Robotics Applications Based on Merged Physical and Virtual Reality

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***Abstract*—In this paper, we are focusing on various industry-related aspects and new possibilities of virtual environment-based benchmarking. A brief introduction to augmented virtual reality simulators is given, focusing on the basic concepts and features that make these well suited for collaborative work and benchmarking in mixed virtual and physical reality. Through the concrete example of the VirCA (Virtual Collaboration Arena) system —developed at our centers— the way of involving real industrial robots in a remote collaboration scenario is discussed. Typical uses of a shared infrastructure are reviewed, considering the relationship of the virtual and real entities.**

***Index Terms*—Robotics benchmarking, Virtual Reality, Future Internet, Networked Robotics, Remote Laboratories.**

I. Introduction

The ongoing revolution of info-communication technologies brings completely new paradigms in different overlapping everyday and industrial ICT applications. This is mainly supported by the ever-increasing Internet bandwidth, the headway of Cloud Computing and the Internet of Things [1], [2], [3]. Recent development of display technologies (e.g., UHD TVs, Google Glass project, Oculus Rift) and smart devices also foster the convergence and synergies in the "big picture". These fields together are often referred to as Future Internet research [4].

All these trends point towards new philosophies not only in home and social applications [3], [5], [6], but in industrial ICT as well [2]. As a substantive result, the classical Sensing, Decision making and Actuation paradigm became logically and/or spatially distributed services massively relaying on the latest solutions of Cloud Computing and the Internet of Services.

II. The rise of Virtual Reality

Current development is targeting software-based solutions for virtual collaboration, system-level testing and even benchmarking. Complete interactive simulation and Virtual Reality platforms have been created to facilitate sharing best practices in robotics for multi-site projects (e.g., Webots[1]). These are now promoted as R&D platforms, yet finding new domains of applications in the industry. This paper presents current opportunities to use VR software tools for robot benchmarking.

Typically, in industrial robotics, each robot manufacturer have been maintaining a closed proprietary software and controller system—including control algorithms and periphery interfaces (e.g., KUKA.Sims[2]) in order to guarantee the safety and IP of their products [7]. As a result, the development of multi-vendor solutions is in lack of professional support, yet it is badly needed. The situation seems to be slightly changing due to the emergence of the Open Source Robotics Foundation, that teamed with some of the leader robot manufacturers established the Robot Operating System ROS-Industrial Consortium [8], [9]. ROS-Industrial aims to apply ROS in industrial applications allowing for the exploitation of the previously mentioned new paradigms. In Japan, AIST [3] has similar goals based on the RT-Middleware standard [10] and its implementation, OpenRTM-aist [11].

VR has proved to be a practical tool in generalizing and replacing physical components, thus allowing a site with limited hardware to still test and functionally trial its system. This feature is believed to support robotics best practices, since the same standards can be copied over various locations.

Besides robotics, numerous recently developed, and widely used middleware technologies, such as DDS (Data Distribution Service) [12], [13], [14], [15], ROS (Robot Operating System) [16], [17], [18] and RT-Middleware [11], [19] initiated a paradigm shift in the following topics backed up by immersive 3D VR:

- Remote laboratories (e.g., [20], [21], [22])
- Mixing Virtual and physical realities (e.g., [23], [24], [25])
- System of Systems (e.g., [26], [27])
- Cyber Physical systems (e.g., [28], [29])
- Collaborative virtual commissioning of automation systems (e.g., [25], [30], [31], [32])
- Exploiting cloud computing in industrial/service robotics

[1] www.cyberbotics.com

[2] www.kuka-robotics.com/usa/en/products/software/kuka_sim

[3] National Institute of Advanced Industrial Science and Technology (www.aist.go.jp)

scenarios (e.g., [33], [34], [35], [36], [37])
- Education in collaborative virtual environments (e-learning) (e.g., [24], [38]).

III. Simulation in use

The real life simulation of a robotic system is of great importance (either in R&D or the industry), helping to realize the whole complex production system perfect for the first time. Complete virtualization, —where the system exists only in VR— is sometimes not sufficient, especially in cases where nonlinearities cannot be modelled completely, or the lack of knowledge of system parts or parameters do not allow the task to simulate the processes properly. In this case, it has shown to be advantageous to apply a mixed simulation model. Some parts of the system can be included as real machines or components, augmenting the VR. The great advantage of this mixed environment is that these robots/machines do not have to be at one place (as in the real production line would require) nor they have to be under the direct supervision of the user. For example, important complex machines can be added for the trial of the system that belongs to other companies or universities that are interlinked in the mixed VR system. The whole system can then be modelled and tested even before its actual installation or distinct real components can be benchmarked in the design phase using the complement VR environment. This concept leads to a more streamlined component benchmarking, testing and commissioning procedure.

All the bottlenecks and scheduling problems can be evaluated and resolved within the VR system. This option is also available once the real production system is set up and running. In order to carry out servicing tasks, testing or improvement modifications of the system, parts of the real system have to be fully or at least partially separated or taken out from production. This is a lengthy and costly process, not to mention the risk of damaging the production capabilities. The virtual test lines can be easily connected via the VR system that will allow any further real life and real-time testing without even stopping the original production line.

IV. The Virtual Collaboration Arena

VirCA (Virtual Collaboration Arena)[4] framework has been developed while considering the union of the requirements of the various fields listed above. VirCA implements a complex vision by adopting the shareable and fully customizable 3D virtual workspace as a central idea. This concept enables people who are not always at the same location, (or even on the same continent) to create ideas, then design and implement them together in a shared virtual space. VirCA can be considered as a pilot solution which highlights several key tenets of the trend of Future Internet, and as such provides very effective means of collaboration in virtual spaces.

The framework is composed of a VR engine and a web-based system editor. The editor allows for the composition of VirCA applications combining different real or virtual entities including robots, machine tools, static 3D objects and various functionalities such as speech recognition or 3D navigation. The networked component mechanism behind VirCA is based on the RT-Middleware component standard [10] that is originally introduced for component-based robotics, but it also serves well the purposes of VirCA. The VR application is based on the community maintained OGRE engine [39] which is able to visualize spectacular 3D scenes and provide the necessary features for the seamless integration of physics simulators and virtual sensors. Recent version of VirCA is running on Windows and available for free download from the website. Further discussions and examples of VirCA applications can be found in [40], [41], [42], [43].

V. Benchmarking in higher education

The VirCA system can easily be adopted for education of advanced robotic systems and teaching best practices. Some universities or polytechnics are not as well equipped with robots or CNC machines. At most places, real production lines cannot be found (mostly because of the space requirement and the expenses), but there is an existing demand from the industry employers towards fresh engineers for having a greater insight into modern flexible manufacturing systems. This can be solved with VirCA, training sites can work together in the Virtual Collaboration Arena by entering their machines. This is a great advantage, because adding their own equipment to the pool of system they eventually get experience with other machines as well. This opens a great new perspective in virtual production line benchmarking as well, where every virtual/real system can be tested according to the same protocol. Figure 1 shows how the various equipments (located at different locations) can be delegated into the shared VR of VirCA making the access possible for the groups of remote users.

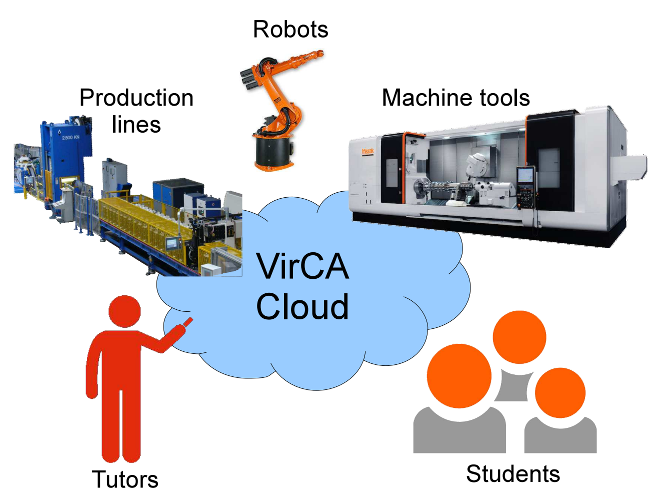

Figure 1. Illustration of the location independent hands-on remote training concept

VirCA is in the early phase of its life-cycle, however it is already applied in several research projects in Europe [44],

[4] www.virca.hu

[45], [46], [41] and in Japan [43]. It is also considered as teaching material at prestigious Hungarian universities (e.g., Óbuda University, Széchenyi István University, Budapest University of Technology and Economics).

VI. Conclusion

The advantage of mixed virtual reality simulators is that there is no need for separate warehouses for storing the large machines or moving them physically for comparative tests. The interlinking of components is entirely arbitrary, so is the capability to employ any benchmarking protocol. Tight coupling of physical robots and system parts and their virtual variations enables an almost infinite complexity in system design. Task-based test, functional trials, safety checks and educational tasks can all be run with on these extended simulators.

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