I. Research Statement

With advancements in the field of computer aided communication and collaboration, software development companies are becoming global in every sense of the word. A large number of companies are breaking the norm of confined space and time in their work environments [1] and are giving their employees the freedom to work remotely from the comfort of their homes. Not only in the field of Software Development (Github, Mozilla), but also in other areas of work such as Design (InVision, SitePen), Media (Upworthy), and even Law (Virtual Law Partners), companies are recognizing the effectiveness of remote work to raise productivity [2]. A recent boom in globally distributed software development has created opportunities for Remote Pair Programming [3]. Remote Pair Programming is a highly collaborative activity. With increased distance comes increased need for natural collaboration.

My thesis research investigates into Augmented Reality as a tool to facilitate collaboration and to bring a higher level of virtual collocation and copresence to Remote Pair Programming. The purpose of this research is to address the following questions.

a) Can Augmented Reality for Remote Pair Programming provide a sense of copresence that is comparable (or better) than video conferencing?
b) What is the most effective way to show the partner's virtual representation?
c) Which non-verbal communication cues can be represented using available augmented reality technologies?

II. Background

A. Pair Programming (PP)

Pair Programming is one of the twelve practices of eXtreme Programming (XP) [4] in which two programmers sit side-by-side at one computer and work on the same task. Research has shown that PP results in increased efficiency - higher quality software products in shorter amount of time [5]. In the chapter 17 of book "Making Software: What Really Works, and Why We Leave It", Williams not only provides evidence for PP as a useful tool in industry, but also in academia [6]. PP is a widely used method in workplaces that use agile methodologies. For effective and natural work flow, pairs of programmers are collocated in a collaborative space with tools such as whiteboards, task boards, and walls covered with design illustrations. This setup provides a way for the programmers to easily interact with each other for a fluid and dynamic work environment. Empirical data collected by Dr. David Socha [7] and ethnographic interaction analysis [8] of software developers working in their natural environment has revealed that workings of the two programmers extends beyond the pair. Remote Pair Programming provides affordance for external interaction as explained in the next point.

B. Remote Pair Programming (RPP)

Like PP, RPP is a practice of Distributed eXtreme Programming (DXP) [9] in which both programmers work on the same task remotely. To bridge the gap of distance and to facilitate a higher level of we-awareness [10] in remote work, programmers use a variety of tools like: (a) video-conferencing tools (Skype, Google Hangouts), (b) collaborative programming tools (gotty, tmate, atom-pair, motepair, VS Anywhere), (c) screen-sharing tools (Screenhero, Skype screen sharing), (d) collaborative note-taking tools (Google Docs, Microsoft Word), and (e) text-based chat tools (Slack, HipChat).

However, RPP is not the same as traditional PP in a way that RPP does not provide the same level of physical presence. For example, when remote programmer #1 points at his screen to discuss about an area on the screen, there is no way that remote programmer #2 can see where remote programmer #1's finger is aimed at with a video conferencing tool like Skype. Only verbal communication, with limited number of non-verbal cues, can be transmitted using the current tools used for remote pair programming. This hinders the natural flow of exchange between the two programmers and could lead to confusion, distraction and sometimes side-tracking because a part of the conversation is not clearly transmitted. Due to these reasons, a lot of context of the conversation is lost while remotely pairing. As Olson et al. note, distance still matters [11] [12].

III. Thesis Research

Due to lack of availability of Augmented Reality (AR) technology at this point in time, this research will initially focus on VR for RPP to explore some of the affordances and limitations that are relevant to both AR and VR until appropriate AR technology is available to my research team. The experimental setup consists of programmer #1 with VR tools (Oculus Rift DK2 and Leap Motion) and programmer #2 with traditional RPP tools. Both programmers will be remotely collaborating on a task of RPP. Their interview responses, along with video stream of them remotely collaborating, will be gathered for analysis, such as for measuring the amount of repair activity in traditional RPP versus VR RPP.

My thesis consists of following major phases.

a) Analysis of VR as a tool for RPP – This phase of research includes performing literature review and study of past research on AR/VR for other collaborative tasks similar to RPP. While doing so, I have found past studies that focus on bringing a higher level of copresence in videoconferencing [13] [14] [15] and in collaborative tasks [16] [17] [18]. My research resides in a relatively under-explored area of natural remote collaboration in Software Engineering (SE).
b) Types and position of virtual representations – This phase of research includes writing code and performing tests to understand the types of virtual representations of remote partner that can be shown in the virtual space. These virtual representations include ghost finger and remote desktop. I have conducted tests to represent the work desk of a research lab using 3D scanning. Leap Motion was used to track hand

movements. Virtual representation of the hands, along with the 3D scanned work desk, was shown in the VR space using Oculus Rift DK2. The purpose of these tests is to investigate how distance in real world can be mapped to distances in the virtual space. Next step is to stream programmer #2's desktop onto programmer #1's virtual monitor. To facilitate a higher level of interaction, the virtual representation of programmer #1's hands (captured using Leap Motion) will be shown as a ghost finger (or a dot on the screen) on programmer #2's screen and vice versa.

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