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Low-fidelity prototyping with simple collaborative tabletop computer-aided design systems

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ABSTRACT

Design processes encompass iterative elaboration and elimination of new and many ideas gathered from a wide range of resources. The higher the diversity of the resources, the higher the chances that the design process will bear expected outcomes. Following that idea, immense amount of effort has been devoted to the development of collaborative computer-aided design (CAD) systems, and process frameworks that drive those systems. We infer from the existing literature that collaborative CAD solution attempts involve holistic approaches in which all aspects of the problem (social and technical) are being addressed. As an attempt to address social and physical aspects of the problem, tabletop systems with complex structures have been proposed by the previous work. Unfortunately, such complexity comes with the lack of reproducibility of the research work, and high evaluation overhead per prototype imposing a low limit on the number of design ideas to be investigated. Sophisticated systems might be required to solve the real-world problems, however, we argue that, with simple setups, rapid collaborative iterative prototyping could be achieved. Such simple setups could lead to high number of *good* ideas ready to be fed into off-the-shelf CAD systems lacking adequate support for collaborative design. We realized and evaluated this idea by implementing a tangible tabletop collaborative design system that facilitates fast and iterative prototype production for residential area design. Based on the case studies conducted with this setup, we show that synchronous collaboration for rapid prototyping could be achieved with lean setups, provide a list of design recommendations for such systems that we derive from our case study observations and existing literature, and finally contribute to the community with an open source tangible tabletop installation tool kit.

1. Introduction

Beginning from 1990s, computer-aided design (CAD) systems have become widespread design and representation medium for a wide range of application domains. Beyond merely being used as a representation tool, CAD systems have been fostering emergence of new opportunities, approaches, and methods for engineering and architectural design.

Along with the improvement on the computational capabilities and the Internet technology, interest for collaborative design efforts has increased both in academic and industrial worlds. Much research has been done to investigate various aspects of computer-supported cooperative work (CSCW) in the context of design (See [1] for an in-depth survey.). Not only the technical and infrastructural problems have been addressed, but also social, behavioral, and even cultural aspects have been investigated. Theoretical analysis, social investigations, and computer architectural aspects of the phenomenon seems to be well studied.

Despite all these previously mentioned work, collaborative design endeavor still seems to remain as sophisticated *prototypical* set of solutions since existing off-the-shelf CAD products are far from satisfying all those proposed collaborative functionality. One of the justifications for this situation could be that the collaborative design solutions could be inherently complex as it involves many subproblems involving but not limited to synchronization, communication, provenance, aggregation, and context tracking. Consequently, the body of research in this field remains as irreproducible scientific effort which could potentially be a bottleneck in the improvement of successful collaborative design products.

However, the problem still remains: Teams have to work in collaboration and all the current CAD products seem not to support

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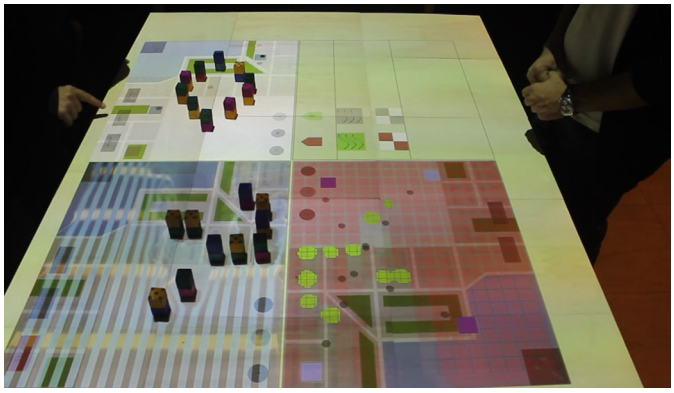

Fig. 1. InitialInsights: a collaborative tabletop computer-aided prototyping setup. The setup supports multiuser interaction and rapid prototyping iterations.

collaboration as good as they are promised by the literature [2–4]. Currently, the common practical solution for the establishment of collaborative design context is the use of computer-mediated communication (CMC) tools (e.g. chat, teleconference) along with the (real time or near real time) CAD products. Nevertheless, this approach also has a downside: It does not motivate iterative low-fidelity prototyping which is crucial in the early stages of the design process. Off-the-shelf CAD products such as SketchUp [5] provides the capability of rapid prototyping and idea sharing, however, such approaches are far from supporting concurrent prototyping and scenario-based design. The designers have to communicate frequently and make high number of product design iterations during the low-fidelity prototyping phase, and this is not supported adequately in the existing CAD products leading to initial design decisions to be made merely based on meetings or informal discussions. One of the participants of our case study stated that they often evaluated the feasibility of their design without investing much time on the preparation of the map sheets as it is not convenient in most cases.

We propose that a significant level of improvement could be achieved for the current CAD products by facilitating simple yet functional low-fidelity prototyping setups. As a proof of concept, we developed a tangible tabletop design system, namely *InitialInsights*, that facilitates low-fidelity prototyping through the use of simple mock-ups, and enables high level of iteration for the prototyping process. At any time of the iteration, selected *good* design ideas (low-fidelity prototypes) could be exported as metafiles that could be fed into CAD products for further refinement and improvement of the selected prototypes.

Based on a case study that we conducted with a group of architecture students and a professor, we state that the lean design of the prototyping tool is the key factor for the success of rapid prototyping tools. The straightforwardness of the CAD tool reduces the time and cost overhead per prototype leading to opportunity for the evaluation of many design ideas. Furthermore, uncomplicated tools increase the reproducibility of the research, which in turn could increase the speed of advancement in collaborative CAD system research, unlike what current research offers in general. To boost our contribution to the society involved with collaborative design and prototyping, we also share the technical installation details and source codes of InitialInsights as an open source project.[1] (Fig. 1)

We agreed on a list of design recommendations for the design and development of tabletop collaborative low-fidelity prototyping tools based on our observations that we performed during the implementation of InitialInsights and the case study. The design recommendations comprises a list of general suggestions that we believe will bear productive prototyping cycles, however, they are open to be improved by other researchers as they are merely based on this reported study.

2. Previous work

Collaborative design attracted much attention from many researchers as a challenging and complex problem [6]. Collaboration in design context seem to have many aspects such as the theoretical frameworks and processes [7,8], technical issues or solutions [9–11], and social problems [3,12]. In general, technical approaches involve integration of design processes [13] and the establishment of shared understanding in order to raise the perception [14].

Collaborative idea development has been an attractive topic since the emergence of computer-aided tools to address engineering design problems. C-Sketch [15] is an early attempt to explore collaborative idea generation processes with detailed lab studies providing inspiration for further studies [16].

Quick idea sharing and fast prototyping are key factors for the success as appreciated by the industry. For example, CAD tools such as SketchUp™ [5] and AutoCAD™ [17] have been excelled in fast model transformation and idea sharing allowing iterative low-fidelity prototyping at the early stages of the design process. We believe that our approach differs from these kinds of tools in several ways. InitialInsights has been designed to support trial (and elimination) of many different scenario ideas. With almost real time tangible interaction, it supports quick evaluation of *what-if* scenarios. On the other hand, SketchUp excels on design and production of models rather than working with scenarios. Moreover, most of the off-the-shelf products seem to support online or on screen sharing of ideas whereas InitialInsights supports synchronous local collaboration with physical objects and tangible almost real time interaction. And finally, InitialInsights aims at rapid and *concurrent prototyping* cycles on various scenarios in a collaborative fashion (e.g., wind and pedestrian movement) whilst, we believe, SketchUp focuses solely on sequential prototyping and addresses problems of the later stages of the design process.

Involving multiple users (co-located or in remote location), the collaborative computer-aided design processes are inherently social interactions which happen on computer-mediated communication tools on remote collaboration [18] or face-to-face when the designers are co-located [19]. Several groups reported promising results in remote collaboration [20,21], however, they still seem to be far from being common commercial solutions due to the major social problems such as communication [22].

As suggested by Scott et al. [23–25], tabletop systems have the potential to facilitate a social and collaborative working environment and enhance the idea sharing during the analysis and design processes as a remedy to the communication problems emphasized by the literature [26,27]. Up to date, numerous approaches have been integrated with the CAD systems to benefit from the capabilities of tabletop systems with different focuses and challenges such as implementation of augmented reality on tabletop systems [28,29], gestural interaction [9], tactile interaction with the digital 3D model and also projection of the simulated information onto three-dimensional model [30], and real time tactile interaction for controlling 3D terrain models [31,32].

Tabletop approaches aim to alleviate the social problems by facilitating co-location of the designers. Furthermore, current body of research has several other alternative enhancements for human-related issues of the problem. For example, such approaches involve the use of design templates to eliminate possible mistakes [33], application of integrative group decision making [34], experience-based design team formation [26], and well-structured communications [35,36].

[1] https://github.com/cad-lfprototyping/InitialInsightsToolKit

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