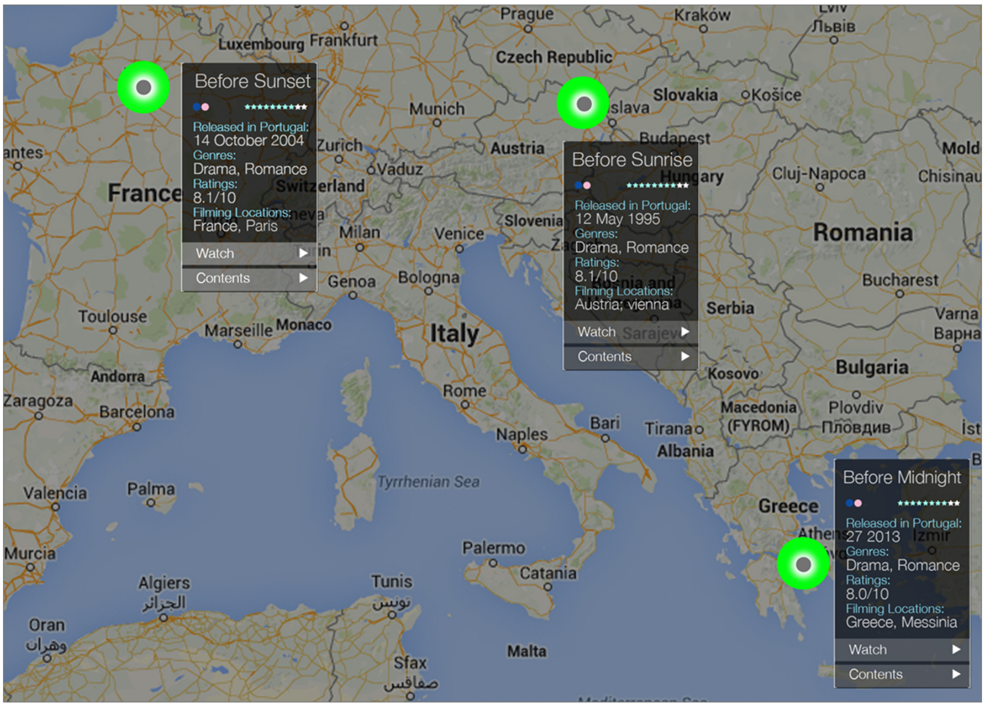


Figure 4.31. Movie Sequels by location.

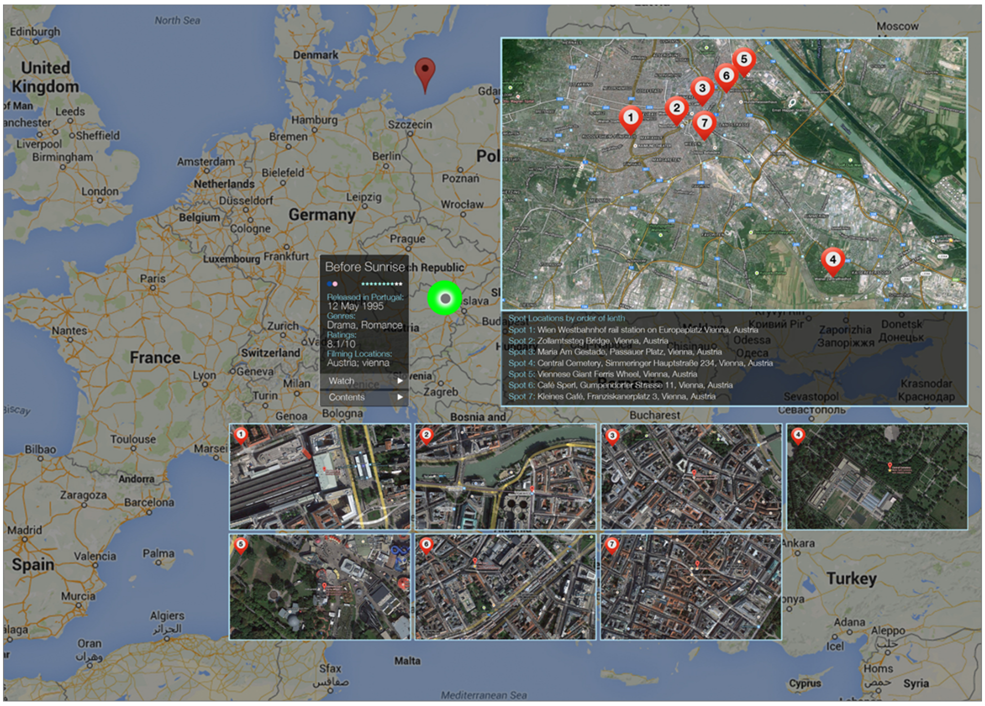


Figure 4.32. Details on all the trajectories shot in one movie.

4.4.3 Interaction Example

After wandering through information about the Romance genre releases in Austria (a), the user chooses one to watch (b). After watching the movie (c), they are curious about the places where it happened and explore all the locations where the movie was shot (d).

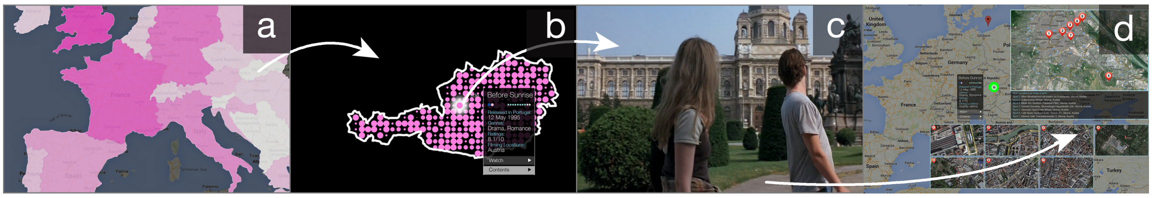


Figure 4.34. Navigation: From amounts of romantic movies by country to one movie in Austria, to other movie scenes filmed in that location.

4.5 Movie Collections in Space and Time

Locations are represented and narrowed towards trajectories, complementing the space dimension with time. Firstly, we present trajectories in movies by maps, and secondly, zoom in and detail the information, allowing to relate and compare trajectories by speed and date of the shooting.

4.5.1 Rationale and Concepts

The link of movie locations and trajectories to a map through their spatial coordinates is an interesting feature to explore due to the richness and complexity that information about places in the world contains. The possibility for the user to explore countries and cities by the information retrieved in movies provides interesting criteria to browse movies, and as far as we know this type of variables is not widespread for common use.

As metaphors, we keep on using brightness to depict quantity, and the footprints that in concept, originated them. Bright green turns brown when representing the ageing of trajectories, according to the passage of time of the tree leaves.

The user might be a movie director doing the spotting of a location for future shootings; or a researcher that aims in studying a city regarding its development over time; or a tourist that wants to be aware of places to visit before doing so, or a movie fan wanting to explore the locations where the scenes took place.

4.5.2 Design Studies

Movie trajectories released by location in a limited period of time are addressed. Larger and brighter representations correspond to the places where more movies were shot.

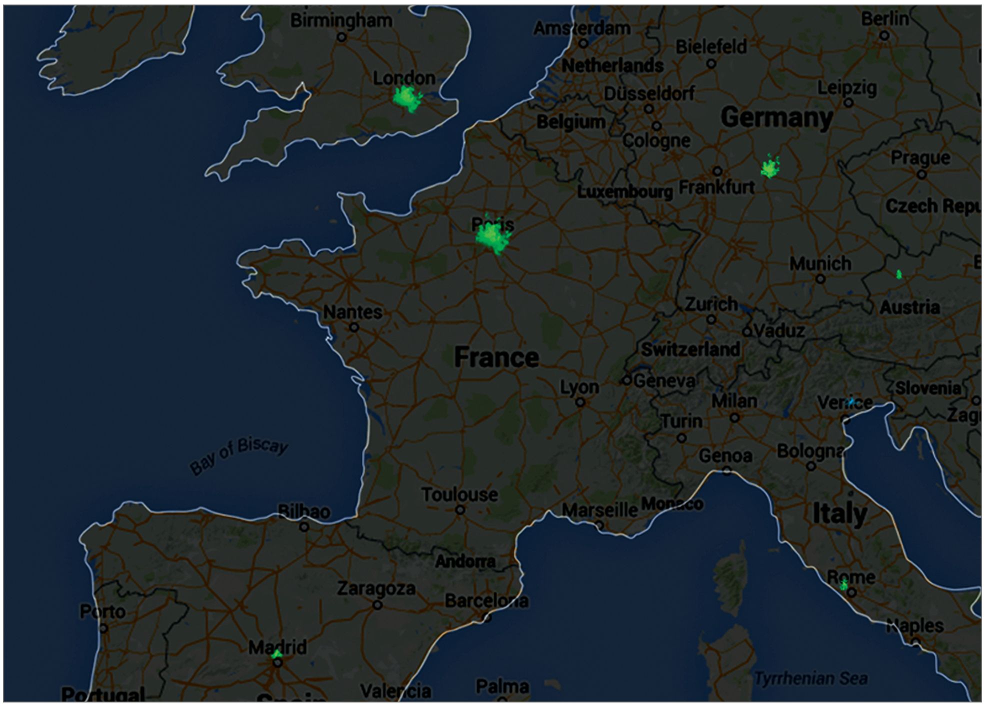


Figure 4.35. Trajectories in movies, by location.

Very simple and clear, the visualization in Figure 4.35 allows to have an overview of the trajectories shot by location, and on hover, a tag with accurate information about the movies turns visible.

For more accurate information, the user can zoom in one specific area (Figure 4.36). As in previous cases, the brighter the color, the higher the amount of trajectories shot. Overall level of light is optional in order to allow the user to choose between lighter or darker background. If lighter, the background enhances the detail on the locations on the map, while the darker increases the contrast, and thus clear the represented amount of tracks. Users might filter the search by criteria relating time and space (e.g., the most shot location in Lisbon, at 9 p.m.), and choose several trajectories to explore.

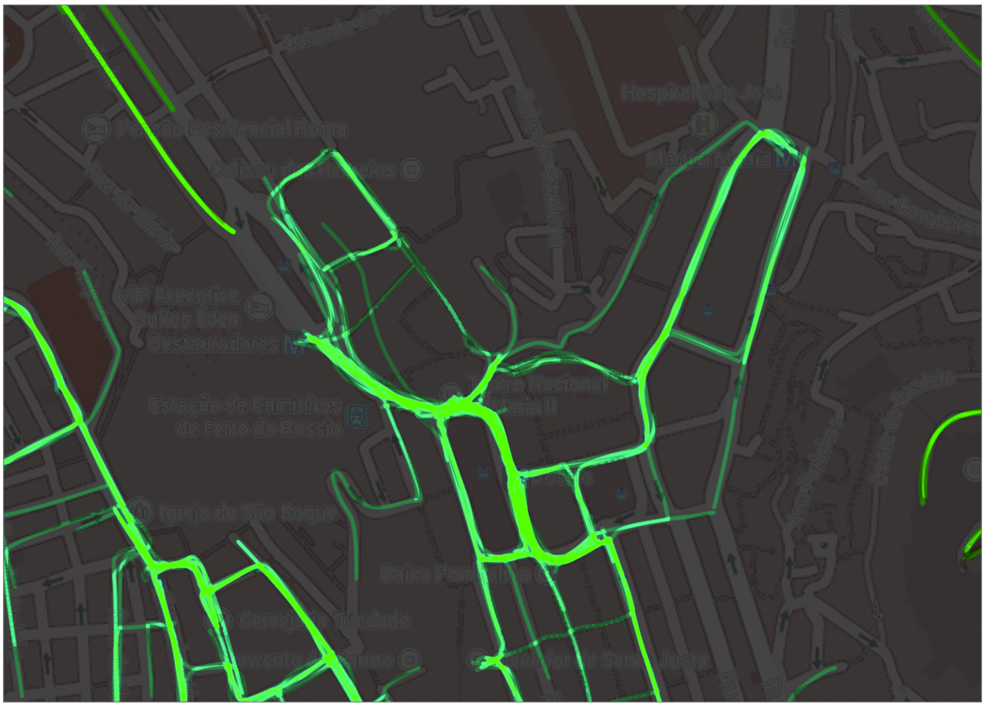


Figure 4.36. Trajectories - Zoom in on closer area.

Details on trajectories by speed and date of the shooting

A 3D representation complements the previous information, allowing to compare speed and date of the shootings among geo-referenced trajectories (Figure 4.37-4.38). By dragging, the users choose the angle view that better shows the information they requested. The height of the arcs correspond to the duration of the shooting and thus, the higher they are, the slower the tours, whereas lower arcs depict faster tours. The color represents age in association with nature: the brighter green the arcs, the more present in time the trajectories.

In Figure 4.37, the start and end of the trajectory, along with the closeness and dispersion of the shootings perspective area, are more important than the specific streets that constitute it, since this information is already in focus in Figure 4.36. It can be seen in detail, though, by dragging the visualization towards a bird’s eye view perspective. Visualization in Figure 4.37 is clearer in showing trajectories’ location giving a loose idea about their date and duration, whereas visualization in Figure 4.38 allows to better relate and compare the date and duration of the tours, since both height and color are easier to compare due to its perspective and flat black background.

As a principle held in all visualizations, accurate information about numbers can be switched on/off, depending on the user's interest. They might prefer to turn the information invisible to allow a clearer idea of the relations between the length and age of the videos.

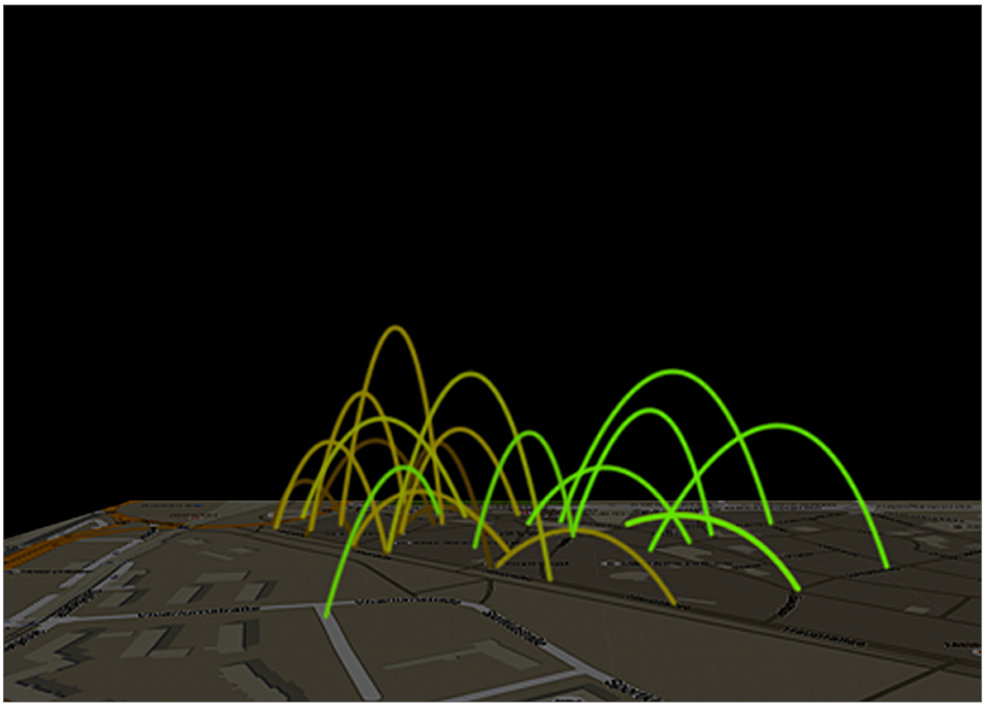


Figure 4.37. Details on closer area by location, speed and date of the shooting.

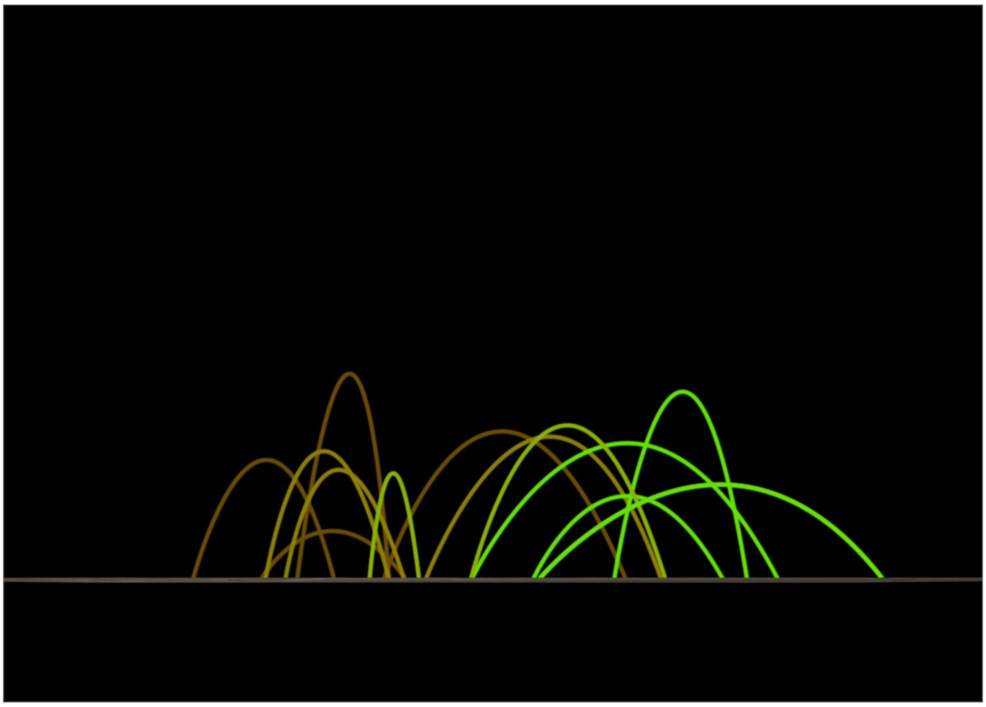


Figure 4.38. Another view on Details, where speed (higher arcs) are easier to compare.

Details on one trajectory by speed

Visualization in Figure 4.39 represents the zoom in with details on one trajectory, as if the user had selected one tour from the visualization in Figure 4.37. Represented in bright green, its thickness varies depending on the speed, corresponding the thinner parts to the fastest and the thickest to the slower moments of the tour. Very simple by holding only one variable, this visualization serves specific uses, e.g., a moviemaker that might want to be aware of the most detailed moments of the trajectory, that might be the most beautiful ones.

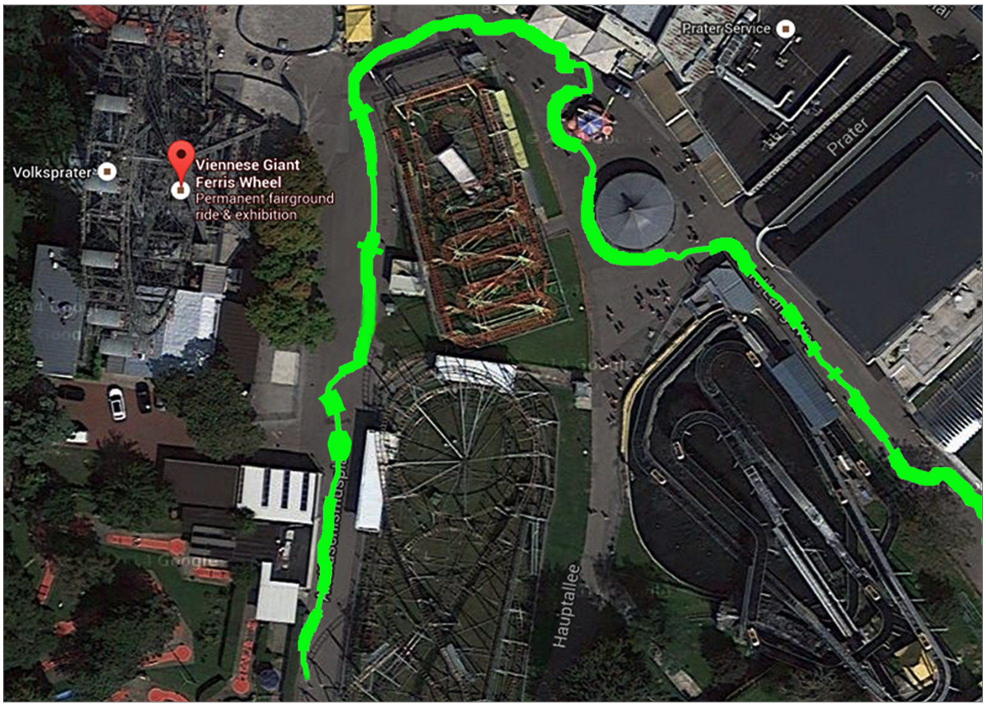


Figure 4.39. Zoom in and details on one trajectory by speed.

From here, the user navigates to other levels of detail of the selected trajectory and can be aware of its content properties (Figure 4.41).

4.5.3 Interaction Example

In Figure 4.40, one navigation path is suggested. The researcher is investigating the development of one location in time through the movies that were filmed there (a). They start by choosing the most dated tours, and continue to the newer ones in order to see the changes of that area over time. They choose the slower ones aiming in getting the most details possible (b) and narrow that information toward one trajectory that shows different levels of detail throughout the tour (c), They watch the scene that shows that trajectory (d).

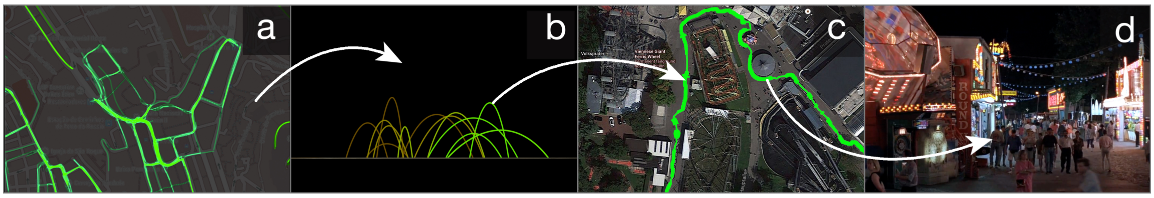


Figure 4.40. Navigation: The user details the information about the movies shot in a particular area by speed and date of the shooting, after which they choose one to know more about.

4.6 Movie Content in Space and Time

We now zoom in the movie content relating both to space and time. Firstly, we address the information of one trajectory by image, audio amplitude, most spoken words, and information about other trajectories shot in the surrounding area. Secondly, both dimensions are gathered in an expanded visualization that represents the entire movie by image, motion, colors, scene length, audio, speech and emotions.

4.6.1 Rationale and Concepts

It is common sense to refer and characterize movies as emotional experiences. From here, we suggest that movies store emotions, and thus they are remembered, as well as felt, later in time.

We deepen emotions both by the footprint metaphor, as if people were leaving behind their personal experiences, emotions and thoughts during the tour through the information that was stored in images, audio amplitude and words, and by presenting the entire movie content through its visual and audio attributes.

Potential users are people interested in the analytical and emotional environment and content of movies, and locations. They can be movie directors, editors, someone in the tourism business.

4.6.2 Design Studies

We present the content of a movie. The next visualizations allow the exploration of movies both relating specifically to one of their trajectories, or to their attributes relating to image, audio and words. The user might go from exploring one trajectory and decide to be aware of the movie that contain it, or do the inverse, i.e., after exploring one movie content, narrow the information of the trajectory of one specific scene.

Movie Content in Space and Time: based on trajectory

This visualization follows the visual concept of the visualization in Figure 4.19, and thus the level of summarization can be adapted to the interest of the user, i.e., depending on the requested detail, images are more, or less detailed (Figure 4.20).

According to the previous visualizations that represent contents, the user can have an overview of the filmed place, e.g., from images, to know about the brightness or darkness of the shooting, if it was filmed outdoors or indoors, or if it is nature or city like. The low or high audio amplitude might reflect a calm or fun street; and the words that were recorded might refer to the place thus complementing information. Other places that were shot near the addressed trajectory are represented for the user to better explore the area. On hover on the image, the respective frame turns visible, and on click, the movie plays.

The next features are available in the visualization (Figure 4.41):

- **geo-referenced position**: represented on a map, it allows the user to be aware of the precise location by the name of the streets and the start and end points of the tour;
- **images**: priority on the images of the trajectory demands for a more detailed, and thus longer summarization;

Figure 4.41. Movie Content in Space and Time: based on timeline, by location, image, audio, speech, neighbour connections, frame of the selected moment in the video length.

- **colors**: since the level of summarization is customizable by the user, the dominant colors of the tour might be explored;
- **audio amplitude**: represented through color contrast over the trajectory, in blue, it can be changed in opacity depending on the interest of the user, i.e., it is transparent for a major focus on the images of the trajectory, while more opacity corresponds to more accurate information about the audio variations. We believe this information can add an idea of the mood of the trajectory, e.g., if it is noisy, or quiet;
- **spoken words**: speech is represented in *Tag Clouds* based on their frequencies. It might characterize the tour, especially when words relate to the location that is being shot. These tags are represented aside the trajectory, in white;
- **neighbour connections**: connected to one specific tour and follow outward other streets. Other paths are shown through small red circles specifying also the direction, suggesting the streets which the user can choose to navigate in order to further explore their location;
- **frames and the movie playing**: the moments throughout the movie duration might be visible for a real awareness of the trajectory. On mouse hover, the user can see the frame of interest displayed, and on double-click, the movie plays.

A complementary view through the third dimension adds information about the speed and date of the shooting. The user can zoom in for details. Also, all the represented properties might be switched on, or off, depending on the intention of the user.

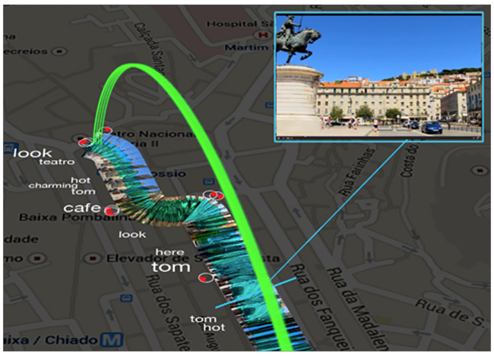


Figure 4.42. Details on Movie Content in Space and Time:
based on timeline, by the adding of speed in 3D.

Movie Content in Space and Time: based on timeline

Finally, we expand the visualization presented in Figure 4.16 by combining spatial and temporal dimensions. As such, it stands for an entire movie being composed by circular tracks that synchronize with the timeline.

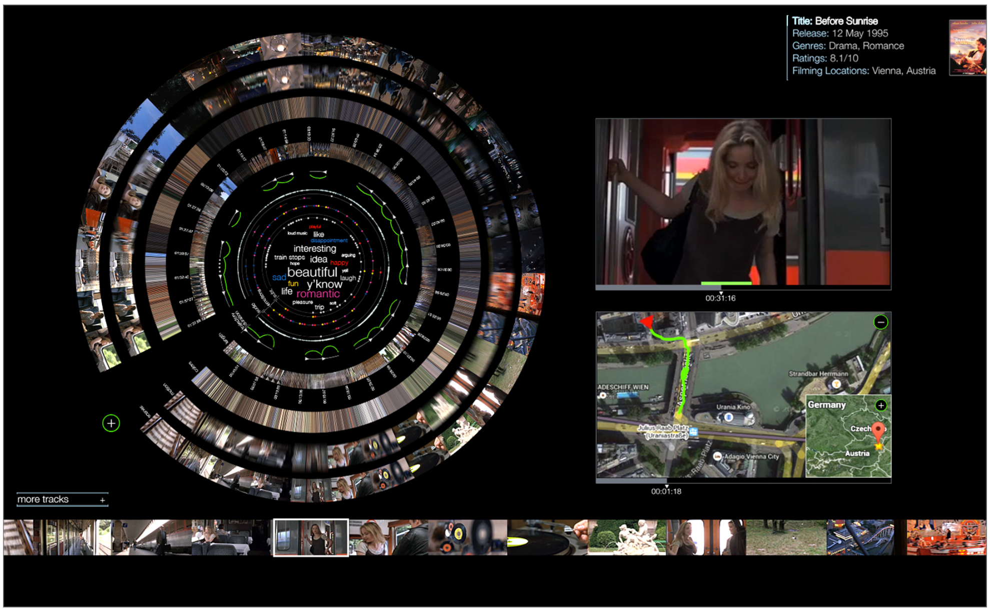


Figure 4.44. Movie Content in Space and Time: based on timeline: Movie content by: image, motion, colors, scene length, trajectory duration, audio amplitude, emotions (in audio, felt by users and in words), most spoken words, movie playing and related information.

The interactive visualization in Figure 4.44 enhances the exploration of the space and time dimensions in a single visualization that allows the user to navigate to other levels of information. Through the combination of both dimensions of one movie content, the user might either disclose information about the movie in focus, e.g., the dominant emotions or where it happens; or even to navigate to previous visualizations either, e.g., to be aware of other movies with the same genres released in the same month (Figure 4.13), or all the locations filmed in this movie (Figure 4.32).

Professional users might be able to take more advantage of all the variables considered in this visualization. The combination of time and space information, and the number of variables allow to complement, while disambiguating information, e.g., 'Washington' means both the name of a city, and of a person.

Figure 4.45. Details on circular tracks and *Tag Clouds*.

The design presented in Figure 4.44 visually combines, and expands, the temporal visualization of Figure 4.21 by adding features to the circular tracks and timeline, with the spatial one in Figure 4.32 and 4.36, but not only those. Similarly to the former, the user gets an overview of the movie at a glance through the images, colors, and emotions, and interacts with the visualization by dragging and clicking either the circular elements or the timeline. The place where the movie happens and the trajectory from the selected scene are also visible at first sight, in a map, and correspond to the spatial dimension of the representation.

The features of the visualization are presented next and zoomed in, in Figure 4.45. Relating the circular tracks, from inside out:

- ***Tag Cloud***: represents the most spoken words (represented by shades of gray), and emotions (represented according to the emotion-color match present in Figure 4.1. When clicked, the spots of the respective tracks highlight in order to show the scenes where they happen (Section 4.3);
- **spots**: corresponding to the words in the *Tag Cloud*, by click on one spot the word stands out, and on double.click the scene is selected. Spots stand for spoken words and audio events that are represented in shades of white; and mood in audio, felt emotions and emotions in speech, represented through the emotion-color match (Figure 4.1).

- **audio amplitude**: as in visualization in Figure 4.41, audio is represented with a line that changes its thickness depending on the audio amplitude, i.e., the louder the sound, the thicker the line;
- **trajectories**: in scenes that include trajectories, they have the beginning marked with a white arrow. Still shots are represented by spots. Trajectories are represented in acid-green, and the showing of information about speed goes according to the visualization presented in Figure 4.37, i.e., the higher the arc, the slower the trajectory. The user can explore the selected scene through the map located on the right in the visualization;
- scene length: through summarization, the more visually compressed the longer the scene. An accurate mark in numbers shows seconds, minutes and hours to the user, so they can control time throughout the movie's duration;
- **colors**: the dominant colors are shown;
- **motion**: by growing blur, the motion of the scenes is represented (Section 4.3);
- **scene thumbnails**: present by default, the images that correspond to the first frames of the scenes are shown, segmenting the movie story.

Similarly to the visualization in Figure 4.21, both circular tracks and the timeline move in synchrony when dragged by the user. Both the circular tracks and the timeline hold similar features, being the tracks of the timeline hidden by default for a clearer visualization. The user might add perspectives below it by selecting them on 'menu tracks' in the left side of the visualization near the timeline, and properties become visible (e.g., words in speech from each scene in Figure 4.46). While the *Tag Cloud* in the middle of the circular tracks show the most frequent spoken words in the entire movie, by disclosing this information in the timeline the user becomes aware of the most referred words by scene. The view goes up in the layout in order to clear the tracks below the timeline.

Figure 4.46. Details on most spoken words by scenes in the timeline.

The information about trajectories in the scenes represented by circular tracks is complemented through the interaction of the user with a map, on the right in the visualization. The trajectory is displayed and marked with a red arrow that moves according to the scene, as the movie is playing (Figure 4.47). The user might click on the trajectory in the map in order to place the action in that frame. They can also zoom out the map in order to have a bird's eye view of all the locations shot in the entire movie through spots, as shown in the larger map of Figure 4.32.

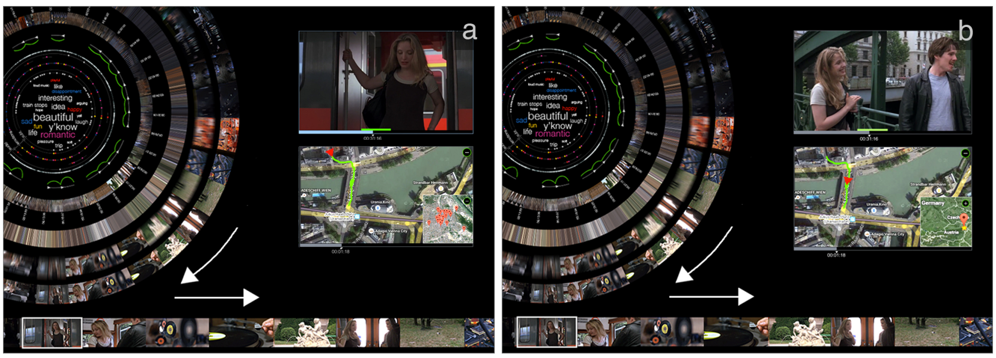


Figure 4.47: Details on the space dimension: two different moments of the trajectory are shown on the map, from a) to b).

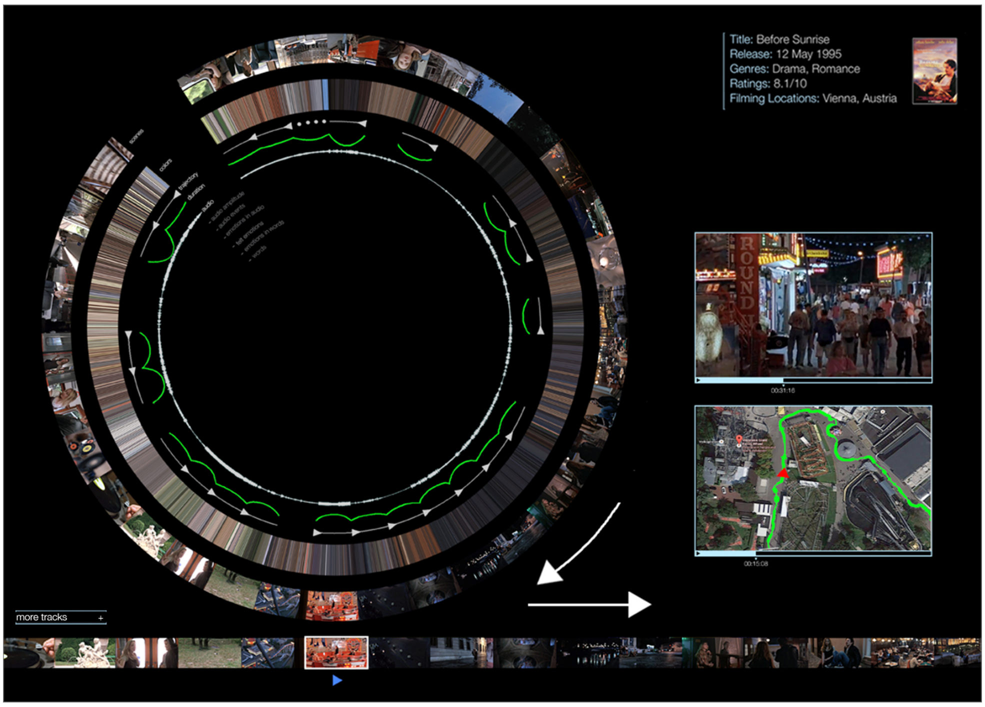


Figure 4.48. Details on thumbnail images (default), colors, trajectories, and audio amplitude, while the other properties are hidden.

Figure 4.48 shows an overview with few perspectives visible. As referred, the user can choose to turn visible the tracks of interest to explore, and the tags from the hidden properties become darker, although visible, to be selected at request. In the example, the thumbnails of the scenes (default); colors; trajectories; and audio amplitude are the visible tracks.

The user can choose a scene of interest by clicking on the respective thumbnail, or by dragging the visualization until the thumbnail image of the requested scene fits the white frame on the timeline. In Figure 4.49 and 4.50, two different scenes were chosen and different features were selected for exploration. The former shows information about motion, trajectories, emotions, and most spoken words, while the latter presents audio amplitude, audio events, emotions, and the most spoken words. In both, related information maintains its location up right in the visualizations, with information about the title, date of release, genres, rating and location of the shootings.

If the user is interested in knowing more about the filmed trajectory, other trajectories from the same location might be requested (Figure 4.51). In the example, three trajectories from other movies' scenes are presented on the right, allowing for the user to relate and compare them, along with the information in the circular elements and the timeline. By clicking on each trajectory on the map, the respective tracks from both the circular elements and the timeline lean aligning vertically, while the scene starts playing.

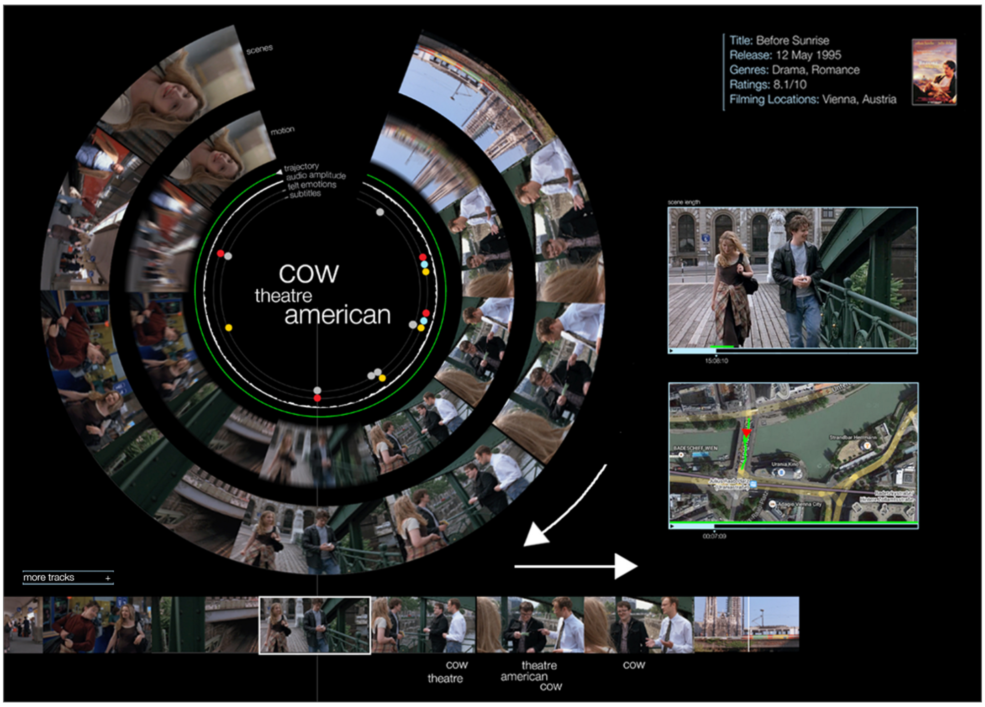


Figure 4.49. Details on one scene by motion, trajectory, emotions and most spoken words.

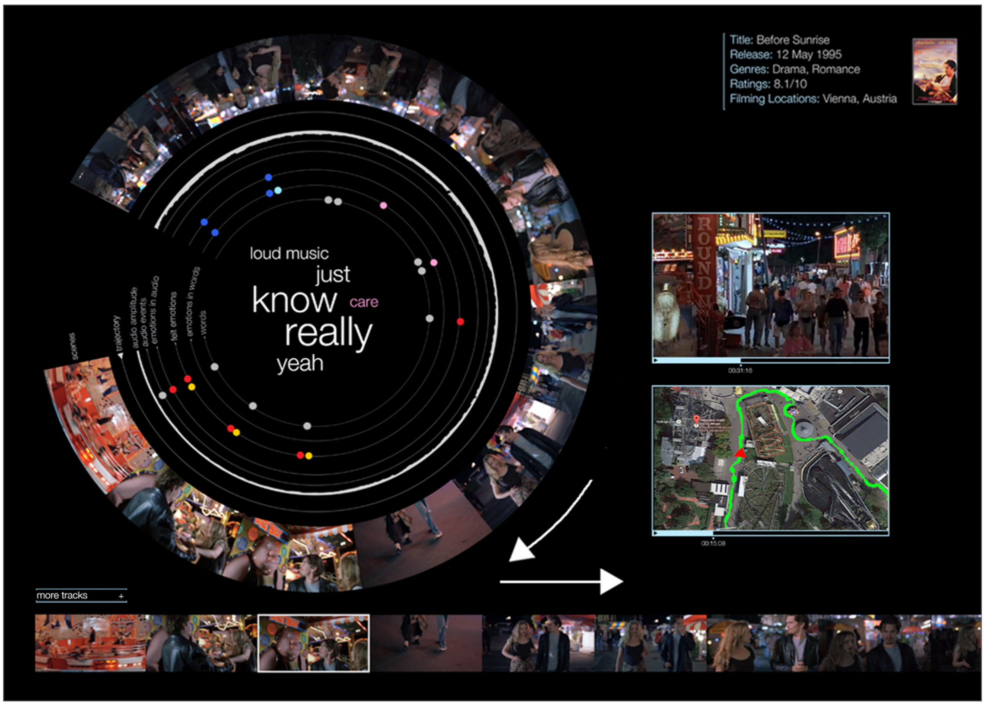


Figure 4.50. Details on one scene by audio amplitude, audio events, emotions and the most spoken words.

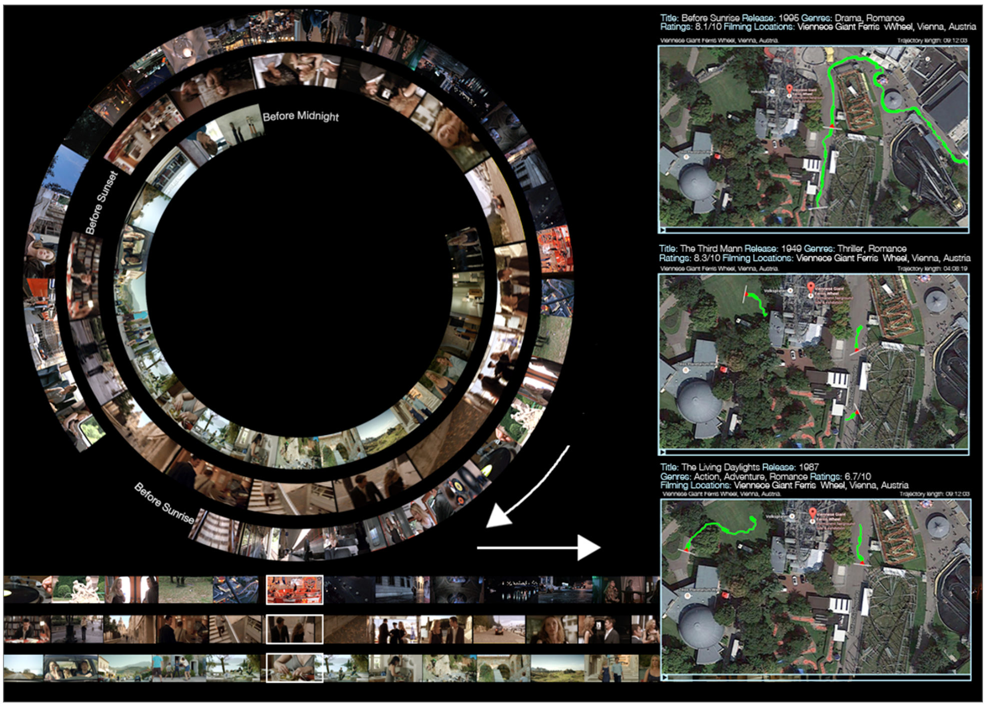


Figure 4.51. Three movies' trajectories shot in the same location.

The display of the movie is optional, i.e., the user might be interested in locating the trajectories on the map, and in this case the display of the scenes is hidden (Figure 4.51). Eventually, they can turn the display visible and watch all the trajectories displaying in the scenes.

4.6.3 Interaction Example

In Figure 4.52, a navigation is suggested. An editor is exploring a movie (a), and for that, after turning visible the tracks of interest only (b), they choose the most dynamic scenes of the movie, those with more slang language, where the dominant emotions are Happy and Energetic, and the faster trajectories (c). After observing the tour and location in that scene, they might end up exploring the trajectory of that scene (d).

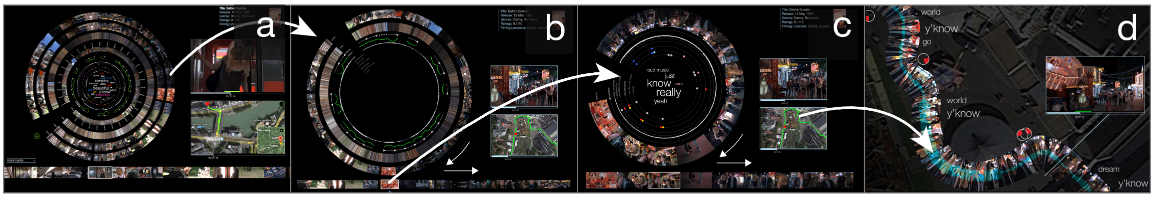


Figure 4.52. Navigation: The user explores one scene in the movie content view, by turning visible only the tracks of interest, after which they detail the trajectory of that scene.

4.7 Browsing Visualizations in Space and Time

Many paths are possible to be explored, going through either time or space dimensions alone, or by combining them. In Figure 4.53, visualizations consider navigation from movie collections, overviews (1a-e, 2abc) or trajectories (3abc), to individual movie contents details (bottom) (4 and 5).

Time: the user can observe quantities of movies released over a year by genre (1a), and ask for details through titles by List (1b), where the most rated movies are highlighted; or by Spots (1c), each spot corresponding to one genre of the selected movie (half dimension, e.g., corresponds to a movie with two genres). Suited for exploration and to find a movie to watch, (1d) allows to compare movies in order to know about their images, speech, audio amplitude and genre, represented in circles that reflect the duration, being possible to disclose the title, plot, images of a requested moment of the movie (by hover), or the scene playing (by click). Visualization in figure (1e) is clear when the task is to identify and relate movies' dynamics and thus possibly more suited for movie professionals due to its perceived accuracy, also reflecting the “mood” of the movie and its evolution over time.

Space: the genres released by location are represented (2a), being exemplified the detail of the romantic movies (2b) and choosing one to watch from Austria (2b-c). These visualizations are simple to use since genre and maps are commonly used by people.

Spatiotemporal: after being aware of the country with more movies shot (3a), one area can be zoomed in towards the more shot (3b), and detailed to the more dated (brownish) and slower (higher) (3c) trajectories.

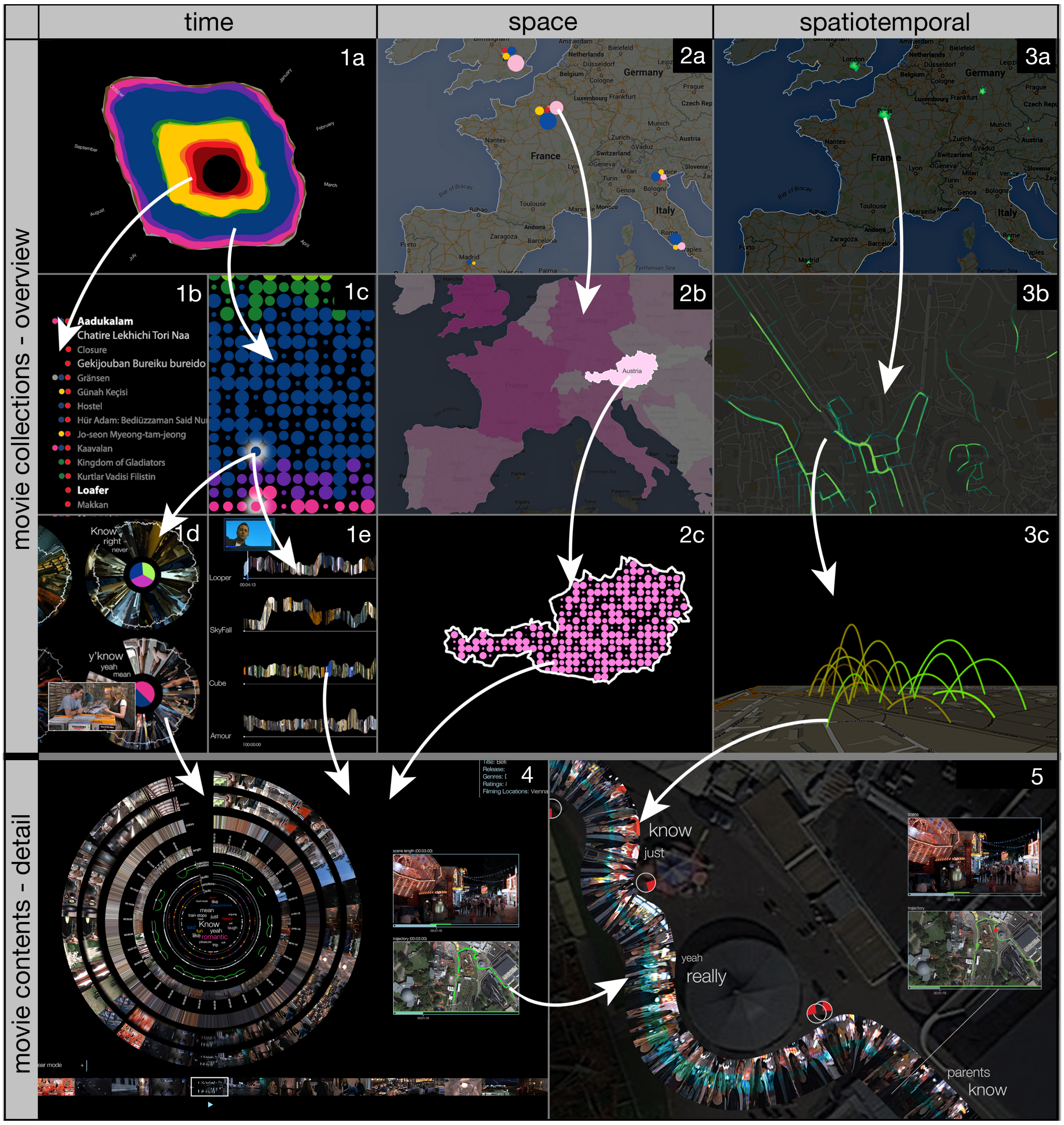


Figure 4.53. Interactive Spatiotemporal Visualizations of Movies. All visualizations allow to access more information; and to navigate, as shown by the arrows.

Movie contents: show the properties of an entire movie (4) through circular elements that represent properties over time/duration (motion, colors, scene length, audio, speech, expressed and felt emotions) with the selected property highlighted as a *Tag Cloud* in the middle. The user drags the circular elements that rotate in synchrony with the timeline. On the right, current scene is playing, synchronized with corresponding trajectory, in a map that can be zoomed. The possibilities both to hide and turn visible the tracks of information, and to change properties are worth noting. Visualization (5) represents one trajectory content in a map through image, audio amplitude, speech and other videos shot in that area, allowing to play video at the clicked position in the trajectory.

5 Design Principles and Visualizations

We characterize the interactive visualizations through the design concepts and principles presented in Chapter 2, which we consider should shape visualizations toward efficiency. We follow the structure of the referred chapter.

5.1 Designing for Function, Usability and User Experience

Design can, and should enhance interactive visualizations toward function, usability and user experience through the principles that shape them. Firstly, we address contents, as the elements that convey meaning; secondly, the focus is on the structure that organizes the elements in the layout; and thirdly, interaction, as the way to achieve other levels of information. The three components are to be taken into account since they constrain each other. Figures 5.1 and 5.2 show a table with the characterization of the presented interactive visualizations. For each visualization, charactering principles are highlighted in grey.

5.1.1 Content

The graphic elements that guide the user toward the navigation and access to information are addressed and explained next.

Metaphor

As a whole, interactive visualizations ground on *emotions*, or moods, the unifying concept that lays in the idea of movies being both a trigger and a result for emotions, on the influence they have on the viewers, either when they are watching a movie or when they are choosing one to watch. We use this metaphor (Figure 4.2-4.12, 4.16, 4.21, 4.27-4.30, and 4.44) in the idea that it might reflect the viewers' mood, according to the emotion-color-genre matching concept presented in Figure 4.1 (e.g., Happy-yellow-*Comedy*). On the other hand, emotions are reflected in the images from the contents (Figure 4.16, 4.19, 4.21, and 4.41-4.44), which we explore in great extent in visualizations, that either for their brightness, darkness, vivid or dull colors reflect mood in the movies' length.

The circular way people conceive the passage of time, either through the clockwise movement (Figure 4.4-4.10, 4.16, 4.21, 4.44 and 4.51) or the left-right direction in timelines (Figure 4.2, 4.3, 4.12-4.14, 4.19, 4.21, 4.44 and 4.51) is present in visualizations that consider the time component, while space-oriented visualizations have their representations based on maps (Figure 4.27-4.51).

Narrowing metaphors throughout visualizations, *Flowing River* (Figure 4.2 and 4.4) *Tag Clouds* (Figure 4.3, 4.5 and 4.8) and *List* (Figure 4.13 and 4.14) are the ones used for these visualizations.

For representing the date of the shooting in visualizations in Figure 4.37, we use the concept of nature-like *Ageing of Leaves* in the trees (the more dated the shootings, the brownish the color of the trajectory's representation). The *Footprint* metaphor is used as if the steps of the person who filmed were being imprinted in bright ink during the trajectory (Figure 4.35, 4.36 and 4.39), resulting to the most travelled tour, the brightest mark. Furthermore, we conceptualized these *footprints* as filled with experiences the filming or filmed person felt while doing the trajectory in the colors, images, audio, and words they show (Figure 4.41 and 4.42).

Text Legibility

Text is present both by representing data through the *Tag Cloud* concept (Figure 4.3, 4.5, 4.8, 4.16, 4.21, 4.41, 4.42 and 4.44) and by complementing information in all visualizations (by hover). In either case, *text legibility* was taken into account avoiding overlaps between elements. We are aware of the text legibility challenges posed by colored *Tag Clouds*, especially when frequencies are low and colors are dark. We kept them for aesthetic reasons and due to the possibility to observe the same information in *Region of Colors*. Referring to the latter representation, *text legibility* is maintained by not being used big chunks of text, allowing for further information to be available by user's request only. Even then, it does not exceed a few phrases (e.g., movie plot). Moreover, text is often presented in light gray in order to assure a good reading.

Colors

All visualizations display colors that we use as main matter, both in the coding of information and throughout the movies' length. They serve to *label* information with genres (Figure 4.2-4.13, 4.16, 4.21, 4.27-4.30, and 4.44) and emotions (Figure 4.21 and 4.44); *measure* information by either sizing shapes (Figure 4.2-4.10, 4.27, 4.35-4.36, 4.39, 4.41, and 4.42), progression (Figure 4.13-4.14 and 4.37) and by repetition (Figure 4.21 and 4.44); *represents reality* through both *River Flow* visualizations (Figure 4.2 and 4.4) and the *Ageing of the Leaves* from a tree (Figure 4.37); *enliven* all visualizations through the harmonic set of colors built to code genres and emotions, and the leaves gradation colors(Figure 4.37).

The same color code concept is present in all visualizations in order to prevent confusion during navigation. On the one hand, we use the emotion-color-genre matching that allows the user to, e.g., navigate from amounts of released genres over time (Figure 4.2-4.13 and 4.27-4.30) to emotions in the movie's contents (Figure 4.21 and 4.44). On the other hand, we use bright green to represent trajectories, and thus whether the user is navigating from the number of trajectories shot (Figure 4.35 and 4.36) to either a selected trajectory (Figure 4.37 and 4.39), or a trajectory that was waved in the content of a movie (Figure 4.44), the color matching is maintained.

We had in mind the expectations of the users regarding the meaning of colors and followed the literature and common practices, hoping that evaluation would help in the assertion of the most correct match to adopt. We did not consider people with different approaches to colors, but although the appeal of visualizations depends on colors, a monochrome interface was also considered, through the use of patterns and gray shades in the coding of genres and emotions.

The use of colors was limited to the essential and moreover, the user can hide, or turn them visible by interest.

The effect of colors on the viewer was taken into account and as referred previously, it enriches the conceptual design, e.g., by allowing yellow (Happiness) or dark blue (Sadness) to stand out or be restrained in the layout, respectively.

5.1.2 Structure

All visualization structures were built with simplicity in mind by organizing information using the *Gestalt laws* of perception, and by considering the desired aesthetics.

Organize and Segment Information

Proximity, Similarity, Symmetry and *Focal Point* were used in the organization of the information in all visualizations and *Common Fate* through the interaction of the user (Figure 4.16, 4.21, 4.44 and 4.51).

Information was segmented by *Category* in all visualizations due to the relation they hold among each other; by chronological *Time* in all but map-based only visualizations; by *Location* in the visualizations represented by maps (Figure 4.27-4.51); and *Alphabet* in the *List* (Figure 4.13 and 4.14). The ordering in *Continuum* is present in both *Lists*, in the growing brightness that depicts the more rated movies (Figure 4.13 and 4.14).

Hierarchy of Information

Clear in all visualizations, the *hierarchy of information* is found both in simple and complex visualizations, helping to guide the eyes of the user throughout the interfaces. The most important information is read at first in a two-step view layout, e.g., the user sees the strong colored shapes representing genres, and secondly the light text that informs them about the months they refer to (Figure 4.2-4.10).

In the most complex visualization (Figure 4.44), and similar to this (Figure 4.21 and 4.51), the circular shapes attract the viewer's eyes as the core information to be perceived, being followed by the information on the right. Related information is upright in the interface as to be read only by request, since it is the external metadata about the movie in focus, and thus, information that relates to the movie's content is viewed at first.

We show data coherently and without any distortions by complementing visual information with text and numbers, when required by the user. Moreover, we use various levels of detail that the user can disclose by request (in all visualizations).

Iconic Representation

We follow Arnheim (1974), Gombrich (2000), and Damásio (2010), and built schematic representations based on geometric shapes, mostly circles and rectangles in order to ease the understanding of information. We do not use visual elements that resemble and stand for external meanings - icons -, though.

Layers of Information

All visualizations show various *Layers of Information,* e.g., in Figure 4.2, thirteen layers correspond to the genres, and another one to the information of the months; or in Figure 4.44 where *Tag Cloud*, spots, circle elements, timeline, movie and trajectory playing, locations of the shooting and related information correspond to eight layers of information.

The main interest of the topic is to assure that the various *layers of information* do not collide among each other, and moreover, that richness and complexity was added, with the different layers, while keeping visualizations simple.

Relate and Compare Side by Side

Information is observed by *proximity* in all visualizations, e.g., movies released over the year by genre (Figure 4.2-4.10), and genres released by location (Figure 4.27-4.28).

5.1.3 Interaction

By having in mind Rudolf Arnheim's theory upon which people understand images by growing complexity, we designed visualizations that allow the exploration of information by user's request, through interaction, e.g., by hover, the user is aware of more information about the movie, and on click watches the scene of interest (Figure 4.16).

They can navigate forward or backwards depending on their goal, e.g., watch a movie and decide to know more about one of its trajectories (Figure 4.39), or the inverse, e.g., being in a location of the world, request the movies that were shot there (Figure 4.37).

Loose and accurate navigations are possible, allowing the user to either go on an *Exploratory Browsing* potentiating a discovery of a movie by chance (Figure 4.12 and 4.30), or to go toward a *Look Up* way, and rapidly find the information they need (Figure 4.13 and 4.14). Navigating throughout the movies' contents may also permit unexpected findings, either related with time (Figure 4.16 and 4.21), space (Figure 4.41-4.42) or both (Figure 4.44).

Visualizations allow for analytical observations in the second level of information through interaction, e.g., the user might start by visualy comparing audio amplitude throughout scenes (Figure 4.16), and secondly get the accurate information that relates to each scene (Figure 4.44).

Micro and Macro Readings and Overview, Zoom, Filter and Details

Micro-Macro Readings and *Overview-Zoom-Filter-Details* imply the narrowing of information from a bird's eye view that permits to have an idea of what is presented to a deeper observation of other levels of information.

Regarding *Micro and Macro Readings*, the user, e.g., sees the area of the city where most movies were shot (Figure 4.36) and go deeper in the information by relating two or more trajectories of the whole (Figure 4.37). *Overview, Zoom, Filter and Details* allow the user to interactively navigate information by narrowing the findings (e.g., from Figure 4.2 to 4.12 to 4.16 to 4.44). The user can also disclose hidden information (in all visualizations). All visualizations allow the user to start by observing the overview in order to have an idea of the information, to zoom in and out to clear the information, or to filter the information of interest to get details.

Levels of information to be disclosed through interaction do not imply much effort from the user's memory. They start by retaining little amounts of information in the first glance overview. For the simpler visualizations, the *short-term* or *working memory* is suficient although the *long-term memory* might be needed in order to simplify images through past experiences, e.g., the visualizations that resemble bar charts (Figure 4.2, 4.4 and 4.19), the common *List* (Figure 4.13, 4.14), or maps (Figure 4.27-4.51). More complex visualizations (Figure 4.37 and 4.44) demand additional time for the user to fully understand the visualizations.

Focus and Context

With interaction, features are highlighted in order for the information of interest to stand out, and this happens in all visualizations on hover, and to measure rate in *Lists* (Figure 4.13 and 4.14).

Shrink, Hide and Embody

All visualizations have *shrink* information in order to clear the layout, e.g., the visualization in Figure 4.44 stands for one '*shrinked'* movie. Information is *hidden* and it is possible to be turned visible by clicking in all visualizations, e.g., in Figure 4.16, where on hover, the plot appears. *Embodied* information is present in all visualizations by the data that the user does not have to read about to know, e.g., red *Spots* represent Action movies (Figure 4.12).

The simplification of the layouts went done according to the ten principles proposed by Maeda (2006), i.e., by reducing the elements in the layout; by organizing information in a way that they seem less in number; by trying to save the time from the user through the easy accomplishment of tasks in hand; by easing the learning of the system both through the fewer elements in the screen as possible, and the use of common features, such as the hover to show hidden information; by using contrasts between great simplicity and complexity that imprints rhythm to the layouts and navigation; by taking advantage of all the space in the screen to present information, including the periphery; by reflecting as many emotions as possible; by efficiently guiding the user to their goal; by assuming that information is to be represented despite its number, rather that taken out; and through the representation of useful and meaningful information only.

In all the visualizations, *aesthetic* qualities should allow the user to interact with some degree of emotion, which according to Norman (2013, pp.49–54) favours navigation toward knowledge. Aesthetic properties were balanced with function in order to let the user to disclose information efficiently, while motivated. Through the *visceral processing level of perception*, we expect the user to feel attracted to the visualizations' layouts. In the *behavioural* step, we offer the user simple and expected features already presented in interfaces like *YouTube*, e.g., to hover in order to turn visible the title and plot of a movie, and click to watch a scene (Figure 4.16). Referring to the *reflexive processing level of perception*, we expect that after experimentation, the user wants the visualizations available in order to explore them toward both the gaining of information about movies, and to access movies to watch.

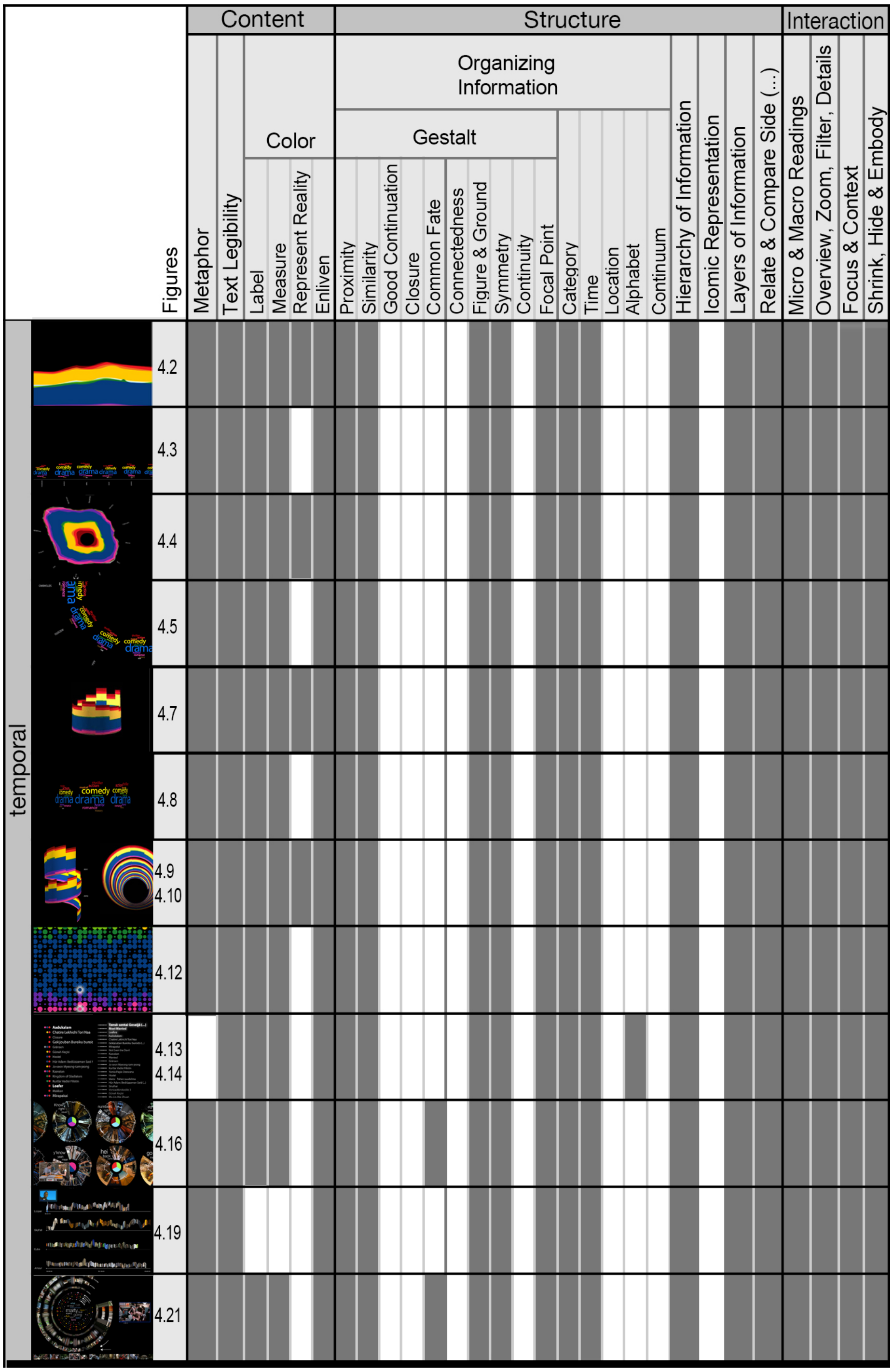


Figure 5.1. Characterization of the Interactive Visualizations regarding the Design Fundamentals. The main principles addressed for each visualization are highlighted in grey.

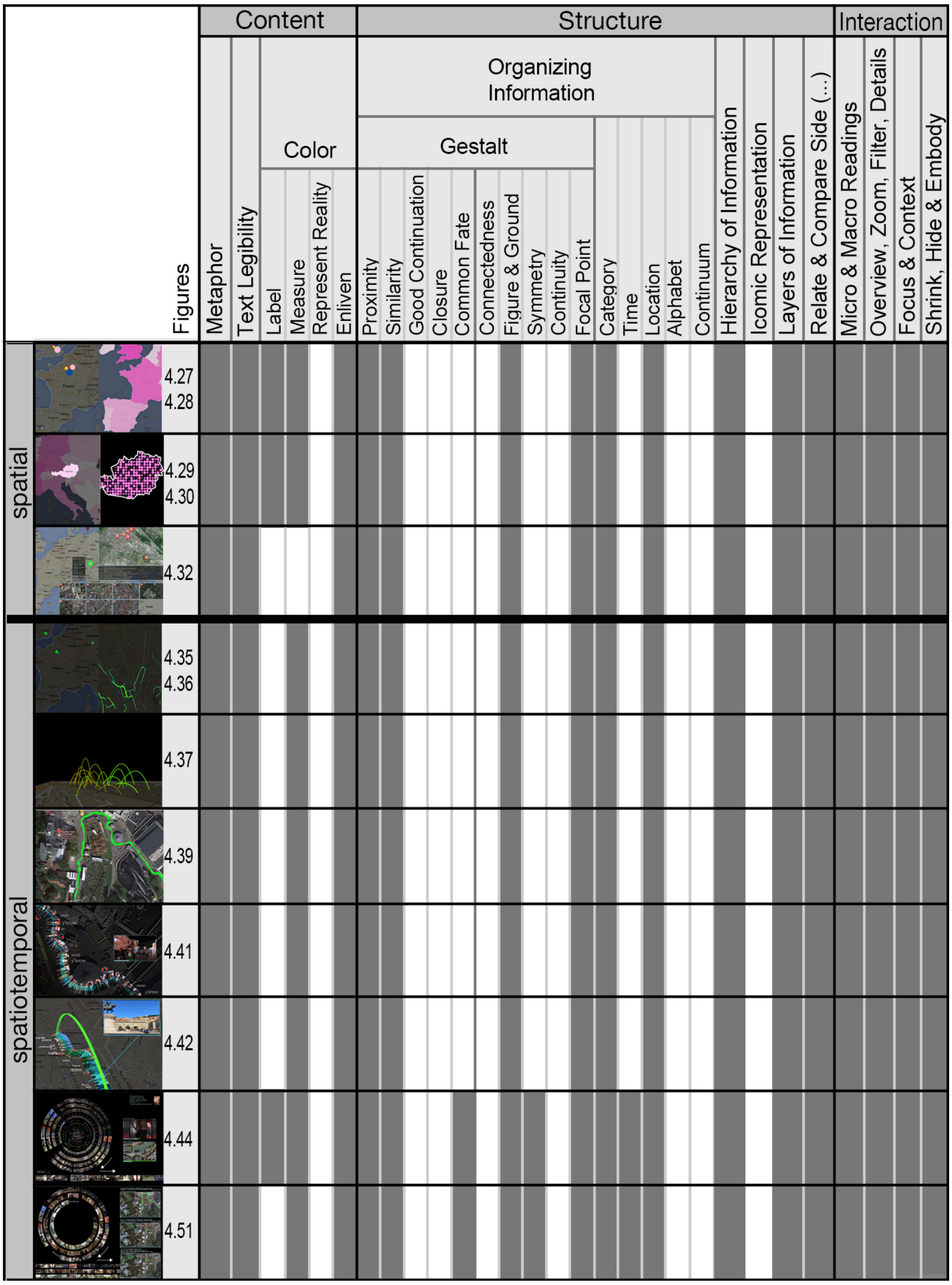


Figure 5.2. Characterization of the Interactive Visualizations regarding the Design Fundamentals. The main principles addressed for each visualization are highlighted in grey (continued).

5.2 Time and Space Representation

The representations of space and time demand for specific considerations in the design of interactive visualizations, which we address in this section. Figures 5.3 and 5.4 show a table with this characterization addressing the structure, data and representation of the interactive visualizations.

5.2.1 Structure

Regarding *Time and Space* components, only space-oriented visualizations do not allow for *points* and *intervals* of information (Figure 4.27-4.32). *Linear* time is represented with timelines (Figure 4.2, 4.3, 4.12-4.14 and 4.19). *Circular* time represents one unit of time, e.g., one year, one movie length (Figure 4.4 to 4.12, 4.16, 4.21 and 4.44-4.51). Both *linear* as timeline and *circular* representations of time are presented (Figures 4.21, 4.44 and 4.51), and *branching* time is not represented in any visualization.

Points and *Area* are restricted to visualizations with the Space component (Figure 4.27-4.51). *Discrete*, *Absolute*, and *Determinacy* of information are presented in all visualizations, meaning that information is precise.

5.2.2 Data

The representation of data is Abstract in the visualizations presented in Figures 4.2 to 4.21, 4.44 and 4.51, and *Spatial* in those that are represented upon, or have information complemented with a map (Figure 4.27-4.51). All visualizations hold more than two variables and thus they are *Multivariate.* *A*lthough they might present *abstract data* in the first level of information (excluding Figure 4.13 and 4.14), *concrete data* is hidden, possible to be disclosed by interaction.

5.2.3 Representation

All visualizations are *Interactive* and only those in Figure 4.7 to 4.10 are represented in 3D. As referred, visualizations are static although those in Figure 4.21 and 4.44 can be dynamic if the user chooses the circular tracks and the timeline to move in synchrony with the movie playing.

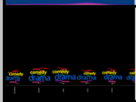
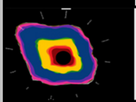
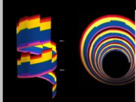
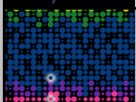
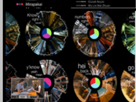
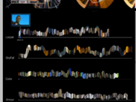
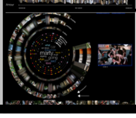
<table>
<tr><th colspan="3"></th><th colspan="6">Structure</th><th colspan="3">Data</th><th colspan="2">Repres.</th></tr>
<tr><th colspan="3"></th><th colspan="2">Time</th><th>Space</th><th colspan="3"></th><th colspan="3"></th><th colspan="2"></th></tr>
<tr><th colspan="3">Figures</th><th>Points | Intervals</th><th>Linear | Cyclic | Branching</th><th>Points | Area</th><th>Discrete | Dense</th><th>Absolute | Relative</th><th>Determinacy</th><th>Abstract | Spatial</th><th>Univariate | Multivariate</th><th>Concrete data | Abstract</th><th>Static | Dynamic | Interactive</th><th>2D | 3D</th></tr>
<tr><td rowspan="12">temporal</td><td></td><td>4.2</td><td>P/I</td><td>L</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>2D</td></tr>
<tr><td></td><td>4.3</td><td>P/I</td><td>L</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>2D</td></tr>
<tr><td></td><td>4.4</td><td>P/I</td><td>C</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>2D</td></tr>
<tr><td></td><td>4.5</td><td>P/I</td><td>C</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>2D</td></tr>
<tr><td></td><td>4.7</td><td>P/I</td><td>C</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>3D</td></tr>
<tr><td></td><td>4.8</td><td>P/I</td><td>C</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>3D</td></tr>
<tr><td></td><td>4.9
4.10</td><td>P/I</td><td>C</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>3D</td></tr>
<tr><td></td><td>4.12</td><td>P/I</td><td>L/C</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>2D</td></tr>
<tr><td></td><td>4.13
4.14</td><td>P/I</td><td>L</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>2D</td></tr>
<tr><td></td><td>4.16</td><td>P/I</td><td>C</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>2D</td></tr>
<tr><td></td><td>4.19</td><td>P/I</td><td>L</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/I</td><td>2D</td></tr>
<tr><td></td><td>4.21</td><td>P/I</td><td>L/C</td><td>-</td><td>Di</td><td>A</td><td>D</td><td>A</td><td>M</td><td>C/A</td><td>S/D/I</td><td>2D</td></tr>
</table>

Figure 5.3. Characterization of the Interactive Visualizations regarding the Spatiotemporal Fundamentals

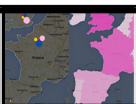
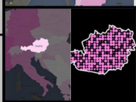
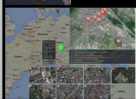
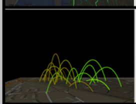
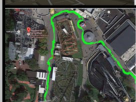
			Structure						Data			Repres.	
			Time		Space								
		Figures	Points | Intervals	Linear | Cyclic | Branching	Points | Area	Discrete | Dense	Absolute | Relative	Determinacy	Abstract | Spatial	Univariate | Multivariate	Concrete data | Abstract	Static | Dynamic | Interactive	2D | 3D
spatial		4.27 4.28	-	-	P/A	Di	A	D	S	M	C/A	S/I	2D
		4.29 4.30	-	-	P/A	Di	A	D	S	M	C/A	S/I	2D
		4.32	-	-	P/A	Di	A	D	S	M	C/A	S/I	2D
spatiotemporal		4.35 4.36	P/I	L	P/A	Di	A	D	S	M	C/A	S/I	2D
		4.37	P/I	L	P/A	Di	A	D	S	M	C/A	S/I	3D
		4.39	P/I	L	P/A	Di	A	D	S	M	C/A	S/I	2D
		4.41	P/I	L	P/A	Di	A	D	S	M	C/A	S/I	2D
		4.42	P/I	L	P/A	Di	A	D	S	M	C/A	S/I	3D
		4.44	P/I	L/C	P/A	Di	A	D	A/S	M	C/A	S/D/I	2D
		4.51	P/I	L/C	P/A	Di	A	D	A/S	M	C/A	S/I	2D

Figure 5.4. Characterization of the Interactive Visualizations regarding the Spatiotemporal Fundamentals (continuation)

6 User Evaluation

A user study was conducted at two different moments in time to evaluate the visualizations. The first to be evaluated were the visualizations that represent movies by genre and rating, in terms of their usability, efficacy, and strength as representation concepts with a focus on the temporal dimension (Jorge & Chambel, 2014). We wanted to know how interesting users found the different visualizations to view and browse in different perspectives and to get overviews and details about the movies. Also relevant was to find out about how to browse to watch the actual movies and which type of visualizations were preferred for the different tasks.

In a second moment, a more extended evaluation continued testing movie contents and added the space dimension, focusing on the trajectories filmed in movies, and also narrowing the movie space and zooming in the information toward contents (Jorge et al., 2015). Although the visualizations tested in the first phase were not evaluated in the second phase, they were presented and explained to the participants in order for them to be aware both of the visualizations' features, and their place and role in the whole navigation.

We tested the intuitiveness and clearness of the visualizations, relating, both to the meaning of the representation's features (e.g., is the user able to identify the representation of the trajectories?) and of the overviews (e.g., does the user figure out the mood of the movie?). The evaluation continued by addressing the visualizations in terms of their ability in guiding the user to interactively reach the information of interest (e.g., is the user able to select one scene to watch?). Lastly, we tested navigations with user scenarios in order to know the relevance of this project in daily uses (e.g., would the user like to choose a movie to watch using the presented visualizations of movie contents?). It was our intention to know about the strengths and weaknesses of the interactive visualizations and, therefore, to infer about their usefulness, satisfaction and ease of use. Moreover, we want to know the relevance and meaning to the users.

In the following sections we detail the method, the participants and the results. As a general consideration, users accomplished with success almost all the tasks and showed high appreciation for most of the visualizations. The results for the questions are shown by the mean (M) and the standard deviation values (Std) and are complemented with explanations of the most relevant results, comments obtained from the users and our observations during the study.

6.1 Method

We performed Task-oriented evaluations based mainly on Observation of the users' ability to complete the tasks, their performance, hesitations and errors, using paper and a pen to register, and semi-structured interviews about the tasks with the different visualizations (Nielsen, 1999). Both sessions began by explaining the purpose of the evaluation and telling the subjects about the visualization prototypes. Then, the interview began with some demographic questions followed by questions about their preferences in the access to movies and geographical locations, then by a task-oriented activity throughout which the users were encouraged to comment while viewing and navigating throughout the different interactive visualizations, answer USE-based questions (Lund, 2001) about perceived *Usefulness*, *Satisfaction* and *Ease of use*, using a five point *Likert* scale; to choose perceived ergonomic, hedonic and appeal quality aspects from the complete list (Hassenzahl et al., 2000), and had the opportunity to provide comments and suggestions as qualitative feedback. The scripts used in the evaluations are presented in Appendix A.

When relevant, within-subject approach was adopted by changing the order of the visualizations and tasks, especially when there were alternatives for the same type of information, to avoid bias introduced by the order of view. Our approach adopted a mix of field and laboratory experiments, in contexts of use like work or home, and proposing low and high-level tasks (Amar & Stasko, 2004), in sessions lasting on average one hour per participant.

Particular aspects related with the evaluation method are detailed throughout the results' presentations in each visualization test.

6.2 Participants

In the first phase evaluation that comprises visualizations presented in Figure 4.2 to 4.13, the target users of our application were the general public and especially people interested in accessing information about movies. We recruited 10 participants from different backgrounds, 2 female and 8 male with age ranging from 25 years old to 58 years old (M:37.5; Std:11). Half were students or professionals in informatics, and the other half worked on diverse professions like mechanical engineering, architecture, and graphic arts. All of them, though, use the computer daily for work and watch movies at least twice a week, either on the cinema, TV or computer. These have profiles of target users, and 5 users usually allow to find the large majority of usability problems, and to get trends and insights to drive the design choices (Nielsen, 1999).

In the second phase evaluation of the visualizations, from figure 4.14 onwards, we considered both casual users such as engineers, journalists, researchers, professors, photographers, and radio producers; and professional users such as movie directors, movie editors, film critics, and sound technicians for the second, 7 female and 13 male ranging 22 to 64 years old (M:47;

Std:11). All participants use the computer in their daily work and for entertainment. They access websites and applications related to movies such as IMDb, YouTube, and Netflix monthly in average, and the preferred ones are IMDBb (84%) and YouTube (75%). When considering map-based websites and applications, Google Maps is the most used, on a weekly basis to know directions. Users prefer to watch movies in the cinema (89%), TV (84%), and the computer (63%).

6.3 Results: First Phase

Interactive visualizations representing movies by genre and rating were evaluated, from collections to the individualization of movies.

Genre-color Matching

Due to the importance of colors in the visualizations, we firstly tested the match between colors and genres (yellow-happiness). In this phase of the evaluation only eleven genres were presented: War, Romantic, Musical, Historic, Comedy, Terror, Western, Adventure, Thriller, Action, and Drama.

Participants were presented with a paper sheet with a list of genres (on the left) and a list of colors (on the right) and asked to make the links they found adequate. The results corroborated the assertion that the color meaning is subjective and personal, e.g., red was assigned by the participants to such contradictory genres as Thriller, Drama, Horror, War, as well as Musical, Comedy, Adventure, Romance, and Action. Romance-pink was the most consensual match, aligning with our choices with more than a half of the participants choosing this tagging.

Movie Collections in Time

We evaluated visualizations that represent large amounts of movies in 2D and 3D, by genre and rating through *Region of Colors* and *Tag Clouds*, information that is detailed and zoomed, allowing for the individualization of the movies.

Linear Representation by Regions of Colors and Tag Clouds

In order to measure the efficacy of the visualizations, as the first step, the various versions differing in the representations of time (linear vs. circular) and data (*Region of Colors* and *Tag Clouds*) were tested and compared. Users were asked to identify, locate and compare information in the visualizations, and to rate the perceived ease (and in consequence speed and adequacy) to perform the task.

Results are presented in Tables 6.1 to 6.5 and commented next.

Table 6.1, 6.2, 6.3, 6.4 and 6.5. Efficacy of the Visualizations (0: did not hit. 1-5: success level): *Region of Colors and Colored Tag Clouds*

Table 6.1. *"Identify the movies released in May"*

Visualizations	Time			
	Linear		Circular	
Region of Colors	M: 5.0	Std: 0.0	M: 4.7	Std: 0.5
Colored Tag Clouds	M: 5.0	Std: 0.0	M: 3.0	Std: 0.8

Table 6.2. "*Which genre was more released over the year?"*

Visualizations	Time			
	Linear		Circular	
Region of Colors	M: 5.0	Std: 0.0	M: 5.0	Std: 0.0
Colored Tag Clouds	M: 4.9	Std: 0.3	M: 3.8	Std: 0.8

Table 6.3. *"Which genre was less released over the year?"*

Visualizations	Time			
	Linear		Circular	
Region of Colors	M: 4.8	Std: 0.4	M: 4.9	Std: 0.3
Colored Tag Clouds	M: 2.7	Std: 0.5	M: 3.5	Std: 0.8

Table 6.4. *"Comparing Action and Horror in May, which genre was more released?"*

Visualizations	Time			
	Linear		Circular	
Region of Colors	M: 4.3	Std: 0.5	M: 3.4	Std: 0.5
Colored Tag Clouds	M: 3.0	Std: 0.7	M: 3.3	Std: 0.7

On average, all the tasks were easy to accomplish, and even better when they represent high frequencies, with a slight difficulty on the circular *Tag Clouds* visualization, since the words are more difficult to read sideways or upside-down, especially in the colors with lower contrast, although visualizations might be rotated by dragging. On the other hand, when the frequencies are low, or similar (Table 6.3 and 6.4), the participants showed more difficulty due to the small fonts and region dimension in the representations. *Tag clouds* may also be misleading in ordering frequencies, because although the font size corresponds to the correct frequency, the size of the actual word can have a misleading effect (e.g., the word Adventure is often larger than 'war', even if its font is smaller), a known disadvantage of the clouds for this purpose (Viégas & Wattenburg, 2008; Chambel et al., 2013). Colors can also either help or obstruct the reading of information depending on their contrast against the background. However, tags are more direct and flexible, since they hold more semantics without the need for a mapping.

In order to test the success of cyclic temporal representations to show patterns of information regarding months or years of releases, we presented the participants with i) two circular 2D visualizations for different years, side by side, varying in data representation (*Region of Colors* and *Tag Clouds*) (Figure 4.4 and 4.5); and ii) one 3D visualization for a two-years representation, in a helicoid (Figure 4.9.) in Table 6.5. This task scored the easiness of the finding of some pattern of information by the participants (e.g., that more movies are released in October). The *Region of Colors* concept was the representation that allowed an easier comparison and establishment of relations and patterns in the information. Again, reading text sideways and in less contrasting colors may be difficult. In what concerns the 3D representation, the participants referred the fun when using this dimension although it was mentioned the hiding of information by the visualization, making it possible to compare only months chronologically near from each other (e.g., Jan-Mar) in the same or different years (e.g., Mar 2010 and 2011). Although this visualization can be viewed all around in space, if not unwrapped, it does make it difficult to compare information that is not presented close to each other. But it was easier to compare sequences across years (e.g., Dec 2010 and Jan 2011). Even so, the average value *Ease of use* when completing the task was 3.8, which may indicate these and other positive aspects like the appeal may have been taken into consideration for this score.

Table 6.5. "*Which relations/patterns do you find between the two years of information presented in these visualizations?"*

Visualizations	Time & Dimensionality			
	Circular			
	2D		*3D Helicoid*	
Region of Colors	M: 5.0	Std: 0.0	M: 3.8	Std: 0.8
Tag Clouds	M: 2.8	Std: 0.6	-	-

Participants were asked to rate *Usefulness*, *Satisfaction,* and *Ease of use* of the visualizations, according to their features (Table 6.6, 6.7 and 6.8). Results show that linear *Region of Colors'* representations were the most useful, satisfactory, and easy to use, in accordance with the results from the tasks above. Colored *Tag Clouds* were considered less easy and *3D Cylinder* slightly less satisfactory than the other visualizations, including the *3D Helicoid*. It has similar disadvantages of occlusion and less flexibility and potential for capturing the time linearity over the years.

For a richer characterization of the different features, the participants were asked to classify the main visualizations (linear *Region of Colors*, linear *Tag Clouds*, and *3D Cylinder* with *Region of Colors*) with most relevant (in what they thought applicable) perceived ergonomic Quality aspects (Hassenzahl et al., 2000). Table 6.9 presents, from the left, the number of participants choosing that term; the H, E or A categories that stand for Hedonic, Ergonomic, and Appeal terms, respectively; and the chosen terms, from which the negative ones are in italic.

Table 6.6, 6.7 and 6.8. USE (0: did not hit. 1-5: success level):
Region of Colors and Colored Tag Clouds

Table 6.6. USE – Usefulness

Visualizations	Time & Dimensionality					
	Linear		Circular			
	2D		2D		3D cylinder	
Region of Colors	M: 4.6	Std: 0.7	M: 3.9	Std: 0.9	M: 3.3	Std: 0.9
Colored Tag Clouds	M: 3.9	Std: 0.7	M: 3.6	Std: 1.0	-	-

Table 6.7. USE – Satisfaction

Visualizations	Time & Dimensionality					
	Linear		Circular			
	2D		2D		3D cylinder	
Region of Colors	M: 4.3	Std: 0.7	M: 3.7	Std: 1.6	M: 3.2	Std: 0.9
Colored Tag Clouds	M: 3.5	Std: 1.1	M: 3.3	Std: 0.7	-	-

Table 6.8. USE – Ease of use

Visualizations	Time & Dimensionality					
	Linear			Circular		
	2D		2D		3D cylinder	
Region of Colors	M: 4.3	Std: 0.8	M: 3.4	Std: 1.3	M: 3.6	Std: 1.2
Colored Tag Clouds	M: 3.4	Std: 1.1	M: 2.9	Std: 1.1	-	-

All three visualizations were considered *Comprehensive*, *Pleasant*, *Aesthetic* and *Simple* as the top of the Table, with the *Region of Colors* visualization receiving higher frequencies of positive results. Unlike the 3D circular visualization, the linear representations (*Region of Colors* and *Tag Clouds*) were considered *Familiar*. Furthermore, almost all the results were positive and it is interesting to note that the negative ones that were mentioned by a couple of users were Obstructing for *3D* and *Tag Clouds,* and Confusing for *Tag Clouds*. These results align with the feedback obtained from observations while performing the tasks and answering to the USE Evaluation (scale 1-5) (already commented above), and still were considered *Predictable*; and *Complex* for the three visualizations. We see it with a positive perspective, by considering the potential for large amounts of information and several features. Plus worth noting, for each negative term chosen, at least the same number of choices was made for the opposite positive term: *Obstructing-Supportive*, *Confusing-Clear*, *Complex-Simple*.

Table 6.9. Quality Terms:
Linear Region of Colors, Linear Tag Clouds,
and 3D Cylinder Region of Colors

Linear Region of Colors			*Linear Tag Clouds*			*3D Cylinder Region of Colors*		
10	E	Comprehensible	8	E	Comprehensible	7	E	Comprehensible
10	A	Pleasant	7	A	Pleasant	6	A	Pleasant
10	A	Aesthetic	6	A	Aesthetic	6	A	Aesthetic
9	E	Simple	6	E	Familiar	5	E	Controllable
8	E	Supportive	5	E	Simple	4	E	Simple
8	E	Clear	5	A	Good	4	H	Interesting
8	H	Interesting	5	H	Interesting	4	E	Innovative
6	E	Familiar	4	E	Predictable	4	H	Original
7	E	Controllable	4	E	Clear	3	E	Predictable
6	H	Innovative	4	E	*Confusing*	3	E	Clear
6	A	Good	3	E	Controllable	3	E	Supportive
1	E	*Complex*	3	E	Supportive	2	E	*Obstructing*
			3	E	*Obstructing*	1	E	*Complex*
			3	E	*Complex*			

H: Hedonic; E: Ergonomic; A: Appeal

Details by genre through Tag Clouds – colors vs. monochrome

To compare the two versions of *Tag Clouds* in terms of the use of color, participants were asked to choose among circular *Tag Clouds* in color (Figure 4.5), and monochrome with the selected genre highlighted (Figure 4.6). They could choose one, both, or none. 70% of the participants preferred to have both available, referring the complementarity of value. 20% preferred the monochrome version only, while none chose the colored version only, and 10% preferred not to have these visualizations. The monochrome version allows to make the frequencies more clear and easily comparable to each tag cloud, due to legibility in terms of contrast and the subjectivity color brings to the tags relative weight, also aligned with Viégas and Wattenberg (2008) findings.

Region of Colors representations by presenting them side-by-side.

When comparing linear visualizations (Figure 4.2 and 4.11) almost all the participants chose the smooth transitions wave-like shapes, referring its aesthetics as a priority property and enough to get the main idea about the information evolution. However, when asked to choose one of the circular ones (Figure 4.4 and 4.11) and although the wave-like shape was slightly more rated, almost all the participants mentioned the difficulty when looking for information near the middle of this representation, stating that straight lines worked as guides. It was suggested by the participants, for the circular wave-shape representation, the existence of radial guides to separate the months visually.

Movies by Region of Colors – hard vs. smooth transitions

The *Region of Colors* visualizations presented and evaluated above (Figure 4.2 and 4.4), have smooth transitions between months in wave-like shapes. Smooth transitions do not show very accurate information in what relates to the beginning and end of the months (if based on monthly averages presented in interpolated values over time), when compared with the hard transitions (Figure 4.11), based on monthly straight lines segments, more traditional and very common in bar and pie charts, and also comparable to the monthly *Tag Clouds* representations adopted. In smooth transitions, the user can ask for details, and on 'mouse over' have that information available. But even so, we wanted to test the strengths and weaknesses of both visualizations.

Zoom in and details through Spots and List

Participants were asked to categorize Detail visualizations of *Spots* for movie genres (Figure 4.12) and *List* with brightness for rating and colored genres (Figure 4.13 and 4.14) in USE dimensions and Quality terms. Both representations were considered very useful, satisfactory, and easy to use, with very slight negligible differences (table 6.10).

Table 6.10. USE (0: did not hit. 1-5: success level):
Spots and List Visualizations

Visualization	*Usefulness*		*Satisfaction*		*Ease of Use*	
Spots	M: 4.1	Std: 0.9	M: 4.0	Std: 0.7	M: 4.1	Std: 0.9
List	M: 4.1	Std: 0.7	M: 4.1	Std: 0.7	M: 4.2	Std: 0.8

Table 6.11. Quality Terms:
Spots, and List

		Spots			*List*
8	E	Comprehensible	10	E	Comprehensible
8	A	Pleasant	9	E	Simple
7	E	Supportive	7	E	Supportive
7	a	Good	6	A	Pleasant
7	E	Clear	6	E	Clear
7	A	Aesthetic	5	A	Controllable
7	H	Innovative	5	H	Predictable
5	E	Simple	5	H	Interesting
5	H	Original	5	E	Familiar
5	H	Interesting			

H: Hedonic; E: Ergonomic; A: Appeal

In what concerns the list views, both the alphabetic and rate ordering were considered equally important. In Quality terms (Table 6.11), *Comprehensible* was the most rated in both visualizations, followed by *Pleasant* and *Supportive*. More distinguishing terms were: *Good*, *Aesthetic*, and *Original* for *Spots*; and *Controllable*, *Predictable*, *Familiar*, and higher rating for *Simple*. These results complement the feedback from the other evaluation aspects and user comments.

Browsing Visualizations

We tested navigations with the intention of showing the participants possible scenarios of use. Visualizations are to be explored alone and also by detailing and zooming the information toward specific goals.

Participants were shown the navigations and asked to measure *Usefulness*, *Satisfaction,* and *Ease of Use,* and to express opinions that we registered. The results were encouraging with the participants highly rating the USE aspects. Differences between casual and professional users were not found.

Choosing a movie by genre through Region of Colors

We wanted to know if participants would like to use *Region of Colors* and *Spots* (Figure 4.2 to 4.12 to the movie) in order to find a movie to watch.

Participants liked this navigation with many of them considering it very useful and satisfactory (Table 6.31). The finding by chance, - having though the possibility to get information about the movie - was well considered by them.

Table 6.31. USE (0: did not hit. 1-5: success level):
Choosing a Movie by Genre through Region of Colors

Visualization	*Usefulness*		*Satisfaction*		*Ease of Use*	
Choosing a Movie by Genre through Region of Colors	M: 4.6	Std: 0.5	M: 4.4	Std: 0.5	-	-

Choosing a movie by genre through Tag Clouds and List

We measured the access of movies through *Tag Clouds* and *List* (Figure 4.5 to 4.6 to 4.13 to the movie).

Comparing to the finding by chance in the previous navigation, these results (Table 6.32) were better rated due to the titles, referred as being important information to have available when choosing a movie to watch. Almost all the participants considered the navigation useful (M:4.9; Std:0.3), and many of them considered it satisfactory in showing information.

Table 6.32. USE (0: did not hit. 1-5: success level):
Choosing a movie by genre through Tag Clouds and List

Browsing	*Usefulness*		*Satisfaction*		*Ease of Use*	
Choosing a movie by genre through Tag Clouds and List	M: 4.9	Std: 0.3	M: 4.6	Std: 0.5	-	-

The presented evaluation allowed us to gain awareness about the main strengths and weaknesses of the visualizations in terms of usability, efficacy and user preference. It was encouraging to know that the participants found the possibility to browse and access movies through the presented visualizations useful and fun. Genre was considered one of the most relevant properties to access movies and the use of colors to code them was very appreciated. Linear visualizations were preferred over circular, although the latter demonstrated to be more effective in showing patterns of information.

6.4 Results: Second Phase

Interactive visualizations based on time, and space, were evaluated, from collections to the individualization of movies, to contents.

Emotion-color-genre Matching

Regarding the contents of movies, along with genres, emotions are addressed and thus, the emotion-color-matching was evaluated (e.g., Happiness-yellow-Comedy).

We asked the participants to measure the assertiveness of the matching by rating it from 1 (lower) to 5 (highest) and the results were positive (M:3.8; Std:0.4). One participant suggested that various emotions might tag one genre, though. The user customization of the color palette was argued to be possible by two participants, for more flexibility about individual preferences.

Romance-pink-Love was once more the most consensual match, although the Romance genre was also matched to dark red, red, yellow, bright blue and violet by one participant, and Love and Enjoyment, by two.

Movie Contents in Time

We evaluated visualizations that represent movie contents by criteria related with image, audio and speech.

Movie Content by Image, Audio, Speech and Genre

We wanted to know if this visualization (Figure 4.16) assists the viewer in choosing a movie to watch. Firstly, without explaining the participants the meaning of the representations, we tested the design of the properties alone in order to know if they reflect their meaning in a natural and clear way (e.g., the audio amplitude is represented by a white stripe). After telling the participants about the visualization's meaning and goals, we tested it as an overview, measuring the perceived easiness (speed and adequacy) of the participants during the performance (e.g., click to watch a scene playing). We used a 0-5 scale (0: did not hit; 1-5: success level). Finally, we tested its relevance comparing it with Netflix, one of the most used applications to find a movie to watch.

When asked to *"Identify audio amplitude"*, and *"Identify the most spoken words"*, participants showed that those representations are very easy to figure out (M:5,0). Regarding the tasks that demanded for interactive manipulation, both *"In order to watch a scene of the movie, how do you proceed?"* (M:4.3; Std:1.6) and *"In order to identify the represent genres, how do you proceed?"* (M:4,9; Std:0.5) showed good results, with only one participant not hitting the former one.

We wanted to know in which degree this visualization was considered for current use. After being aware of all the functionalities and information available in the visualization, the participants were asked to interpret the visualization by accomplishing the task *"Which one of these movies would you rather watch? Why?"* and the large majority accomplished it with success (M:4.4; Std:1.3) with one participant not hitting the goal, and another one demonstrating difficulty in doing it. When asked if they would like to have this visualization available, the results were also encouraging (M:3.8; Std:1.2).

Table 6.12. USE (0: did not hit. 1-5: success level):
Movie Content by Image, Audio, Speech and Genre

Visualization	*Usefulness*		*Satisfaction*		*Ease of Use*	
Movie Content by Image, Audio, Speech and Genre	M: 3.9	Std: 0.9	M: 3.9	Std: 0.9	M: 4.1	Std: 0.9

Almost all the participants considered exploration and emotion as the right words to define the visualization: "*Absolutely! It allows to explore movies through mood, by being emotional rather than descriptive*", and "*It could lead to a reflection about my choices through a challenge, as in a game*". The movie director João Mário Grilo felt it as an "*Evocation of the film*" due to its ability to reflect emotions. He argued though, that more information is needed in order to have a consistent idea of the contents. The g*enre* was seen as important information to be visible, and it was suggested that it might change for emotions, and some participants would prefer to have the *title* visible by default.

Participants were asked to measure Usefulness, Satisfaction, and Ease of use (Table 6.12), and to characterize the visualization through Quality terms (Table 6.13). In general, they considered the visualization a good way to find a movie to watch. All participants found it *Supportive*, *Interesting* and *Pleasant*, and the great majority thought it is was *Comprehensible*, *Controllable*, *Innovative*, *Good*, *Controllable*, *Aesthetic*, *Innovative*, *Good* and *Aesthetic*. *Strange*, *Complex* and *Unpredictable* were referred by 8, 7 and 5 participants respectively, which in our perspective are not negative considerations. On the one hand, it reflects the natural strangeness participants felt in the first visualization of this evaluation set, and on the other hand, the good results on the positive side of the table make these three adjectives as a value, demonstrating instead the novelty of the visualization.

Table 6.13. Quality terms:
Movie Content by Image, Audio, Speech and Genre

Positive Terms			*Negative Terms*		
20	E	Supportive	8	E	*Strange*
20	H	Interesting	7	E	*Complex*
20	A	Pleasant	5	E	*Unpredictable*
16	H	Original	1	E	*Incomprehensible*
15	E	Comprehensible	1	E	*Uncontrollable*
15	E	Controllable			
15	H	Innovative			
15	A	Good			
15	E	Controllable			
15	A	Aesthetic			
15	H	Innovative			
15	A	Good			
15	A	Aesthetic			
13	E	Clean			
12	H	Exciting			
10	E	Simple			
10	E	Predictable			

H: Hedonic; E: Ergonomic; A: Appeal

Table 6.14. Visualization's relevance (0: did not hit. 1-5: success level):
Movie content by Image, Audio, Speech and Genre

"Which visualization would you rather have?"

Movie Content by Image, Audio, Speech and Genre		*Netflix*		*Both*	
M: 3.8	Std: 0.4	M: 3.6	Std: 0.5	M: 0.5	Std: 0.5

When asked to choose between this visualization and *Netflix* (Table 6.14), as a corresponding way of searching for a movie to watch, the majority chose the first (M:0.8 vs. 0.6). Almost all of them found our visualization more exploratory, challenging and less accurate, and thus able to prompt finding of movies by chance. *Netflix* was viewed as more targeted to persuade viewers to watch the movie, and some participants suggested the combination of both interfaces as they complement each other (M:0.5; Std:0.5) being the images of the movie perceived at first glance referred as important to have an overview of the movie. The possibility to customize the number of scenes visible in order to get more detailed information was seen as a plus.

Although accurate tasks were not taken into much consideration before the evaluation, surprisingly, both casual and professional participants enjoyed the visualization. Casual users defended the visualization as a way to loosely explore movies to watch, saying, *"Less directed, less informative, less predictable, and thus more interesting. I'm not sure of finding what I'm looking for, but it is more interesting beyond question", "It is better than Netflix to navigate toward a not expected movie to watch."* and *"It is more intuitive and emotional"*. Among the professional users, opinions went toward a more accurate and use-related direction, *"It is better for research, and thus it could be useful for me when I'm writing about the movies."* and the cinema critic *"Through this movie summary I would go forward and backward throughout the movie's length in order to better reach a scene of interest to my text"*.

Movie Content by Image, Audio and Title

With similar goals as the previous visualization, we wanted to know if visualization in Figure 4.19 was considered a value to explore, compare, and/or choose a movie to watch. Again, we started by testing the value of the various representations of attributes (e.g., audio amplitude) in showing meaning, and continued by testing the visualization as an overview in a 0-5 scale (0: did not hit; 1-5: success level). In the end, we compared it with the previous visualization and *Netflix* to infer about its relevance for the users.

Without being aware of the meaning of the representations, the participants easily identified the most dynamic movie (M:4.9, Std.0.5), and when asked to turn visible one of the images of the movie in its length, they confidently clicked on the summarized image (M:5.0). Participants demonstrated that this visualization was very easy to figure out because it emulates the usual bar charts. On the other hand, they were more used to this kind of representations after the performance with the previous visualization.

After the visualization's goals were explained to the participants, they all identified the duration of the movies (M:5.0), although they have found it more difficult than in the previous visualization to choose a movie to watch (M:3.9; Std.1.8). Although most participants found the rhythm an accurate feature to reflect the movie, and moreover, having a cinema director arguing in favor of it, saying that it shows the "organics" and the structure of the movie, the results show that this visualization lacks clear images. Although images might be shown in more or less detail depending on the user's interest through the summarization level, great detail implies a long timeline stripe (Figure 4.20).

As referred, this visualization was associated with bar charts. Titles were referred as a plus, and clear images of the movie were referred as a need.

Table 6.15. USE (0: did not hit. 1-5: success level):
Movie Content by Image, Audio and Title

Visualization	*Usefulness*		*Satisfaction*		*Ease of Use*	
Movie Content by Image, Audio and Title	M: 3.8	Std: 1.0	M: 3.8	Std: 0.9	M: 4.2	Std: 0.9

Participants were asked to rate *Usefulness*, *Satisfaction*, and *Ease of use* (Table 6.15), and the results were good, with more than a half of the participants rating the three values with 4 or 5 (14 and 13, respectively). Relating to Quality terms, the most referred ones were *Controllable*, *Aesthetic*, *Supportive*, *Clean*, *Interesting*, *Original* and *Pleasant* terms (Table 6.16). *Strange*, *Complex* and *Unpredictable* were referred by 5, 4 and 2 participants respectively. The lower values were contradictory with the same participant naming terms such as *Unpredictable* and *Confuse vs. Supportive* and *Controllable*, and other one naming *Incomprehensible* and *Unpredictable vs. Supportive* and *Controllable*.

Table 6.16. Quality terms:
Movie Content by Image, Audio and Title

Positive Terms			*Negative Terms*		
16	E	Controllable	5	E	*Strange*
16	A	Aesthetic	4	E	*Complex*
15	E	Supportive	2	E	*Unpredictable*
15	E	Clean	1	E	*Obstructing*
15	H	Interesting	1	E	*Confuse*
15	H	Original	1	E	*Uncontrollable*
15	A	Pleasant	1	H	*Boring*
14	E	Comprehensible	1	A	*Unpleasant*
14	E	Simple	1	A	*Non Aesthetic*
14	H	Innovative			
13	E	Predictable			
13	A	Good			
10	H	Exciting			

H: Hedonic; E: Ergonomic; A: Appeal

When asked to choose between this visualization and *Netflix*, most participants chose the former (Table 6.17), arguing in favor the fact that it is less inductive, gathers more information and reveals the rhythm and dynamics of the movie. In favor of *Netflix*, participants reiterated that images are very important to have an idea of the movie. Some participants defended that the best option would be to have both, since they complement each other in the image information.

Table 6.17: Visualizations' relevance (0: did not hit. 1-5: success level):
Movie Content by Image, Audio and Title

"Which visualization would you rather have?"

Movie Content by Image, Audio and Title		*Netflix*		*Both*	
M: 3.8	Std: 0.4	M: 3.5	Std: 0.5	M: 3.5	Std: 0.5

When comparing the present visualization (Figure 4.19) with '*Collections of Movies through Image, Audio, Words, and Genres*' (Figure 4.16) the results were clear in showing the preference for the latter. Participants seemed a little divided, though, saying "*This one is more interesting while the previous is more exciting*"; and "*I prefer this one but the circular* visualization *gives more information and is visually more interesting*"; and "*The previous visualization represents the essence of the information about the movie, and I believe I can figure out the dynamics through the variations in audio*". To gather both was also defended, one of the participants arguing "*this visualization is more capable of helping me choosing a movie, and the previous in reflecting emotions* ".

Table 6.18: Visualizations' relevance (0: did not hit. 1-5: success level):
Comparing Movie Content by Image, Audio and Title
with *Movie Content by Image, Audio, Speech and Genre*

"Which visualization would you rather have?"

Movie Content by Image, Audio and Title		*Movie Content by Image, Audio, Speech and Genre*		*Both*	
M: 3.3	Std: 0.5	M: 3.8	Std: 0.4	M: 3.1	Std: 0.3

Regarding casual and professional uses, the presented visualization was seen as accurate and analytic, with the cinema critic demonstrating the desire of having it as associated with the information of the trailer. In the same direction, a digital artist argued in favor of this visualization saying that it would help with research. The majority of the participants, though, considered it more suited for analytical roles: "*More appealing, more functional*".

Movie Collections in Space and Time

We evaluated interactive visualizations that represent collections of movie trajectories, that can be zoomed in and detailed by speed and date of the shooting.

Quantities of trajectories - Zoom in on closer area

As simple as this visualization is (Figure 4.36), we wanted to know if it is clear in reflecting the trajectories shot by location.

All participants figured out the visualization at first glance with the great majority demonstrating the will to have it available (M:0.8). Surprisingly, it was found very interesting by the participants, with various uses being suggested depending on the task at hand.

Table 6.19. USE (0: did not hit. 1-5: success level):
Quantities of trajectories - Zoom in on closer area

Visualization	*Usefulness*		*Satisfaction*		*Ease of Use*	
Quantities of trajectories-Zoom in on closer area	M: 3.6	Std: 1.4	M: 4.7	Std: 0.4	M: 4.3	Std: 0.8

Casual users defended it, saying that "*It is very interesting and innovative*", and "*A place of many shootings is popular, and thus it deserves to be visited*", while a movie maker considered it as a way to be aware of locations that are too explored in movies, and prompting the choosing of other places to shoot. Another idea from the participants was to use this visualization in order to track the trajectories from movies, being suggested that it could be included in applications such as *Google Maps,* as a complement.

Relating to *Usefulness*, *Satisfaction,* and *Ease of use* (Table 6.19), it became clear that most participants liked the visualization even when they did not figure out a use for it, with two participants saying that they would like to have it "*Just because"*. Professionals that work with movies and casual users that are curious about locations in the world were the ones who rated better the visualization.

Details on Trajectories by Speed and Date of the Shooting

We wanted to know if participants were able to relate and compare trajectories through this visualization (Figure 4.37). The evaluation started after telling the participants about the represented variables and the way to interactively explore the visualization.

The majority of the participants achieved the goal of identifying the most dated and fastest shooting with success (M:4.4; Std:0.8) but they found it difficult to interpret the visualization by choosing a trajectory to visit (M:4.0; Std:1.5). Four participants suggested that height in arcs should correspond to faster trajectories due to its more dynamic shape, which had notorious implications in the results of the evaluation, and will allow us reflect about the intuitiveness of this visualization.

Table 6.20. USE (0: did not hit. 1-5: success level):
Details on Trajectories by Speed and Date of the Shooting

Visualization	*Usefulness*		*Satisfaction*		*Ease of Use*	
Details on trajectories by speed and date of the shooting	M: 3.8	Std: 1.2	M: 3.8	Std: 1.1	M: 3.8	Std: 1.1

The high Standard Deviation values for *USE* (Table 6.20) reflects the Quality terms table. Contradictory terms were named (*Supportive* and *Incomprehensible*, *Controllable* and *Unpredictable*) although more than a half of the participants had referred *Supportive*, *Controllable*, *Interesting*, *Comprehensible*, *Clean*, *Original*, *Pleasant* and *Good*.

This was the visualization participants indicated most strangeness about, although much more positive than negative terms were considered as characterizing the visualization. Interesting to cite, one participant referred *Strange* as one of the *Quality terms,* emphasizing that, contrary to previous visualizations, "*This is strange. And I mean strange!*".

When asked to choose between this visualization and *Google Maps* (Table 6.22) participants chose ours (M:0.6), which is a good result due to the familiarity participants have with *Google Maps*. Some participants chose to have both (M:0.5) in order to complement each other, as an embedding of our visualization in *Google Maps*. They highlighted the number of information available while expressing the need to include images.

Table 6.21. Quality terms:
Details on Trajectories by Speed and Date of the Shooting

Positive Terms			*Negative Terms*		
13	E	Supportive	4	E	*Incomprehensible*
13	E	Controllable	4	E	*Complex*
13	H	Interesting	4	E	*Confuse*
12	E	Comprehensible	4	E	*Strange*
12	E	Clean	3	E	*Obstructing*
12	H	Original	3	E	*Unpredictable*
12	A	Pleasant	3	H	*Disinteresting*
12	A	Good	2	E	*Uncontrollable*

11	E	Simple	2	H	*Boring*
11	E	Predictable	2	A	*Unpleasant*
11	H	Innovative	2	A	*Bad*
11	A	Aesthetic	2	A	*Non Aesthetic*

H: Hedonic; E: Ergonomic; A: Appeal

Table 6.22: Visualization's relevance (0: did not hit. 1-5: success level):
Details on Trajectories by Speed and Date of the Shooting

"Which visualization would you rather have?"

Details on trajectories by speed and date of the shooting		*Google Maps*		*Both*	
M: 0.6	Std: 0.5	M: 0.5	Std: 0.5	M: 0.5	Std: 0.4

Relating to the target for this visualization, all participants referred its analytical role as the one to emphasize integrated with the exploration of trajectories, both for daily uses and in professional roles, e.g., in the tourist business.

Details of One Trajectory by Speed

We wanted to know the relevance of adding time to a single trajectory (Figure 4.39).

Results show that the representation is very intuitive and clear, with all the participants being able to locate the slower and faster moments of the trajectory (M:5.0). 15 participants demonstrated the will to have it available for their own use, but when measuring *usefulness*, *satisfaction* and *ease of use*, the results seem to contradict this information, which may reflect a first glance opinion about the visualization vs. its use toward a specific goal. Participants seem to have found the visualization interesting, but when considering a task to use it in, they could not easily figure it out.

Table 6.23. USE (0: did not hit. 1-5: success level):
Details on trajectories by speed

Visualization	*Usefulness*		*Satisfaction*		*Ease of Use*	
Details of one trajectory by speed	M: 3.5	Std: 1.4	M: 4.5	Std: 0.7	M: 4.3	Std: 1.0

Professionals defended the visualization as able to rebuild the path of a movie or to figure out the rhythm throughout its duration.

Movie Content in Space and Time

We evaluated visualizations that represent movie trajectories relating to their contents by criteria related with image, audio and speech.

Movie Content in Space and Time through One Trajectory

The goal was to know if this visualization assists the viewer in the exploration of trajectory contents (Figure 4.37).

In this stage of the evaluation, participants were already familiarized with this type of representations, and the results show it: *"Was this trajectory shot by day or by night"* (M:4.9, Std: 0.2), *"Which part of the trajectory would you consider having louder audio? Why?"* (M:5.0) and "*In order to watch an image of the shooting, how do you proceed?"* (M:5.0). The results were plain in showing maximum success with only one participant accomplishing the first task of reaching a level 4.

Table 6.24. USE (0: did not hit. 1-5: success level):
Movie Content in Space and Time: based on trajectory

Visualization	*Usefulness*		*Satisfaction*		*Ease of Use*	
Movie Content in Space and Time: based on trajectory	M: 0.4	Std: 0.9	M: 0.4	Std: 0.9	M: 4.5	Std: 0.9

USE resulted were dispersed through the participants, with half of them *Agreeing Strongly*, and the other half divided between *Agreeing Somewhat* and *Neutral*. The Quality terms (Table 6.25) confronts the *USE* test by showing very positive results, with all participants considering it *Supportive* and only 3 of them naming *Complex*, *Unpredictable,* and *Strange*.

Table 6.25. Quality terms:
Movie Content in Space and Time: based on trajectory

Positive Terms			*Negative Terms*		
20	E	Supportive	3	E	*Complex*
17	E	Controllable	3	E	*Unpredictable*
17	H	Original	3	E	*Strange*
16	E	Comprehensible	2	A	*Non Aesthetic*
16	E	Clean	1	E	*Incomprehensible*
16	H	Interesting	1	E	*Uncontrollable*
15	H	Innovative	1	H	*Disinteresting*
15	A	Pleasant	1	H	*Boring*

15	A	Good	1	H	*Conservative*
14	E	Simple	1	A	*Unpleasant*
14	E	Predictable	1	A	*Bad*
13	A	Aesthetic			
12	H	Exciting			
11	E	Familiar			

H: Hedonic; E: Ergonomic; A: Appeal

The large majority of the participants chose terms from the positive side of the table and 15 of them did not find any negative term to characterize the visualization. Although very appreciated in its original way of thinking about tours, participants demonstrated strangeness when inquired about concrete uses for it. No distinctions were found between casual and professional uses, which might reflect a lack in the right target being tested. Perhaps tourist professionals are to consider in the future for such evaluation.

Movie Content in Space and Time

The maximum success of this visualization in reflecting an idea of the movie it represents was demonstrated by asking the participants if the movie looked sad, and where it happened, without any prior information about it (M:5.0). For the easiness of these tasks, one participant referred the colors of the movie and the spots that depict emotions. The images, though, both of the movie display and the map were pointed out by several of them as most relevant.

Secondly, with the goal of testing the clearness and intuitiveness of the represented features, we continued by asking the participants if they were able to identify them (Table 6.26). All the participants were able to rapidly and successfully locate *Images of the movie, Audio amplitude* and *Most spoken words* (M:5.0). Also easy to figure out was the representations of *Colors, Trajectories* and *Emotions. Scene length* (M:3.8, Std:2.1) and *Motion* (M:2.1, Std:2.4) were not successful representations, though, with 4 to 10 participants respectively, not figuring them out.

Table 6.26. Interpretation of the representations
with no prior knowledge of their meaning
(0: did not hit. 1-5: success level):

Movie Content in Space and Time: based on timeline

Images of the movie	M: 5.0	Std: 0.0
Audio amplitude	M: 5.0	Std: 0.0
Most spoken words	M: 5.0	Std: 0.0
Colors	M: 4.9	Std: 0.2
Trajectories	M: 4.9	Std: 0.3
Emotions	M: 4.8	Std: 0.5
Length of the scenes	M: 3.8	Std: 2.1
Motion	M: 2.1	Std: 2.4

Regarding *Scene Length*, all participants understood the meaning of the numbers that stand for the beginning time of each scene, but most of them could not identify the longer and shorter scenes. Some of the participants thought that the meaning of the image summarization was the opposite, i.e., longer scenes corresponding to less summarized parts of the movie since, they argued, *"If the scene is longer, we are able to watch it in a greater length, letting the scene more identifiable"*.

In order to try better design approaches for *Scene Length* and *Motion*, we tested both by comparing different representations with the ones that were evaluated.

For the *Scene Length* representation, we tried a more analytical design through a gray area in the thumbnail images: the larger the area, the longer the scene. Both representations were placed side-by-side and the participants were asked to choose from the two, the one that better shown the longer scene. The results were even, with almost all the participants referring the more analytical view of the gray representation, and the appealing aspect of the summarized images.

In addition to test the *Scene Length* representation, we wanted to infer the level of importance participants assigned to this feature, and therefore, if it should constrain the whole visualization by reshaping the other tracks. Participants were asked, *"Which visualization do you prefer regarding Scene Length representation? Why?*" The results show that this feature is not important to the participants (M: 0.9 vs. M: 0.5), one of them suggesting to have both, with the previously presented by default. Aesthetics was referred again as a priority in the choosing.

Table 6.27. Interpretation of the representations
with awareness about their meaning
(0: did not hit. 1-5: success level):
Movie Content in Space and Time: based on timeline

"In order to choose a scene of interest, how do you proceed?"	M: 5.0	Std: 0,0
"Locate the daylight part of the movie."	M: 5.0	Std: 0,0
"Where was the movie shot?"	M: 5.0	Std: 0,0
"Identify a romantic scene."	M: 5.0	Std: 0,0
"Identify a scene where someone laughs"	M: 4.9	Std: 0.3
"In order to explore the location of the selected scene, how do you proceed?"	M: 4.4	Std: 1.6
"Identify one of the most dynamic scenes of the movie."	M: 4.4	Std: 1.6
"Which is the genre of the movie?"	M: 3.9	Std: 1.5
"Identify one of the shorter scenes of the movie."	M: 3.6	Std: 1.7

Regarding to the representation of *Motion,* comparing tests demonstrated it was not easily understood due to its low variations throughout the movie. The current way to show information through image distortion (Figure 4.44) was compared with a more analytical representation using shades of gray. When asked "*Which scene is the most dynamic?",* the majority of the participants considered the current representation as better in showing the information (M:0.8 vs. M:0.2), while referring aesthetics as the reason for their preference. In addition, in order to narrow the information about the success of this representation, we placed two movies with contrasted dynamics side-by-side (*Back to the Future* and *Before Sunrise*), and asked the participants *"Which movie is the most dynamic?*" This time the results were plain with all the participants rapidly accomplishing the task (M:5.0). The latter test made clear that high variations of motion throughout the movie turns information very clear.

We conclude that contrary to the *Scene length* representation that clearly needs further reflection, *Motion* is well designed.

Table 6.28. USE (0: did not hit. 1-5: success level):
Movie Content in Space and Time: based on timeline

Visualization	*Usefulness*		*Satisfaction*		*Ease of Use*	
Movie Content in Space and Time: based on timeline	M: 4.3	Std: 0.8	M: 4.2	Std: 0.8	M: 4.4	Std: 0.7

Table 6.29. Quality terms:
Movie Content in Space and Time: based on timeline

Positive Terms			*Negative Terms*		
20	H	Interesting	11	E	*Complex*
20	H	Original	4	E	*Confuse*
17	E	Supportive	4	E	*Strange*
16	E	Comprehensible	1	E	*Incomprehensible*
16	E	Controllable	1	E	*Uncontrollable*
16	H	Innovative	1	A	*Unpleasant*
16	A	Pleasant	1	A	*Bad*
15	A	Good			
14	A	Aesthetic			
12	H	Exciting			
11	E	Clean			
10	E	Familiar			

H: Hedonic; E: Ergonomic; A: Appeal

In order to infer about the memory load needed by the user to manage the visualization, after being told about the meaning of the representations the participants were asked to perform tasks by interpretation and interaction (Table 6.27). When asked *"In order to choose a scene of interest, how do you proceed?", "Locate the daylight part of the movie"*, *"Where was the movie shot?"* and *"Identify a romantic scene"*, all participants found it very easy to accomplish the task (M:5.0). It was interesting to note that participants used the three possible ways to select a scene, either by clicking on one thumbnail scene by dragging the circular tracks, or by clicking on the spot of a particular emotion, which indicates intuitiveness in the disclosing of information by interaction.

"Identify a scene where someone laughs", a task for which the participants had to click on the *audio events'* track in order to disclose the information had almost all the participants achieving the goal with maximum success, with only 2 achieving the level 4 (M: 4.9; Std: 0.3). *"In order to explore the location of the selected scene, how do you proceed?"* (M:4.4; Std:1.6) and *"Which is the genre of the movie?"* (M:3.9; Std:1.5) had also very encouraging results, particularly the task that relates to locations with 18 participants achieving it immediately. Participants found some difficulty in knowing the movie genres due to the visual strength of the main corpus of the visualization constituted both by the circular tracks and the movie plus the trajectory playing. It is not for concern though, since as referred earlier, this information is placed upright in the visualization not to interfere with the main information about the contents, which is the one to disclose at first, i.e. the related information about the movie corresponds to the second level of information.

It became clear though, that time for exploration is needed for the user to be able to manage the visualization in its full functionalities.

Given the complexity and number of variables of this visualization, we consider both the *USE* (Table 6.28) and Quality terms (Table 6.29) results very encouraging. Regarding *USE,* the results were very balanced, with almost all the participants achieving the 4 and 5 levels, and only 2 to 3 as *Neutral* (level 3).

Quality terms reiterated the previous results, with 17 participants finding it *Supportive*, and 16 using *Comprehensible* and *Controllable* as terms to describe it (Table 6.29). All the participants characterized the visualization *Interesting* and *Original* (Table 6.29), and 16 thought it was *Innovative* and *Pleasant*, which gives it a supported value for design and appeal. 5 to 4 participants referred *Confuse* and *Strange*, respectively, relating these terms to the surprise they felt when presented with such original design.

Asserting the pertinence and importance of features

Having in mind future developments toward a final interactive application, we wanted to know which features to develop by asking the participants which tracks from the visualization they choose to be visible and which ones to erase (Table 6.30).

Table 6.30. Tracks to be visible and to erase:

"Which tracks would you choose to be visible?"		*"Which tracks would you erase?"*	
11	Emotions	8	None
5	Motion	3	*Scene duration*
5	Location	2	*Audio amplitude*
4	Genre		
4	Images		

Emotions, was by far the most appreciated feature when the characterization of movies is in focus. 5 participants named *Motion* and *Location*, and 4 *Genre* and *Image,* as attributes able to characterize movies. All properties were argued to be useful enough to be maintained, though, due to the possibility for the user to either hide or turn tem visible.

Most participants considered this visualization positively and able to provide useful and effective insights. The movie director argued about the possibility that it might mislead the user by presenting both analytical and casual design approaches, i.e., by gathering two different codes: the *"impressionist"*, and the *"accurate"*. Therefore, he stated, in order to correspond to the professional needs, more technical properties are to be added, and suggested the change from *Color* to *Light*.

Some participants expressed surprise and confusion when presented with the visualization, but the contrary was observed during the execution of the tasks, which seems to show the intuitiveness of the representation overview. Being the first time participants saw this design, and the fact that it holds features that demand new ways to interact with, they were able to perform almost all the tasks easily.

The possibility to explore time and space in synchrony was very appreciated. As one particular moment of the tests, the reaction from the participants, both positive and with surprise when we change, by clicking, the moment of the trajectory that is being followed by the actors, causing the movie to play ahead. Also interesting and motivating was the will from the participants to experiment the demo for themselves: *"Can I explore it by myself?*

Browsing Visualizations

We wanted to know if participants would like to use this navigation (Figure 4.16 to the movie) in order to find a movie to watch, or to compare movies relating their contents.

This navigation was referred to as being likely to be chosen, and useful, as shown in Table 6.33. As referred by the participants, due to the novelty of the visualization and the impossibility from the participants of interacting themselves throughout a range of time, *Satisfaction* and *Ease of* *use* results were not highly rated. Nevertheless, casual users referred using it within the entertaining realm, as a way to navigate and choose a movie through a more visual, emotional and interesting way. Professionals have shown interest in using the visualization in order to easily and rapidly find a scene of interest, e.g., the movie critic suggested the view of scenes for the recalling of certain moments of the movie. The same participant suggested the forward and reverse direction with the intention of either navigating throughout the contents to choose a movie to watch, or to go to the scenes they had watched for accurate information.

Table 6.33. USE – Usefulness, Satisfaction and Ease of use:
Choosing a Movie to Watch by Image, Audio, Words and Genre

Browsing	*Usefulness*		*Satisfaction*		*Ease of Use*	
Choosing a Movie to Watch by Image, Audio, Words and Genre	M: 4.6	Std: 0.6	M: 4.4	Std: 0.7	M: 4.2	Std: 1.0

The study of emotions over time was suggested as an interesting way to explore the visualization toward analysis, but as referred, the majority of the participants considered this navigation an interesting and effective way to choose a movie to watch in a more creative and challenging way.

Exploring and detailing movie contents

This test aims at evaluating the exploration of movie contents by the user, going from an overview that reflects an idea of the movie to a scene of interest (Figure 4.44 to 4.48 to 4.49).

Table 6.34. USE USE (0: did not hit. 1-5: success level):
Exploring and Detailing Movie Contents

Browsing	*Usefulness*		*Satisfaction*		*Ease of Use*	
Exploring and Detailing Movie Contents	M: 4.4	Std: 0.9	M: 4.5	Std: 0.8	M: 4.3	Std: 1.0

This navigation was well received by almost all the participants being central to the results (Table 6.34) the possibility to make visible only the properties of interest (Figure 4.48), in order to simplify the displayed information in the screen. It was possible to observe differences in the replies of professional and casual targets being the better ratings from the professionals. Casual users, though, also considered of interest the possibility to explore and analyze movie contents, being emotions and locations the most appreciated features. For both targets, related information was referred as important to have present throughout the navigation.

The movie director that earlier in the evaluation had alerted us to the fact that the user might become misled by the first overview, due to the apparent technical support, shoed interest in this navigation. He strongly suggested, though, the refinement of the tracks toward a more specific and technical group of features.

Selecting one trajectory to explore

The evaluation of this path tries to assert the interest of participants in choosing a trajectory to visit by comparing several tours in one location of interest (Figure 4.36 to 4.37 to 4.41).

The possibility to explore trajectories from movie scenes was very appreciated, with participants stating, *"It is an interesting way to explore places in the world"* and *"An idea I've never thought about"*. The second visualization of the path (Figure 4.37) brought some issues to the navigation, as expected after its evaluation, and thus, we could assert that the results were favored in great extend (Table 6.35) by the visualization in Figure 4.41, referred to as very simple, interesting and exciting to use in the exploration of locations and trajectories.

Table 6.35. USE (0: did not hit. 1-5: success level):
Selecting One Trajectory to Explore

Browsing	*Usefulness*		*Satisfaction*		*Ease of Use*	
Selecting One Trajectory to Explore	M: 4.2	Std: 1.0	M: 4.4	Std: 0.6	M: 4.2	Std: 0.8

Exploring trajectories from the same location

This test focuses on the participants' interest in exploring locations by navigating from the movie they are watching to other movies that happen in the same geographical location (movie to Figure 4.32 to 4.39 to 4.31 to 4.51 to other movie scenes).

This path was very appreciated from both professional and casual participants, and although some of them have shown interest by curiosity, it was seen as original and interesting to have available by all of them. The main functionality for the professional field was referred to be the tourism one, and it was referred that this navigation combines and complements information. The USE results are in accordance to this feedback, and we consider them very satisfactory and coherent (table 6.36).

Table 6.36. USE (0: did not hit. 1-5: success level):
Browsing Trajectories from the same Location

Browsing	*Usefulness*		*Satisfaction*		*Ease of Use*	
Exploring Trajectories from the same Location	M: 4.7	Std: 0.6	M: 4.7	Std: 0.6	M: 4.7	Std: 0.6

Choosing movies by genre and location

The evaluation of this navigation discloses the curiosity and interest of participants in exploring amounts of movies by genre and location (Figure 4.27 to 4.28 to 4.29 to 4.30 to the movie).

This navigation was clearly chosen for entertainment reasons and participants expressed more interest in the second half of the navigation, i.e., the choosing of a movie by location. Analytical tasks were considered less useful although reflecting curiosity by the participants. It was considered a new and interesting way of choosing a movie to watch and this was corroborated by the values in Table 6.37.

Table 6.37. USE (0: did not hit. 1-5: success level):
Choosing Movies by Genre and Location

Browsing	*Usefulness*		*Satisfaction*		*Ease of Use*	
Choosing Movies by Genre and Location	M: 4.6	Std: 0.8	M: 4.9	Std: 0.3	M: 4.9	Std: 0.3

Final Remarks

In the last phase of the evaluation, we addressed the project as a whole in order to find out about the liking, the impact, and the memorability of the participants regarding the presented interactive visualizations.

Although visualizations were new to the participants and thus some strangeness had been expressed in the beginning of the evaluation, at the end of the tests that feeling totally disappeared and visualizations were easily and gladly remembered and talked about.

Preferred Visualizations

We asked the participants to express their ideas about the visualizations they remembered best, and to choose the preferred ones as those they would like to have available for later use. One participant demonstrated the will to have them all, to use depending on the tasks at hand, and half of them referred both the temporal and the spatial dimensions as very interesting to explore. Referred as the most innovative feature in the visualizations was the circular way to place the content features. We show visualizations by order of preference in Figure 6.1.

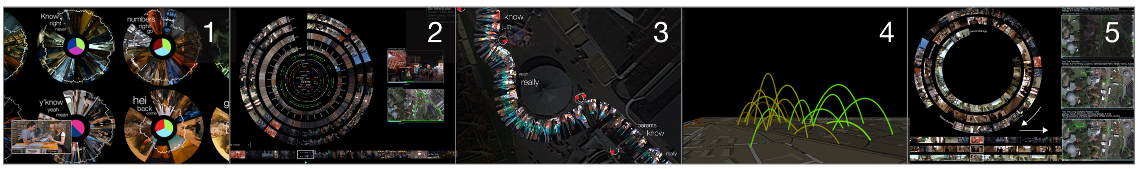


Figure 6.1. Visualizations by order of preference.

1 - *Collections of Movies in Time through Image, Audio, Words, and Genres:* In accordance to the first results in Section 6.5.1, the participants reiterated their liking for this visualization and demonstrated that if it had been tested ahead in the evaluation, when asked if they wanted this visualization available the results would have been much more satisfactory. The relevance of emotions was highlighted as a main feature to explore movies, some of the participants suggesting the possibility to change from genres to emotions, as a more meaningful attribute, and in higher accordance to the emotion concept of the visualization. Speech was referred sometimes throughout the evaluation, and again in this section, as not accurate in the characterization of movies, being keywords considered a better option by some participants. The title was suggested to be visible at first level of information.

2 – *Movie Contents in Space and Time*: We found very interesting the fact that the most complex visualization is the second preferred of all. We believe that in the end of the evaluation participants were already able to think about the visualizations in a more accustomed way. They emphasized the original and easy way of exploring contents and the diversity of information possible to be navigated. Location features were highlighted.

3 – *Trajectory's Contents:* Participants expressed great surprise and satisfaction when presented with this original and unexpected view of a common trajectory. It seemed that they had never thought of exploring trajectories through movies.

4 – *Collections of trajectories – Details by date and duration:* It was very surprising that the visualization that caused more strangeness is among the preferred ones. In general, maps and locations held great attention from people. As referred, the final phase of the evaluation was the moment for the participants to have become used to the visualizations, and therefore, to be able to think of them in a more natural and also comparative way.

5 – *Collections of Movies in Space and Time* allowed for a surprising feedback since it was not considered as one of the main visualizations due to its similarity with *Movie Contents in Space and Time*. It alerts us though, to the fact that locations and time can, and should be combined for the exploration of geographical information, feature demonstrated to be of great interest to explore and compare movies by the participants.

Best Attributes to Characterize Movies

Participants were asked to rate by order of importance the attributes that best characterize movies when the goal is to choose one movie to watch.

In Table 6.38, the first column corresponds to the order of the rating, the second to the number of the participants that chose them, and the third, to the features.

Emotions consensually resulted in the most appreciated feature. We name the preferred attributes from participants by order of importance:

1 – *Emotions*: although some participants have referred the emotions retrieved by contents as more reliable due to the fact that they are not mood-dependent, it was complicated for most of them to understand the difference between these and the emotions biometrical measured in viewers. Considered as a general concept, it was rated by 13 participants as the most characterizing feature of movies;

Table 6.38. Characterizing attributes in movies
by order of importance and number of participants

1	9	*Emotions (contents)*
	4	*Emotions (viewer)*
	8	*Images*
	2	*Music mood*
	1	*Motion, Words, Audio events and Audio Amplitude*
2	4	*Images and Colors*
	3	*Shooting locations*
	2	*Emotions (contents and viewer), Words and Music mood*
	1	*Motion, Audio Events and Audio amplitude*
3	5	*Motion*
	4	*Music Mood*
	3	*Colors and Words*
	2	*Images, Audio amplitude and Shooting locations*
	1	*Audio events*

2 – *Images*: this feature was referred to throughout all the evaluation as being of main importance in order to have an idea of the movie, especially in casual uses. We believe its importance is larger than the results indicate, since most of the time participants considered them as a default and in fact, they are present in the three ratings of the table;

3 – *Motion*: considered as an "*organic*" way of analyzing the structure of the movie by a movie professional, *motion* was considered by 5 participants to be the third more important feature to have in mind when characterizing movies. It is referred in the three ratings of the table, which seem to reiterate its importance;

4 - *Music mood*: referred to by 2, 2 and 4 participants to be the first, second and third attribute respectively, to better characterize movies, it underlines the importance of music to express and induce emotions in movies;

5 - *Colors*: rated by 4 and 3 participants with the second and third attribute to be considered, respectively, demonstrated its relevance to have in mind;

Participants demonstrated some difficulty in the choosing of only three attributes to characterize movies. *Colors* and *Shooting locations* were not referred by any participant as a first choice, and *Emotions* was never rated in third, which indicates that participants value it very much or do not value it at all.

Visualizations' Characterization

From the 17 participants that performed this task, all of them considered visualizations *Controllable* (Table 6.39). 16 and 15 respectively, found them *Supportive* and *Comprehensible,* which reflects the consideration of the interactive visualizations in allowing a good usability and experience of use. Regarding the conceptual frame, all the participants referred *Original*, and 16 named the *Innovative and Interesting terms*.

Table 6.39. Quality terms:
All the interactive visualizations presented in the evaluation

Positive Terms			*Negative Terms*		
17	E	Controllable	3	E	*Complex*
17	H	Original	2	E	*Unpredictable*
16	E	Supportive	2	E	*Strange*
16	H	Interesting	1	E	*Obstructing*
16	H	Innovative			
16	A	Pleasant			
15	E	Comprehensible			
14	A	Aesthetic			
12	E	Familiar			
12	A	Good			
11	E	Clean			
11	H	Exciting			
10	E	Predictable			

H: Hedonic; E: Ergonomic; A: Appeal

As mentioned, many participants were not able to choose among opposite *Quality terms* due to the imprecision, or otherwise mixed meanings, e.g., when expressing their opinions out loud they would say *"It is not simple, but it is not complex, either"*, and the same for "*Clean*" *vs.* "*Confuse*", and "*Familiar*" *vs.* "*Strange*". Thus, some terms are difficult to interpret, and perhaps the most inaccurate of them is *Complex,* referred in this direction by four participants. When comfortable with new interfaces in daily-life, participants immediately referred visualizations as *Complex* while emphasizing its positive meaning of representing large quantities of information.

Table 6.40. USE (0: did not hit. 1-5: success level):
All the interactive visualizations presented in the evaluation

Visualizations	*Usefulness*		*Satisfaction*		*Ease of Use*	
All the interactive visualizations presented in the evaluation	M: 4.5	Std: 0.7	M: 4.2	Std: 0.8	M: 4.6	Std: 0.7

When asked the participants to rate visualizations in relation to their *Usefulness*, *Satisfaction*, and *Ease of Use*, the results were those in Table 6.40. The *Ease of Use* values are the most surprising ones since this was the issue that participants referred more times due to the impossibility to experiment the demo for themselves. In general, participants liked the design of the visualizations and would be glad to have them to use in the future.

Overviews and Details

Regarding the detailing and zoom in by navigation, many participants considered it as the main asset that complements and adds value to the work (M:4.7; Std:0.5). It was made aware by one participant belonging to the professional target of users that the path of the navigation must be done very accurately. This participant referred as a concern the accuracy of the structure of the navigation in order to prevent some of the visualizations from spoiling the flux of information. We regard this information for future refinements of our work, to be reflected upon, redefined and reshaped having in mind the present evaluation, toward refined, specific and relevant goals.

Contexts of Use

Both casual and professional uses were suggested by the participants as relevant to have in mind. Relating to casual, *"For fun!"* and *"It resembles The Total Work of Art from Wagner!"* were two expressions used by cinema viewers to characterize what they considered interesting ways to explore and access movies. As referred, emotions were highlighted in the choosing of a movie to watch according to the viewer's mood, and the possibility to explore and navigate locations to visit received large attention from these users.

Regarding the professional use of the visualizations, the considerations were also very positive, one participant saying, *"It would be great to have movies located geographically, I mean, to locate movies in space. This could help political decision-makers to decide about the utility of specific movies."* Set designers looking for, and comparing environments for movies to be shot, movie editors, and tourist agents promoting tours were also referred to be able to take advantage of the presented visualizations.

Throughout the evaluation, participants were gradually more comfortable and happy in performing the tasks, often asking if they could interact themselves in order to explore the visualizations. Most of them referred prior experience in order to raise the evaluation results.

It was interesting to note that older participants showed higher ability to interpret and assign meaning to the visualizations, to which we believe visual experience played a determinant role. On the other hand, younger ones were faster in performing tasks through interaction, more related with the use of applications such as YouTube, and games.

The presentation of the visualizations was always very challenging and rewarding given the joy almost all the participants showed when performing the tasks.

Lessons Learned

The results were very encouraging since almost all the visualizations were appreciated and most proposed tasks were readily accomplished. Regarding the 4 questions:

1. Regarding the intuitiveness and clearness of the representations alone, results were very positive. All the representations were understood, excluding Scene Length. Motion showed some unclearness due to the lack of motion variations in the presented movie. Its effectiveness in showing meaning was demonstrated in the following test in which participants were presented with one movie with visible variations of motion;

2. Visualization overviews have demonstrated the ability to show in a glance what they represent through colors and images that seem to have the power to reflect the movies they represent. Overviews also guide the user in the navigation to other levels of information, through the usual and simple ways used to interact with them;

3. The navigations that allow the user to explore different levels of detail were also positively rated, especially those that include locations and trajectories;

4. Both casual and professional targets remonstrated interest in the visualizations considering final user scenarios.

The potential of the work was assured, which allow us to consider the development of the most successful features in future projects.

7 Conclusions and Future Work

Movies, with their rich contents conveyed in images, text, music and narration, along time, tell us stories of different places and have great emotional impact on us. Moreover, the movie industry is very active and the advances in technology are enhancing the access to movies and videos over the Internet and interactive TV, making them accessible with associated metadata. However, the richness that makes these media so interesting and accessible, both inside each movie and where they relate to each other, and the fact that movies are not structured and change over time, make the data access a difficult task, with a challenging complexity, highlighting the need for new and powerful ways to access, browse, and view them, where interactive visualization can play an important role.

In spite of the several contributions to this field, most approaches and services for movies and video access do not fully support this richness, and the approaches to visualization in time and space do not usually address video and movies. This thesis presented interactive visualizations that aimed at both fostering the navigation and access to movies, and the information that is waived in their contents by new and richer ways of browsing, built upon coherent and relevant design fundamentals that we identified.

In order to design the spatiotemporal interactive visualizations that we present in Chapter 4, we focused on the way the user perceives and seeks information, and the specifics of the representation of time and space, word frequencies on speech and emotions. From here we could build a set of fundamentals to consider throughout the design process, including both concepts and principles. In Chapter 3, the related work allowed us to explore and reflect about both the existent representations of time and space, and the ways to navigate and access information about movies and videos. We reflect on the characterization of the presented visualizations in Chapter 5 by applying the design fundamentals identified earlier to the visualizations, and in Chapter 6, we evaluated them.

7.1 Contributions to the Field

We believe we have contributed with the following:

1) Framing and contextualization of the perceptual and cognitive concepts that should inform and shape the design of efficient interactive visualizations.

We present here clues about the way the human perception works in order to constrain the design of the visual graphics that constitute the interactive visualizations, and thus foster efficiency, by allowing the user to easily read their meaning and through it, interact with the visualization. We start with the capabilities of the brain addressing perception, and continue with the cognitive and emotional processes to the strategies the user takes when seeking for information.

2) The design fundamentals that shape spatiotemporal interactive visualizations.

We started by addressing function, usability and user experience, and continued with the visual elements that guide the user toward the navigation, the structure that organize them in the composition, and interaction, through which the user navigates to other levels of information.

We characterized time and space, going from their components (primitives and structure) to data (abstract, spatial) and to representation (2D, 3D). The *Tag Clouds'* matter allowed for an understanding of this technique as a way to represent frequencies, and emotions, as a complex matter, allowed to reflect on the way they should be represented in order to be easily perceived in their meaning.

3) Survey of the work that addresses the time and space dimensions.

We presented ways to visually aggregate information, to browse and access information about movies, and ways to show the entire contents of movies.

4) Design proposals of innovative spatiotemporal interactive visualizations.

The core of the thesis was presented as the interactive visualizations that allow for both accurate and ludic ways to navigate and search information about movies, from collections to individualized items, to contents. All the visualizations allow for various levels of information to be disclosed by the user, from a birds' eye view to zoom in and detailed information.

5) Characterization of the visualizations based on the principles identified in Chapter 2.

We characterized visualizations through the design concepts and principles presented in chapter 2, in order to show their relevance and application, emphasizing the ones that were more relevant in each case.

6) Evaluation that validated the presented visualizations while allowing to know their strengths and weaknesses.

The aim of the tests was to gain awareness about: i) the clearness of the representations' meaning as the elements that compose the visualizations, e.g., the user was able to identify the scenes of the movie contents when the audio is louder; ii) the power of visualizations in both reflecting meaning, e.g., the user is able to figure out the mood of the movie at first glance; and guiding the user toward interaction, e.g., the user is capable of clicking on the scene thumbnail in order to watch the respective scene playing, and understand the content in the different tracks of subtitles, audio, image, emotions, etc; iii) Navigations, to access information from different levels of detail, e.g., go from one scene to other movie that was shot in the same location.

7.2 Reflections on the Research Questions

We identified the most important design fundamentals that should shape interactive visualizations in order to achieve efficiency. Those principles guide i) the graphic elements that constitute the visualizations, ii) the structure through which they are organized in the screen and iii) the ways to enhance interaction. In addition, we addressed the specifics of time and space representation. We relied on this substantive support to the design of the presented interactive visualizations, while addressing the first Research Question (RQ 1): “How can design be fostered towards efficient interactive visualizations of movies that consider the time and space components?”

The second Research Question (RQ2): “How can the movie contents be explored, filtered and retrieved in order to be used either for professional and ludic purposes?” was addressed through creative exploration that made possible the finding of graphic solutions, that complemented with specifics of the interaction resulted in an efficient while fun exploration and filtering of the information contained in the movies. For a viewer that wants a movie to watch, the basic elements of its narrative are shown reflecting its mood and major characteristics, whereas the professional that wants to narrow the information of the movie, might go to other levels of information through interaction.

The evaluation was able to validate the interactive visualizations as clear, easy to learn and relevant to the user, both in casual and professional uses. The users were able to interpret, navigate and access information, related to the movie collections or movie contents.

7.3 Directions and Future Work

The presented design proposals can be considered for different interactive applications depending on their scopes and purposes. They aimed to provide awareness about the acceptance and relevance of different ways to browse information about and inside movies and videos, based on temporal and spatial dimensions. Moreover, we wanted to know which information to consider in the interactive visualizations, and by whom. Due to the rich information that is included in movie contents, it was our goal to represent as many properties as possible, aiming at presenting complexity in a simple and clear way.

Future developments include work in different directions, concerning the interactive access and visualization of movies and videos in time and space, in applications aimed at: casual users, movie goers and movie professionals; tourism industries; or users that generate, share and access videos capturing their experiences in different places and times.

Next steps related to movies and videos include the refining and extending of current visualizations based on the reflections prompted by the evaluation towards effective, rich, expressive and, in some contexts, artistic visualizations that can help to provide insights about movies and their impact on us. We intend to refine and adapt the movie content features presented, and get more movies processed in these perspectives. The representation of series is also possible to develop, in a way that captures their evolution. The system could also trace and present personal movies viewing histories, allowing users to reflect on the movies they tend to watch in different periods of their lives, and even compare the emotional impact the movies had on them, and relate that to their contents.

More related with trajectories, the sharing and access to georeferences recorded tours and experiences, in different contexts and paces, e.g. calm or fast, depending on the tourists' preferences, could be developed further, possibly linking to movies and documentaries shot in the same places, increasing awareness about tourism, culture and history around the world. The exploration of immersive videos through geo-referenced 360º panoramic videos could also be of interest to explore, providing increased sense of presence and realism. Moreover, the integration of these media with multimodal interfaces would provide more natural, flexible and effective interactive content access (e.g. based on shape, speed and time), following our previous work, e.g. (Serra et al,, 2014 & 2015; Ramalho & Chambel, 2013).

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Appendix A User Evaluation: First Phase

Part 1. Interview Script

1.1 Demographic Information

a. Participant's profile

Name:	Age:
Occupation:	

b. Your interest about movies, is:

(1 none, 5 huge)	1	2	3	4	5
Observations:					

Considering the movies, you like to know:

c. Title

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5
Observations:					

d. Genre

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5
Observations:					

e. Rating

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5
Observations:					

f. Duration

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5
Observations:					

g. Summary

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5
Observations:					

h. Information about the contents of the movie

(e.g., many shots, slang language, a theme of interest, emotions).

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5
Observations:					

Part 2. Colors

2.1 Genre-color matching (Figure 4.1)

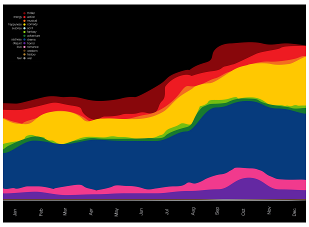
a. Match genres with colors

War	Romantic
Musical	Brown
Historic	Bright red
Comedy	Violet
Terror	Gray
Western	Bright green
Adventure	Dark green
Thriller	Purple
Action	Orange
Drama	Yellow
Romantic	Dark blue

Part 3. Visualizations

Movie Collections in Time

3.1 Linear representation by Regions of Colors (Figure 4.2)



a. Identify the movies released in May

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Which genre was more released throughout the year?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

c. Which genre was less released throughout the year?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

d. Comparing Action and Horror in May, which genre was more released?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

e. Quality terms (Hedonic, Ergonomic, Appeal).

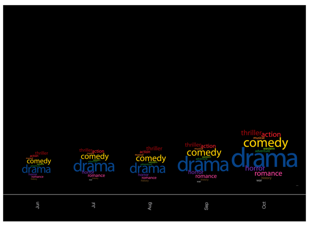
	Positive (+)	Negative (-)
	Hedonic	
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
	Ergonomic	
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
	Appeal	
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

f. USE (1low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

3.2 Linear representation through Tag Clouds (Figure 4.2)



a. Identify the movies released in May

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Which genre was more released throughout the year?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

c. Which genre was less released throughout the year?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

d. Comparing Action and Horror in May, which genre was more released?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

e. Quality terms (Hedonic, Ergonomic, Appeal).

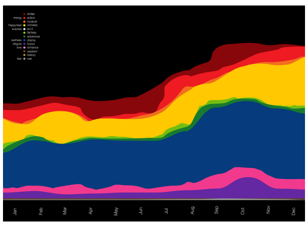
	Positive (+)	Negative (-)
Hedonic		
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
Ergonomic		
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
Appeal		
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

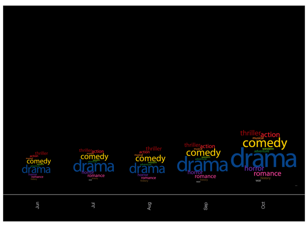
H-Hedonic, E-Ergonomic, A-Appeal

f. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

3.3 Comparing Regions of Colors with Tag Clouds (Figure 4.2 / Figure 4.3)

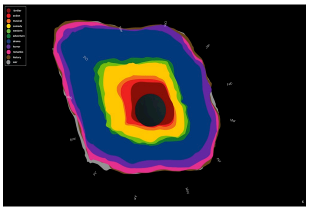




g. Which app do you prefer to have? Why?

Participant's reply: Left I Right	Observations:

3.4 Circular representation by Regions of Colors (Figure 4.4)



a. Identify the movies released in May.

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Which genre was more released throughout the year?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

c. Which genre was less released throughout the year?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

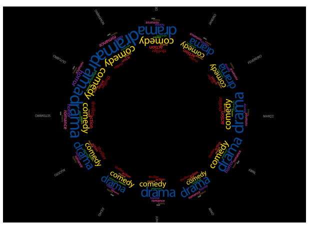
d. Comparing Action and Horror in May, which genre was more released?

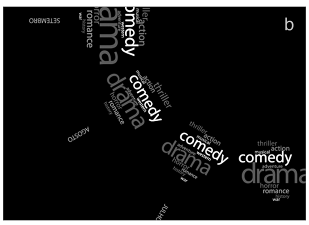
(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

e. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

3.5 Details by genre through Tag Clouds – colors vs. monochrome (Figure 4.5 / 4.8b)

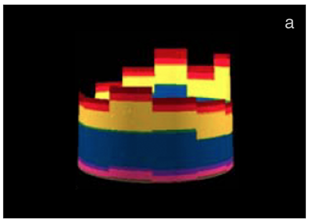




a. Which app do you prefer to have? Why?

Participant's reply: Left I Right	Observations:

3.6 3D Circular representation by Regions of Colors (Figure 4.7)



a. From this point of view, which movies were more released?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Quality terms (Hedonic, Ergonomic, Appeal).

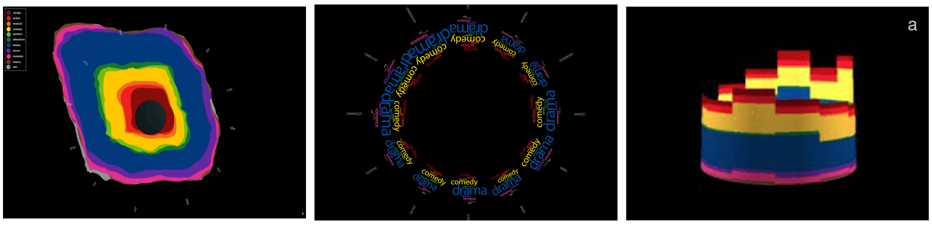
	Positive (+)	Negative (-)
	Hedonic	
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
	Ergonomic	
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
	Appeal	
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

c. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

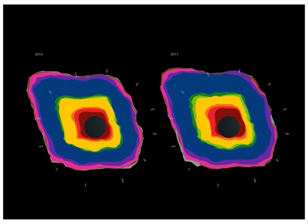
3.7 Comparing circular Regions of Colors and Tag Clouds (Figure 4.2 / 4.5 / 4.7)



e. Which app do you prefer to have? Why?

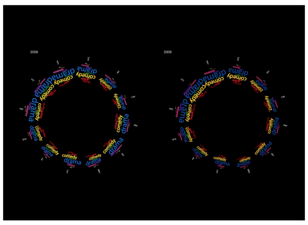
Participant's reply: Left I Middle I Right	Observations:

3.8 Comparing and relating two year information in circular representations (Figure 4.2)



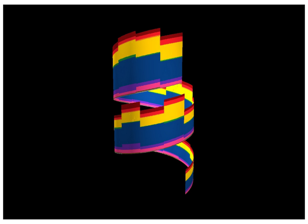
a. Which relations/patterns do you find between the two years of information presented in these visualizations?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						



b. Which relations/patterns do you find between the two years of information presented in these visualizations?

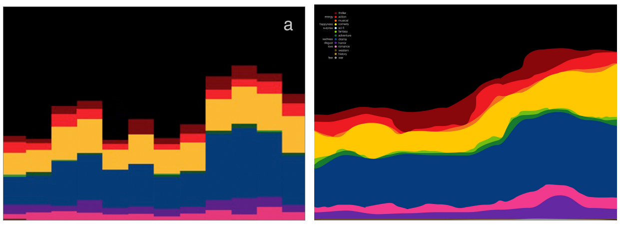
(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						



c. Which relations/patterns do you find between the two years of information presented in these visualizations?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

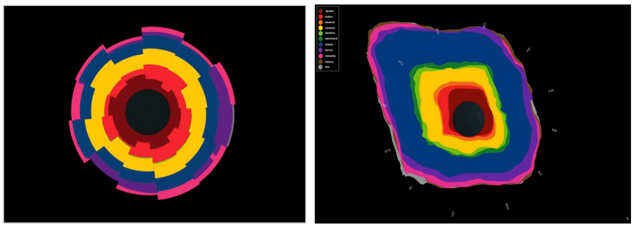
3.9 Regions of Colors overviews - hard vs. smooth transitions (Figure 4.11a / 4.2)



a. Which visualization would you prefer to have? Why?

Participant's reply: Left I Right	Observations:

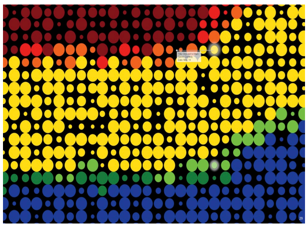
3.9 Regions of Colors overviews - hard vs. smooth transitions (Figure 4.11b / 4.4)



b. Which visualization would you prefer to have? Why?

Participant's reply: Left I Right	Observations:

3.10 Zoom in and details through Spots (Figure 4.12)



a. Quality terms (Hedonic, Ergonomic, Appeal).

	Positive (+)	Negative (-)
Hedonic		
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
Ergonomic		
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
Appeal		
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

3.10 Zoom in and details through List (Figure 4.13)

a. Quality terms (Hedonic, Ergonomic, Appeal).

	Positive (+)	Negative (-)
Hedonic		
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
Ergonomic		
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
Appeal		
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

b. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

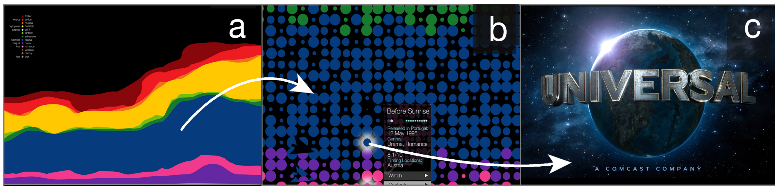
3.11 Comparing rating and alphabetic order (Figure 4.13 / -)

a. Do you prefer the rating, or the alphabet order?

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5
Observations:					

Part 4. Browsing Visualizations

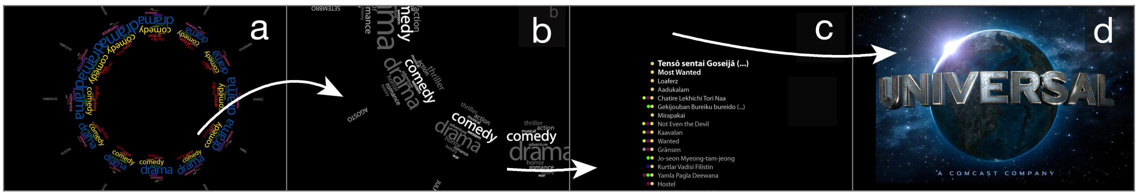
4.1 Choosing a movie by genre by Regions of Colors



a. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

4.2 Choosing a movie by genre through Tag Clouds and List



a. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

Appendix B User Evaluation: Second Phase

Part 1. Interview Script

1.1. Demographic Information

Participant's profile

Name:		Age:			
Occupation:	Professional user			Casual user	

a. How often do you use the computer?

monthly	weekly	daily	twice a day	more often
1	2	3	4	5

b. How often do you access websites or apps about movies?

never	weekly	daily	twice a day	more often
1	2	3	4	5

c. Which ones?

Imdb	YouTube	Netflix

Other:
Purpose:

d. How often do you access websites or map based applications?

never	weekly	daily	twice a day	more often
1	2	3	4	5

e. Which ones?

GoogleMaps	GPS	Mic

Other:
Purpose:

f. With which frequency do you watch movies?

monthly	weekly	2 per week	3 per week	more often
1	2	3	4	5

g. In which device do you watch movies?

Cinema	TV	Computer	Tablet	Phone

Part 2. Colors

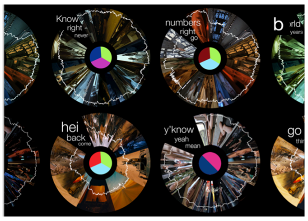
2.1 Emotion-color-genre match representation

a. Rate the matching among emotions, colors and genres

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5
Observations:					

Part 3. Visualizations

3.1 Movie Contents by Image, Audio, Speech and Genre



3.1.1 Without being aware of the representation's meaning:

a. Identify audio amplitude

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Identify the most spoken words

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

c. In order to watch a scene of the movie, how do you proceed?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

d. In order to identify the represented genres, how do you proceed?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

3.1.2 After being aware of the representation's meaning and functionality:

a. Which one of these movies would you rather watch? Why?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Would you like to have this visualization? Why?

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5

Participant's reply:	Observations:

c. Quality terms (Hedonic, Ergonomic, Appeal).

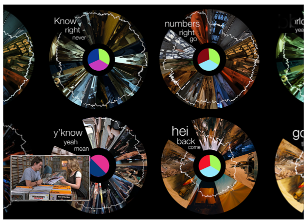
	Positive (+)	Negative (-)
Hedonic		
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
Ergonomic		
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
Appeal		
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

d. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

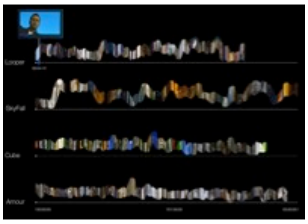
3.2 Comparing Movie Content by Image, Audio, Speech and Genre, with Netflix



a. Which app would you prefer to have? Why?

Participant's reply: Left I Right	Observations:

3.3 Movie Content by Image, Audio and Title



3.3.1 Without being aware of the representation's meaning:

a. Which movie is the most dynamic?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. In order to see one image of the movie, how do you proceed?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

3.3.2 After being aware of the representation's meaning and functionality:

a. Which movie is the most dynamic?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Which movie is the shorter in duration?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

c. Which movie would you rather watch? Why?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

d. Quality terms (Hedonic, Ergonomic, Appeal).

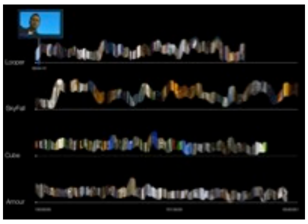
	Positive (+)	Negative (-)
Hedonic		
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
Ergonomic		
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
Appeal		
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

e. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

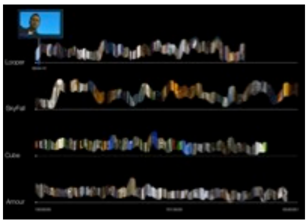
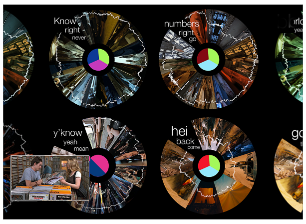
3.4 Comparing Movie Content by Image, Audio and Title, with *Netflix*



a. Which app would you prefer to have? Why?

Participant's reply: Left I Right	Observations:

3.5 Comparing Movie Content by Image, Audio and Title, with Movie Contents by Image, Audio, Speech and Genre

a. Which app do you prefer to have? Why?

Participant's reply: Left I Right	Observations:

3.6 Quantities of trajectories - Zoom in on closer area (Figure 4.36)

a. Locate the most shot streets.

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

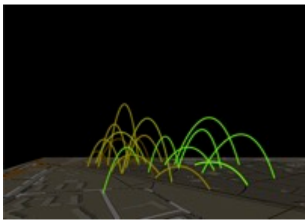
b. Would you like to have this visualization? Why?

Participant's reply: Yes I No	Observations:

c. USE (1low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

3.7 Details on Trajectories by Speed and Date of the Shooting



a. Which trajectory is the most dated and fastest?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Which trajectory would you choose to visit? Why?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

c. Quality terms (Hedonic, Ergonomic, Appeal).

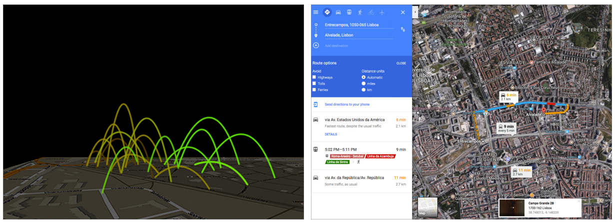
	Positive (+)	Negative (-)
	Hedonic	
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
	Ergonomic	
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
	Appeal	
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

d. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

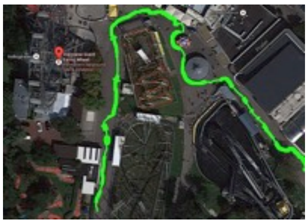
3.8 Comparing Trajectories by Speed and Date of the Shooting, with *GoogleMaps*



e. Which app do you prefer to have? Why?

Participant's reply: Left I Right	Observations:

3.9 Details of One Trajectory by Speed



a. Identify the slower parts of the trajectory.

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Would you like to have this visualization? Why?

Participant's reply: Yes I No	Observations:

c. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

3.10 Movie Content in Space and Time: based on trajectory

a. Was this trajectory shot by day or by night?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Which part of the trajectory would you consider having louder audio?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

c. In order to watch an image of the shooting, how do you proceed?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

d. Quality terms (Hedonic, Ergonomic, Appeal).

	Positive (+)	Negative (-)
	Hedonic	
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
	Ergonomic	
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
	Appeal	
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

e. USE (1 low, 5 high)

Usefulness	**1**	**2**	**3**	**4**	**5**
Satisfaction	**1**	**2**	**3**	**4**	**5**
Ease of Use	**1**	**2**	**3**	**4**	**5**

3.11 Movie Content in Space and Time: based on timeline

3.11.1 Without being aware of the representation's meaning:

a. Would you say it is a sad movie?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Where does it happen?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

Circular tracks represent properties of the movie's content.
Which ones do you identify? (0: did not hit. 1 – 5: success level)

c. Images of the movie	0	1	2	3	4	5
d. Quantity of movement	0	1	2	3	4	5
e. Colors	0	1	2	3	4	5
f. Length of the scenes	0	1	2	3	4	5
g. Audio amplitude	0	1	2	3	4	5
h. Emotions	0	1	2	3	4	5
i. Most spoken words	0	1	2	3	4	5
j. Trajectories	0	1	2	3	4	5

3.11.2 After being aware of the representation's meaning and functionality,

a. In order to choose a scene of interest, how do you proceed?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

b. Locate the daylight part of the movie.

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

c. Identify one of the sorter scenes of the movie.

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

d. Which is the genre of the movie?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

e. Where was the movie shot?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

f. Identify one of the most dynamic scenes of the movie.

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

g. In order to explore the location of the selected scene, how do you proceed?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

h. Identify a scene where someone laughs.

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

i. Identify a romantic scene.

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

j. Which tracks would you choose to be visible?

Participant's reply:	Observations:

l. Which tracks would you erase?

Participant's reply:	Observations:

m. Quality terms (Hedonic, Ergonomic, Appeal).

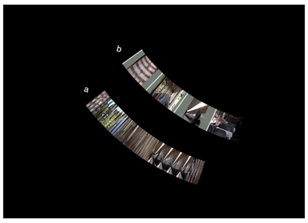
	Positive (+)	Negative (-)
	Hedonic	
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
	Ergonomic	
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
	Appeal	
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

n. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

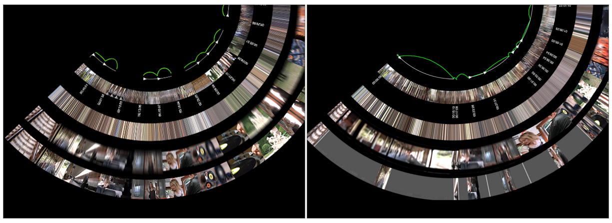
3.11.3 Comparing two alternatives of the Scene Length representation



a. In order to know which scene is longer in length, which visualization do you prefer?

Participant's reply: Left I Right	Observations:

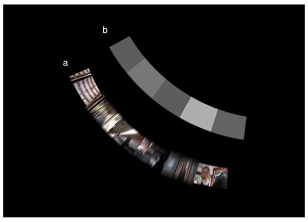
3.11.4 Comparing two alternative visualizations of the Scene Length representation



a. Which visualization do you prefer, regarding scene length representation? Why?

Participant's reply: Left I Right	Observations:

3.11.5 Comparing two alternatives of the Motion representation



a. In order to know which scene is more dynamic, which visualization would you choose?

Participant's reply: Left I Right	Observations:

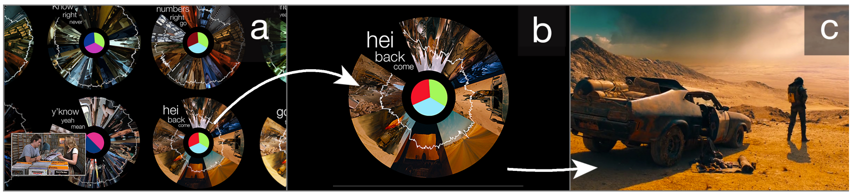
3.11.6. Comparing two movies through Motion representation

a. Which movie is the most dynamic?

(0: did not hit. 1 – 5: success level)	0	1	2	3	4	5
Observations:						

Part 4. Browsing

4.1 Choosing a movie by contents



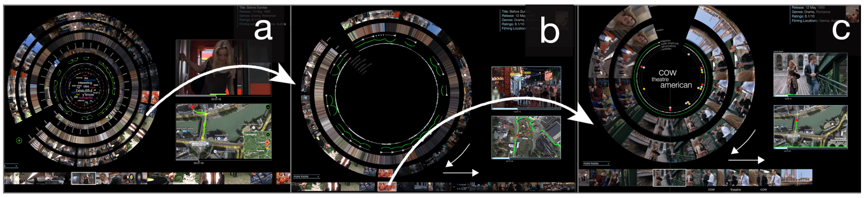
a. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

b. Suggested user scenarios from the participants

Participant's reply:	Observations:

4.2 Exploring and detailing movie contents



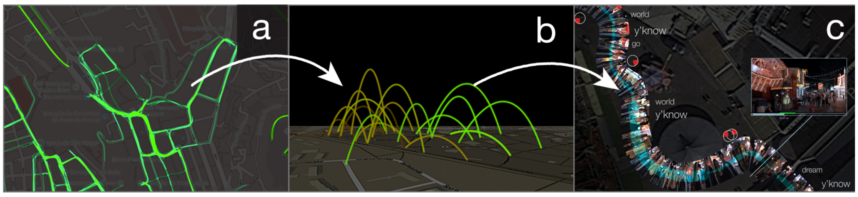
a. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

b. Suggested user scenarios from the participants

Participant's reply:	Observations:

4.3 Selecting one trajectory to explore



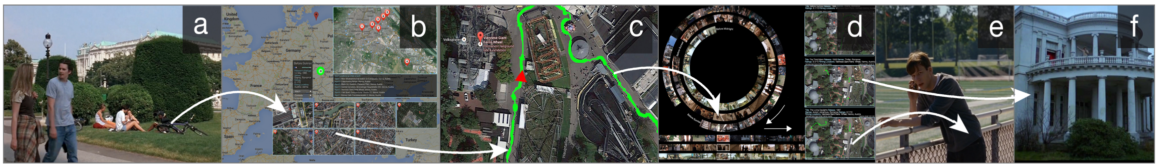
a. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

b. Suggested user scenarios from the participants

Participant's reply:	Observations:

4.4 Exploring trajectories from the same location



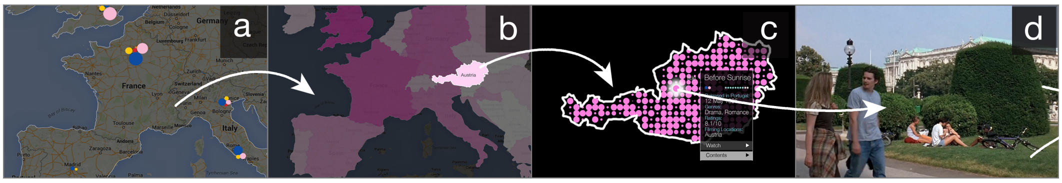
a. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

b. Suggested user scenarios from the participants

Participant's reply:	Observations:

4.5 Choosing movies by genre and location



a. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

b. Suggested user scenarios from the participants

Participant's reply:	Observations:

Part 5. Final Remarks

a. Of all the visualizations, which ones would you like to have? Why?

Participant's reply:	Observations:

b. Rate by order of importance, the 3 properties you consider that best characterize a movie.

Images of the movie	Amount of movement	Colors of the movie	Emotions (contents)	Emotions (viewer)
Spoken words	Audio events	Audio Amplitude	Music mood	Shooting locations

c. Quality terms (Hedonic, Ergonomic, Appeal).

	Positive (+)	Negative (-)
Hedonic		
E1	Comprehensible	Incomprehensible
E2	Supportive	Obstructing
E3	Simple	Complex
E4	Predictable	Unpredictable
E5	Clean	Confuse
E6	Controllable	Uncontrollable
E7	Familiar	Strange
Ergonomic		
H1	Interesting	Disinteresting
H2	Exciting	Boring
H3	Original	Banal
H4	Innovative	Conservative
Appeal		
A1	Pleasant	Unpleasant
A2	Good	Bad
A3	Aesthetic	Not Aesthetic

H-Hedonic, E-Ergonomic, A-Appeal

d. USE (1 low, 5 high)

Usefulness	1	2	3	4	5
Satisfaction	1	2	3	4	5
Ease of Use	1	2	3	4	5

e. Other: ____

f. Rate the importance of the overviews and details throughout navigations.

(1 strongly disagree, 5 strongly agree)	1	2	3	4	5
Observations:					

g. In which contexts would you consider to use these functionalities?

Participant's reply:	Observations: