VirCA NET: A Case Study for Collaboration in Shared Virtual Space

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Abstract—To take up the challenge of global distributed companies, Industrial Manufacturing has to be accomplished in a worldwide collaborative way. Design and development of production processes and their execution are nowadays spread all over the world. To ensure quality standards and to create synergies between spatially distributed entities, distance collaboration tools must be provided to allow cooperation even over large distances. The Virtual Reality (VR) is thereby offering beneficial capabilities to exchange dedicated planning stages, identify problems and solve them cooperatively. This paper introduces a new approach for distance collaboration, which enables users to work in a joint virtual space, nearly as if they were working together in-place. Therefore two full-immersive CAVE-like systems are interconnected using VirCA (Virtual Collaboration Arena). The paper describes the requirements of Mechanical Engineers towards distance collaboration tools and the technical challenges solved with the enhanced VirCA framework. This working prototype is one premier application in the field of spatially distributed collaboration. A typical use case scenario is provided to highlight the interaction and cooperation capabilities offered by VirCA NET.

Index Terms—3D Internet, Virtual reality, Augmented reality, Collaboration platform, Factory layout design, Digital factory

I. INTRODUCTION

Manufacturing Engineering is facing with the continuous adaptation of factories regarding changing requirements of markets, supply networks and emerging product complexity. Simultaneously economic efficiency must be ensured [1]. Crucial thereby is the inclusion of multiple stakeholders to the adaptation processes along the factory life cycle. Several divisions and employees must be involved, to avoid suboptimal planning and exploit their special planning expertise and profession [2]. This task gets even more complex, if spatially distributed entities are involved. Nevertheless tailoring of production systems according different local constraints is required to fulfill the demands of worldwide markets, respect the cultural diversities and consider existing local conditions. To overcome this challenge the support of manufacturing engineering by means of collaboration, to handle the key characteristics of spatially distributed but synchronous planning is proposed in [3], [4]. Especially for multinational corporations, operating multi-site production systems, capabilities offered by VR should be taken into account. Configuration and reconfiguration processes of flexible production factories demand for features supporting multi stakeholder decision making and joint validation of planning results [5].

Hence factory planning is identified as one key-domain applicable for collaborative VR and Augmented Systems. The capability to lay out real environments by the use of virtual objects and the integration of human intuitiveness make this field predestined to be enhanced by VR tools. The proposed main collaborative tasks can be summarized as modelling of the factory, validation of the planning stage and subsequent optimization of the production system [6]. This is coherent with [7] who stated that often the most effective way to describe, explore, and summarize a set of numbers is to look at the picture of those numbers. Therefore the distance collaboration approach introduced in this paper will focus on the simultaneous usage of a shared virtual environment to enable simultaneous investigation on the same virtual model by spatially distributed users. This approach is beneficial as it fosters the existing workflow of mechanical engineers for factory planning tasks. Users are enabled to work within their used processes and known problem solving strategies, but extended to the distance collaborative aspect [8].

The paper is structured as follows: Section II discusses the end-user requirements and defines the crucial points on witch the development of distant collaboration tools must be focused. Section III...

II. MANUFACTURING ENGINEERING REQUIREMENTS

To grasp and fulfil user demands against a VR distance collaboration tool for factory planning, the following section will describe three main requirements coming from the field of mechanical engineering. Derived from the initially sketched situation that factory planning is faced with the following features are identified as crucial:

1) shared model visualization
2) model interaction
3) human interaction, knowledge exchange

The 3D virtual model of the production system is the base on which adaptations of the factory are planned, analyzed
and evaluated. Therefore it consists of geometric descriptions of objects (environment and manufacturing related) and additional information from the production system dealing with process descriptions for example [9]. Sharing this virtual model with all planning participants and allowing a comprehensive, distinct view for all users is a key requirement of a distance collaboration tool [3]. VirCA NET is tackling this objective by providing a joint shared virtual environment, which visual appearance is equal at all remote sites.

In addition to the shared visualization of factories, interaction with the virtual world must be also integrated into VirCA NET. The understanding of production processes and the investigation of simulation results out of the virtual environment is facilitated by bidirectional interaction with the virtual model. On the one hand, there are collaborative features to interact between users and virtual agents, but there are interconnections between several virtual agents as well. The major objective of distance collaborative tasks is not to develop a new model or product. Rather investigating models and solving problems cooperatively is focused. Accordingly, cognitive features must be integrated into the distance collaboration tool; social interaction metaphors beyond the data visualization must be provided [10], [11]. Hence one objective is to support knowledge transfer between remote sites in a social oriented way. In detail, knowledge related to personal skills that was not graspable formerly, but tacit knowledge that is hardly transferable without direct personal interaction must be considered [12]. Therefore human-human interaction must be also integrated into the VirCA NET.

Concluding these requirements a typical application field for VirCA NET can be sketched up in the scope of factory layout development. The core idea is to transfer a well-known working situation, namely the co-located domain-overlapping planning situation into a shared virtual environment. Spatially distributed planning partners should work together as if they were in-place (discuss, introduce problems, exchange points of view, find solutions and so on). The model will allow a simultaneous investigation, while users chose their focus and point of interest by their own. The distributed intelligent agents are influencing each other and user actions will be transmitted to each remote sites. The interconnected VR systems will react as one entity and users should have the impression as if they were co-located like in the so-called FPS computer games played in network mode. Augmenting this technical setup by social human-human interaction capabilities will complete the perception of direct collaboration. This is beneficial since the exchange of implicit knowledge exchange is simplified and supported by direct personal contact between planning partners. Due to close correlation to known working situations, discussions among a digital model of the current planning stage should lead to the same optimization as developed in a co-located scenario.

III. THE VIRCA NET FRAMEWORK

In this section, the VirCA NET framework is introduced focusing on the previously discussed requirements. Virtual Collaboration Arena (VirCA) is a platform (or operating system) for component-based applications wherein the components are reusable and can be running at different locations on the Internet enabling various types of collaboration. An introduction to VirCA can be found in [13] where it is discussed from the aspect of the Intelligent Space concept [14]. VirCA framework incorporates the following three underlying functionalities:

- Immersive or non-immersive 3D visualization of a shared virtual world
- Unified communication middleware to involve different kind of devices and knowledges into the scene
- Web-based system manager to build and manage complex systems from reusable components composing the VirCA NET scenarios

VirCA NET is a specific usecase of the VirCA platform where multiple instances of VirCA are interconnected making an advanced collaboration possible between remote users who become able to design, simulate and operate complex systems in a shared virtual reality.

A. Basic concepts

Some basic technical concepts are defined here:

Collaborator
In VirCA NET context, Collaborator is understood as a person or a group of persons who are interacting with the shared virtual reality at the same location. For example a team of 4 persons working in the CAVE system at University of Kaiserslautern considered as one Collaborator of the VirCA NET session.

Master VirCA
The VirCA instance which the other VirCA instances are connected to. Master VirCA acts as a hub for the interconnected VirCAs.

Slave VirCA
A VirCA instance that is connected to the Master VirCA. Multiple slaves can be connected to a single master. Slave VirCAs are cloning the virtual space maintained by the master VirCA.

VirCA NET connection
The communication channel between the master VirCA and a slave VirCA. This channel is responsible for the synchronisation of the virtual space and for the transmission of user actions in order to ensure that all collaborators receives the same information from the shared virtual space.

RT-Component or RTC for short
Reusable software component that complies the Robot Technology Component Specification [15]. Different type of capabilities (e.g. machine vision, balancing, etc.) and hardware interfaces (e.g. sensors, actuators, complex devices) can be implemented in form of RTCs. In VirCA context, RTC is a reusable building block that is directly not appears in the vir-
tual space but operates as background knowledge or interfacing the virtual objects and real-world objects.

Cyber Device or CD for short

Cyber Devices are special type of RTCs which appears as 3D objects in the shared virtual space. Machine tools, robots and other visually manifested parts of the production system are implemented in form of Cyber Devices.

Input Device

Input devices are software components interfacing different UI hardware (e.g. pointing devices, MS Kinct, etc.) to VirCA.

System Editor

VirCA System Editor is a web application for the management of the collaboration session. Collaborators can build the system from Input Devices, RTCs and CDs as building blocks.

For more details, please consult the documentation on the VirCA website [16].

IV. THE CASE STUDY

In this section, we introduce a concrete use case scenario that illustrates the capabilities of the VirCA NET framework.

A. The Scenario

For the purpose of pilot tests we made up a realistic scenario that covers some essential issues of collaborative factory planning. In this story, a manufacturing company prepares the installation of a new manufacturing cell composed by a machining centre and a robot in an empty shop-floor. The company as procurer is in contact with a machine tool supplier and a robotic system integrator company in order to select, test and purchase the proper equipments. These three partners are considered as collaborators in the planning project. They should come to decision on the sort of the machines, the exact location of the machines within the shop and they should test the whole manufacturing cell in operation. The test should be performed in a semi-real semi-virtual manner, which means that the whole system is put together and operated virtually in VirCA NET while some of the system elements (e.g. the robot) are working in reality as well.

B. Implementation Details

C. Discussion

V. SUMMARY

In this paper, the Virtual Reality based multi-user remote collaboration were studied considering a factory planning use case scenario. The requirements against the collaboration system were discussed from the viewpoint of manufacturing engineers as end-users, then the VirCA NET platform were introduced focusing on its capabilities that fulfill these requirements. A concrete example of collaborative planning of a small manufacturing cell were investigated and the technical details of the implementation were discussed. The here studied pilot application serves as an experimental testbed for CogInfoCom related research offering the possibility to investigate different CogInfoCom channels in a real-life scenario.

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