New Technologies as a Driver for Business Success

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Abstract—In Austria technical education is taught at federal secondary colleges of engineering (HTL) at a quite high level of ISCED 5. Despite mechanical engineering, design with industrial standard 3D programs being state of the art in industry and education, technologies using Internet of Things (IoT) and Augmented Reality (AR) are still at an early stage. This publication describes the introduction of the IoT platform Thingworx at Austrian HTL for mechanical engineering, with focus on AR and IoT from an educational perspective as well as the training aspects from the platform developers' perspective. Additionally, some diploma thesis with AR supplement and the experiences made so far are presented.

Keywords—Augmented Reality (AR), Internet of Things (IoT), Engineering education

1 Introduction

Through the development of technology, the products of today which are connected to the internet are quite complex and require a constant exchange of operational data via the Internet. For instance, passenger cars are a good example of how rapidly mechatronic products have been integrated with computing power, something that was unthinkable not so long ago. The computing power and connectivity possibilities that such devices contain provide brand new avenues for product development. Particularly when the customers have received the products and are first using it, we can obtain data which allows us to improve the next product generation's technology. In addition, AR can be used in product development and to support technicians and companies' staff in several service cases.

Porter and Heppelmann [1] describe the five different stages of industry boundaries, where product and smart product are state of the art. Currently smart connected product is on the focus list of every technology leader and should be from the authors perspective on the list for short-term educational implementation too.

Furthermore, interesting research work about IoT and AR has been conducted. For example AR for usability testing was done by Choi and Mittal [2]. They did not only do simple augmentation, they also undertook a project and conducted a survey about

AR in a very early stage of product development, and used different items like a play card or a 3d printed handheld to use the AR. Concerning IoT Abraham [3] did a project and survey in which they established IoT connections with the sensor data of the participating students' cellphones, whereas Cvjetkovic [4] developed an IoT project connected with Pocket Labs. Restivo and Cardoso [5] investigated the integration of AR and Virtual Reality (VR) into engineering education with several projects like an electrical circuit using AR, whereas the work of Elsaadany and Soliman [6] inquiries the alternate points of view of students, instructors and learning executives on IoT. They argue that IoT can transform the educational environment because of the increasing amount of accessible connected devices, which will lead to changes in students' and educators' behaviors.

The basis for IoT technologies is the increasing number of connected objects via the internet [7] (forecast 50 billion in 2020) as well as decreasing costs of sensors [8] (average sensor cost: \$1.30 in 2004 falling to \$0.38 in 2020) and the possibility to connect them via the Internet.

However, the disadvantage of IoT applications is the security aspect. Sensor and user data and their connection via cloud services to an IoT platform can be manipulated or be the target of cyber-attacks [9]. Bradley et al. [10, p. 67] describes some incidents of this.

The research question in this work is to screen the existing literature for best practise examples and additionally examine the extent to which the two technologies AR and IoT could be integrated into the curriculum and daily engineering lessons of the Austrian HTL in order to meet the requirements of industry regarding digitization.

2 Introducing IoT and AR to secondary colleges – An Educational Perspective

Since the future workforce in engineering will have to work with AR und IoT technologies and tools [7], there seems to be a chance to introduce it to students within their education. Fernandez-Miranda et al. [11] mention that "students will have to master the combination of mechanical engineering and IT". They also find that universities will educate the future workforce with the skills needed, but see a "close relationship between the competencies that the students acquire at the universities with the needed professional profile". Education at Austrian HTL with their compulsory internships seems to address exactly these topics.

Schuh et al. [7, p. 1390] mention several challenges in product development for Industry 4.0:

- "How should products and the product development be orientated?"
- "Which data is available and which role does it play?"
- "How is an Industry 4.0-specific communication and collaboration defined?"
- "Which resources, methods and tools are needed for Industry 4.0?"

Some might believe that classic approaches and methodologies could be substituted for by IoT technologies. Like the situation in the 90s as CAD technologies were introduced in industry and education, they did adopt the way we are designing machines. For example, hand sketching is still part of engineers' education, but creating technical drawings and documents is done with CAx technologies. Moreover, new jobs like IT technicians or CAD administrators were created. In connection with this Robertson and Radcliffe [12] investigated the impact of CAD tools on creative problem solving in engineering design. They found amongst other issues"… the strengths of the current, most widely used 3D mechanical CAD programs lie more at the detailed stage of design than the conceptual stage" The new IoT technologies will adopt and support engineering daily practice, and present new possibilities to engineers but of variable strength in the different stages of the development process

2.1 Use cases and benefits of using AR and IoT in engineering lessons

Especially for education of mechanical engineers there seem to be the opportunities to use AR and IoT technologies into the following daily engineering lessons:

- Mechanical engineering design education
- Laboratories
- General engineering education to explain the mechanical structures of a machine
- Workshops to create work or assembly instructions

Additionally, AR could for instance be used in general education to explain the sun system in a 3D model to students. From the authors perspective there seem to be some benefits in using AR and IoT technologies in engineering lessons:

- Good visualization of machines, equipment and maybe factories
- Good supplement for currently-used technical drawings, which are sometimes hard to understand
- Easy transfer of knowledge about how things are working
- Concerning the IoT platform Thingworx the benefits are:
- Usage of existing 3d CAD data of engineering design lessons
- No programming skills are needed to create an AR experience
- Creation of an AR experience is easy to do and very quick
- Sensor data can be accessed within the Thingworx platform

2.2 Challenges using AR and IoT Technologies

Whereas introducing AR to engineering design lessons is comparatively easy because of having a lot of 3D CAD data available, setting up and lecturing in an IoT lab is a challenge. Fig. 1 shows workflow regarding how 3d CAD data for AR and sensor data are collected and processed to generate an IoT experience available to users' mobile devices or HoloLens.

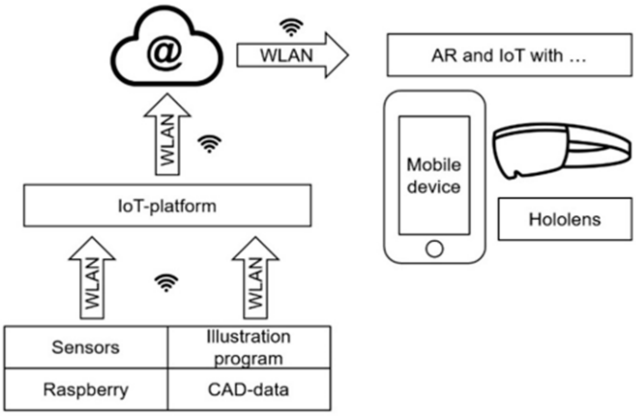

Fig. 1. AR and IoT with Thingworx

Unlike CAD programs, which are installed once a year by the user, the program Thingworx and the technology behind it is changing constantly, the web-application user-interface can even change overnight. Additionally, there is a lot of information available via the web, but few people with AR and IoT knowledge available – like every technology in its early stages, this is especially a problem if someone is seeking support or instructors. Unlike CAD software no company has years of experience with this kind of software and technology, this sometimes leads to a bottleneck related with instructors and support technicians.

2.3 Training courses for AR and IoT technologies at Austrian HTL

The aim is to introduce IoT and AR technologies in all HTL for mechanical engineering and industrial engineering in order to integrate current topics into teaching on the one hand and to increase the attractiveness of these branches of education on the other. With regard to the introduction, a task force of the Austrian Federal Ministry of Education was first formed with the aim of familiarizing themselves with the IoT and AR topics. For this purpose, a basic training course and an advanced training course were conducted. The IoT topics were trained using a Raspberry Pi with sensors connected with cables and an IoT training server (see Fig.2 left).

At the same time, a server was installed at the HTL Mödling which has been operated since then. For wider use in the approx. 35 HTL, colleagues from this task force will hold further internal training sessions, but with modified content, which is adapted to the HTL needs. The reason for using HTL teachers as instructors is that the number of instructors available for these technologies is also low in companies. 50 teachers are planned to participate in a basic training course in spring 2019. The aim is to integrate the IoT and AR topics with the academic year 2019/20 into the HTL in the classroom.

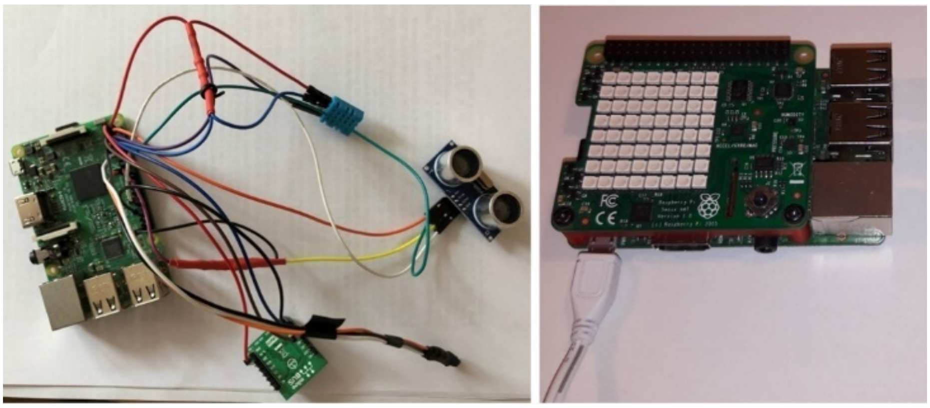

Fig. 2. Raspberry with sensors and cables (left), Raspberry Pi with sensor board (right)

With regard to the training environment, some changes will be made for the training courses in the academic year 2018/19 compared to the first training courses. The IoT server operated by HTL Mödling is intended as a platform for the IoT application and user administration. In addition to Raspberry Pi, an Arduino is also offered as a possible platform. Both the Raspberry Pi and the Arduino use a sensor board with approx. 5 sensors (see Fig. 2 right) instead of individual sensors with cables (see Fig. 2 left) which eliminates the wiring. The sensors on the boards are already configured and programmed for use in training, and the focus of the training itself is on integrating the sensors and their measured data. This is important for the authors because the training participants are mechanical and industrial engineers with limited programming knowledge. In addition, the authors expect these factors to increase acceptance of the IoT platform. Further training courses are planned for the next few years with the aim, among other things, of controlling actuators.

2.4 Integration of AR and IoT Technologies into Curriculum

There is currently an agreement with the Austrian Federal Ministry of Education to introduce AR and IoT in education at different HTL without changing the current curricula. The reason for this is the fact that a curriculum change sometimes takes several years and with the added risk that the changes made are no longer up-to-date. This is to be feared especially with such dynamic technologies as AR and IoT are. Additionally, the task force has worked out how AR and IoT technologies can be integrated into daily engineering lessons of all 5 years of HTL education. Besides using AR and IoT technologies in mechanical engineering design lessons, the focus is also on the areas of engineering workshops and laboratories. At least one aim is to establish an AR and IoT lab in the education of mechanical and industrial engineers. Additionally, AR and IoT present the possibility to establish remote laboratories. Andujar et al. [13] conducted some research work about remote laboratories for electrical engineering and reported their findings which are referenced here.

3 Diploma Thesis for New Technologies

3.1 IoT - Implementation in the mechanical engineering environment

Augmented reality, virtual reality glasses and the Internet of Things (IoT) are widespread today and are already integrated into the life of most people. Digitization is progressing steadily, also in the mechanical engineering world [14]. Therefore, this diploma thesis has taken up this topic and intends to combine the core competences that are taught at the HTL with the Internet of Things and augmented reality. For this purpose, the diploma thesis was divided into three sub-topics to provide demanding exercises for the 1st to the 5th grades.

It is the authors aim to test the new technologies with a research pilot project including several diploma projects to get knowledge if the AR and IoT technologies are feasible for secondary engineering students and have the potential to provide additional valuable content to the existing curriculum.

Mount for a roll of splicing tape: First grade students produce a mount for a roll of splicing tape in the workshop. It is difficult for them to understand technical drawings and the production steps because they have no experience in the technical field. Therefore, AR is used as a teaching aid for better understanding [15]. The students have to design a 3D model of the mount with the help of a CAD program in the theoretical lessons. Here augmented reality helps to visualize the product with the help of a mobile phone (see Fig. 3 left). The assembly of the mount is augmented as well, to make them understand the steps which have to be done in the workshop (see Fig. 3 right).

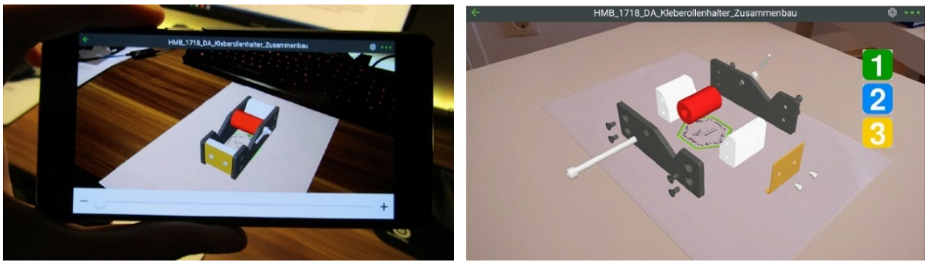

Fig. 3. 3D model data AR at the workplace of a student (left), The AR assembly steps (right)

In the last step the production process has to be included in the digitization, and for this purpose, videos of each stage were made in the workshop. They are stored in a cloud and can be downloaded via the augmented reality (see Fig 4).

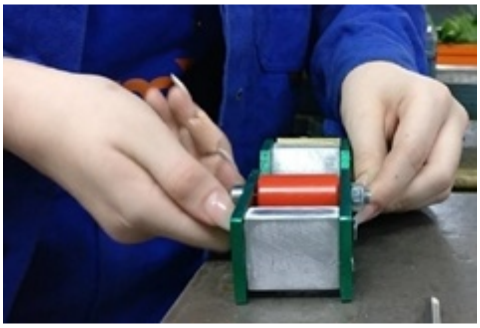

Fig. 4. Production process videos

Electrically driven skateboard: This project is used in the theoretical electrical engineering and programming lessons. An ordinary skateboard is electrified, and sensors are attached to monitor the current status. First of all, the electric parts, like the motor, cables and batteries, are assembled on the skateboard (see Fig. 5 left), which is then designed in a CAD program to get an augmented reality (see Fig. 5 right).

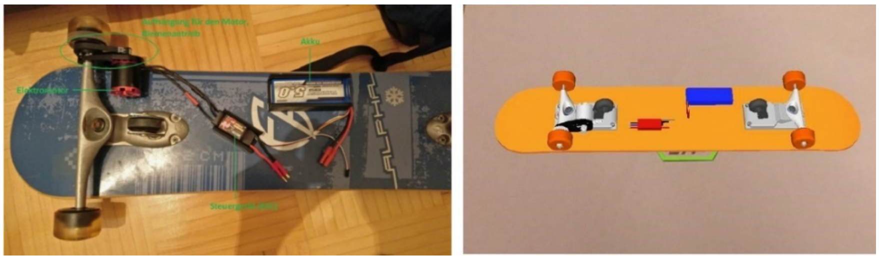

Fig. 5. Electrically driven skateboard (left), Augmentation of the skateboard (right)

In the last step sensors (GPS, speed and temperature) are attached to the skateboard. The data can be visualized in the augmented reality and retrieved all over the world (see Fig. 6).

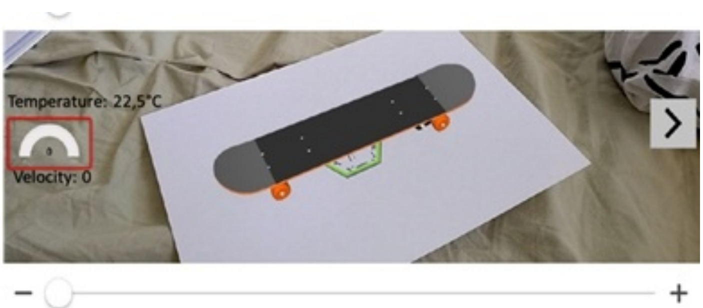

Fig. 6. Augmented sensor values

Automated cocktail machine: For the last grades a mixing cocktail machine (Fig. 7) was designed and constructed. The main goal of this project is to get to the level of in-depth programming and to create handling objects in the augmented reality to control the machine via the Internet.

Fig. 7. Cocktail machine

First, the mixing machine is programmed in one of the laboratory lessons. After this, an augmented reality is created and handling objects in the augmented reality are used to call the programmed algorithm via the Internet. In the end the cup can be positioned under every bottle and various cocktails can be mixed. This can be done with a smart phone.

3.2 Internet of vehicle demo system for autonomous driving exercises

The purpose of one diploma thesis project in the department of mechanical engineering at TGM in Vienna was to devise a modular demo system (see Fig. 8), which allows experiments and gaining experiences in fully automated cars [15]. The modular design offers different scenarios. It is easy to enlarge and carry. Active elements like traffic lights enable the controller to represent situations realistically. Each unit of the entire demo system consists of microcontrollers and an intelligent bus system and each module can be exchanged with anyone to design virtual traffic situations.

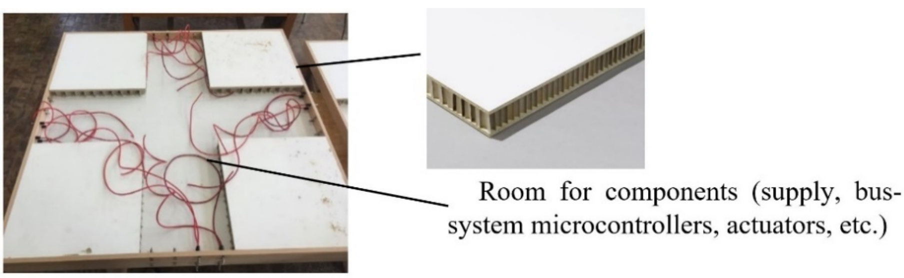

Fig. 8. Prototype with cross section (bottom view)

Each module is supposed to represent a particular exercise concerning autonomous driving, for example:

- Various crossroads
- Motion within a roundabout
- Self-parking

As mentioned above, this flexible model plant is easily expandable, and the functions of new sensors, actuators and communication systems can be tested as well.

The modules and the cars (see Fig. 9) are provided with different built-in sensors and actuators.

Fig. 9. Prototype of the model car and circuit diagram

This demo system (see Fig. 10) can be utilised in the classroom so that the students can gradually get used to the complicated issue of internet of vehicles.

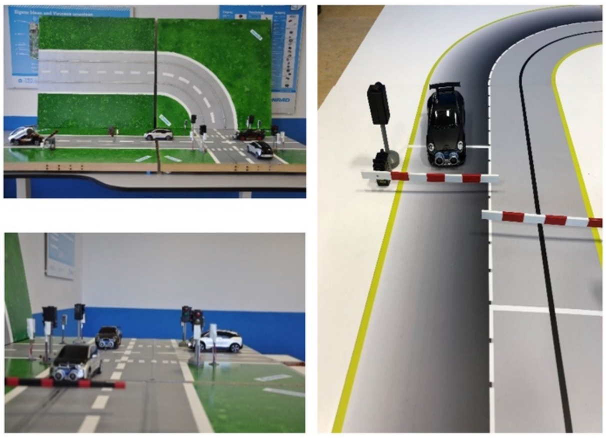

Fig. 10. Demo System for autonomous driving

4 Conclusion and Outlook

Augmented Reality and Internet of Things are in their initial phase at Austrian secondary colleges of engineering (HTL). Though the first steps are (like every new technology) quite interesting and labor-intensive, these technologies might have a positive impact on engineering education, from the author´s perception, especially in mechanical engineering. The opportunities to introduce the technologies into daily engineering lessons have been determined, attempts to use them without any changes in existing mechanical engineering curricula at HTL are being made. In these diploma thesis, examples of various projects in the mechanical field were generated to teach Augmented Reality to students of every grade. These examples are introduced in theoretical and practical lessons and are the first step for students of the TGM to get a deeper insight into in the field of Augmented Reality and Internet of Things. In the next few years new and previous projects will be dealt with in classes. Therefore, the authors hope that the use of these technologies will make mechanical engineering more attractive for potential students, since this core field of engineering is presented in a new and modern way without old fashioned prejudices, so that male *and* female students are being addressed.

The industry, experts, as well as the Austrian Economic Chamber have conducted several surveys in order to ascertain the requirements of the market to adapt the vocational education to these new demands.

The new focus lies on digitalization ranging from the areas of smart cities, smart buildings, and autonomous mobility to smart industrial plants including augmented reality.

Accordingly, a new curriculum named "New Technologies and Smart Mechanics" has been developed and taken effect at the beginning of the year 2018/19 at TGM. It has been well received by the students.

The program is being scientifically evaluated. The findings of this assessment are going to be integrated into the new standardized curriculum.

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