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Procedia CIRP 84 (2019) 341–346

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29th CIRP Design 2019 (CIRP Design 2019)

Student driven learning in Synthetic Environments

R.G.J. Damgrave*, E. Lutters

University of Twente, Department of Design Production and Management, Drienerlolaan 5, 7522NB Enschede, the Netherlands

* Corresponding author. Tel.: +31-53-489-5364. *E-mail address:* r.g.j.damgrave@utwente.nl

Abstract

113 master students of multiple engineering study backgrounds were challenged to develop solutions for the Fraunhofer Project Center at the University of Twente (FPC@UT). In 20 groups the students had to develop a synthetic environment to monitor, manage and control a pilot plant or virtual factory. The assignment was carried out in the context of the study Industrial Design Engineering, in the course 'Virtual Reality'. During the course the students had to provide a strategic, yet concrete proposal and demonstrator on how to realize a solution using virtual and augmented reality technology and to find balance between generic tools and specific applications. The students had the Virtual Reality Lab and Smart Industry Lab to their disposal during this 10 week, 5 ECTS, course. Based on a brief introduction by the FPC@UT the students had to set their own goals and deliverables and convince the client that their envisaged solution would be beneficial. The course is based on student driven learning, in combination with project led education. This resulted in a situation where the students were in charge of their education and had to decide for themselves which knowledge and feedback they would need in order to achieve their deliverables. Eventually the resulted solutions could be used by FPC@UT to further integrate in their (future) clients.

Peer-review under responsibility of the scientific committee of the CIRP Design Conference 2019.

Keywords: Digital twin; Virtual Reality; Virtual factory; Engineering education

1. Introduction

The broad context of Industry 4.0 (I4.0) requires a well-thought educational approach, where students learn how to make decisions in such a way that they can deal with uncertainty, unpredictability and risks. Understanding the possibilities of current and future technology, and the impact changes have on existing environments is essential for a future engineer. Being able to make a well-thought decision between available options, while not being limited by a single stakeholder perspective.

Smart manufacturing systems, such as Industry 4.0, require engineers to deal with a large variety of data, and challenge them to make this data insightful and instrumental [1, 2]. Based on for example simulations, historical data and what-if analyses the effects of future changes and possibilities can be examined in a virtual environment. Virtual dashboards [3] are on the frontier of enhancing the potential of pilot plants, while technologies such as Virtual Reality (VR), Augmented Reality (AR), Cyber-Physical Systems (CPS) and the Internet of Things (IoT) increase the availability of data and the communication thereof. Collaboration between different stakeholders requires insight and understanding of different perspectives, while the seamless blend between real and virtual elements allows for tailoring information and the way it is presented. The use of Synthetic Environments (SE) as design environment bring together real and virtual components to allow for adequately experiencing shared information [4]. They range from small setups, representing e.g. working with a new machine, to large systems for the conjoint development of an aircraft interior. SEs are composed out of a wide variety of tools, techniques, hardware and software components.

This artificial environment represents an alternative reality, which acts as commensurable to a real environment as required. This alternative reality uses both virtual and augmented reality techniques to allow the various stakeholders to interact with it (e.g. make adjustments to it) in a way that is easier, more transparent, more purposeful and more controllable than in

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Peer-review under responsibility of the scientific committee of the CIRP Design Conference 2019.
10.1016/j.procir.2019.03.270

reality, while requiring less effort. This makes it possible to quickly evaluate multiple configurations, and also to review the consequences of possible choices. A SE can be adjusted while it is in use in real time and it therefore allows stakeholders to deal with design information in an interactive way. Therefore, it is easier to evaluate features and experiences under a wide variety of circumstances. As a result, the stakeholders become more conscious of their decisions and the related interdependencies. This is mainly because the information is presented to every stakeholder in an understandable format/way that is independent from the stakeholder's background or expertise.

2. Project scope and set-up

The University of Twente (UT) started an educational program on Industrial Design Engineering (IDE) in 2001. The mission and intended learning outcomes of the Master's programme IDE purposefully position Industrial Design Engineering as a strongly interdisciplinary domain. Since 2010 the master's programme of IDE offers a specific course on Virtual Reality. The course aims at exploring the possibilities of virtual reality tools and solutions by making the combination between theoretical knowledge and background and practical application. The focus is on the integration and combination of available VR tools, rather than developing new ones. These tools include different possibilities to stimulate the visual, aural and tangible human senses. During the course the students must develop the best fitting virtual solution for a case provided by an external company. The main challenge is the conversion of a theory to a workable situation using virtual tools of among others the Virtual Reality Lab and Smart Industry Lab of the University of Twente (VR/SI-lab) [5].

While keeping in mind that the virtual tools should support, and not obstruct, the involved stakeholders. The term 'virtual reality` includes all kinds of digital tools varying from a simple display to a full-blown 3D environment. The students will have the opportunity to try to find new applications for technologies available inside and outside the lab environment, and create new tools for product development projects. Based on (guest) lectures, workshops and consultancy meetings the students work on a thorough description of the virtual tool and functional prototype, while taking into account aspects such as product life cycle, information management, multi-user environments and interaction possibilities.

The learning goals of the course are

1. Interpret the role of virtual reality in product development
2. Identify communication and collaboration issues in a specific case study
3. Analyse which forms of virtual reality apply to a provided case
4. Convert functional specification into technical demands for a virtual reality tool
5. Relate different virtual reality tools to specific use situations
6. Compose a virtual reality solution for a chosen use situation
7. Design a virtual reality environment fitting the proposed virtual reality solution
8. Apply virtual reality in a professional environment
9. Evaluate a virtual reality solution

The extend of the course is 5 ECTS per student, which is spend over a time period of 10 weeks, starting in April. The course is part of the IDE masters' programme but is open for students who already have background knowledge on product development, CAD modelling and design methods. Most of the participated students have an engineering background.

The course objectives are:

- Exploring the possibilities of virtual tools in the context of engineering and product development
- Making the combination between theoretical knowledge and background & practical application with the focus on the integration and combination of available techniques, rather than developing new ones.
- Create new VR solutions by combining existing tools with while taking into account aspects such as: product life cycle, information management, multi-user environments, interaction possibilities, etc.

The structure of the course builds on project-led education [6, 7], mainly to immerse students quicker and more profoundly in the field of expertise they are educated in. With the emphasis on design methodologies and problem-solving strategies underpinned by a solid theoretical foundation. The course is based on the philosophy of 'Student Driven Learning' (SDL) [8]: education that is not fully pre-structured, where the student takes control and ownership of his/her own learning. This implies that the students and teachers have a conjoint responsibility in education and learning [9]. The different subjects of the course should form an integrated whole, where each element contributes to this, and makes use of the knowledge and skills of other elements. Moreover, the form of education should support a dynamic atmosphere in which student and teacher can adapt to each other. With this, the student influences multiple aspects of learning, such as planning and ways of learning, but also learning goal. This obviously requires significant attention for communication, guidance and feedback between the teaching staff (including researchers) and students. For example, feedback given by professors is no longer limited to the specific field of expertise, but also addresses the learning process itself. While actual research or design questions should directly be integrated in the lectures. The teacher is not positioned as an expert in the complete field of Virtual Reality (no 'sage-on-the-stage'), but elaborates his role in the desired synergy of multiple engineers (the 'guide-on-the-side') [10]. Student are allowed (or even challenged) to alter the course and content of meetings, based on the developing needs of the student. This requires a flexible organization in terms of form of education, and content of lectures – not to mention the required mental agility of the teaching staff [11]. The educational model of this course is based on the use of a lab environment. In this setting, the lab is often available for the students, and all organized and non-organized education will be provided in this environment.

2.1 Didactic approach and learning goals

The assignment of this course challenges the students to develop a VR-solution for a specific client. The students are requested to not only develop a physical working demonstrator of the proposed solution, but also explain the trajectory towards it. The main focus is on determining the desired functionality of a VR-solution, isolated from the current technologically possibilities. Since the developments in the field of VR technologies and devices are at such a high speed, the focus must not lay in becoming a master in the use of a certain VR device. On the contrary, the focus is especially on mastering the process of recognizing a certain need and converting that into the desired functionality a Synthetic Environment should contain. In a second phase a selection must be made from the current available VR technologies and devices to come to the most appropriate solution possible at this moment. The rational of the selection of appropriate tools is essential. This also implies that the developed demonstratable final solution is not the only possible configuration that will lead to the desired functionally, nor is it the best possible or most ideal configuration. Over time new possibilities will arise that enable new configuration to be realized that will even better fit the desired functionality.

The implementation of VR in industry is the scope of this course, therefore the conversion of the theoretic determined desired functionality towards a practical working setup to demonstrate the expected added value, is important. The students themselves have to determine the boundary conditions for their solution. These boundaries have to be underpinned to position the VR-solution in the broad scope of industry. The students are supported in this by providing them an supporting structure presented in a blueprint visualized in figure 1 [4]. This triggers to students to determine the requirements and set the boundaries on the following subjects:

- Hardware
- Software
- Users
- Information
- Knowledge
- Resources
- Environment
- Workflow
- Working methods

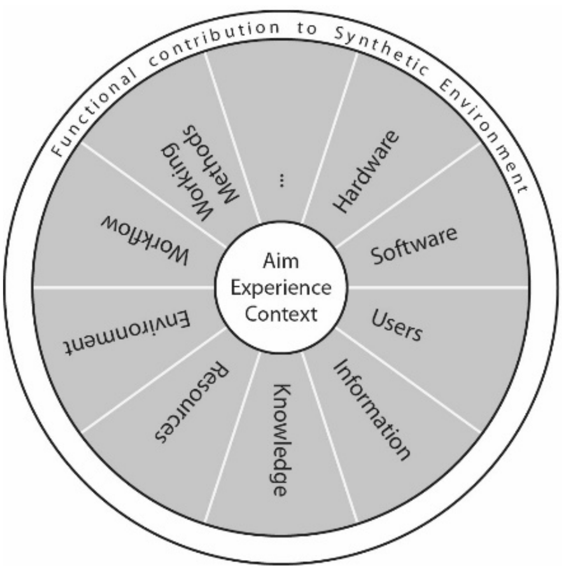

Fig. 1. Blueprint to structure relevant requirements

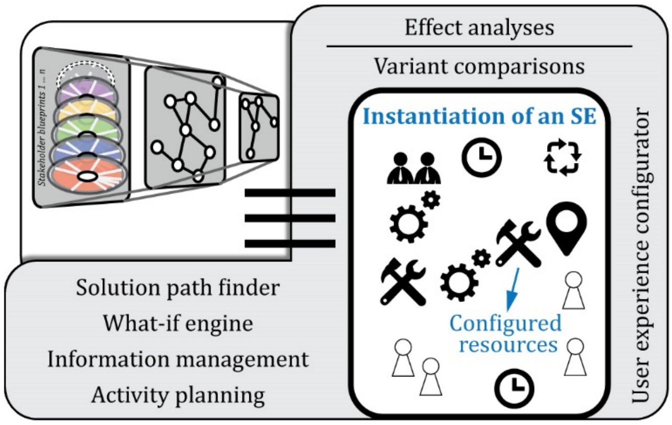

Fig. 2. Provided Synthetic Environment architecture

The provided architecture in figure 2 [4] only indicates possible decisions the students need to make, but does not force a certain trajectory, methodology or process. Nevertheless, the students will be forced to find and realize combinations between the above-mentioned items.

Each group presents the results of the project in a digital explanation. The explanation contains all information that is required to explain and underpin the design rational of the final VR-solution that has been developed. The final VR-solution is the overall concept including the requirements and boundaries. It describes possible variants; the conversion of the idea to a practical demonstration and realisation, a description of the approach and underlaying framework/architecture of solution. Furthermore, it contains advice for client on how to integrate this in future environments, to what extend this can be tailored and what the dependencies are. Based on the test session the students also have to give an indication on robustness and flexibility of their solution.

The assessment criteria of the course are divided in seven different criteria, assessed on a scale from 1-10, with a certain weight on the final grade.

- Foundation of chosen subject (5%)
  Which design phase, recognition and ratification of problem
- Conversion of problem into solution (30%)
  Necessary information/data, Desirable interaction, input/output possibilities
- Construction of the VR-solution (30%)
  Selection and combination of items
- Translation of VR-solution into workable setting (15%)
  Selection and combination of tools
- Test (5%)
  Method of testing, review of the design
- Final design (10%)
- Report and communication (5%)

2.2 Setup

During the kick-off meeting of the course the students get acquainted within the field of Virtual Reality. The meeting starts with a two-hour introduction that starts with explaining what is considered VR, directly followed with sections discussing why we want or need VR, discovering where VR could help, explanation of the fundamentals of VR and closing with the topic of ‘when to use VR’. After this last topic the students are briefed about their assignment. More details about the assignment is provided in chapter 3. The students have to work on this assignment as a group of 5 or 6 students.

In this course many of the responsibilities are with the students themselves. Students are expected to have a critical attitude during their studies, which makes them more conscious about the decisions they make. Every decision or activity should be well-thought and it should be clear why that step is the most appropriate activity regarding the expected outcome. Students are challenged to understand how to make choices and what the impact and consequences of it will be.

In the VR course this starts with the composition of the groups. This is performed by the students themselves and is done after the first lecture. In the composition of groups there are no rules regarding the background of the students. This results in groups consisting of students from all the same study programmes, up to groups consisting of students from five different study programmes. The composition of the group will already influence the scope and direction of the team. The students have to complete the group composition in one day.

After the kick-off the students have to work on an assignment proposal (figure 3) in which they describe what they will developed for the project and what their deliverables will be. This description has to be handed in and presented – using only one sheet - to all the groups after one week. This assignment proposal will be the starting point for the further activities of the group. Throughout the first four weeks three additional lectures are organised which go more into depth in certain topic regarding VR, but will also broaden the scope by incorporating information regarding the link of VR with different topics such as the Internet of Things (IoT) and Industry 4.0. Throughout all the ten weeks the students are free to use the VR/SI-Lab for two days a week. All the VR equipment in the lab is available to the students, but no explanation about every device will be given; the students must find out how to integrate the devices themselves.

Since the focus of the course is not only on realizing or building a certain VR experience, but mainly on the process towards the VR solution is more important, the students first have to present what their solution should offer, independent of technology or devices. Furthermore, the final deliverables ought to be proposed and a first impression of the practical implementation should be given. This process of decision making is something the groups have to explain to all other groups during a 5-minute mid-term presentation after 5 weeks. During this presentation all the other groups are present, as well as the company providing the assignment. After each presentation there is 5 minutes time for questioning and discussing the proposed solution and rational behind it.

After this mid-term presentation the students have 4 weeks left to work towards a workable demonstrator and the documentation thereof. A demonstration session is organized during the last meeting of the course. In this session each group has 20 minutes to give a demonstration of their VR solution to the client. This demonstratable VR-solution is build by the students themselves by integrating software, hardware and data in order to communicate the desired final experience and benefit of the VR-solution.

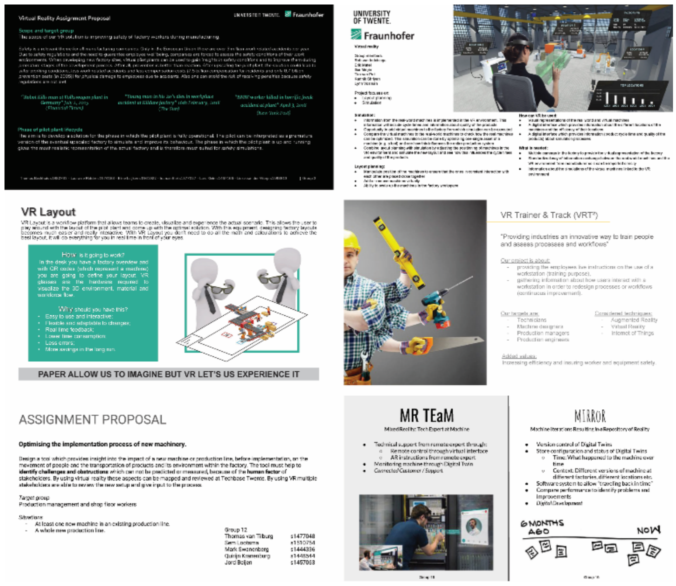

Fig. 3. Selection of proposals

The last week of the course is used to finalize the documentation of the solution. This documentation should be handed in as digital explanation, including the possibility to share the results digitally with the client. Also the results from the demonstration test session should be included in this deliverable. The client should be able to continue the work on the proposed solution and the first upcoming steps need to be clearly communicated.

2.3 Resources

The resources offered to the students consist of the information provided in the sheets of the lectures, complemented with a selection of relevant publications provided via the digital learning environment. These publications can be used as background material but are not mandatory to incorporate in the final solution. Part of the course is also that the students themselves find relevant articles and make optimal use of them. Furthermore, during the two days a week when the VR/SI-Lab is available the lectures of the course will be available to provide feedback and support. The student groups are free to select themselves if the make use of these consultancy-moments, the lectures will not actively monitor the progress of the groups between the organised presentation sessions. If a group needs any additional information from the client, the students are free to make contact with the client themselves. Since the students work on an open assignment; the students decide themselves what to do and where to be assessed on.

3. Contextualization: company involvement

Since the structure of the course builds on project led education, the provided subject for the project is of utmost importance. The course adopts an educational concept with an increased focus on autonomous study and the attitude this requires. The ability to discern, plan, prioritise, monitor, execute and evaluate work is assumed to be an implicit and obvious capability of a master’s student. Within the topic of Industry 4.0 and Synthetic Environment the involvement of external parties providing the assignment keeps the link to industrial application as short as possible. An external company is for both the students and lectures the desirable since they will bring a relevant and actual problem to the students and can provide unprepared questions to the students. Compared to a complete internally design assignment this has more unpredictability and uncertainty involved. This will challenge the students more to ask the right questions to the client and to gain more understanding on the consequences and implications certain decisions will have. The developed solutions of the students should be aligned with the current available possibilities within industry and must include an implementation plan. This is all more realistic with the involvement of a company, which is in return for the company also a very useful project that should lead to new insight and solutions.

The topic of the 2018 project was provided by the Fraunhofer Project Center at the University of Twente (FPC@UT). During the kick-off meeting (figure 4) the company introduced themselves to the student and presented the assignment.

FPC@UT asked the students to develop support for the development of pilot plants and virtual factories, with the use of technologies in the field of Synthetic Environments. More specific the assignment asks to develop a cockpit to monitor/manage/control a pilot plant and/or virtual factory. The students had to provide a strategic, yet concrete proposal and demonstrator on how to achieve this with technologies such as AR/VR/IoT. The balance should be found between generic tools and specific applications. The solution should enable control and view of, and interaction with, the factory from a distance. The questions asked to the students were regarding what is needed to know by the user in order to make the solution instrumental. This also leads to questions such as what kind of information dashboard should be most effective for this, what kind of sensors are needed to achieve the solution and what is most important to control.

The assignment focusses on creating the framework and overview of the potential solution. The selection of currently fitting hardware, software and methods should just be an outcome of the current state. It is important to communicate the dependencies of the solution and mention the required input and desired output. Furthermore, the consequences for the factory, such as changes for current workflow and methods and timeline for integration should be part of the deliverable.

The company is very much interested in the robustness of the system. An often-asked question was on how predictable the behaviour of the solution will be, and how flexible the solution is to adapt to changing conditions. Since the assignment is very broad, the students had to find application area themselves, but were asked to keep their eyes open on how this would fit the perspective of different stakeholders. Understanding the impact on different aggregation levels is hereby essential.

A clear implementation plan should be provided, including a clear statement on what data is needed to make the solution work, and how to know what the right data is. The same applies for required knowledge, an approach to understand what knowledge is available and what should be available is part of the solution.

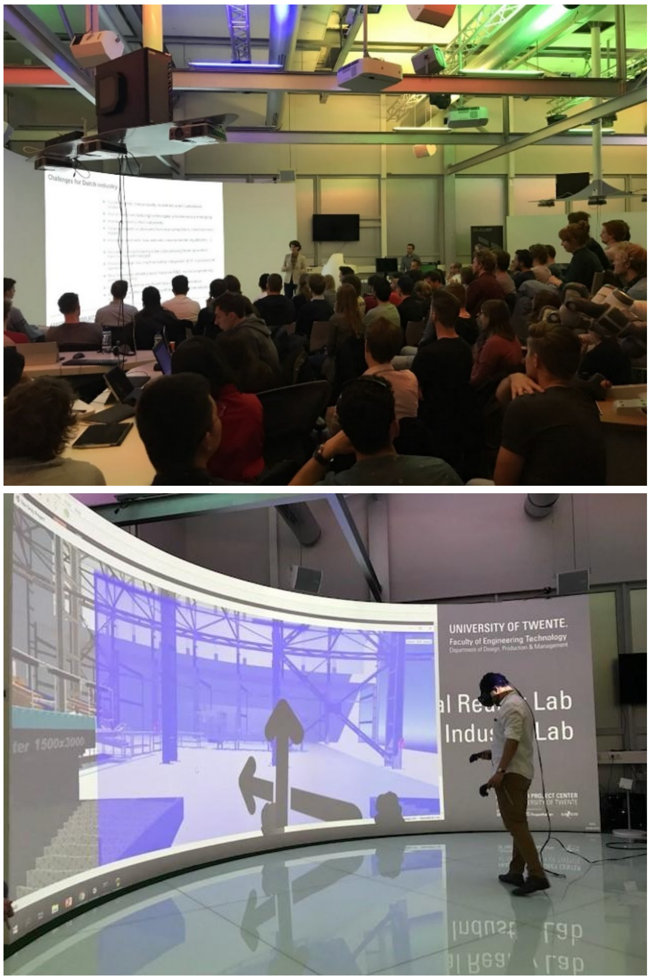

Fig. 4. Impression of the meetings

To support the students with the process lectures were organized that covered topics regarding Digital Twin, IoT, Virtual Dashboards, Synthetic Environments and Pilot Plants. All the organised lectures were focussed on configuring the solutions as reusable items for the future of FPC@UT. The developed solutions, and their demonstrators, were considered as reconfigurable building blocks that could be tailored to fit a more specific use condition and could be further improved in the upcoming future.

4. Conclusion

Eventually 20 project groups, with a total of 113 students, finished the course by handing in their digital explanation and providing a workable demonstrator (figure 5). An impression of the results is visible in figure 4. During the test session three employees of FPC@UT tested the solutions and provided feedback on the experience. The results of three of the project groups were used during an AR/VR-event organized by FPC@UT three weeks after the course deadline. The results from these projects were on such a level that FPC@UT was able to directly use them as a showcase on how Synthetic Environments can support the development of pilot plants and virtual factories.

Giving the students a lot of responsibility throughout the course led to a situation where students were extreme critical about every step they made during the process. Since the field of industry 4.0 is extremely broad, it is not possible to make students expert in the field within only one course. Nevertheless, focusing the course on realizing Synthetic Environments which should be able to be directly integrated in an industry setting made the students encounter many different elements, perspectives and opinion on this complexity. Since the realized Synthetic Environments are described as one potential instantiation of a desired solution, the most promising results can be further developed by others. Every realized solution adds up to a repository of potential solutions including their characteristics and potential.

From the client perspective the critical questions by the students, and the open-minded approach were considered highly valuable. The combination of multiple students with different educational background leads to a better understanding of the impact of decisions and changes. It also made the students more capable of dealing with uncertainty, unpredictability and risk management.

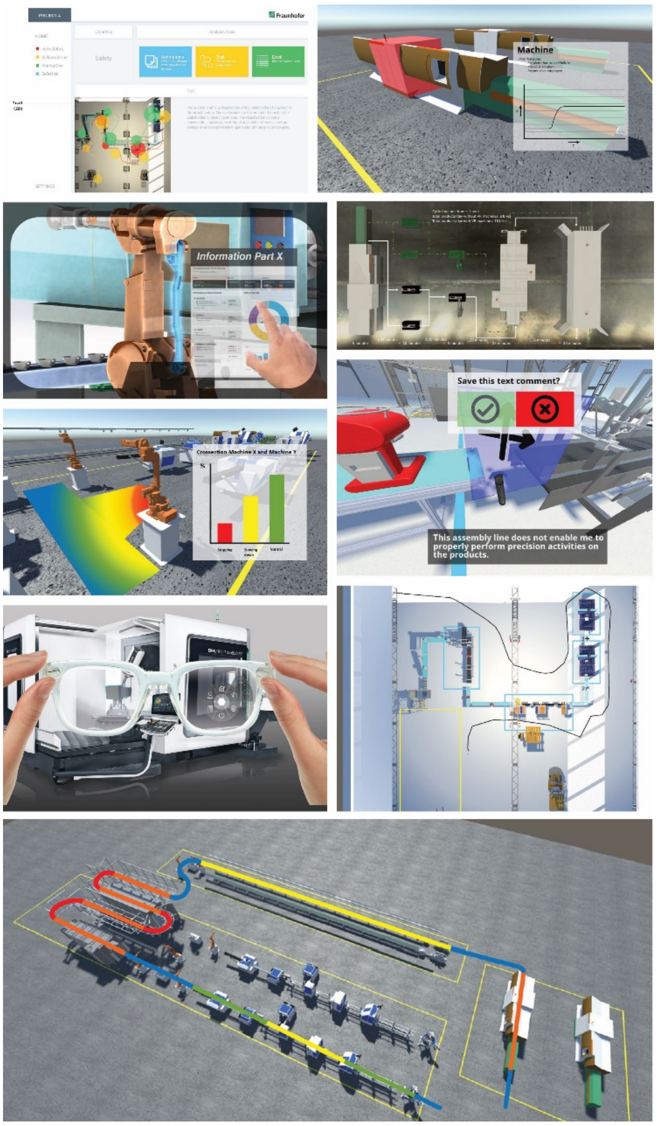

Fig. 5. Impression of resulting solutions

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