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Visualization experience and related process modeling

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ABSTRACT

The visualization process is a transformation of information content into knowledge via a visual representation. *Visualization experience*, proposed herein, reflects human sensations arising during the visualization process. It provides a basis in which to objectively measure and evaluate human participation in the visualization process; and thereby provides methods of control. Visualization experience modeling allows leveraging on the natural environment to augment understanding, therefore improve decision making. The application emphasis in this paper is on the theoretical development of visualization experience in the visualization process as applied to Ambient Assisted Living and Clinical Decision Support Systems.

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1. Introduction

The visualization process is a transformation of information content into knowledge via a visual representation. It involves visualization systems that transform content into pictures termed visualizations and humans who transform these visualizations into knowledge. Humans have roles of users and thinkers. As users, humans can alternate visualizations by interacting with the systems whereas as thinkers, humans cognitively formulate knowledge based on the visualizations.

The broad term, *visualization experience*, is introduced in this paper to reflect human sensations arising during the visualization process and representing a degree of cohesiveness, knowledge formulation, and satisfaction in the visualization environment. Visualization experience is natural and inherently preexisting in human interactions with visualization systems. However, without precise modeling of this, the potential to harness human experiences during the visualization is limited. An important goal of the visualization process is to maximize the degree of knowledge that humans as thinkers can obtain from visualizations. This can be achieved by enabling the visualization systems to generate visualizations that in turn promote and facilitate maximal knowledge formulation. The visualization experience provides a definitive basis in which to objectively measure and evaluate the cohesiveness of the visualization environment for humans as users and thinkers; and thereby provides methods of control over the visualization process. An “excellent visualization experience” implies no need of control as the evaluations would indicate high knowledge formulation, whereas a “poor visualization experience” provokes interaction since the evaluations indicate possible improvement opportunities. Although various visualization processes, systems, and human-centered models have been proposed in the past, the extent of the cohesiveness coupled with human satisfaction and knowledge formulation as implied in the definition of visualization experience seems holistically lacking in such previous works. The development of such a precise model allows leveraging on the natural environment to augment understanding; and hence, lead to expected better decision making.

The focus in this paper addresses the development of a visualization experience model. A visualization process is defined which forms the basis for the objective parts of visualization experience, namely, measurement, evaluation and control. There are two main components in the

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processing modeling: information streams and visualization stages. Information streams connect systems and humans in terms of information flow. Visualization stages are defined as transformations of the information streams during the visualization process. Visualization experience is measured via visualization metrics that reflect the qualities of information flow and user involvement in the system–user interaction. These metrics in turn can be used to affect the visualization process in form of suggested methods of control. Such a model can be applied to various types of visualization systems that serve a diverse end-user community. The application emphasis in this paper is on the theoretical development of visualization experience in the visualization process as applied to healthcare systems, and in particular, to Ambient Assisted Living (AAL) and Clinical Decision Support Systems (CDSS).

The end-users of healthcare systems are varied, from domain specialists who use such visualizations as a means of investigation of certain phenomena in their area of expertise to patients who typically are more interested in their well-being. Such phenomena might range from statistical patterns in health records to real-time patients' activity. Consider an example of CDSS which are expected to provide insightful suggestions to medical professionals: in such cases as when they interact with the system via displays, they are involved in the visualization process. Therefore, the quality of their performance may well depend on the quality of visualizations. Yet, a survey on CDSS architecture and deployment evaluation between 2008 and 2012 shows that a user interface (therefore, the visualization process) is not considered as an important component of the CDSS in the majority of cases ([1–14]). The present paper employs the visualization experience in process modeling to prototype an interface for AAL systems, such as [15,16], that include CDSS as a component (from a visualization point-of-view).

The rest of the paper is organized as follows. Section 2 briefly discusses development of the visualization models in terms of human involvement in the visualization process. Furthermore, it provides several examples of work related to the application of this paper. Section 3 models the visualization process. It is divided into several subsections, namely, overview (3.1), information streams (3.2), and visualization stages (3.3). This section provides theoretical models necessary to define visualization experience. Section 4 introduces the main contribution of this paper, namely, visualization experience. Section 5 introduces the application system of this research that illustrates the theory. The last section concludes the paper and reveals future research plans.

2. Related work

The early visualization process models [17,18] leave very little flexibility to the human: to obtain and manipulate visualization results users had to have a total control over all of the visualization steps which also implied an in-depth knowledge of the problem domain [19]. Recently, there is a visible evidence of the importance of human perception, cognition, and interaction incorporated in the visualization process [20–23]. Also, there are number of works connecting visualization science with related disciplines through techniques [24] and frameworks [21,25]. Nguyen et al.'s Faithfulness model [26] extends the van Wijk model [20], placing more emphasis on the role of data in the visualization process and less emphasis on the human role.

The visualization pipeline in this paper is similar to the one in Chen and Jaenicke's paper [21], but focused less on the theoretical aspects and more on the visualization mechanics. Chen and Jaenicke compare communication and visualization systems from the perspective of information theory and the stages of visualization are described as stages of signal transmission affected by errors. The pipeline in the present paper is focused on transformation of abstract data to visual information in order to facilitate human knowledge. On the system side, a multi-layered interface organization is proposed as a way to simultaneously visualize information of different complexity targeted at various user groups. The importance of it is discussed in [27]. The emphasis on multiple visual layers has led to incorporation of parallel pipelines into the visualization process model. An example of a similar technique is found in [28].

User feedback, as modeled in this paper, enables manual or automated control of the visualization process via adjustment of visualization parameters and functions. The methods of manual control can vary from direct manipulation [29], to more complex system–user relationships when cognition is recognized as a property of interaction [25]. Automated control can be performed via automated mapping [30], 2D layout [31], 3D modeling [32], and virtual camera control [33–35].

Work related to the application side of this research is focused on the design and usability considerations of the CDSS interfaces. Yang et al. propose several usability metrics for CDSS systems [36], namely, learnability, efficiency, effectiveness, error handling, and user satisfaction. Different from the metrics described in the present paper, these five measure usability post-factum. There is no adjustment during the interaction involved. Frize et al. suggest criteria for successful CDSS deployment [37]. Somewhat related to the present research are user-friendliness, simplicity and effectiveness of visualizations together with the requirement of demanding the least amount of physician time possible. All of these are qualities of an “excellent visualization experience”.

Other application-related work is healthcare applications of avatars and data visualization in 3D environments. In [38], the authors use virtual personal assistants to communicate to Alzheimer's disease people. The work has been validated with a focus group and results show that an interface like that is intuitive and easy to use. In [39], the authors use personal assistants to help users to cope with special disease related exercises. Personal assistants guide users and help them to perform tasks. In [40], the authors visualize a smart living environment in the Smart Condo project. The visualization shows the user's position via an avatar placed in virtual 3D representation of the condo. Also, it partially involves sensory data visualization. In [41], sensory data is mapped to a 3D model of environment, with humans as well represented as animated 3D models. The work uses realistic representation of a wireless network's environment, visualization of a

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