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# Improving Virtual Design Team Performance Through Use of a Collaborative Sketching Application

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## ABSTRACT

As virtual teamwork in engineering becomes more central to the daily design activities of organizations around the world, it is increasingly important for team members to be able to easily and effectively share their visual ideas with remote teammates. However, sharing visual representations of ideas among virtual teammates is generally difficult and commonly hampered by various factors, making the process time-consuming and non-intuitive. In laboratory experiments and a case study, involving students from six different universities across the U.S. working as teams to build unmanned aerial vehicles (UAVs), the authors quantify how a collaborative sketching application (CSA) provides a significant benefit to design engineering activities for virtual teams. From the experiments and the case study, it was observed that such a tool improved users' understanding of each other's ideas when working in a virtual setting, improved the perceived equality of teammate contribution, and decreased the level of frustration experienced when working remotely.

## KEYWORDS

Computer Supported Cooperative Work, Engineering Design, Sketching, Virtual Teams

## 1. INTRODUCTION

Virtual collaboration, or members of teams working together from different geographic locations via Internet or network-based tools, is an increasingly common and important form of collaboration among team members. In a survey of hundreds of private and public organizations, WorldatWork found that in 2013 more than one third of organizations in the manufacturing, consulting, professional, scientific, and technical fields offered positions for employees to work remotely full-time (Worldatwork, 2013). Furthermore, roughly half of organizations in those fields also offered positions which required virtual collaboration at least once a week. Salomo, Keinschmidt, & De Brentani argue that in order for new product development teams to compete successfully in a global marketplace, organizations

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must leverage the diversity of experiences, cultural sensitivities, and perspectives a geographically dispersed virtual team can offer (Salomo, Keinschmidt, & De Brentani, 2010).

Common tools used to accomplish this work include email, phone calls, and services such as Webex, Google Hangouts, Google Drive, and IBM Sametime. These tools enable teammates to collaborate via media such as text chat, audio or video chat, screen-sharing, or database sharing. Collaboration by virtual teams using these tools is an area of active research (Olaisen & Revang, 2017; Orta-Castañon, Urbina-Coronado, Ahuett-Garza, Hernández-de-Menéndez, & Morales-Menendez, 2017).

One critical need in the early stages of a design project is for a team to communicate ideas visually. Yang found a statistically significant relationship between the quantity of sketched ideas in the early stages of a product development process and the quality of the design outcome (Yang, 2009). The ability to communicate ideas visually (sketching) is also considered important by companies that employ engineers and designers, according to De Vere (De Vere, Melles, & Kapoor, 2012).

This, however, presents a unique challenge to geographically dispersed design teams. Many tools that allow communication over a distance do not include sketching - at least sketching to which both parties can contribute simultaneously. Attempting to explain visual ideas solely with audio or textual symbol types is less effective, if not an outright invitation for misunderstanding, similar to asking directions when traveling through an unfamiliar area.

Peters and Kress describe virtual collaboration tools and research efforts going back as far as the 1960s, including the development of some shared visual editing tools during the 1990s (Peters & Kress, 1997). However, few, if any of these tools are commonly used in industry today. While a few modern tools do exist that allow multiple people to draw on a shared canvas and see each other's contributions as they are added (GoodCode, n.d.), it is much more common to find these types of visually collaborative, virtual tools in other areas, especially in entertainment and video games. For example, the hit game Minecraft enables players to interact with each other's avatars as well as the virtual world around them in real-time (French, Stone, Nysetvold, Hepworth, & Red, 2014). Each player is aware of the context created by the other players and the environment.

In the engineering world, only a handful of tools have attempted to provide this kind of real-time, multi-user ability in the product development process. Research tools, such as NXConnect (Red et al., 2010; Red, French, Jensen, Walker, & Madsen, 2013; Red, Jensen, French, & Weerakoon, 2011) have enhanced existing CAD software tools (i.e. Siemens NX) to provide a real-time, multi-user environment. Onshape has developed a commercial, cloud-based CAD tool with comparable capabilities (Onshape, 2015). Hepworth et al. developed a tool to enhance communication and task distribution when working in a virtual design team (Hepworth, Halterman, Stone, Yarn, & Jensen, 2015). While these tools provide a needed and major step toward enabling true virtual engineering design teamwork in many stages of the product development process, not all design work is done in CAD (Polar Services Company, 2005; Schutze, Sachse, & Ro, 2003). Different stages within the design process necessitate different types of tools to improve collaboration in a virtual team environment.

This paper introduces a new multi-user collaborative drawing and annotation tool to better fill an apparent need in virtual team design activities. The motivation and background for this tool are presented in Section 2, followed by the tool description in Section 3. Section 4 discusses the experiments conducted to measure the effectiveness of synchronous collaboration using this new tool and Section 5 presents the results from these experiments. Section 6 presents the findings from the multi-university case study and Section 7 concludes this research. Taken as a whole, sections 4-6 represent a mixed-methods approach to the research, including both quantitative and qualitative elements that we feel provide a sound and meaningful view of the topic.

# Customizing Multimedia and Collaborative Virtual Environments

Paulo N.M. Sampaio, Ildeberto A. Rodello, Laura M. Rodríguez Peraltaand Paulo Alexandre Bressan (2009). *E-Collaboration: Concepts, Methodologies, Tools, and Applications (pp. 202-210).*

www.irma-international.org/chapter/customizing-multimedia-collaborative-virtual-environments/8786