“PILOT”
an AR-based assembly assistant

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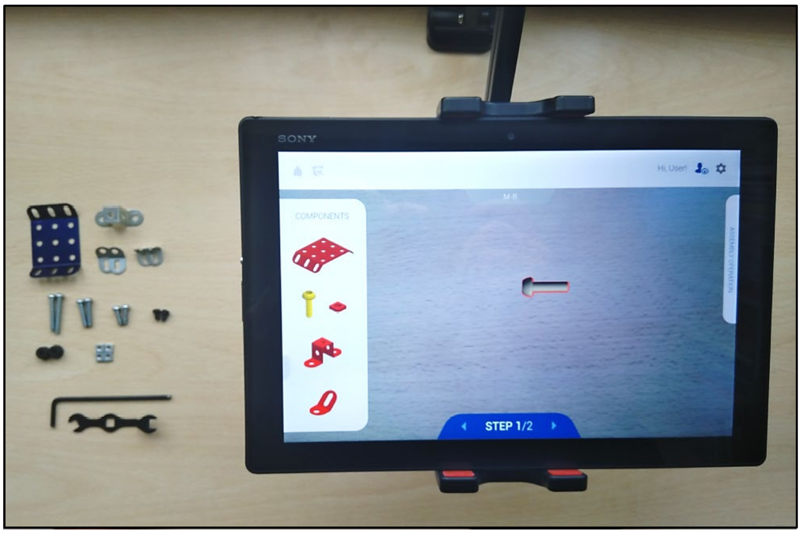
Executive summary

In partnership with Physik Instrumente (PI) – worldwide leader in the manufacturing of nanopositioning products – the project aimed at investigating the typical industrial applications of augmented reality (AR), virtual reality (VR) and mixed reality (MR), and at identifying the most relevant one for PI, to be implemented in a functional demonstrator. Such prototype was expected to address PI’s general requirements of reducing the delivery time, improving the efficiency of its processes and being scalable to its many international branches.

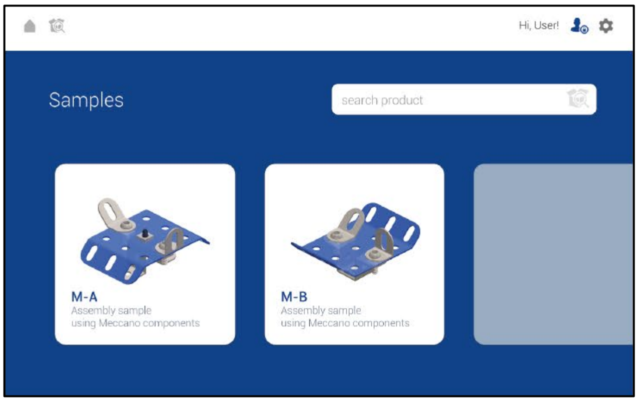
Once understood that the most promising application for PI could pertain the AR-based optimization of its assembly procedure – since it was highly manual and hence prone to human error – the team ideated, developed and tested an AR-based assembly assistant called “PILOT”. Drawing on ‘poka-yoke’ (i.e. mistake-proofing) and ‘user-centred-design’ as main drivers of innovation, PILOT allows for a continuous but non-invasive check on the assembly status and progress.

Key Words

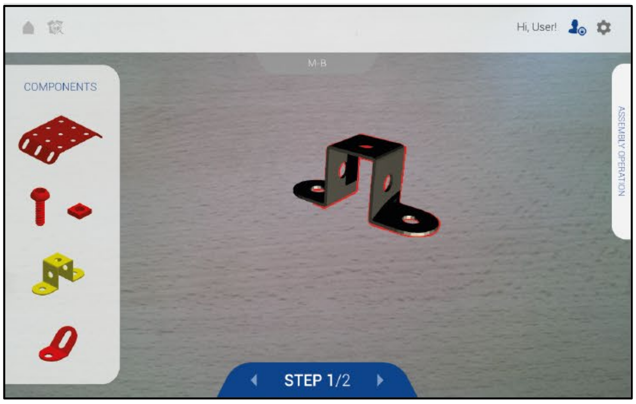
augmented reality, industrial sector, assembly assistant, poka-yoke, user-centred design



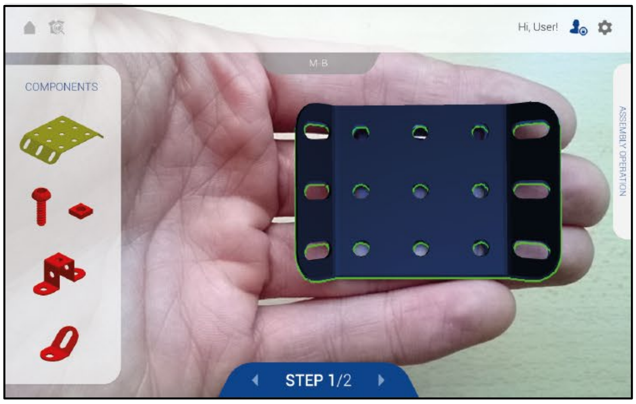
Exemplificative setup



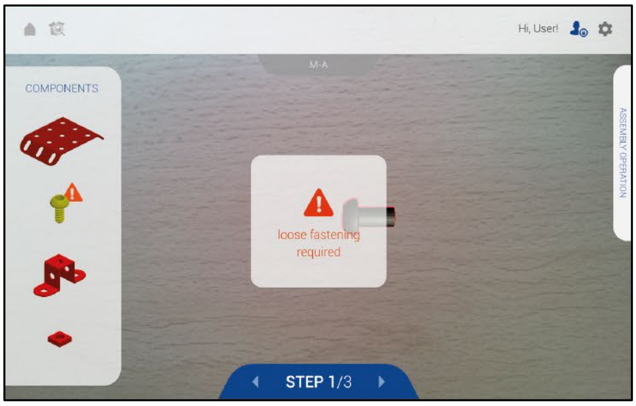
1. Menu for selecting the model to be assembled



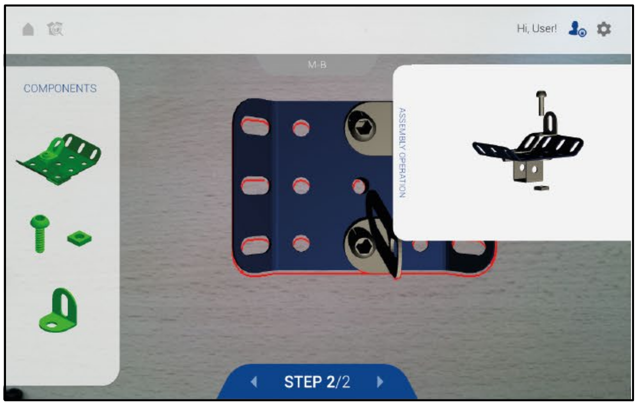
2. Component recognition



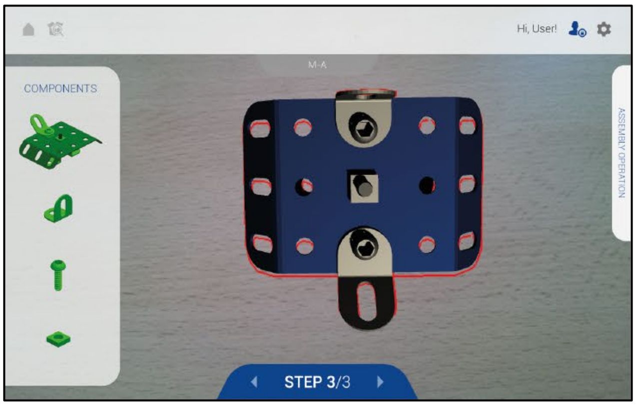
3. Component being recognized



4. Additional information related to the selected component



5. Animated instructions



6. Assembly recognition

(Botto et al., 2020). $ÕÒÉÎÇ tÈe ÐÒoÊeÃt, ÖaÒÉoÕÓ ÓËÉllÓ, ÂotÈ ÈaÒÄ aÎÄ ÓoÆt, ×eÒe ÓtÉÍÕlateÄ, ÉÎÃlÕÄÉÎÇ tÈoÓe tÈat aÒe tÙÐÉÃal oÆ aÎ aÃaÄeÍÉÃ ÒeÓeaÒÃÈ ×oÒË. 4ÈÉÓ ÓtateÍeÎt ÉÓ ÓÕÐÐoÒteÄ ÂÙ tÈe ÆaÃt tÈat ÒeÓÕltÓ oÆ tÈe aÂoÖe ÓtÕÄÙ ×eÒe ÉÎÃlÕÄeÄ ÉÎ a ÐaÐeÒ tÈat ×aÓ ÐÒeÓeÎteÄ ÉÎ a ×oÒËÓÈoÐ oÆ)%%% 62 2020, a ×oÒlÄ×ÉÄe, ÆlaÇÓÈÉÐ ÃoÎÆeÒeÎÃe oÎ 6ÉÒtÕal 2ealÉtÙ aÎÄ ÒelateÄ teÃÈÎoloÇÉeÓ.

The team drew upon vertical knowledge in *computer engineering* and *user experience design*. As is clear, such "hard skills" were fundamental for dealing with, respectively, the technological and human sides of the project, which were not just theoretical but real in that they referred to a prototype to be actually built and to existing users with actual needs and attitudes.

Indeed because of the "reality" of the challenges encountered, a series of "soft skills" also proved to be very useful. Among the others, a *creative problem-solving approach* proved essential, since all the team members were "beginners" in terms of practical use of AR technology. Also, *mediation* was necessary for aligning the diverse interests of the various stakeholders involved in the project, which include ASP, SEI, PI managers and PI employees. Concerning the latter, *empathy* was key in approaching them through in-person interviews, also considering the consistent limitation encountered by both the interviewers and interviewees in not using their mother tongue for talking.

Goal

Within the SEI context, the main goal of the project was to get a "real-life experience" concerning the application of a particular technology to answer a real company request. Therefore, besides literature review and landscaping activities, emphasis was put on experiencing AR, VR and MR *first-hand*, so to get a practical idea of the challenges it implies in both de design and use phase. It followed that experimenting with the technology opportunities and limitations, was a priority over the absolute innovativeness or the solution that was ultimately proposed. Moreover, the solution was developed in light of PI's specific interests and needs, even though a broader analysis of its relevance was made.

Given the "learning by doing" imprint of the project, its extended goal became that of testing, in a statistically relevant way, the efficacy and limitations of the proposed solution.

Regarding PI's goals, along with getting a functional prototype, it aimed at getting an overview of the possible applications of AR, MR and VR technologies in the industry sector, which was aligned with our landscaping activity.

Understanding the problem

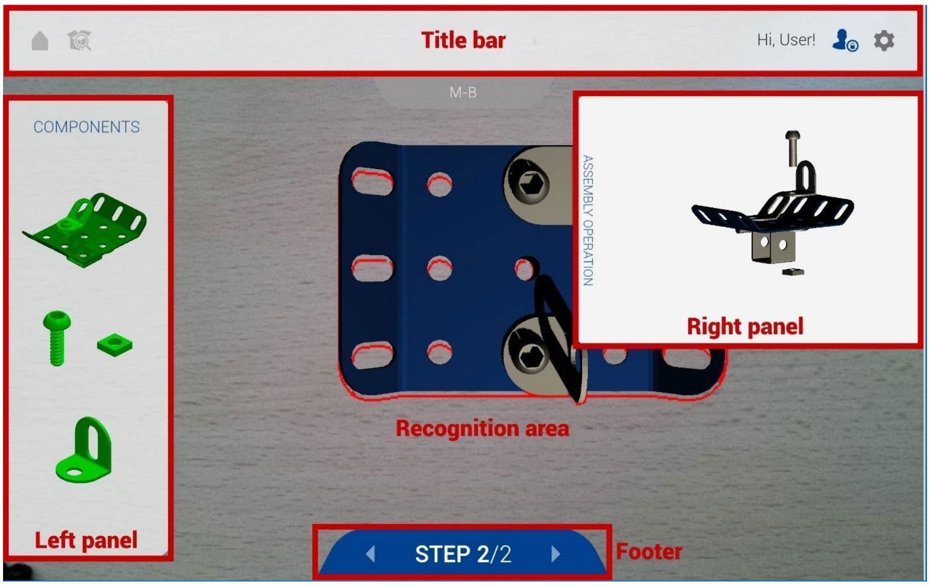
Project-brief wise, PI did not express any explicit problem expected to be solved through the application of AR, VR, or MR. It rather stated its interest in understanding how such technologies could potentially be beneficial in terms of reducing their average delivery time, increasing the processes' efficiency of its processes, and facilitating communication/coordination with its international branches and/or clients.

A visit to the company headquarter in Karlsruhe, south-west Germany, was vital in identifying – via interviews with five senior employees – at least one major issue which the company was indeed experiencing. Given the very frequent request by PI's clients for highly customized products, the company had to keep its assembly operations quite flexible, which prevented them from being automated: relying almost entirely on *manual* assembly made these operations *prone to human error*.

Interviews unveiled that such errors were typically related to *forgetfulness* – i.e. forgetting to assemble parts (e.g. screws) or add liquid components (e.g. glue, grease), *imprecision* – i.e. remembering to perform a certain task but performing it imprecisely (e.g. assembling screws too loosely/tightly; or using too much/little glue), and *"specification"* – i.e. using wrong parts and/or assembling/applying them in the wrong place. Also, if such categories of errors appear common to all kinds of products, it had to be considered that their frequency is reasonably higher for nanopositioning products, which are often made of many, usually small, and sometimes very similar parts. All of this added to PI's frequent products customization (which implies slightly different procedures almost every time) shows how the assembly phase was quite critical.

Interviews also unveiled that PI employees were not familiar with *high-tech* products and applications (both in their professional and personal life), which could constitute a problem if the proposed prototype was not designed with a user-centred perspective. This fact implied to think of solutions in terms of their *intuitiveness* (i.e. being easy to understand), *handiness* (i.e. being practical to adopt in one's already established working routine) and *unobtrusiveness* (i.e. providing a sense of familiarity, not generating any sense of alienation).

In parallel, literature review was so to identify opportunities of AR, VR, and MR technologies in the industry sector (Lamberti et al., 2014). In-depth research on AR-supported assembly showed how AR assistance typically concerned with 'identification and handling', 'alignment', 'joining', 'adjustment and 'inspection' (Radkowski et al., 2015). It was also found that 'adjustment' and 'inspection' were overlooked by many AR-based solutions, and that instruction provided were typically of a 2D or static kind (Nee, A. et al., 2013).



Interface elements

SEI DEMO DAY 2019 | Our external partner referent, Dr. Markus Simon, trying PILOT

Exploring the opportunities

The literature referred to ‘poka-yoke’ – from Japanese “mistake-proofing” – as a structured approach to preventing errors during the manufacturing procedure, which however seemed not adopted (at least integrally and explicitly) in the AR-based solutions found during the landscaping. By ‘*setting limits* on how an operation can be performed’ and *implementing ‘automatic alerts’* all along the process, it was found that such approach could optimize the assembly operations in terms of (1) *checking* if the employee gathers the correct components before starting to assemble them; (2) providing additional information in case of “ambiguous” tasks (e.g. when glue is required, specifying its exact quantity); and (3) checking if the employee has properly executed the assembly step, once completed.

Imagining instead to optimize the assembly operation by *improving the fruition of the assembly instructions*, the on-field investigation at PI’s headquarter unveiled how the currently used digital manuals – accessed via tablets placed at the corners of the assembly working desks – could be improved, by making their content contextual, three-dimensional and interactive.

The two opportunities for assembly optimization as *continuous checking and feedback* and as more *intuitive assembly information* were found both relevant by the company and thus combined as complementary aspects in a single solution.

Additionally, various hardware solutions were considered. The use of a tablet was preferred to smart glasses, given the letter's higher cost and higher intrusiveness (Riedlinger et al., 2019). The process was kept hands-free by mounting the tablet on a holder mount clamp.

Generating a solution

PILOT is AR assembly application for Android-compatible tablets, which provides assistance in terms of continuous assembly status checking and intuitive assembly instruction – this latter consisting in visual 'parts listing' and 3D animated explanations of each assembly task.

After the selection of the model to be assembled through a dedicated menu, the application initiates the recognition of the components needed step-by-step. The components in the menu list are coloured depending on their recognition status; the user is expected to make the tool recognize all the components before starting to assemble the model; the recognition occurs when the user superimposes the right component on the AR 3D model until its outline becomes green. Dynamic assembly instruction – as exploded animated views – are available to explain the assembly process visually. The operation ends with the recognition of the fully assembled part.

Experienced operators can enjoy a 'flexible starting point' feature, meaning that if they are uncertain about the execution of an intermediate step, they can receive assistance directly from that step on: the correctness of the assembly checking won't be compromised, because, before assisting in the further step, the application has to recognize the starting sub-assembly as correct.

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