



A systematic review of shared visualisation to achieve common ground[☆]



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ABSTRACT

This paper reports a systematic review of shared visualisation based on fifteen papers from 2000 to 2013. The findings identified five shared visualisation strategies that represent the ways implemented to process data sharing and knowledge to arrive at the desired level of understanding. Four visualisation techniques were also identified to show how shared cognition is made possible in designing tools for mediating data or knowledge among the users involved. These findings provide research opportunities in integrating rich interactive data visualisation for mobile-based technologies as an effective mean in supporting collaborative work. Finally, social, task and cognitive elements which can be significantly supported by shared visualisation and a guideline for future researchers seeking to design shared visualisation-based systems are presented.

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1. Introduction

Achieving common ground or shared cognition is one of the major aims in the development of Collaborative visualisation systems. Collaborative visualisation is defined by [31] as “the shared use of computer-supported, (interactive,) visual representations of data by more than one person with the common goal of contribution to joint information processing activities”.

In this definition, the term “shared use of ... visual representations” refers to any form of joint viewing, interacting, discussing or interpreting within a group of members

to amplify shared cognition that can be augmented by the use of visual representation. This shared cognition can be mediated and developed through any type of visual representation shared among the users, such as shared display (i.e. input technology) or using multiple displays as medium in shared devices. The use of shared visual representation, which remains one of the concerns of many researchers, is how data or knowledge can be captured, represented, presented and analysed among the users involved. Consequently, in the context of shared mental model, sharing cognition is described as having many types and aspects, which may later; result in different kinds of results of shared cognition.

According to Isenberg et al. [31], shared cognition can be initiated in several scenarios within two types of collaborative visualisation environment, which are distributed and co-located. A distributed collaborative visualisation involves how collaborative contributions can be effectively structured and integrated into a shared visualisation directed to the division or spread of resources such as design artefacts, design knowledge or design team to

Abbreviations: (CoVis), collaborative visualisation; (SMM), shared mental model; (SSC), socially shared cognition; (SSA), shared situation awareness; (HCI), human–computer interaction

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form common ground. Such activities are performed via video conferences and email-based data discussions. On the other hand, a co-located collaborative visualisation is where these collaborative works are initiated into a shared visualisation in the same locations, where design team can conduct further discussion via wall displays or shared tables. In order to understand the implication of strategies demonstrated in both types of collaborative visualisation environments, this study aims to identify the implications of different visualisation strategies and techniques of shared visualisation applications as well as how they can be applied to designing collaborative visualisation systems. In particular, we are interested in determining the strategies and techniques that have been undertaken by researchers in handling the datasets in shared visual representation to reach a particular result of shared cognition.

2. Related works

The concept of a shared mental model in human–computer interaction is derived from the field of teamwork and collaboration [3]. Following the publication of an article by Payne [3], there has been much interest in shared mental models in the context of computer technology, particularly in the area of human–computer interaction (HCI). However, until now there is no substantial research review related to the use of systematic literature reviews in shared visualisation and which above all, focuses on developing a shared mental model.

Isenberg et al. [31] provided a detailed review on 5 real world examples of scenarios in which collaborative visualisation tools were used. The study urged researchers to extend their investigations into collaborative visualisation (CoVis). One of the specific challenges found in the research space intersecting collaborative work and visualisation is the visual representations aspect to support the process of social interaction to reach a common understanding in terms of dataset.

Grimstead et al. [26] reviewed 42 CoVis systems, which were grouped and compared in terms of four application areas: collaborative problem-solving environments, virtual reality environments, multi-player online games and multi-user enabling of single user applications. The study concludes that a CoVis system that needs to support many simultaneous users must be scalable if it is designed to maximise the use of distributed resources and network facilities.

In summary, these studies only describe the importance of shared cognition or shared application in CoVis systems. However, none of them analysed the shared visual representation for building a shared mental model, although this is one of the major aims for CoVis systems.

3. Research design

This systematic review follows the guidelines given by Kitchenham and Charters [34] that have been used in the software engineering field, as well as in other domains, including computer education [4] and business process measurement ([1]. Ref. [34]’s guidelines state that a

literature review should be systematic and minimise researcher bias. Two protocols are necessary: first, a set of research questions that captures the rationale for and objectives of a review should be developed; second, a search strategy that details search terms, library databases and study selection criteria. The process by which papers and data for this review were extracted is further described.

3.1. Research questions

The main purpose of this systematic literature review is to present research on using shared visualisation to achieve a shared mental model. This review aims to identify the shared visualisation strategies and techniques that can facilitate the development of shared mental models (SMM); it addresses the following specific research questions:

- RQ1: What is the trend in SMM studies of shared visualization, focusing on two types of spatial collaborative environment approaches, socially shared cognition (SSC) and shared situation awareness (SSA)?
- RQ2: What and how is the strategy being applied in shared visualization?
- RQ3: What and how is the technique being used in shared visualization?
- RQ4: What is the technology being implemented in shared visualization?

Fig. 1 gives an overview of how the four research questions link to one another to give a comprehensive view of the review topic.

3.2. Searching strategy

In this study, specific keywords were used to search for the relevant literature. Although the term “shared visual representation” had been used above, the term “shared visualisation” was preferred in the literature search as it is more specific than “shared visual representation”, which may refer to any visual representation that can potentially be shared. Although there has been a considerable amount of cognitive and design research on shared visualisation, there is also a long list of shared cognition research in the fields of group cognition and collaborative design. The term “shared visualisation” is therefore used in this review to refer to a particular visualisation that is explicitly designed for sharing information.

3.2.1. Search terms

Databases were searched using the search string constructed from these keywords:

(Shared visualisation AND (shared mental model OR shared cognition))

If this search produced no hits, the terms “shared mental model” and “shared cognition” were removed from the search string.

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