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Global Challenges and Innovative Technologies Geared toward New Markets: Prospects for Virtual and Augmented Reality

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Abstract

Effective applied research is based on close collaboration between research and industry, which, taking the findings of basic research on customer demands as its starting point, creates new means to develop and market innovative products. What is more, growing demands for innovative and sustainable results of research and development are prompting the examination of global trends such as demographic change, growing megacities, rising energy consumption and increasing traffic and the resultant social challenges. These trends and increasing traffic in particular are giving rise to new fields of work, especially for digital technologies, as a social responsibility, e.g. on driver assistance and traffic control systems that increase safety. The social challenges are increasingly affecting markets and requiring new innovative products, efficient production processes and integrative forms of human resource development and training and qualification. The virtualization and digitization of objects and processes is becoming an enabler of the development of new strategies and concepts such as smart cities, green energy, electric vehicle networks, smart manufacturing and smart logistics.
This paper examines means by which digital engineering and virtual and augmented reality technologies can support the creation of sustainable smart manufacturing and smart logistics processes as well as on-the-job training and qualification and knowledge transfer

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Keywords: Virtual Reality, Augmented Reality, Digital Engineering, Global Trends, Social Challenges, Production, Logistics

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1. Introduction

Applied research on behalf of business and society is frequently geared toward individual clients' current and foreseeable, future needs. To assure the sustainability of its results, viable applied research will, however, additionally have to be oriented toward the global trends and resultant social challenges in the coming years and decades.

Experiences in Germany have revealed that intensive networking of industrial, basic and applied research and higher education establishes a research environment that supports the entire life cycle of innovative products from their development, manufacture, marketing and use through recycling (Fig.1). Universities assume the task of suitably assimilating research findings in research and teaching and thus contribute to assuring their sustainability and to educating young researchers by systematically by developing academic and qualification programs [6].

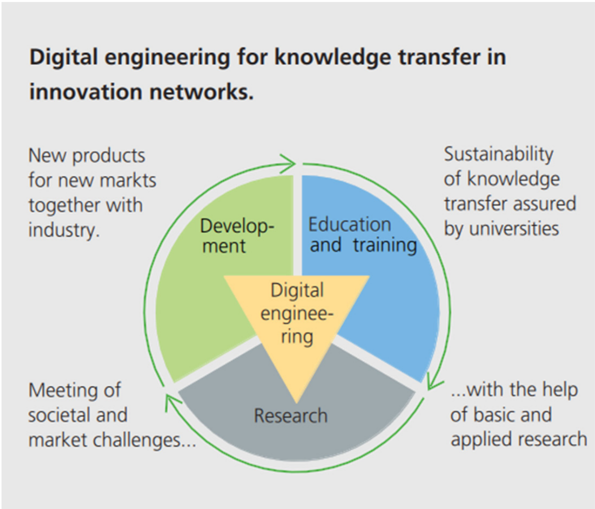

Fig.1. Digital engineering for knowledge transfer in innovation networks; © Fraunhofer IFF

This does not happen automatically, though. New forms and processes of collaboration among everyone involved are required, thus making technology development doubly important: Innovative technologies are needed as an integral part of new products as well as to support the life cycle of innovative products throughout their development, manufacture and use.

The automotive industry is a prime example. On the one hand, its products – motor vehicles – have become inconceivable without integrated digital technologies and, on the other hand, the development, manufacture and maintenance of vehicles have become inconceivable without digital engineering.

This trend is ongoing. An integral part of digital engineering, virtual and augmented reality technologies are assuming a key role in different forms of communication. Whereas virtual and augmented reality and simulation systems were developed, used and marketed largely independently from one another in the past, the future trend is toward integrated engineering platforms that combine real and virtual work systems and information and communications technologies with application domains [1,4,5].

The distinctive feature of such platforms is their support of technical, semantic and organizational interoperability with different digital technologies and their facilitation of process-driven forms of interaction between humans and machines, machines and machines, and humans and humans. The focus on current and future fields of application is a significant factor for successful development of sustainable technologies.

Nevertheless, technology development strategies are frequently still developed by research organizations and universities in their role as a "provider" and oriented – if at all – only toward their own circle of clients. How can long-range megatrends, e.g. population growth, the depletion of raw materials, urbanization, etc., be incorporated in new market segments as "consumers" of innovative technologies? This paper addresses this issue in the fields of production and logistics and presents examples of applications that highlight prospects for future applications of virtual and augmented reality technologies.

2. Global Trends, Social Challenges, New Markets

The largest applied research organization in Europe, the Fraunhofer-Gesellschaft attaches great importance to the social challenges resulting from megatrends for the definition and strategic alignment of its fields of research. It employs its so-called Fraunhofer process incorporating all of the Fraunhofer-Gesellschaft's sixty institutes to identify research topics derived from social challenges. It has repeated this process every three years since 2005. Culs et al. describe its objective thusly, "In order to differentiate from the rather technology-driven processes of the past, a new approach was sought. This new strategy process should orient itself more towards demand-driven questions. That means following the principles of corporate social responsibility and developing new ways for Fraunhofer research markets of the future." [9] The multi-stage Fraunhofer process, the methodology of which is also presented in detail by Cuhls et.al., was most recently employed in 2010. The outcome was the identification of five challenges: energy, health care, environment, mobility, and security. [9]

Fig.2. Challenges – "The Markets Beyond Tomorrow"; © Fraunhofer-Gesellschaft

These five Fraunhofer Challenges were adopted as an integral part of the "Industry-Science Research Alliance Prospect Study" and have become mainstays of the German government's High-Tech Strategy and its related research grant programs [3]. They are thus also opening prospects for the development of new technologies, services and products for use in future markets (See Fig.2.)

A member institute of the Fraunhofer Group for Production, the Fraunhofer Institute for Factory Operation and Automation IFF is working to identify emerging research topics in the fields of production and logistics in these potential markets, factoring in the institute's core technological expertise.

Table 1 presents a selection of the Fraunhofer IFF's fields of research related to relevant fields of application in production and logistics and lists best practice projects that employ virtual and augmented reality technology in the new fields of application (see section 3).

Table 1. Select fields of production and logistics research

Markets Beyond Tomorrow	Fields of Research	Best Practice Projects
Production and environment	Resource-efficient production and logistics	Review3D
	Resource-efficient production	Virtual Repository
	Worker assistance	Visual Assistance
Energy and living	Infrastructures for renewable energy systems, smart grid	3D Decision Room
Mobility and transportation	Electric vehicle networks and smart grids	Harz.EE-mobility
Safety and Security	Smart logistics zones	Virtual Bird's-Eye View

Digital engineering technologies interconnect these seemingly diverse research topics. Digital engineering combines digital tools from different domains with the goal of enabling users to experience future products and their functions in interactive virtual environments and thus establishes the basis for further research activities:

Digital engineering denotes the integrated use of digital methods and tools throughout product design and production and is intended to improve the quality of planning and control throughout the entire product life cycle.[7] Digital engineering involves not only physically correct modeling of every relevant product feature but also software features (e.g. embedded systems). The interoperability of the tools used is an essential prerequisite for early simulation of the production process during planning and for simulation that supports operation. Three levels of interoperability are distinguished, namely technical (e.g. compatibility communication protocols), semantic (compatibility of data exchanged between tools) and organizational (integration in operations). Interoperable digital engineering tools are combined to produce interactive models that target all human senses relevant for engineering decisions.

3. Best Practice Projects

3.1. Production and Environment: Review3D

Eighty percent of a product's manufacturing costs are established in the planning phase. In other words, the outcome of planning substantially dictates the resource efficiency of production. Factory and plant layouts are increasingly being planned digitally with 3D CAD tools. In order to improve the sustainability of planning as a whole, the three-dimensional data must also be used in downstream planning processes. Generating and simultaneously updating two-dimensional layouts to represent simulated processes schematically is ineffective, redundant and error-prone. Depending on the context of their use, interactive 3D visualizations and animations in lieu of 2D representations can additionally deliver various advantages and improvements, e.g. analyses of potential collisions of workpieces and equipment during production, clear presentations of complex systems and animations of manual equipment (Fig. 3).

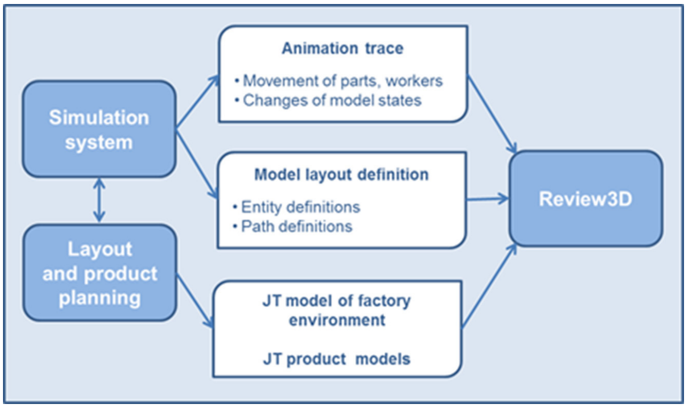

Fig.3. Review 3D architecture; © Fraunhofer IFF

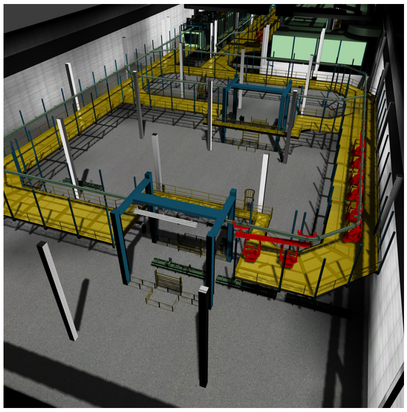

Fig.4. Review3D view into the test environment of a functional digital factory; © Fraunhofer IFF

Review3D was used to develop a tool for simulation-based planning of resource-efficient factories, which links into a company's specific digital production planning interfaces [12]. Automatic and manual simplification procedures were considered for planning data with a very high level of detail to generate interactive 3D visualizations (Fig. 4). Augmented reality can be used to provide domain-specific information that meets users' needs.

In keeping with the digital factory's sustainability requirement, such models can naturally be used for more than just the actual planning process, e.g. for marketing, training or operational planning.

3.2 Production and Environment: Virtual Repository

Research on resource-efficient production also includes the development of processes to handle waste, especially high-level radioactive, heat-producing nuclear waste from the production of electricity. In keeping with international standards for its disposal, concepts for deep geological repositories are being pursued.

Fig. 5. 360° presentation environment: Experimenting in a virtual deep geological repository; © Fraunhofer IFF

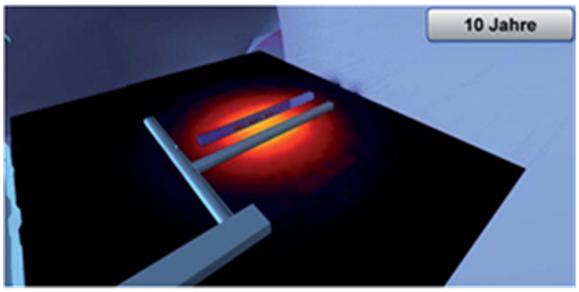

Fig. 6. Simulated temperature distribution around two heated adits; © Fraunhofer IFF

Constructing a deep geological repository and assuring the waste's safe containment for a very long time require extensive experience with and expertise on the characteristics of the host rock itself as well as the system consisting of the waste and technical components such as systems that seal boreholes, adits and shafts. The virtual deep geological repository in a salt dome, was developed to provide an efficient tool that can be used to assess the processes taking place in a deep geological repository and test deep geological repository concepts [14].

This tool combines efficient visualization software for geological models and data from simulation calculations with functions to manage material and project data. The Virtual Repository tool is thus both a VR software platform and a data hub for the visual interactive planning, execution, analysis and presentation of the results of simulation-based experiments in a salt dome (see Figs.5 and 6.)

In the future, the Virtual Repository platform will be made accessible to researchers and the entire world using cloud computing and the Internet of the future.

3.3 Production and Environment: Visual Assistance

Since 39% of the German labor force will be older than fifty by 2020, the need to provide older employees on-the-job support is increasing rapidly[†]. New concepts for different forms of assistance systems geared toward individual needs are being developed in the field of ambient assisted production research. Visual assistance systems that guide assemblers in real time while working and inspect the quality of their finished work are already a great advance toward saving time, increasing job safety and thus preventing loss of production.

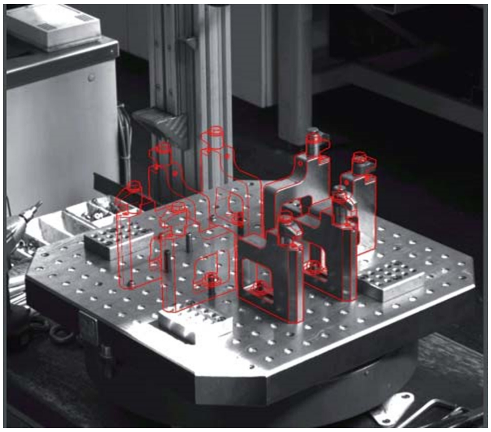

Fig. 7. Red contours over the camera image indicate assemblies' target positions in real time (©Fraunhofer IFF)

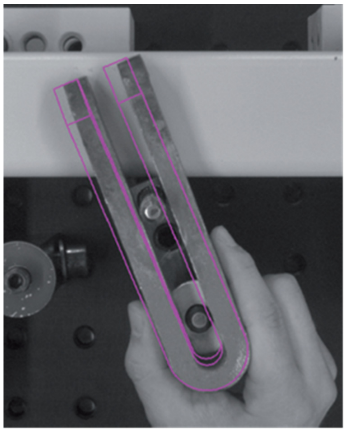

Fig. 8. An intuitive, augmented reality presentation of assembly steps (©Fraunhofer IFF)

The Fraunhofer IFF developed a visual assistance system based on augmented reality, which supports assemblers directly at the workplace with virtual assembly manuals and important instructions [2]. An assembler's real work area is outfitted with several high resolution cameras that transmit live images on one of the monitors according to the specified assembly sequence (see Figs. 7 and 8). Using 3D CAD models, the parts being assembled are overlaid in the correct position and aligned on the monitors in real time. Assemblers can follow their actions directly on their monitors and thus only have to position and secure parts so that they correspond exact with the overlay presented on the monitors (see Fig. 8). The integration of the assistance

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† http://www.stiftung-industrieforschung.de/Weitere-Themen/demographischer-wandel-neue-konzepte-fuer-aelter-werdende-mitarbeiter

system in the workflows at a medium-sized machinery manufacturing company reduced assembly times there by 30 %. By intuitive presenting work steps, augmented reality technology simplified assemblers' work significantly. Augmented reality could also potentially be used for the assembly entailing a variety of models and mobile assembly workstations.

3.4 Energy and Living: 3D Decision Room for Participative Overhead Transmission Route Planning

The energy transition in Germany will make it necessary to add around 200,000 km of transmission lines to the grid in order to transport electricity from renewable energies, especially from wind turbines in the north to primary consumers in the south.‡

The objectives of future infrastructure development projects are growing more and more complicated, their constraints are becoming more and more differentiated and the need for interdisciplinary and sustainable solutions is increasing steadily [10]. In addition to technical issues, additional demands are becoming priorities, e.g. intensified and early involvement of stakeholders (affected citizens, environmental protection agencies, government representatives, etc.) both in the development of a project and in the establishment of acceptance of a project by the general public. The related processes of participative decision-making require new communications platforms. Using multi-touch tables for multi-user interaction in 360° projection facilities, 3D spaces for experiments and decisions are focused on integrated planning methods that make it easier to involve interest groups early on and thus are instrumental in generating acceptance of projects (see Figs. 9 and 10).

Fig. 9 Photorealistic 3D model of an overhead line in a virtual interactive environment; © Fraunhofer IFF

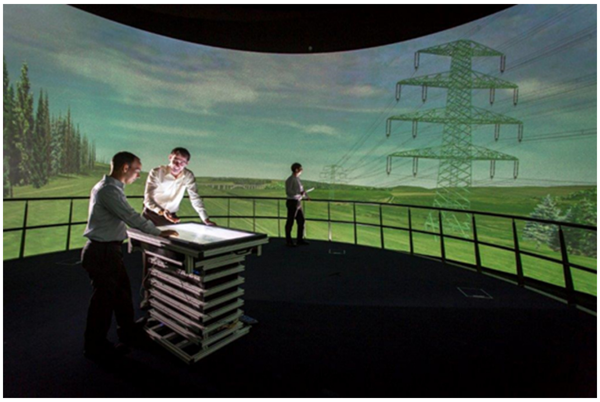

Fig. 10 Photorealistic 3D model of an overhead line in the interactive 3D Decision Room; © Dirk Mahler

New developments in virtual reality enhance forms of interdisciplinary communication and collaboration, thus responding to the steadily growing complexity of projects [11]. Photorealistic 3D models paired with VR work and analysis systems facilitate the discussion of plans for infrastructure actions long before their actual implementation. Only project planning that is communicated effectively at an early stage is understood holistically by stakeholders and broadly accepted by residents affected by it.

‡ "Die Welt kompakt", 12.12.2012

3.5. Mobility and Transportation: Harz.EE-mobility

Alternative technologies for future mobility are being researched in order to develop clean and renewable energy sources for innovative automotive drive systems. Electric motors are favored at present. Germany's goal of bringing one million electric cars on the road by 2020 makes clear that electricity will increasingly have to be produced from renewable sources. The discontinuous availability of renewable energy sources due to weather presents confronts the control of electrical grids with huge huge challenges. In order to keep the grid stable, excess energy must be stored and resupplied to the grid as necessary.

The Fraunhofer IFF developed a smart electric vehicle network control system [13], the heart of which is a central transportation control center (see Fig. 11). It controls and monitors the charging of electric cars and communication with their drivers.

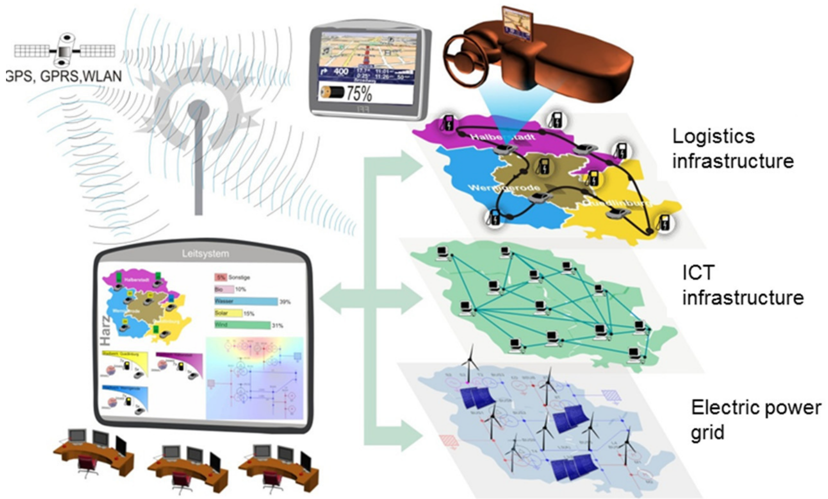

Fig. 11 Concept of an electric vehicle network control system ©Fraunhofer IFF

The system is chiefly intended to integrate renewable energies in the grid, using electric vehicles as flexible storage systems. Connected electric vehicles can supply power to the grid and charge energy from it. Users can choose a price model that allows the system operator to reschedule charging to times when the volume of solar and wind power is high, thus assuring that the desired charging level is reached and customer demand is met. The system was successfully tested in the Harz model region with twenty real and one thousand virtual electric vehicles.

The quantities of data and information generated by measurements in the real grid by simulation, which are produced in the transportation control center while monitoring its condition, furnish potentials to facilitate operator perception and interaction with virtual and augmented reality and to open other fields of application for mobile interactive driver assistance systems using cloud computing.

3.6 Safety and Security: Smart Logistics Zones

Assessing situations and detecting unusual ones at an early stage on large premises in logistics hubs, passenger terminals or on event grounds is generally problematic. While such premises can be nearly fully monitored with a large number of cameras, the multitude of image sources and different installation locations and viewing angles make it difficult to represent information for operators, which is user-friendly and meets their needs. Control centers, however, depend on having all information available at a glance. The virtual bird's-eye view provides an overview of all events in real time, thus making it possible to detect spatially complex problems early and to develop potential solutions [8].

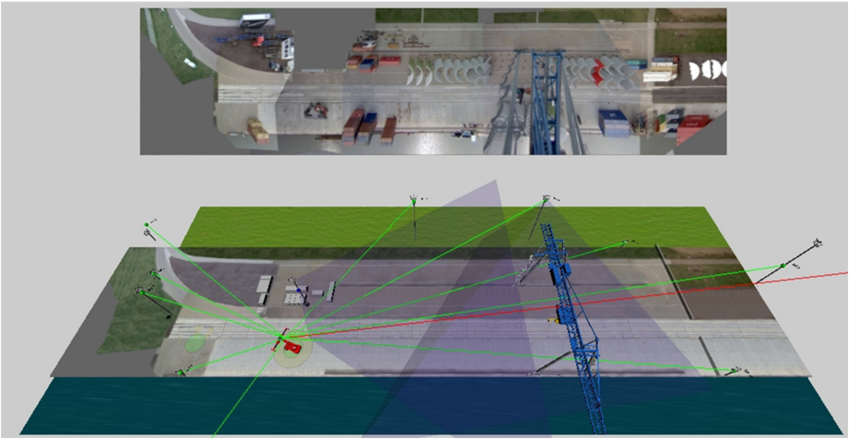

Fig.12. Time-synchronous map of the process situation in the virtual bird's-eye view and in a VR model ©Fraunhofer IFF

The virtual bird's-eye view compresses video images from distributed camera views to generate status maps refreshed in real time. An overview of free and full storage areas is always transmitted to managers in the control center even when storage in the area is extremely dynamic. Abstract data, otherwise only available in an inventory management system, are visualized so that they are intuitively comprehensible. In addition to providing an easily understandable overview map in real time, its software interfaces can upgrade the virtual bird's-eye view with data from other sources. The integration of positioning data on individual dynamic objects is particularly interesting. As visualization module, the virtual bird's-eye view additionally opens options for augmented reality applications. The virtual bird's-eye view and equipment positioning systems can be used to monitor work areas defined for individual pieces of equipment. The virtual bird's-eye view itself can be inserted in a VR model as a viewing level, thus augmenting the VR representation with real images (see Fig.12). Based on this, the utilization of individual areas of a terminal can be analyzed automatically and mapped continuously in the VR model.

4. Conclusion

Efficient support of on-the-job qualification and training requires VR work systems that integrate the aforementioned virtual technologies. It is imperative that the design and simulation tools implemented in the process chain have coordinated interfaces and the data is thus consistently integrated.

Such virtual reality applications are well on their way to becoming an integral part of corporate operations as information and communications technologies. Real work systems for on-the-job qualification and training will increasingly be supplemented or supplanted by VR work systems. This will necessitate incorporating educational methods in VR technology development concepts. The Fraunhofer Institute for Factory Operation and Automation IFF is home to interactive high level VR environments that can be specially applied to a broad range of industrial training programs.

Since digital engineering already allows the virtually seamless integration of real working systems in virtual environments and vice versa, both the basic technological and economic conditions will make the widespread use of interactive VR technologies in basic and advanced vocational training of technical specialists possible in the near future. These processes constitute the foundation for research of the educational and technical potentials of VR systems. This provides the basis for conceptual theory that is being pursued to research learning actions in real and virtual technical systems.

International cooperation networks in Horizon 2020 program can be taken advantage of to promote and disseminate innovative technologies and solutions and thus assure their acceptance by international users.

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