

Using Augmented Reality Guides for Insertion Task: A qualitative Study

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1. Introduction and Rationale

One of the major challenges of industrial manufacturing processes is assisting human during manual assembling operations where automation is not cost-effective [1]. Many experiments have been conducted to support this goal by using augmented reality (AR) [2, 3, 4]. While these studies provided strong evidences for the value of AR, they mainly focused on two ways to provide visual aids. The first one is displaying 2D information that is relevant to what is under observation e.g. the order of the operations the user need to follow to perform the task [5]. The second is displaying 3D virtual objects inserted within the real environment in spatially registered positions that can represent 3D indications [6]. These aids are added to the real components of the assembly task. They represent external information that do not exist outside the framework of the experiment. As a result, they can lead to an overload of the real scene and therefore increase the mental workload [7]. Moreover, these previous studies did not address the visual occlusion issue that happens during blind assembly tasks when objects or parts of objects are occluded.

In this study, we focus on integrating extra geometric information useful for blind assembly. The information should represent some important, intrinsic properties of the objects that are not directly visible to the users. The information can be implicit (symmetries, axis) or explicit (portions of objects that are occluded during the task). We believe that by visualizing hidden information with AR, one can perform blind assembly tasks that would otherwise be difficult or even impossible to accomplish.

2. System design

To achieve our purpose, we designed an AR prototype system consisting of:

A head mounted display: In order to stay as close as possible to actual real-life situations and provide a high ecological validity system, we chose to design a completely portable, lightweight and easy to handle set-up. Our choice went on Microsofts HoloLens [8]. The HoloLens built-in tracking system accuracy was not acceptable in our set-up, so we implemented a more accurate tracking procedure based on a marker-based approach, using the Vuforia 6 SDK¹.

Objects to be assembled: We created our own blind assembly system with three objects: one box and two boards that one can insert with each other through slots. Then, we defined two “insertion” operations: (1) insert the first board through the box from left to right and (2) insert the second board into one slot on the top of the box, then through the previously inserted board.

AR visual assistance: Last but not least, we designed two ways to provide visual AR aids to users:

- *Wireframe overlay:* We improve the perception of relative placement of the objects by virtually representing visible and invisible contours. This allows users to get an inside view of the objects, providing a form of simplified X-ray vision.
- *Axes overlay:* We display the axes of the objects and their insertion features (slots) so that their relative position become explicit. This allows users to know how to align the different pieces during assembly.

¹ Vuforia AR platform, PTC Inc., United States
<https://library.vuforia.com/articles/Solution/Optimizing-Target-Detection-and-Tracking-Stability.html>

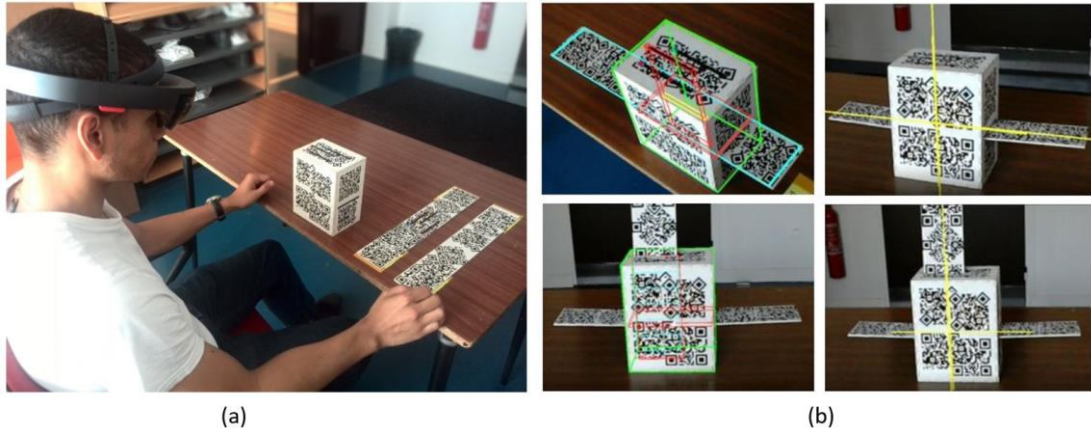


Figure 1. (a) A participant before starting the experiment. (b) First-person view on the HoloLens at different stages of the task. On the left, the “wireframe” overlay. On the right, the “axes” overlay.

3. User evaluation

We run an experiment with 30 participants (21 males, 9 females, $M = 29$ years, $SD = 10$ years). We used a within-subject design with one factor: the assembly mode with 3 possible values “default”, “wireframe” and “axes”, representing respectively a baseline condition (i.e. no AR overlay) and the two visual overlays. The participants were seated at a table in front of the objects to be assembled with the HMD on their heads (including in the baseline condition). During the evaluation, each participant had to perform the two operations three times per assembly mode, once for each slot -on the top of the box- according to a number given to him by the evaluator. We assessed user satisfaction by collecting a subjective dependent variable in the form of a post-questionnaire (5 point Likert scales) divided on three groups of items: the difficulty perceived in each mode (from 1 point being very easy to 5 points being very hard), user preference (ranking of the assembly modes), and the prior expertise with HMDs. Our central hypothesis was that our AR visual aids improve the user acceptance compared to the “no AR overlay” condition.

4. Results and discussion

We computed a Friedman’s test on the difficulty perceived by participants which revealed a significant effect of assembly mode (Friedman chi-squared = 19.631, $df = 2$, p -value < 0.001). Consequently, we computed a pairwise comparison using Nemenyi multiple comparison test [9]. The post-hoc test revealed a statistical significant effect of “wireframe” ($p < 0.001$) and “axes” ($p < 0.05$) modes, meaning that AR modes are clearly perceived by participants as easier compared to the default mode. Moreover, the questionnaire indicated a strong preference of participants for both wireframe and axes mode: participants were asked to rank the assembling modes in order of preference. We found that 42% of the participants preferred the wireframe mode, 36% preferred the axes mode and 22% preferred the default mode.

Informal post-test interviews also confirmed our intuition about the potential value of the AR modes. However, it was reported that in some cases, overlaying exhaustive geometric information (wireframe mode) might become counterproductive and actually obfuscate important visual assembly cues. Simplified, more abstract features with high information value (holes, axes, slots, etc.) like in axes mode are then logically preferred and perceived as more useful. It might therefore be interesting in future work to modify the wireframe mode to display only the truly useful parts for the assembly.

5. Conclusion

In this study, we designed and evaluated an augmented reality setup that consists of tangible objects coupled with AR visual modes presented with a personal see-through device. We assessed the effectiveness of our AR system through a user evaluation in which we measured the user satisfaction during blind assembly tasks with occlusion situations. Users reported an excellent acceptance of the system and we found that participants perceived AR visual modes as making them more effective at performing their tasks.

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