Towards Networked and Structured VR European Research Area: Intuition Network of Excellence and Future Research Challenges

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Abstract

The massive research and development process concerning Virtual Reality (VR) technology has reached a degree which makes a pan-European structuring and integrating effort an absolute necessity. Despite the fact that VR/AR technology has started being used to an extent in different industrial applications, this has been processed though in an unorganised way, lacking of long-term vision and dealing with case-by-case scenarios. Thus, a critical milestone is to facilitate the adoption of Virtual Environments (VEs) in industrial processes and assess the impact of its “penetration” into the workplace and everyday life. INTUITION works towards this direction, with the prime objective of promoting and facilitating the development and application of VR/VE technology in even more industrial domains, establishing thereby European excellence in this area. Moreover, INTUITION partners attempted to investigate the existing barriers for further penetration of VR into industrial applications and recognise the most important drivers that will lead to enhanced and wider use of VR/AR. An additional scope of this paper is to propose the main research areas and challenges in the field of VR/AR as idientified through INTUITION Working Groups throughout the last couple of years.

1. Introduction

The expression “Virtual World” describes worlds existing with the support of computers or computer networks only. Virtual worlds can be completely fictive as well as representations of real worlds. Virtual worlds are not necessarily three dimensional and realistic. Some authors consider even text based environments (e.g., chatrooms, etc.) as virtual worlds. In the context of INTUITION, a Virtual World is composed of three dimensional objects, light sources, grids and three dimensional user interfaces. The all encompassing term “Virtual Reality” (VR) is used to describe the technology in general. It addresses the required hardware, basic software and applications, which are necessary to give a user access to a virtual world. A “Virtual Environment” (VE) is defined to consist of a VR-installation and at least one virtual world. A VE provides the users the immersed examination of and interaction with virtual worlds.

Within recent years research on the relative scientific field has expanded on the one hand. On the other hand, there were a number of reasons that prevented the broad establishment of VR technology and relevant tools in the product creation process. The high costs concerning infrastructure and needed equipment was probably the dominant reason. In addition the lack of major VR applications enhanced the industrial tendency to stick to more traditional tools. Having some applications as a background the major advantages that VR technology can introduce to extended services and product development approaches were easily highlighted. These advantages, along with the fact that VR technology became more “mature” and able to cope with increasing demands on interaction and virtual representation, led to a number of additional industry-supported research activities.

Although that was a step forward, these activities were more a result of individual efforts, leaving Europe to follow evolutions coming mostly from the other side of the Atlantic. Several research teams have been working all across Europe focusing on VEs from different aspects. Towards this direction, INTUITION, which is a Network of Excellence funded under 6th EU Framework, aims to combine and structure their efforts providing Europe with a pan-European network that can lead future evolutions on the relative sector, assist to establish VR as a major tool in product and process design and establish a training basis allowing new researchers to join this field or helping them to broader their knowledge on an international cross-application platform.

INTUITION includes 58 European partners, stemming from various fields such as industrial representatives, Small and Medium-sized Enterprises (SME’s), key research institutes, universities and major international organizations or associations. INTUITION’s major objective is to bring together leading experts and key actors across all major areas of VE understanding, development, testing and application in Europe, in order to overcome fragmentation and promote VE establishment within product and process design. Its major objectives include the integration of resources and VR equipment all around Europe, the structuring of European Research Area in VR and the promotion of Europe as a leading force in this field world wide.

To perform this, a number of activities have been already carried out in order to establish a common view of VE technology current status, open issues and future trends. These activities include integration of human and infrastructure resources, research structuring, spreading of excellence and dissemination tasks. The quite large consortium is controlled by a firm managerial structure. Strong links with National relevant Networks, current National and EU-funded projects and clustering activities with new initiatives as well, assist in structuring the VR European Research Area (Blach et al. 2006).

This paper aims to provide the main barriers for further penetration of VR in industry, some of the drivers for change and the main research challenges in the field of VR, as identified by INTUITION working groups' activities. The main part of this paper content derives from INTUITION Research Roadmap that was the outcome from the specialised Working Groups roadmaps. Apart from that, the state of the art in the field has been identified in several deliverables, namely the Terms of References of the WGs, the common State of the Art report and the User Requirements Document. All these documents have been created by a broad range of European VR/AR experts from various disciplines and different organizational background reflected in the members of the INTUITION network.

The WG roadmaps have been derived via:

- State of the Art summary
- Focal point identification
- Research position papers
- Workshops on roadmaps

2. Identified Barriers for Further VR Penetration and Drivers for Change

2.1 Barriers to Change

The barriers and challenges which have to be tackled to overcome the limitations of today's systems and make them freely available can be structured in following major categories:

2.1.1 Technology

The main technological barrier is the inadequacy of both hardware and software development for simulation technology to provide simultaneously necessary accuracy and real-time data. Apart from this, the bandwidth for stimulation of the human sensory system is still relatively low (e.g. display resolution, colour depth, frame rate, field of view, etc.), while spatial registration and tracking of user and environment are not accurate and not available in a really ubiquitous manner. Additionaly, the lack of efficient application/content development systems and the insufficient synchronisation of multimodal and multi-sensory components is one extra barrier, that technology research has to tackle with. Finally, the premature hard- and software for VR-systems in terms of usability, stability and complexity and the necessary provision of ubiquitous access to virtual environments especially in AR, along with the improvement of power consumption in portable devices may be considered as secondary technological barriers.

2.1.2 Interaction concepts

The lack of immersive 3D-UI paradigm (comparable to the 2D WIMP paradigm) and the fact that spatial interaction is not properly understood at cognitive level are the main barriers in terms of interaction. Furthermore, the non existence of evaluation methodology for spatial interaction and presence constitutes a negative factor for further VR penetration. Finally, the missing knowledge of how to represent abstract data in space and whether VR/AR interaction techniques can assist in improving understanding and access to abstract data is the last identified barrier of this category (Kennedy et al. 1993, 1997).

2.1.3 Integration

Lack of integration and interoperability in VR systems and related applications such as CAD, CAE, PLM, is one of the most important barriers. This can be further decomposed in the lack of widely accepted standards (Data, Behaviour and Interaction), the lack of integration of VR/AR in existing applications and into the existing workflows.

2.1.4 Socio-Economic issues

Last but not least, some socio-economic issues such as the high cost of VR-systems are avertive factors towards VR penetration, especially concerning small SMEs and industries. Of course an important reason is also the fact that utilisation of new interfaces breaks with learned habits and there is still long way to go for making enough mature the ground for further VR penetration to industry.

These categories are interdependent and advances have to be achieved in more than one area to achieve a major improvement.

2.2 Drivers for change

In the previous section, the barriers for further penetration of VR were presented in terms of technology, interaction concepts, integration and socio-economic factors. On the other hand, some very important drivers for change of the current scenery in the field of VR have also been identified by INTUITION Working Groups and presented in the following paragraphs. Drivers outside the technology advancements themselves can be found in the further need of processing more data and more efficient access technologies to these data. Besides the hardware oriented point of view, we have identified the following other driving forces:

2.2.1 Industry requests

Several industries gain already a benefit from VR/AR-technology. Virtual prototypes pay off (from design and early prototyping to training applications and maintenance) in companies where 3D digital data is ready at hand. The request for improvement with the will to invest is an important driving factor (Chryssolouris et al. 2004).

2.2.2 Socio-Economic

The socio-economic drivers may be summarised to the following hints:

- Complexity of information grows, therefore new access techniques are required.
- Next generation of computer users with VR/AR interface awareness is growing.
- There is increased interest of investors in novel technology opportunities.

2.2.3 Technology

From the technological point of view, the following drivers have been identified:

- Graphic cards develop fast and independent of VR/AR. The game industry is technology driver for real-time 3D graphics hardware.
- Projector and display technology develop fast and independent of VR/AR.
- Integration of VR/AR Technology in other human computer interfaces.
- More collected data is 3D (products, terrain, etc.) e.g. CAD goes 3D, Google Earth.
- Mobile phones and PDAs are wide-spread and can be the computing platform for VR/AR in the future. Even complex algorithms can be performed in future terminals.

3. Proposed Research Fields by INTUITION

In the previous chapter, a series of barriers that must be overcome has been presented. These barriers are principally related to the lack of visibility on real benefits of VR as an enabler to fast, cost-effective and valid product management, and to still difficult implementation of technologies and systems, which still present narrow application envelopes.

Moreover, the drivers which encourage investing into research activities have been presented. These drivers are related to the opportunity to extend the virtual approach to the whole product lifecycle management, increase the coverage of performances both by multi-domain simulation and interactive experience of users and engineers and contribute to the process agility and fast reaction. All these can be achieved through extended co-locate and remote collaboration among engineers, decision makers and users.

3.1 Interface Technologies

3.1.1 Components of multimodal interfaces

Visual display technology for immersive environments

Novel display technology for 3D-representation has to be developed. Unencumbered displays that free the user from unnecessary equipment, such as lightweight high resolution head mounted displays with wide field of view, flat panel active or passive stereo displays, auto-stereoscopic displays, volumetric display, true holographic displays, etc should be further explored, which can also be implemented for mobile VR systems.

Aural spatial display technology

Novel aural systems for low- and high-end spatial sound synthesis. Wave field synthesis is a novel technology which allows for true spatial aural rendering. Directed sound systems or noise cancellation systems could be exploited for interactive systems. New lightweight systems for unencumbered use should be developed.

Multi-user displays for the visual and aural channel

To support true co-located collaboration all users should have their own view or sensory experience (Experts Group on Collaboration@Work 2006). The generation of multi perspective views for the aural and visual perceptual system without personalized systems like ear-phones or head mounted displays, is still not solved although some approaches have been presented already.

Haptic display technology

Haptic displays consist of haptic devices and the haptic rendering software. Mechanics, electronics, automation and control, the integration of smart materials and technology, etc. are involved. Haptic rendering software (the computer-based contribution in the generation of a haptic feedback to the user) involves algorithmic components to design the haptic "core" library, including haptic specific collision detection, texture mapping, etc.

Tracking/Estimation of position and orientation

Tracking technology should become more accurate and more user friendly. New approaches to overcome these limitations comprise marker less and/or model based tracking, source less tracking as, e.g. gyroscopic systems, hybrid tracking and large area tracking. Moreover, tracking must evolve towards multi-user systems, to help enabling VR-based collaboration.

Gesture and Posture recognition

Gesture and posture recognition are based on tracking and other measurement technology where the dynamic spatial behaviour is interpreted as user commands sometimes clear sometimes supportive. In this field sophisticated dynamic pattern recognition algorithms that are able to be used without tedious individual calibration procedures should be developed.

Integration of Speech recognition

Speech recognition is an independent research field, which fits well in immersive environments. Existing systems have to be integrated and interaction concepts must be developed, to allow even more natural communication with the virtual world or the underlying simulation system.

Integration of mobile devices

Existing mobile devices ought to be made 3D aware, while proper interaction techniques should be also developed.

3.2 Content Technologies

3.2.1 Realistic behaviour of VEs

Visual realism

Visual realism has to be improved in the field of virtual prototyping. New techniques as hardware based shader or real-time ray-tracing are still not optimal and it is essential that they are improved for general use. This is also related to material and lighting modelling which should capture more of the physical correct behaviour of surfaces. In non-real-time computer graphics, valuable models have been developed. These have to be adapted to real-time environments.

Physical behaviour and Haptic realism (Rigid body, deformable objects, EM, CFD)

To describe realistic environments, real–time algorithms for dynamic systems are indispensable. Although near real-time systems for restricted problems are available, there are no generalized solutions, especially not for large data sets. Also a good general description model for the physical behaviour and the capturing of the necessary parameters is not solved yet. For convincing haptic rendering these models are also crucial.

Data acquisition of physical properties

The transfer of real world data and physical properties for mapping real world in virtual environments is still a manual process with only some tools to support the process. Examples for such processes are texture generation or more sophisticated image based acquisition of material parameter, 3D-scanning based on different technologies, but also the parameterization of an acoustic or haptic virtual environment from real world objects. Therefore, there is a great need for the development or extension of algorithms and tools to render the process as automatic as possible.

3.2.2 Representation of real and virtual humans

Virtual Humans

The simulation of virtual humans is used for training, education and entertainment as representation of remote user or intelligent agents. Human models exist already but better physical behaviour has to be developed. The movements should be more natural, the programming should be simple, while the simulation should be efficient and scaleable, so as for multiple representatives to be used in the same virtual environment (Badler et al. 1998).

Virtual humans are also used in the industry for ergonomics and model based product interaction studies. Better behavioural representations, environment awareness and adaptation, and possibly cognitive and emotional capabilities (in the long term) are of great application potential.

3.2.3 Content Management

Content development tools

To combine the interface technology with the content and to utilize multimodal interaction concepts specific application development systems are necessary. In the last decade very specialized tools have been developed. In the future they have to integrate into the standard workflow of content or software development. New architectures or novel open integration schemes have to be explored. Also, these content development tools have to enable designers (not programmers) and domain experts to create contents for VR applications (Musse & Thalmann 2001).

3.3 System and Integration Technologies

3.3.1 Software Architectures

Architectures of VR/AR systems

Under this sector, protocols and drivers for multi-domain real time product simulation have to be developed while at the same time research must particularly focus on Plug and play architecture for multi-domain simulations and define standardized architectures for VR/VE systems with clear interfaces among components. This would certainly lead to improvement of technologies, specifically mobile and remote.

Architectures for distributed and collaborative systems

To combine multimodal systems with collaborative interactions and remote and local multi-user support, new architectures have to be developed. These systems have to provide mechanisms which guarantee persistence, synchronicity and low latency. To achieve this, shortcomings of network technology also have to be identified and resolved.

3.3.2 Data integration in external systems or processes

Automatic exchange/transformation of data with VEs

It is crucial for the integration of VR/AR-technology in existing workflows that data from various sources can be automatically prepared and adapted to the requirements imposed by the VR-technology. Also the conversion back to the original data sources and their relation has to be carried out. These systems are mainly CAD systems, CAE systems, game/edutainment authoring systems or databases as PDM/PLM systems. Automated techniques have to be researched and tools have to be developed.

3.3.3 Interoperability

Standardization on data, scene description and functionalities

With a well defined ontology a formal data standard can be established where scene content, system configuration and interactions can be described in an unambiguous way and therefore can be publicly available.

VR/AR interface integration in existing applications

A common standardized interface has to be developed, such that new applications can utilize VR/AR-interface technologies in their application development comparable to the process of using WIMP based interfaces.

3.4 Interaction

3.4.1 Generic Interactions

Multimodal Interaction concepts for VEs

Interface components can be bundled to interaction concepts where input and output with different modalities can be combined to an interaction concept, e.g. navigating through a virtual scenery can be realized with haptic and visual rendering as output and haptic input and tracking as input modalities. Only arbitrary concepts exist up to date (Ruddle & Payne 1997).

3.4.2 Application/activity-specific human interaction/interface paradigm

Application specific interactions, which are strongly linked to specific applications, are also a research and development topic. These interaction techniques are described in detail in the respective application oriented research roadmaps. Here only the generic interactions which can be exploited in many application fields are mentioned.

Natural interaction for creation and composing of geometry/objects/worlds in immersive environments (design)

This finds great use in the automotive industry, where through an immersive environment the engineer and designer can virtually shape the automotive structure based on design preferences and safety features. The virtual model replies instantly and the changes take effect immediately providing information to the designers about possible reactions to given situations.

Process Simulator

The research under this area ought to be focusing on VR simulation of simple and complex manufacturing processes.

Education (teacher/learner interaction, abstract concepts)

VR/VE environments are also used for education, training and learning purposes (Bloom et al. 1984). A very good example of such a case is when practical knowledge needs to be passed from a senior to a junior employee for instance. A VR system stores the data of a task executed by a senior employee of an industry, and the data could afterwards be provided to the junior trainee to assess and learn from the process. This is particularly useful when the task involves the use of machinery and dangerous equipment (Regian et al. 1992).

3.5 Human Factors

3.5.1 Basic Research

Human Factors are an important field in human machine interface research because the results not only justify the benefits of a new technology, but also shape the technical design towards a more humane realization and application of this technology. Many questions are raised, which cannot be answered without exploring the technology itself. Many conclusions can be drawn only from existing prototypes, which are built without the gained experience of its application. So, it is an iterative process where the outcome of this research shapes the design of the system and vice versa (Stoaklei et al. 1995).

Presence Research

The question of presence in computer mediated environments, how to measure it and the benefit for the user, has not been adequately explained yet. It may be important to design some VE applications to encourage feelings of presence, e.g. in a training application to train astronauts on maintenance tasks in space in zero gravity conditions. In this example it is important to afford the feeling of zero gravity when conducting these maintenance tasks. Another example is VEs designed to treat people with phobias – if the user feels like he/she is really in the situation which scares her, then there is likely to be a good transfer of any progress into the real world. In the case of design applications, a feeling of presence may refer to an acceptance that the VE represents the real working environment and 'being able to think oneself into an environment in order to design and evaluate it' (Barfield et al. 1995).

Perception/Cognition Research

From cognition research the mapping of basic understanding of immersive interface technology has to be derived. What is space and how it will be perceived? How accurate and how well synchronized should the sensory stimulation be? (Wang 1996, Wickens & Baker 1995)

Understanding of collaboration in immersive environments

The way people collaborate in immersive environments effectively and efficiently should be explored and evaluated, when true collaborative hard- and software systems have been setup.

Evaluation Technologies

Evaluation methods are needed to compare various technologies, systems and concepts, regarding their usefulness, ergonomics and health conformity.

3.5.2 Ergonomics and Design

Design Guidelines and Methodologies

From the above described research fields design guidelines and methodologies can be concluded. These help to standardize the development of VE's and ensure a controlled quality of these environments regarding human factors.

4. Conclusions

A general issue to be taken into account is the support concerning underlying themes for breaking the current barriers in deploying VR technologies. These barriers must be overcome, principally related to the lack of visibility on real benefits of VR as an enabler to fast, cost-effective and valid product management, and to still difficult implementation of technologies and systems, which present narrow application envelopes. Drivers encourage investing into research activities, which are related to the opportunity to extend the virtual approach to the whole product lifecycle management, increase the coverage of performances both by multi-domain simulation and interactive experience of users and engineers during the development, and contribute to the process agility and fast reaction, through extended co-locate and remote collaboration among engineers, decision makers and users.

Concerning the implementation and use of VR technologies in the European industrial sector, the strategic challenges are mainly related to:

- Faster design, validation and production start-up of better products, targeted at the highest personalization, and customer and society perceived added value.

- Shorter reaction time to market dynamics, including anticipating and fostering unexpressed or emerging needs.

These challenges force, in the short-medium term, to improve and extend the coverage of the virtual approach in the current development processes, and in the long term to envisage and implement a new product life cycle management process, truly built around the virtual approach. This is expected to fully exploit a vision consisting of a new product lifecycle management process, in which users (both of product and processes) are thoroughly and consistently involved in all stages: concept definition, design, development, evaluation and refinement, manufacturing design, logistics, training, marketing and presentation, operation and maintenance.

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