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Subjective Information Visualizations

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Information Visualizations (InfoViz) are systems that require high levels of cognitive processing. They revolve around the notion of decoding and interpreting visual patterns in order to achieve certain goals. We argue that purely designing for the visual will not allow for optimum experiences since there is more to InfoViz than just the visual. Interaction is a key to achieving higher levels of knowledge. In this position paper we present a different perspective on the underlying meaning of interaction, where we describe it as incorporating both the visual and the physical activities. By physical activities we mean the physical actions upon the physical input device/s. We argue that interaction is the key element for supporting users' subjective experiences hence these experiences should first be understood. All the discussions in this paper are based upon on going work in the field of visualizing the literature knowledge domain (LKDViz).

Subjective Experience, Action, Interaction, Information Visualization, Design, Literature Knowledge Domain.

1. INTRODUCTION

Information Visualization (InfoViz) relies immensely on users' cognitive processing. It is defined as the process of creating mental models of visually represented data [20]. Users interpret the visual data patterns into meaningful information which in turn satisfies some initial goal, making the visual aspects of great importance when it comes to InfoViz. Lots of research has been conducted in the field which concentrates on coming up with various visualizations some of which are metaphorically based, where creative artistic visual representations inspired from different metaphors are used to visually represent the data. Some examples within the LKDViz are: Butterfly by Mackinlay et al [15] where articles are represented as butterflies, and each butterfly wing represents citation links between documents, and SPIRE by Wise et al [23] which reveals communalities and relationships between documents through a Galaxy metaphor and a landscape metaphor the latter is called ThemeScape.

Interaction, on the other hand, has not been as explicitly studied. It has suffered compared to the visual aspects even though it plays a major role in the success of the experience [9]. We see interaction as the umbrella under which a fulfilling user experience is created. Interaction in the field of InfoViz represents the complete set of activities with which users engage when interacting with the visual representation, making the visual and the interactive tasks complements of one another. We describe this interaction with a set of activities, the mental and the physical. The mental represents the activities that reflect users' mental engagement with the visual representation, whereas the physical reflects the users' physical interaction with the actual input devices. Most of the literature in InfoViz covers the visual representations and its corresponding mental activities, whereas the physical activities are not very well understood.

From our experience in designing and developing LKDViz uncertainties arose with regards to the understanding and design of interactive InfoViz which we solved by understanding the users' subjective experiences. We introduce a different perspective of understanding interaction. We argue that subjectivity of the experience cannot be achieved without interaction, and interaction cannot be designed without understanding users' subjective experiences within the context of the domain.

In this paper we present an abstract of the methodical approach taken in the design of our LKDViz starting from understanding user experiences within the domain context, to deriving an interactive visualization design. In this paper we will be concentrating on designing the physical interactions rather than the visual since it forms our primary challenge. Since our goal is to explore how interaction affects the visualization experience we will be testing our system using an interaction scheme we call *mediated interaction*, where multiple input devices will be used to interact with the system each matching a different interactive task.

2. THE LITERATURE DOMAIN

Prior to starting our discussion on interaction in InfoViz, it is important to give a brief description of what we mean by the literature domain, since it is the scientific field on which we base all of our examples.

The literature domain represents the literature data within an academic context. It includes information such as: authors, papers, citations, journals, etc. Users of such domains are mostly researchers in an academic field, since it is important for them to keep track of the literature being published. In addition, they need to have a complete and global understanding of the community, how it evolves, and how it relates to other research communities.

Visualizations of such a domain tend to reflect information such as: the research community and how it evolved, its latest trends, dominance and influence all within an academic field. In other words, these visualizations tend to give a global view of an academic field. A lot of research has been conducted in developing visualizations that would better represent such information and its interconnected dependencies for example, Envision [18] ,CitWiz [7], CiteSpace [6].

3. INFOVIZ IS A SUBJECTIVE EXPERIENCE

Given the same data users vary in the information they perceive. For example, when interacting with literature data the number of citations a paper gets can be perceived as a factor of dominance by one person, whereas by the other the source of the paper is the dominant factor.

InfoViz excels in its ability to represent huge amount of information, giving it its importance. Due to the large amount of data, in our case in relation to knowledge domains, and due to screen real-estate one would think that interaction must play a major role in the design of InfoViz [8]. However, more recent systems do not seem to reflect these concerns. Nowadays, most LKDViz visualizations are static.

Static visualizations represent information predetermined by the developer, hence limiting the represented data. This limits the gained knowledge, in other words, does not allow for the user to reach or accomplish other goals. For example Chen's CiteSpace [6] in which literature knowledge, and more specifically co-citation data, is represented. The goal of this visualization is to visually determine major turning points in the domain. However, from our experiences studying such a domain [10] literature users, especially researchers, have varying goals, some of which are determined prior to interacting with the visualization and other are developed whilst the interaction process is taking place. Hence, static visualizations limit the experience to the developer's specific goals. From our experience in the LKDViz, we determined that it is important to present to the user the domain data and allow the user the freedom to explore and analyze the data.

Goals are particular and differ from person to the other, as well as differ for an individual at various points in time. It is this variance that causes for the subjectivity of the experience. In order for visualizations to be able to cater for such variance, interaction must be supported and incorporated into the design of the system. Since subjectivity is all about the person, we therefore claim that interaction is the doorway to individualizing users' experiences.

4. INTERACTION AS A SET OF ACTIVITIES

Interaction is the means with which users communicate their needs to the system and hence execute their goals. It is based around a set of activities with which users are engaged. A detailed break down of the underlying meaning and hierarchy of an activity reveals a philosophical description to the relationship between interaction and activity. Such an explanation is the starting point for revealing our notion of interaction as set of mental and physical activities.

An activity, as defined by activity theory, is a group of *actions* directed towards achieving a set of *goals* [16]. Any initiated activity is intended to achieve a higher purpose, in other words, a *motive* which gives meaning to the underlying actions. Each action is executed through a set of *operations*. In comparison, when it comes to the human-computer interaction process, interaction is also seen as the execution of a set of actions to achieving certain goals. After forming the goal, as Norman [17] indicates, users normally pass through a set of three stages which are directed towards executing their goals: forming an intention, specifying an action and then executing the action. By comparing this to the activity's hierarchical structure [13] going from higher to lower: the activity level, the action level and the operation level, the correspondence can be seen (figure 1).

From here, we can see that actions are the core components that allow for goals to be accomplished. By varying the actions, different goals can be achieved and vice versa.

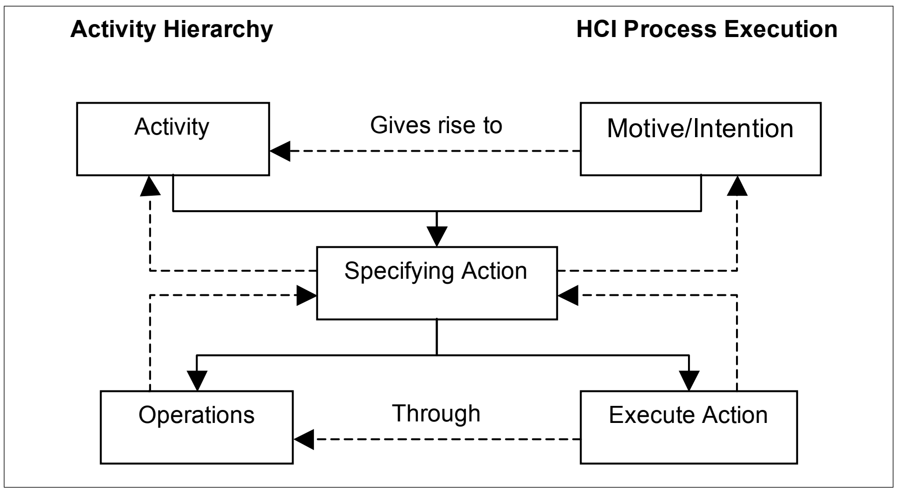

FIGURE 1: Activity Hierarchy and HCI Execution Process

When it comes to InfoViz interaction, we believe that the users engage in two main activates in order to achieve their varying goals: the mental activities and the physical activities. The mental activities, as indicated, are the cognitive processing actions where users decode and interpret the represented visual entities which in turn act as the mediators. The physical activities, on the other hand, represent the physical actions users engage with whilst interacting with the physical input devices in order to manipulate the visualization at hand. The input devices in this case act as the mediators of such actions. Finding a harmonious flow between these two sets of activities, we believe, will allow for a better user experience.

5. INTERACTION IN INFOVIZ

InfoViz mental activities are of utmost importance, since InfoViz relies heavily on mental cognitive processing [20]. They are executed through a set of mental actions such as the perception and interpretations of visual patterns [4]. They represent the main source of the InfoViz knowledge gain process. In order for higher levels of cognition to be achieved this process, we argue, must not be interrupted. We claim physical activities, if not well designed, can lead to such an interruption.

Ideally, each of these physical actions acts as complement to the mental activities. The visual representations respond to the physical commands given by the users, and depending on users' interpretation of such responses the user may decide to issue another command, and so on [17] until the final goal is achieved, hence reaching higher levels of knowledge. Hence, both the mental and physical activities are crucial to the visualization experience as a whole. The challenge lies in understanding the physical actives and how they affect the InfoViz experience in general. Literature has shown that currently when these activities have been added into InfoViz systems little rationale was provided to support the decision. For example: visualizing a knowledge domain in a VR environment [3]. In a work such as this, the interaction style was chosen without any rational behind this decision. It was not clear how this interaction scheme affected the user experience, and whether or not it amplified user cognition. Hence, the benefits of this are not clarified.

We claim that, physical activities as well as mental activities participate in success or failure of this experience. However, how physical activities are to be designed and incorporated into the design of InfoViz is not clear. This represents the main challenge and interest of our work.

6. INVISIBLE INERACTION

We have emphasised that interaction should be incorporated into the design of InfoViz systems in order to allow a subjective user experience. However, the entire interactive process, and more precisely the physical activities, should be incorporated in a manner that would not hinder the experience. In other words, distract the users from satisfying their intended goals which are achieved through mental engagement with the visual actions themselves. Designers of InfoViz systems should strive for *seamless* physical interaction. The goal is to make the entire interactive process invisible to the user in order to amplify cognition by not interfering with the mental activities.

In [9] we argued that mediated interaction would be a means to achieving such seamlessness. We proposed the use of multiple specialised input devices each one specialised for a set of physical activities. Due to the specialization of the input devices, on screen widgets are eliminated. This interaction scheme, we claim, would allow for direct manipulation of the object of interest without the interference of on screen widgets. This scheme is thought to be able to amplify users LKDViz cognition since the flow between the visual and the physical is not broken. Once *seamlessness* is achieved users are to be allowed to concentrate on the visualization's mental activities.

Interaction as presented in this discussion should be incorporated into the design of the InfoViz from the first steps. Some effort has been done in the field of InfoViz which preaches the incorporation of interaction such as Shneiderman's mantra (overview first, zoom and filter, and details on demand) [19] which has been adopted by many sometimes baselessly [5]. We argue that such incorporation should not be done simply for the bare reason of adding interaction to the tool. Incorporating interaction into the design of an InfoViz system must be a well analysed part of the design process. This is missed by many InfoViz developmental models for example, Card et al [4]. We argue that understanding the user experience within context of the domain should be the first step in designing for interaction in other words subjectivity.

7. DESIGNING THE EXPERIENCE

How do we design for a subjective visualization experience?

To answer such a question we propose starting with the source of such subjectivity, the users. Users' experiences within the targeted domain, in our case the literature domain, should be the first step. From there a global understanding is gained. This understanding is then used as the backbone of the visualization design rational. The users' subjective experience is reflected via the interactive physical actions allowed by the system. The decision as to which activities to provide depends immensely on the understanding of the user experiences within the context of the domain. However, the best way to integrate these activities into the system seamlessly is still open to debate with no clear answer.

7.1. Capturing the Experience

As indicated, the goal of interacting with the literature domain is to makes-sense of the domain. However, it is not clear this how this is conducted or what information is needed.

In order to address these concerns we captured users' experiences by conducting a qualitative study with members of the research community. Semi-structured interviewing was used as the data gathering framework due to its flexibility, hence revealing information that was not previously known. Interviews were conducted with researchers of varying experiences in the fields of HCI and Psychology. The interviews were transcribed and analysed using the Grounded Theory methodology [21]. Categories and concepts were revealed which in turn guided the decisions made regarding the next set of interviews with regard to the experience of the interviewee and the questions asked during the interview. After a total of eight interviews a saturation point was reached, which is quite unusual. We think this might be related to the concreteness of the literature domain, or at least the concreteness of the literature domain within these two fields.

The analysis resulted in a descriptive theory [10] which is summarized briefly here:

The literature domain is a very subjective domain. Information that is gained depends immensely on the person's background, knowledge and goals at the time of the interaction. The sense making of such a domain starts with getting to know who the members of the community are since they are the creators of the knowledge. This knowledge is portrayed in the form of literature which is produced by the members. It is through the interaction with such literatures that ideas are generated and personal knowledge is gained. The sense-making process of ones' literature domain is based around users' engagement with a set of activities such as: searching for specific authors, ideas or papers, answering specific questions, and following citation trails. In most cases the gained knowledge is not intentional. For example: during one of the interviews when asked about how the user determined who the influential author in the field was the subject said:

"*… those people that are really important you* ***can't miss the name*** *because they are* ***always cited*** *and they always come up*".

We used this descriptive theory as the backbone for our design rational.

7.2. Portraying the Experience

Since this experience is highly subjective, static visualization is certainly not the answer. The visualization ought to be highly interactive. This result contradicts a majority of LKDViz where entire domains are represented statically for example [6]. Several design decisions were based upon the qualitative data analysis such as:

- It was not necessary for the entire literature domain to be displayed at once on the screen. The users decide upon which areas of the visualized literature is of interest and accordingly interact with the visualization.
- Three main views are used by the system. The main view reveals the authors, and the details view reveals the papers (figure 2). The third view gives an overview of the entire literature domain.
- Citation information is to be presented not just between authors, and between papers but also papers and authors, for example: all the authors that cited a specific paper.

From this information a primary prototype was created (figure 2) which used InfoVis 2004 contest dataset. [11]. It contains the complete metadata of InfoVis conference papers and references from 1995 to 2002.

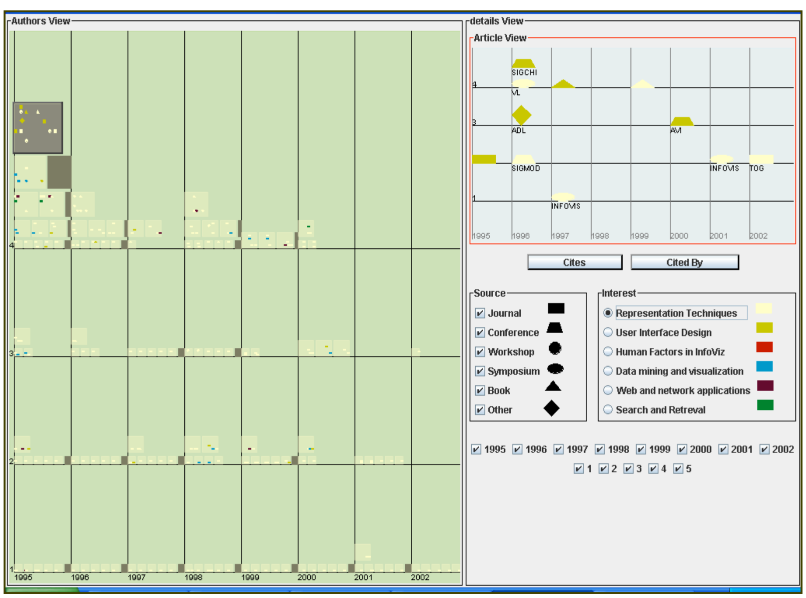

FIGURE 2: Prototype 1 of LKDViz Visualization Tool

In the above figure we can see the two views which are the main view which is the author view and a detailed view which is the paper view. The author view reflects the main views around which most interaction is based. In the above figure we can see that an author is selected and consequently all the author's papers are displayed on the paper view. The shape of the papers reveals the source such as: journal, book, conference etc. and the color reveals the general interest of the paper, for example: representation techniques, user interface design etc.

The philosophy of this design is to allow the user to gain a subjective experience. Hence it is the user that will play a major role in analysing the data and not the system. Consequently, interaction, in other words the physical activities will play a central role in the design of our visualization tool.

7.3. Interaction Design

Designing the visual has already been established by Bertin's ground-breaking research [2] where various graphical encoding mechanisms exist which take into account human's visual perceptions for example, [14]. These works present multiple solutions to the problem of the visual representation of high dimensional data [22]. On the other hand, designing the physical activities has not been addressed as much. Designing the physical activities of the visualization is where the challenge really lies since it is through these activities that the subjectivity of the experience is accomplished. Up to this point we do not understand how interaction design decisions affect the visualization experience as a whole.

To start and understand this we incorporated activities in our prototype that are based entirely upon users' literature domain subjective experiences. Our design rationale is based on the fact that we have to give the user space and freedom to manipulate the visualization in order for higher level of subjectivity to be achieved.

From our descriptive theory we determined that the user must be given the freedom to manipulate the data, examples of such activities are:

- Select and mark authors and papers of interest.
- Browse through the domain data by selecting parameters as: the year of interest, the source of interest, for example: journal, book, conference, etc.
- Reveal and manipulate citation information.
- Compare data different research interests within the domain.

Lots of caution must be carried out when deciding on the best way to implement such activities since, as indicated, it a complementary part to the visual aspects of the InfoVis experience. In our research project we hypothesis that mediated interaction will benefit the InfoViz user experience. We will be paying close attention to the physical properties of the input devices used as a means to achieve invisible interaction.

8. MEDIATED INTERACTION SCHEME

In most InfoVis systems on-screen widgets are used to interact with the visualization tool such as sliders, buttons, etc. The use of such widgets challenges the meaning of direct manipulation (Beaudouin-Lafon, 2000) and hence invisible interaction by forcing the user to drift their attention away from interacting with the data in order to interact with the onscreen widgets (Faisal et al, 2005). We hypothesis that *mediated interaction* might be a way to achieve directness of the interaction, where multiple task specific input devices are to be used. The term mediated was chosen because it is these devices that are the mediators between the user and the object of interest. Hence we feel that choosing the right input device will have a major influence on the InfoVis experience as a whole.

Designing for the physical is not just the simple process of adding an input device to the tool. Each input device has some strengths and weaknesses making it suitable for certain actions and not others. The choice of the input device is affected by the data properties such as, dimensionality and the desired system feedback all of which is governed by the physical limitation of the device itself. In order to design the physical interaction two components were taken into consideration: physical properties of the input device/s, and the visual feedback, since feedback significantly corresponds to the action taken by the input device. Each individual action allowed by a device causes a reaction to occur on the screen in the form of visual feedback.

The individual physical actions that users perform on input devices are called primitive actions. In certain cases the same input device may be adapted to suit several primitive actions, such as the mouse. The mouse supports both the actions of locating objects on a 2D plane performed through the physical action of moving the mouse on a 2D physical plane such as the desk, and the action of selecting an object performed through the physical action of clicking the physical button located on the top of the mouse. The input device best suits the communication task when the physical action allowed by the device corresponds to the desired feedback needed by the system, for example: due to the physical characteristics of the mouse it is suitable for selecting objects in a 2D plane and not for rotating them. Hence, when determining devices that best suit a certain activity, the primitive actions that the device supports are of utmost importance.

Since our intention is to support a mediated interaction scheme, each input device will be seen as being coupled with a specific function. The coupling is done between the device and the primitive input action and not the object, unlike tangible interfaces [12] where the coupling is done between the objects and the input devices. We will substitute the on-screen widgets of our first prototype (figure 2) with mediated devices. In order to determine the most appropriate input device to use, we started by specifying the required input tasks, followed by the desired system feedback and accordingly determine the primitive actions from which the device will be determined. This schema is used in the case of mediated interaction since on screen widgets are omitted from the visualization.

The testing of our hypothesis would shed light on the importance of physical interaction and its effect on InfoViz experience as a whole, which we hope will setoff the understanding of interaction on InfoViz user experience.

9. CONCLUSION

We believe that interaction is crucial to the success or failure of the InfoViz experience. It supports users' subjective experiences, which, as emphasized, is central to the accomplishment of the user's goal and hence the knowledge gain. Interaction, as we see it, incorporates both the mental and physical activities. The mental activities include users' engagement with the tool in order to reveal and understand patterns from which knowledge is gained. On the other hand, the physical activities include all actions that take place between the user and the input device. As indicated, these activities have not been given enough attention when designing visualizations in general. Finding a meaningful and smooth design harmony between these two views is not evident, hence the difficulty of designing interactive InfoViz.

We also presented a brief discussion of a methodical design approach we used for designing our LKDViz system. We clearly stated that in order to succeed in designing for subjectivity first and foremost, this subjectivity must be captured from the users themselves. A qualitative study was conducted from which a literature domain visualization system was created. The system will be tested with users to validate its usability and subjectivity portrayal.

A mediated interaction scheme will overlay this LKDViz tool and our hypothesis will be tested. The results of such studies, we hope will answer question such as: How will the variance of the input devices affect the visualization experience? Will such variance affect the knowledge gain? Will it allow users to be immersed in the experience and hence amplify cognition? Answers to questions such as these will shed the light on how interaction affects users' visualization experience as a whole.

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