Connectivity and 3-D Technologies for the Future Digital Enterprise

An immersive experience of virtual mobile machines, nowadays requires a 3-D room, commonly known as CAVE. Due to enormous investment costs and restrictions of the 3-D experience during group sessions, the market penetration of such technology is still limited to large corporations and few universities. As a spin-off of the Chair of Mobile Machines of Karlsruhe Institute of Technology, Rüdenauer 3D Technology provides a solution to enable immersive 3-D product experience at low costs for an accelerated digitalisation of today's industry. In the future, mobile machines can be experienced, tested and manufactured virtually via the CrossConnected HoloDeck at real-time boundary conditions. Holodeck allows for synchronised, site independent collaboration of remote engineering teams.

CHALLENGES OF PRODUCT DEVELOPMENT

The market success of a product can like any typical project be measured by means of the dimensions of success of the magic triangle, which describes the quality, cost and temporal targets being required for entrepreneurial success, **FIGURE 1**. A continuous optimisation of the three factors – increasing demand for product quality from customers, development costs, limited by competitive constraints, and the time-to-market – is essential [2]. The Fraunhofer Institute for Systems and Innovation Research ISI [3] subdivides the trend in product development and market trends into four main drivers:

- globalisation
- technical change
- environmental aspects
- human beings.

Under influence of these drivers, the product development has generated approaches to solve the above mentioned, partly contrary targets.

COLLABORATION MEETS THE CHALLENGES

Cross company collaboration and virtual product development have proven to be suitable measures to respond to increasing complexity. "Collaboration requires a team of individuals to work on tasks that not only have shared resources (as in coordination) and shared outcomes (as in cooperation), but most importantly, a shared common goal" [4]. Thus, collaboration incorporates and extends the terms of coordination and cooperation to a higher level.

Since a few years, increasing collaboration in product development can be observed in the automotive industry. Development packages of original equipment manufacturers (OEM) are being out-sourced to suppliers. A recent study carried out by Oliver Wyman consulting company and the Association of the Automotive Industry in Germany (VDA), this development will further increase. Over all, the FAST-study claims that the OEM's share of added value in research and development will decrease from 60 to 47 % in 2025 whilst the supplier's share increases from 32 to 36 % and engineering services almost double from 9 to 17 % [5], **FIGURE 2**. The reason for this development can be deduced from the above mentioned drivers globalisation, technology, environment, and human beings.

Within the off-highway industry, highly individual and crosslinked innovation cycles are typical. These strongly depend on the international customer and market situations. Herein, a major challenge emerges: requirements of local markets need to be considered in global engineering processes in a platform strategy [6]. State of the art development methods such as customer oriented design-to-value [7] emphasize the need for a consequent and iterative integration of all stakeholders, that is to say suppliers, OEMs and customers, during the whole development process. Thereby, a competitive placement of accepted products in a market segment is achievable.

HOLODECK

The CrossConnected HoloDeck exclusively offers the possibility, to gather cross-plant teams around a virtual product, **FIGURE 3**. Users interactively experience a machine, its functionality as well as complex system interactions efficient and at low costs. Via 3-D virtual reality glasses, users are directly projected into

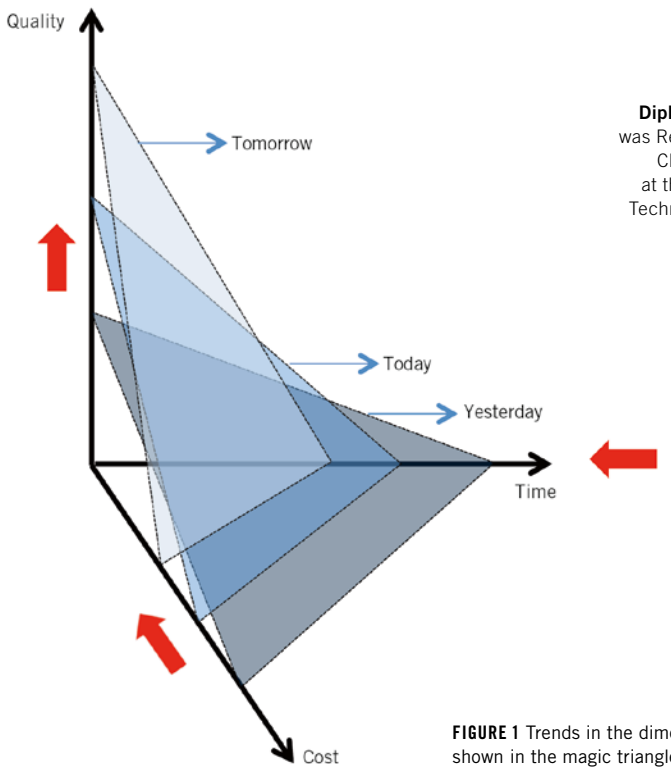

FIGURE 1 Trends in the dimensions of success shown in the magic triangle [1] (© KIT)

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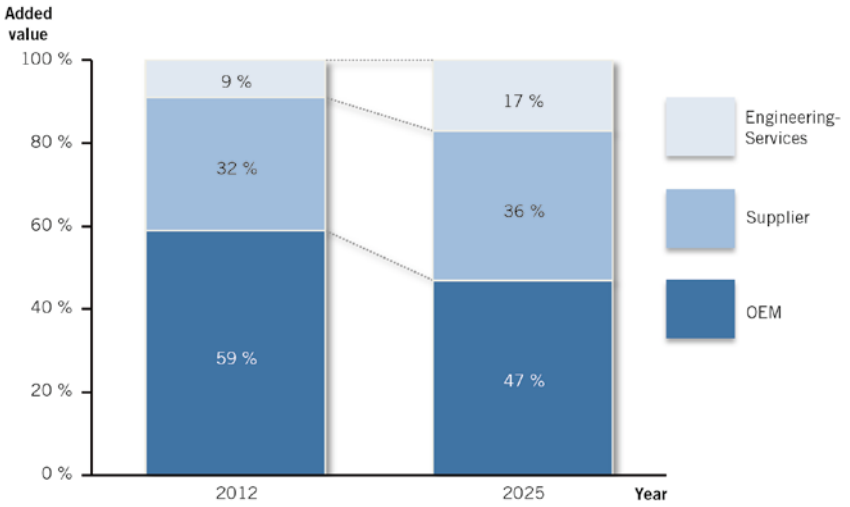

FIGURE 2 Shift of added value in the automotive industry (© KIT)

the environment of a virtual vehicle. This technology offers a high potential for cost reduction in various stages of the product life cycle, especially during development or in user trainings.

Coupling of a priori available 3-D CAD data with real-time machine behaviour data is the core innovation of the software platform Cross Connected. The machine behaviour data can either be acquired from simulation during product development or online and offline measurement data. Thus, a virtually interactive and functional prototype emerges from yet available data via few mouse clicks. Different versions or configurations can easily be generated and investigated. Furthermore, holodeck enables early virtual test runs of the production process of a machine under simulated realistic and dynamic conditions. The consequent use of standard interfaces allows for an automatic workflow for the import and export of design and behaviour data. With low effort, available data can be uploaded to the holodeck environment for an easy cross-plant usage.

Apart from the software package itself, the hardware of the holodeck significantly contributes to the economic usage in the industry, **FIGURE 4**. Precisely captured by stationary 3-D cameras in the equipped holodeck room, the position of current users is mirrored to the virtual scene where specific avatars are rendered. Likewise is the hologram of the virtual machine prototype. The 3-D cameras allow for a full motion tracking of the users. A simple variation of the number of installed cameras enables scaling of the scene to different spaces. Wireless virtual reality glasses offer completely unbound movement in the real and virtual space, letting users explore the scene and product on their own account. Glasses are distinctly assigned to the user for easy and reliable tracking. Data gloves enable the manual interaction with the virtual system. This way holodeck features the most intuitive way of human interaction possible. For instance, objects can be grabbed, moved and placed. Gestures trigger further actions. Different interaction scenarios are being investigated and evaluated with regard to user acceptance. Driven by the emerging consumer market for virtual reality technologies the hardware set can be optimised for professional application.

Each local holodeck is controlled by a holodeck workstation synchronising motion data of all users and the 3-D scene within the local configuration space. To ensure the well-being of the users during a VR conference, a minimised latency is essential [8]. The so-called motion-to-photon latency is a characteristic measure, defined as the over-all latency from a real movement to the visualisation of this very same movement in the virtual scene. Thus, it comprises the sum of all latencies within the VR-system. The motion-to-photon latency should not exceed 15 ms [9].

By connecting the works stations via a Holodeck server, multiple work stations at different locations, and therefor sites, are synchronised. This allows multiple users at different places at real the same time in the same virtual place to interact with each other.

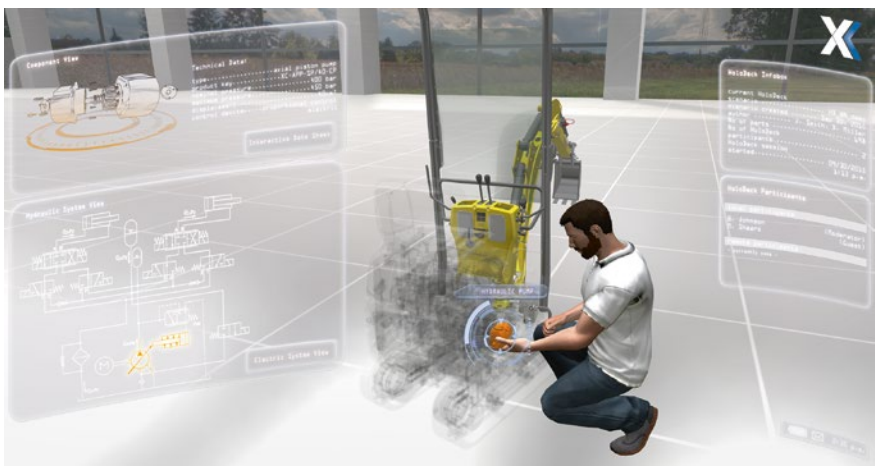

FIGURE 3 Virtual scene in CrossConnected HoloDeck (© Rüdenauer 3D Technology)

APPLICATION SCENARIOS AND BENEFITS

At a fraction of the costs of a CAVE, Cross Connected HoloDeck is optimised for applications in product development, user trainings and machine ergonomics. With holodeck, machines can not only be experienced, but as well be checked for mountability at virtual assembly lines. The need for expensive iteration cycles unveiled at the real assembly line, demanding for a refinement of the product design, can now be reduced to the minimum. Time savings of up to 20 % have been proven in studies [10]. The virtually assembled prototype can later

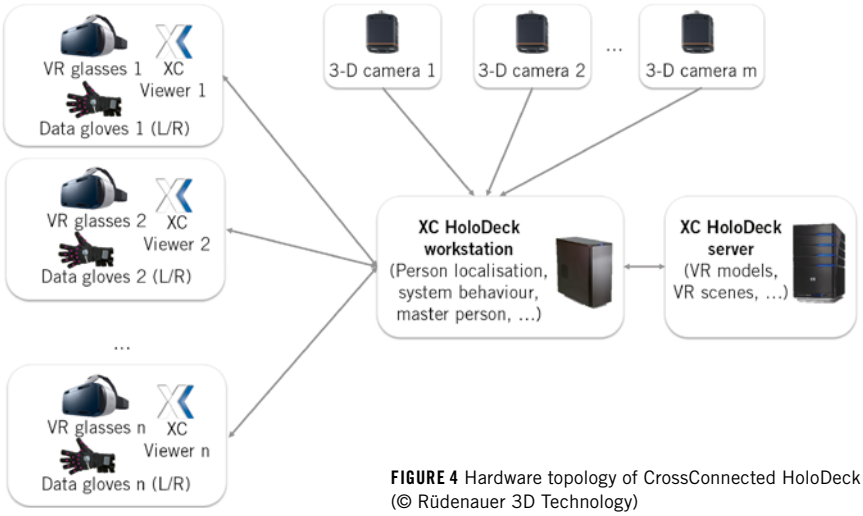

FIGURE 4 Hardware topology of CrossConnected HoloDeck (© Rüdenauer 3D Technology)

be used for training of service technicians and users around the globe. Besides the reduction of maintenance time, a better knowledge of the machine behaviour for users and service personnel leads to a reduction of maintenance errors and misuse. This especially gains importance for internationally sold machines where language barriers and cultural differences need to be taken into account. Furthermore, a better user knowledge supports an efficient machine operation.

Virtual trainings offer ideal conditions to discuss ergonomics and maintenance processes directly with the consumer to feed the first-hand experience back into product development. User interfaces can be experienced itteraly hands-on, be evaluated and optimised even prior to the physical existence of the machine.

SUMMARY

The Cross Connected HoloDeck is the first cost efficient virtual reality platform that links several users on-site and in remote locations. Compared to commercially available VR solutions, the individual 3-D experience of each participant is substantially improved. The portability allows a quick introduction to the virtual product and interactive participation in the development process of globally distributed stakeholders. OEMs have the possibility to establish new business models, for example shift of product tests to the customer in early stages of the development process. Time consuming business trips and tedious coordination processes diminish to the minimum. Compared to a system with similar functionality, that is to say CAVE, the investment costs are significantly reduced. Thus, Cross Connected HoloDeck paves the way for virtualreality technologies into industry and creates a genuine added value to the entire product life cycle.

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