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Using Virtual Reality for scenario-based Responsible Research and Innovation approach for Human Robot Co-production

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***Abstract*—This paper proposes to use Virtual Reality scenarios to explore the reaction of stakeholders within an innovation process in the context of the introduction of robots working in close collaboration with users. The goal is to design the system upfront in such a way, that it is not perceived as a threat to the worker or his/her job. Within the responsible research and innovation approach, the introduction of new technology needs to be accompanied by a careful investigation of the thoughts and feelings of all stakeholders. Especially workers who are currently not working with robots but their workspace is currently undergoing an Industry 4.0 driven transformation, experience fear, that this new technology will make their jobs redundant. On the other hand, it can be observed, that successful robot interaction processes, on the one hand, increase the overall productivity, but also can enhance human well-being. The feeling of "teamwork" with the artificial intelligence entity can develop to be equally positive and motivating. To be able to design future workspaces which will result in a "teamwork" perception instead of the "fear" perception, the use of VR can be applied.**

1. Introduction

Through the accelerating digitization and the resulting changes in everybody's private and work life, the general public is discussing more and more the following question: How does the future of society and work look like in this industrial revolution, digital change, age of artificial intelligence? There are a lot of studies pointing in different directions, which makes it complicated to forge an opinion or even to analyze the situation. Some people expect very negative results, for example, the decline of jobs because of the digitization or even the entire substitution from human labor through robots. Others (and among them the authors) aim to take advantage of this change to improve the situation of the workers and use technology, which is tailored around the humans working in factories and their needs. The discussion on "Industry 4.0" and the digitization of production was and is ten years after the creation of this term very much technology-driven. It has created a lot of impact with a multitude of research funding programs and a huge sum on industrial investment. This has made a lot of research possible – with a strong focus on engineering science. If the underlying idea of an "industrial revolution" is analyzed in more detail, the implication does not only cover technological change but also has a deep influence on work and organization structures [1]. We aim at forming a human-centered design research partnership to investigate the positive effect of next-generation human-computer interaction technology on factory workers.

It is already foreseeable, that the German "Industry 4.0" initiative and corresponding international activities (e.g. Smart Manufacturing, USA Smart Factory, South Korea) will transform the industrial work environment until 2025 [2]. Although this will result in a transformation of labor, it will not necessarily result in a decreasing amount of jobs. Since a lot of attempts to completely automating factories have failed, there are strong indications that human labor will still play a crucial role in the "smart factories" of the future. As Thomas Sheridan puts it 2016 [3]: "All robots for the foreseeable future will be controlled by humans", which is a strong antithesis to the "singularity" thesis [4]. There are more differentiated views in modern AI Safety research [5], particularly about what "meaningful human control" is and its implications for AI safety.

In the upcoming years, it can be foreseen, that the main part of the demographic change will happen, especially in Europe and Japan, which leads to a higher average age of the population and less young "digital natives" who can use new interaction methods within an increasingly complex production environment. Immigration is eventually able to compensate for this but brings the necessity to include new workers with a high variety of skills and cultural background [2]. Furthermore, under the buzzword "re-skilling", the demand for worker qualification for new technologies has been found [6].

As production in Europe needs to cope with i) technological change and ii) social change, it is justified to regard particularly the "smart factories" as socio-technical systems and to understand the role of the "operator 4.0" within this evolving environment, the "human cyber-physical production system" (H-CPPS), which enables a dynamic interaction between humans and machines with the help of "intelligent" human-machine interfaces [7].

Technology can be the vehicle to help people to remain successful and self-determined in a modern manufacturing environment. It is a challenge to design H-CPPS and the accompanying human-computer interaction techniques so that they fit the operators' cognitive and physical needs, and improve human physical-, sensing- and cognitive-capabilities. A possibility to overcome this challenge is embedding the development process in a consequent responsible research and innovation approach (RRI).

In this paper, we present a preliminary concept to use Virtual Reality scenario building, which can be used within a multi-stakeholder assessment approach within a responsible research and innovation process. The goal of the process is to get feedback from stakeholders, especially from workers, on the envisioned H-CPPS. Furthermore, the 3D environment will be used to test visualization methods, whether they are suited to develop a "shared mental model" with the machine.

2. Related Work

2.1. Responsible Research and Innovation

Companies have traditionally focused on making profits. Yet the implementation of Responsible research and innovation (RRI) in industrial companies, i.e. values and goals going beyond the company's profits, is still in its infancy [8]. The approach tries to connect RRI with the firm's strategy in order to develop its corporate social responsibilities. This is realized by including all stakeholders' values. In particular, it needs to be considered, how the company can include the values of (potential) employees when employing robots in production processes and when enabling human-machine interactions.

A first suggestion of how to implement RRI in firms' strategies was provided by [8] in suggesting relevant tools and approaches. This encompasses anticipation (like scenario building), inclusiveness (like stakeholder dialogues), reflexivity (i.e. core values), responsiveness to values and needs (i.e. value sensitive design), and responsiveness to new developments (i.e. flexible and adaptive design). Furthermore, key performance indicators for RRI have been defined: diversity & inclusion, anticipation and reflection, responsiveness and adaptive change, openness and transparency, environment sustainability, and social sustainability.

Our larger aim is to develop a RRI system approach for the use of robots, which would help addressing inclusivity goals of using robots in a systematic way. The overall research question this project part would systematically address is: How can the firm implement RRI in its strategy in a modular and open way? So far only few firms have undertaken de facto RRI activities in an unsystematic way. Yet an integral view of RRI in a business context, i.e. where RRI would be connected to firms' strategies and address their corporate social responsibilities has not been developed yet. This would mean that a firm would have to consider how RRI could add value for its strategy and activities.

2.2. Virtual Reality for scenario building

If we want to enquire a possible envisioned future, the method of scenario building [9] can be used. Here the stakeholders are presented different variants of an envisioned future scenario and can react on it. The method is for example widely applied for customer product design [10].

Virtual Reality describes a real or simulated environment in which a perceiver experiences telepresence [11]. The perceiver immerses him- or herself in the displayed environment with the optimal outcome of completely believing that the environment is real.

It has been proven to be applied for successful scenario building, because the high immersion of the human being can provide valuable insights for an envisioned situation or design. This has been verified for different application areas, for example landscape design [12]. Within the context of this paper, the application of VR within Industry 4.0 scenarios is especially interesting, on which an overview can be found in [13]. This overview is limited to discrete event simulation, but there are also additional use cases for AR/VR within the socio-technical work system, for example, the technology has been used for production planning [14], [15].

Especially within social robotics, the use of virtual scenarios is already very common to study the reaction of human users towards robots. There is for example an active workshop on applying Mixed Reality methods for HRI research [16]. For the application within an manufacturing environment, the method has already been proven to be valuable for the research on interaction with industrial robots [16], [17].

There are a couple of first publications that use Virtual Reality in the context of ethics - mainly in an educative purpose, for example for environmental ethics [18]. We hope that we can contribute to use the Virtual Reality based scenario building within the manufacturing domain in order to be able to design the future of work in such a way, that the overall system performance, but also the human well-being can be optimized.

3. Approach

The underlying problem of human robot co-production is the adaption of the robotic system towards the needs of the workers while optimizing overall system performance and human well-being. There is large discussion on how to embed values into an artificial intelligence entity like robotic algorithms and how to forge the capabilities of the human on the one side and the technical AI system on the other side into a combined "hybrid intelligence" system.

Our approach is displayed in Figure 1 and will be further detailed in the following section. The envisioned situation of

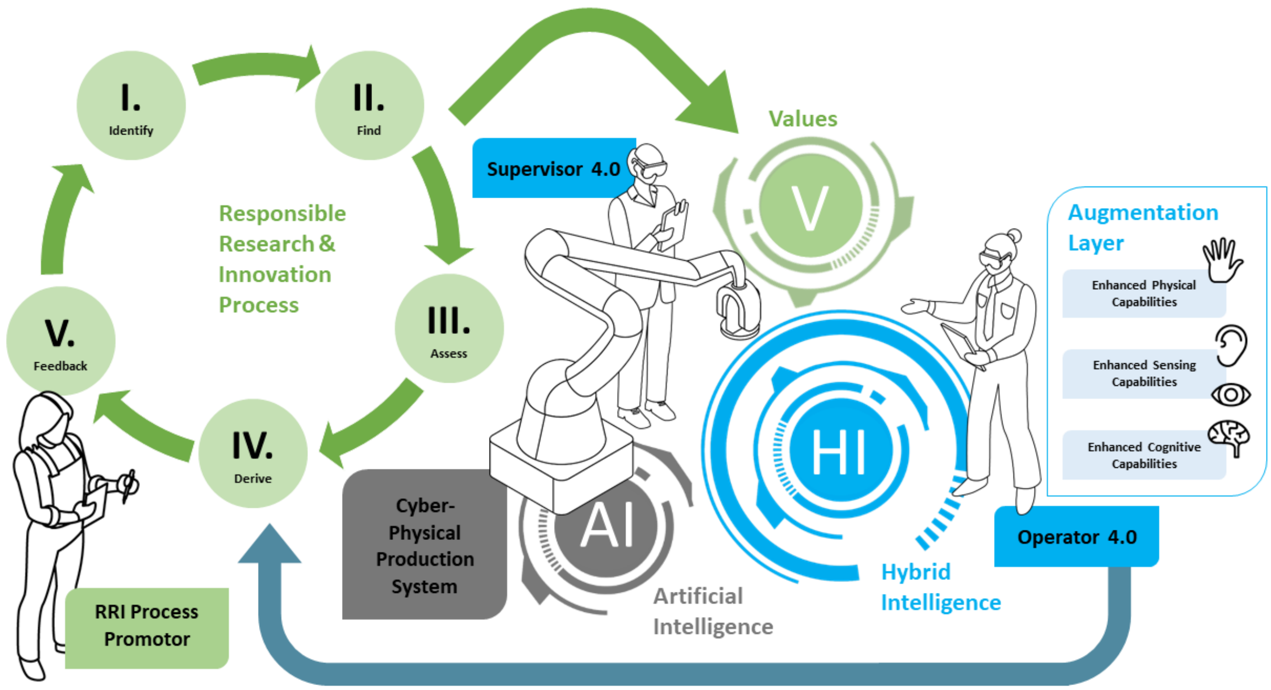

Figure 1. Concept for RRI approach with VR scenario building

human robot co-production is displayed with the help of a Virtual Reality implementation. In this, different factors like additional augmentation of robot feature but also the robot algorithm can be altered freely in order to form different future scenarios. The end user are real workers from the factory that use the VR tool in order to identify desired behaviour. A mixed method approach is used to identify fears, desires, and values from the workers, that can be used for further design iteration. This information is feeded into a RRI cycle, so that the management can ensure the implementation in the future system.

3.1. Application case

We currently focus on the application case of manual assembly within production and collaborate with several different companies on this. During projects which deal with automation analysis, identification of automation potential and the development of partly automated or fully automated solutions, our qualitative research within the design process showed numerous appearances of fear and distrust of the workers. This can, in the worst case, lead to workers refusing to participate in research methods or directly blocking innovation processes. Fueled by the public discussion, that “robots take away jobs” and the current AI hype, workers experience multiple levels of uncertainty. This is why it is of upmost importance to develop RRI methods within manufacturing further and incooperate the approach into design methods.

Figure 2. Virtual Reality future scenario

3.2. VR Implementation

Figure 2 shows an assembly application together with a collaborative robot (cobot). For this visualisation, a digital twin of TU Delft research factory SAM XL has been built. Here, different future scenarios can be tried out and stakeholders like the workers but also the factory re-organisation team can use this in order to explore possibilities automation and co-automation. The scenario was build in Unity engine, is intended to be used with a head-mounted Virtual Reality display (HTC Vive or Oculus Rift), and contains a scenario which has been built out of elements from real production and envisioned production planning and simulation. The

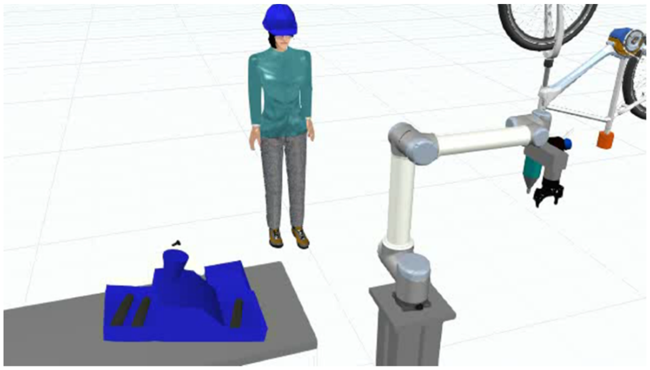

Figure 3. Factory line simulation

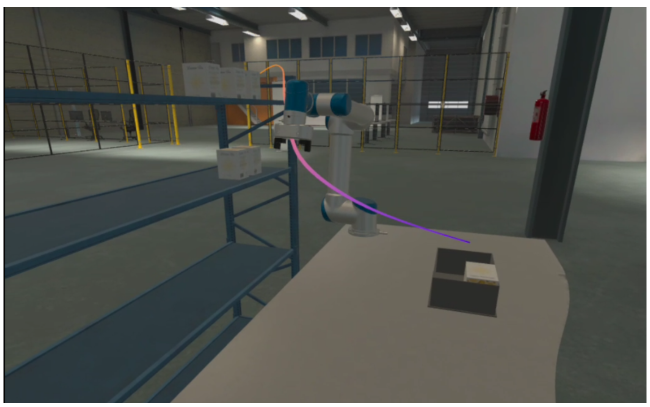

Figure 4. Virtual Reality trajectory projection example

Figure 5. Real prototype example

envisioned elements are displayed in the factory planning software Visual Components in Figure 3. The 3D animated data can be exported to Unity.

The setting in Figure 2 shows an far future scenario with a lot of application of state of the art technology. The worker immerses him or herself into the virtual environment and can freely explore the possible future. The expectation is, that through the immersion, the participant is able to understand more of the envisioned possibilities and can give more valuable feedback.

It is currently envisioned as a single experience. A collaborative robot and autonomous driving robots are presented that interact with the player. The worker is embodied in Virtual Reality by showing his or her hands. Currently the scenario consists on a short interaction with the robots for a bike assembly task: The cobot picks the bicycle frame from an autonomous driving robot and holds it to the user, so that he or she can attach the wheel. Next to this interaction, the user is able to navigate freely through the envisioned assembly line and see other workstations, which display envisioned co-automated situations, but the main focus should lie on the new way of arranging the production line (having driving robots in a line instead of a powered line) and the added collaborative robot.

The current idea is to capture the feedback from the user after he or she has experienced the situation: What did she or he like? Where are aspects that are disliked or even feared? We want to investigate how we can then embed this feature in the design of the workplaces. We are also adding elements like visual annotations. In a real situation these could be viewed with the help of an AR head-mounted device, in VR they can be seen as an augmentation layer. An example can be seen in Figure 4, in which the future trajectory of the robot is displayed.

Next to the generic future scenario which is displayed here, the aim is to also use this method for an iterative design approach: From the abstract future vision the feedback loop and the design process should approach each other so that finally, concretely envisioned new workspace environments can be tested in order to get early user feedback. We envision that we can move from Virtual Reality to real prototype scenarios during this development, an example for a real prototyping situation is shown in Figure 5.

The data collection from the users currently imposes a problem: In an optimal case, we would want to have a fully anonymous setting in which the workers can express their thoughts freely. But as we will heavily rely on qualitative feedback and discussion rounds, the worker need to be willing to participate and share their thoughts.

3.3. RRI Process

The VR scenario needs to be embedded into a RRI process, which is displayed in 1. The different parts of the cycle are described as follows:

1) Identifying structural components: including all stakeholders and their values as well as ensuring a basic digital literacy of all parties involved

2) Finding crucial processes including those to identify shared values
3) Assessing components and processes based on shared values with the help of big data analysis controlling for privacy and security issues, fair welfare distribution, strategic behaviour and biases
4) Deriving (value-related) drivers and bottlenecks of desirable processes with the help of big data and IoT solutions
5) Feeding back big data and IoT based solutions for problems based on shared values into the aforementioned steps 1. and 2.

4. Conclusion

This paper presents the preliminary progress of using Virtual Reality for scenario building within a responsible research and innovation strategy for designing the future of work of production workers alongside robots. It will be used to enquire about the thoughts and fear of production workers who currently have mainly manual tasks, but who are facing an upcoming Industry 4.0 transformation. After the establishment of the theoretical concept and the implementation of the VR digital twin for testing envisioned scenarios, the work will be used to capture the feedback of a multi-stakeholder process. The derived values will be iteratively integrated in the design process in order to create sustainable employment within the fourth industrial revolution.

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