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Position: Mixed Reality Engineering

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Supporting or building products, production capabilities or processes in automotive engineering with Virtual Reality (VR) technology is commonplace and highly valued by engineers and other stakeholders. While some of the benefits of virtual reality engineering are obvious, like shorter times to production or to market, VR only happens within its own domain: the virtual data space. A huge effort is needed to transfer and match the real and virtual domains. In the end, it is about reality we care, so why do we ignore it in the first place? The future might be Mixed Reality Engineering, i.e. combining virtuality and reality as much as we can in all stages of the automotive lifecycle.

The automotive industry was amongst the first to adopt virtual reality technology in product design and engineering. Early systems demonstrated the capabilities of virtual product visualization. All major manufacturers invested in large projection systems like CAVEs and Power Walls and used virtual reality techniques mainly to evaluate the capabilities and limitations of VR and to show technology leadership. Often, those demonstration systems did not really target actual clients or end users, e.g. engineers, but rather aimed at convincing executives and potential clients to invest in this kind of future technology. Therefore, for early VR demonstration systems the provision of prepared data/content was sufficient and no actual data or process integration into the productive environment was necessary.

A second stage of VR applications, which we might call prototypical systems [1], emphasized the role of end users, especially designs engineers in the process and therefore could be used in some productive ways. While virtual product presentations were still *en vogue* it was investigated in which parts of the product's lifecycle VR technology could become a productive tool. The interactive support of assembly and disassembly procedures (packaging), ergonomics simulations, e.g. for reach or visibility and the visualisation of physical parameters, e.g. wind channel or crash simulations have demonstrated that VR can and will be used as an effective and efficient tool in automotive manufacturing.

Today we find VR supporting all stages of the product lifecycle, often so tightly integrated that parts of the cycle already depend on VR. Major CAD systems suppliers link into VR systems or even provide VR functionality themselves; products are designed and presented in 3D throughout the entire design process, and it is expected that VR simulations of product parts and processes are performed alongside the development process. We are heading towards a comprehensive data and process integration of VR.

Such VR integration requires feeding back real world data into the virtualized engineering process. Obvious examples are digitizing of manufactured prototype or mock-up parts, hardware-in-the-loop simulations or contextualized visualizations of produced cars in virtual environments. Such back-integration of the real world usually requires time and resources as it aims to amalgamate reality into the domain-specific model of the virtual environment. Mixed Reality technology might be a promising option here - it narrows the gap between reality and virtual reality by allowing model types of both domains.

Mixed Reality (MR) combines real and virtual objects, runs interactively and in real time and registers (aligns) real and virtual objects with each other [2]. MR spans the spectrum between Augmented Reality [3], where the real environment is augmented with virtual objects to Augmented Virtuality, where a virtual environment is enhanced with real objects. This entire spectrum can and should be exploited in virtual engineering. We will give a factory planning example to illustrate Mixed Reality engineering:

Planning of a new place of industrial production requires a concerted collaboration of many teams with a broad diversity of expertise. Ranging from the definition of the building's architecture (cubature) to the outfitting of recreational areas for workers each planning group uses its own ways of getting their job done. Their software tools, though tailored to their specific needs, all share the ability to provide virtual representations of the planned steps.

Given a suitable virtual reality platform and using its immersive context, teams are able to identify issues that could become very costly during the building phase. Even more important, different teams share this platform to coordinate their efforts. Virtual reality enables them to explore their layered design among other layered designs and within the entire factory context.

Due to its high complexity the creation of a new production place will almost certainly create deviations from the planned model. Those can be e.g. implementation errors or missing detail aspects in the model. Maintenance or retrofitting based on a virtual model only requires the acquisition of a rather complete new real world model e.g. by laser scanning. Mixed reality offers new possibilities here.

Given a suitable augmented reality technology a view of the real production place could be spatially correctly merged with the rendering of the model data. This would allow a user to visually identify deviations between the two domains reality and virtuality. Moreover, perceiving both, the appeal of model and reality and being able to compare it in an immersive way, a human operator is able to constructively incorporate this knowledge and experience into later planning stages.

This type of mixed reality approach can be implemented with the user being on- or off-site. E.g. in an on-site situation a spatially tracked see-through display device would allow the inspection of selected areas, with the operator being able to get directly in touch with the real world.

In an off-site case cameras could acquire (omnidirectional) video

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on-site and relay it to a remote 3D viewer. Depending on how it is integrated with the planning model, this could be both an example for augmented reality or augmented virtuality.

The manufacturing process is always subject to optimizations, which are supported by simulation and flow planning tools. Some of them offer an immersive 3D view that allows human operators to review and tweak the optimization parameters. Important to the success in this task is the availability of sufficient up-to-date information about the running production. While algorithms may work on abstract models, human beings usually favour close-to-reality representations in their 3D view. Data such as assembly line layouts and robot models may already be digitally available from the planning stage, but other data must be acquired by capturing aspects of reality. To minimize this effort, it is not always necessary to create highly accurate and precise models of real objects. As an example, automated drones could be used to capture shelves which only contain the protective equipment for workers not necessarily needed in the process to be optimized. But the acquired models could find their way into the model representation as simple real world props (e.g. as textured, depth-sensed boxes), allowing for easy identification and consideration of its dimensions and placement. Thus, the virtuality of the 3D view would be augmented with reality aspects.

Our factory planning example showed the degrees and stages in which reality can be integrated into the virtual engineering process leading to a concept of mixed reality engineering. Advanced, novel technologies like autonomous and semi-autonomous visual and depth sensing robots or vehicles can assist in capturing essential aspects of the real world to be brought into the virtual data domain. Like with virtual reality engineering, the automotive industry could play a pioneering role in establishing mixed reality engineering.

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