Academia-industry Collaboration for Augmented Reality Application Development

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ABSTRACT

Due to our previous experience in AR development, with this research project we propose to study how Augmented Reality (AR) can be adopted by an industrial partner and which are the major outcomes from which a company may benefit. For this purpose, we partnered with a forward-looking company willing to embrace the idea of implementing new technologies for industrial purposes. In this research we identified that the most significant impact which AR may have for our industrial partner is in providing remote assistance and for product exploitation and marketing purposes. For the latest we developed a customized AR application which is currently available on Apple’s App Store. By analysing the app analytics data, we found out that this application is a success in terms of marketing and not only. For the remote assistance AR app, we chose to use a commercial solution that can be adapted to fit our industrial partner’s needs. We also tested this application and found out that it greatly improves the communication between remote users thus dismissing the required assistance time.

Keywords: Augmented Reality, Remote assistance, Industrial application, AR marketing

INTRODUCTION

Augmented reality (AR) technology has currently reached the maturity level which enables small industrial uses. According to Gartner’s Hype Cycle AR is currently on the verge of moving to the “slope of enlightenment” phase (Gartner Inc., 2018) which is the last step before mainstream
technology adoption. Due to our previous experience in AR development for industrial purposes (Bondrea & Petruce, 2015), (Petruce, Grecu, & Chiliban, 2016), (Čuković, 2015), we propose to study how AR can be adopted by an industrial partner and which are the main advantages from which a company may benefit.

Many of the companies that seek to introduce AR into their work processes talk directly to the software providers, but there are cases when the companies look at an academic partner for example like in (Jakl, Schöffer, Husinsky, & Wagner, 2018). Jackl et al presents two use cases called Real-Time Machine Data Overlay and Web-Based AR Remote Support. While developing the two solutions, they were focusing on efficient data transmission, software that runs on cheap devices that are certified for industrial environments and usability of the proposed solutions. For the first solution, on the hardware part they used the HoloLens Mixed Reality headset as it was already fulfilling several safety standards. On the software part, a combination of OPC UA for machine data and a Node.js proxy server to reduce the OPC protocol overhead when transmitting data to and from HoloLens headset. For the remote assistance use case, the customer that needs support is using a smartphone as hardware. The software of this AR remote assistance solution consists of a mobile application that streams the video to the supporter computer within the web browser. The data transmission is done using WebRTC in this case. There is also a Node.js server that is used at the beginning to help the two peers to exchange their ICE (Interactive Connectivity Establishment) information to be able to establish a peer-to-peer connection. Beside the technical details of the solutions, the authors also present a combined architecture for the two solutions and gives several recommendations for developing an AR application based on their experience while developing these two solution prototypes.

**PROBLEM STATEMENT**

The first step was to identify an industrial partner that presents suitable use cases for AR implementation. The next challenge was to find a forward-looking company willing to embrace the idea of implementing a new technology for industrial purposes. We found our partner in Maier Werkzeugmaschinen, a German trend-setting company, which produces highly customizable CNC machines and automation solutions.

MAIER CNC Swiss-Type Automatics are highly customizable, sophisticated machines, built to the finest client requirements and adaptable to many applications. Because of this complexity, the potential clients are having difficulties in envisioning the capabilities of the finished product based on classic promotional materials such as brochures and presentations. A 3D representation of the machine’s capabilities is often required so that the potential clients better understand the machines characteristics.

On another topic, considering the high complexity of the machines, it is required that Maier’s highly specialized know-how to be shared with the client’s operating personal as end-user support services, so that the machines can be exploited at their full potential. These services cover almost every aspect, from basic instructions such as setting up the machine (Figure 1) to the most complex tasks. Moreover, we have also identified that most of the client’s issues are determined by an improper equipment use due to the client’s failure to comply with the machine’s instructions.

Due to this, often, post product delivery assistance has to be provided at the clients’ location. This, post product delivery assistance, involves maintenance operations, end-user guidance and training, operational improvements (e.g. solutions to improve manufacturing times and/or fabrication processes) and best practices guidance. The issue is that in most cases the travel time exceeds the required operational time. For example, if the client is at a 3-hour drive that means that Maier’s specialized personnel wastes 6 hours just to reach the client and back. In most of the cases, the operational time takes only 20% of the whole delegation time.
Another matter is when highly skilled people are sent to the customer to perform basic operations. This is happening when the customer’s unskilled personnel don’t provide enough information for Maier’s employees to be able to figure out which are the issues or due to poor communication because of language barriers. E.g. a client does not respect the correct procedure of turning on a robot and switching it into automatic working mode. For a skilled worker this procedure usually takes around 5 minutes. However, doing it remotely, over a phone conversation, it can take up to an hour.

Solution description

By analysing the problems mentioned above, we developed several solutions to reduce these limitations. These solutions are based on the involvement of Augmented Reality (AR) into these customer-oriented processes. The solutions that we identified are the following:

- An AR application where the user can view the 3D representation of the equipment with basic instructions and characteristics. This application must be able to detect specific objects from the environment (e.g. specific features from the physical world) and superimpose the right information over them. Within this application, the user must be able to interact with the digital information by gestures or by voice inputs. Beside the equipment’s technical information, this AR application can also provide basic instructions (e.g. start-up instructions) and best practices guidance (e.g. maximum equipment loads).

This application can also serve for marketing purposes, for example when a client looks at Maier’s products brochure it will have an enriched perspective over the product’s specifications by being able to analyse a virtual representation of the product with the aid of AR. Moreover, a client can place a 1:1 scale virtual representation of the equipment over its designated position in the physical world so that it can check if there are any issues (e.g. safety problems, collisions with other equipment, unreachable components, etc.).

- AR aided remote assistance solution which will empower Maier’s qualified personnel to remotely supervise and offer assistance for various purposes. This solution enables that skilled employees can supervise simple maintenance operations remotely where and when needed and additional instructions can be provided as well to the client by using AR. With this solution, expertized process (e.g. machining parameters, robot paths, etc.) evaluations can be remotely performed, and by using AR, and the identified improvements can be remotely highlighted directly over the clients’ physical system. Moreover, the operator that will apply the improvements can be supervised and guided remotely using instructions provided with AR.

Also, these AR applications can be customized based on the client’s needs (e.g. machining operational instructions) and at the same time, similar AR applications can be implemented to improve Maier’s production processes, by replacing or augmenting the production related information supplied “on
paper”. For example, assembly instructions can be provided using AR or technical drawings can be improved with superimposed 3D models.

**Solution implementation**

The first step of the implementation process consisted in identifying which are the desired outcomes from the AR apps. After consulting with the experts from Maier Werkzeugmaschinen the desired outcomes where outlined and it was determined that at least two AR applications were needed. One for product exploitation and marketing purposes and one for the remote assistance services.

**Product exploitation and marketing AR app.**
By analysing the Maier’s existing infrastructure, we decided that Apple’s ARKit is the most suitable AR software development kit to build the product exploitation and marketing purposes app. After choosing the AR development software, the next step involved converting different 3D models provided by Maier, from the CAD format to a retextured model that is compatible with the AR software. CAD models are very complex and in different file formats. Since the application runs on a mobile phone, to improve the performance and to reduce battery consumption of the mobile application, these models needed to be simplified in terms of number of surfaces (Figure 2).

![Figure 2. Converted CAD model imported in Xcode](image)

From all the supported file formats of ARKit we choose to convert the CAD models to a DAE format because it preserves materials, animations etc. Another advantage is that we can modify the DAE file from Xcode IDE (e.g. adds lights to the scene, group different nodes, etc.). During this process, we have identified that we require a CAD software and another software specialised in 3D animation in order to obtain high quality DAE models.
For this purpose, we have tested different CAD software (Catia V5, SolidWorks, ProE and 3Dexperience) to see which can export the highest quality files that are also compatible with the 3D animation software. For the 3D animation software, we tested 3DS Max which is exceedingly complex for our requirements and we ended up using Blender.

After several attempts, we discovered that the best method is to use SolidWorks (because the native files were created in SolidWorks) to convert the whole assembly into separate STL files (STL files are 3D models composed of vertexes with no material or texture properties). After this, STL files were imported into Blender where they were rescaled and a vertex dismissing process was applied. The dismissing process was required because the original files were too big and too complex to be
used in an AR application which is supposed to run on a smartphone. This operation reduces the size of the app by reducing the number of vertexes (e.g. a 110 MB 3D model with 18000 surfaces – approx. 500000 vertexes is reduced to a 11 MB file). This whole process created the required DAE files onto which we could apply material and use in our AR apps.

Further, the interaction methods with the digital content were developed (Figure 3). The following gestures can be used to interact with the loaded 3D model: Taping on the screen: Selects the model, Highlights a node (part) of a model if tapped on a model, Can provide additional information about the node and changes the position of model to the tap position if tapped outside of superimposed model. Pan: Changes the position of the selected model in the 2D plane. Pinch: Changes the scale of the model. Rotate: Rotates the model around its vertical axis. Double Tap: Hides the double tapped node. Long Tap: Makes a hidden node visible again.

![Figure 3. AR superimposed 3D model with interaction capabilities](image)

The last part of the AR app development consists in choosing the right tracking methods for each scenario. Three different tracking methods were tested:

- **2D markerless tracking** – this method is used to superimpose 3D models over 2D representations. We used it to superimpose 3D models over Maier’s brochures.
- **3D markerless tracking** – this method is used to identify 3D landmarks from the physical world and use them as markers for the superimposed 3D models. We use this method to superimpose digital content over the required equipment.
- **World tracking** – this method maps a large part of the physical environment and enables the placement of digital content within the charted area. We use this method to superimpose 1:1 scale 3D model in a designated area (Figure 4).

**Remote assistance AR app:**

For the AR assistance app, we studied multiple solutions from the hardware and software point of view:

- **AR assistance using AR glasses for both the client and Maier’s expert.** Even though this solution is viable it has a big disadvantage. The client is obliged to purchase AR glasses compatible with the ones used by Maier’s experts. Moreover, AR glasses technology has its limitations (computing power, battery life, restricted mobility, etc.) and may violate some privacy and safety laws.
Figure 4. 1:1 scale model (mobile device screen capture)

- AR assistance where only the client uses AR glasses. This solution excludes the compatibility issues, but it does not eliminate the other disadvantages. Additionally, this approach may create supplementary issues regarding connectivity.
- AR assistance using two mobile devices. This approach seems to be the most viable, since almost anyone has access to a smartphone with internet connection.

Regarding the software, several options were tested, commercial (TeamViewer Pilot and Vuforia Chalk) and self-developed. We opted for the commercial solution for this kind of application for the following reasons: high infrastructure requirements, privacy and security concerns, support for multiple devices with different OS and automatic quality selection.

After testing the TeamViewer Pilot and Vuforia Chalk we opted for the Vuforia option due to the advanced 3D annotation possibilities. We have made several tests with the Vuforia Chalk during the remote consultancy sessions. We determined that by using the Vuforia Chalk it significantly improved the communication between us in comparison to a traditional videoconference (Figure 5).

RESULTS AND DISCUSSION

As a highly mediated technology, we expect that by using the AR marketing app at industrial fairs and in other events where there are interactions with potential customers, it will have a great positive influence on the client’s decision in using Maier’s equipment. However, another feature that the AR marketing app enables, is that the client can make a pre-validation (before purchasing and during the equipment production) which will test if the machine will fit, that it won't interfere with other equipment and that it is placed in an ergonomically corresponding position.
Currently the product exploitation and marketing AR app (Maier AR) is available on Apple’s App Store free of charge. By evaluating Apple’s App Analytics Data (Apple, 2019) for our app we can say that it has reached its expectations. Since its launch in 5th of June 2019 till 10th of August the app has been visualized in the App Store by 760 different devices from which 85 visited the product page (Figure 6). All these results were obtained without any marketing for the app.

We also expect that the AR remote assistance app will improve the communication with the clients when remote assistance is required, consequently lowering the intervention times. This translates into a drastically reduced maintenance time (with significantly reduced costs due to the travel expense) and higher uptimes.

Regarding the investment required to implement these AR apps, we can confirm that in our case is very low because we used existing equipment (smartphones and tablets). The only significant investment is the application development costs which include software development, CAD to AR 3D model conversion and the application maintenance and update costs. An operational costs estimation is: Apple Developer account (88EUR/year) for the marketing app; Remote assistance AR app services (from 25EUR/month); Up to 2 months a full-time payed employee that will have the task to maintain and upgrade the AR app.

The most important limitations that we encountered are due to the hardware limitations of the devices we used. E.g. some older smartphones got very hot when using the AR app and crashed. Additionally, we found out that the fluorescent lighting sources strongly interferes with the real-world tracking system due to the flicker rate that it’s invisible to the human eye but highly visible on a variable fps video capturing device (such as the one that we are using for AR).
CONCLUSIONS

From this experience we can conclude that academic research is greatly improved when it is applied in real use cases from industrial partners. During this project we encountered obstacles and developed solutions which in other surroundings would not have occurred. Regarding the developed application, it turns out that the product exploitation and marketing AR app increases the company’s popularity and will attract new clients in the future. Another major impact is that the AR remote assistance app improves the communication with the clients when providing remote instructions. This AR app enables Maier’s skilled employees to perform remote tasks with higher efficiency, lowering the time required for these operations thus lowering the intervention costs.

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