BuildingBlocks: Head-mounted Virtual Reality for Robot Interaction in Large Non-Expert Audiences

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(a) **Fair audience.** (b) **Example view of VR interaction.** (c) **Example build.**

Figure 1: **The BuildingBlocks Virtual Reality application that allows to interact with a robot arm. *Best seen in color.***

ABSTRACT

Virtual Reality (VR) technology empowers users to experience and manipulate virtual environments in a novel way. Further, by using digital twins of real world objects it is also possible to extend the reach of interaction to reality. In this work, we explore how users interact with a robot arm and its programming by using a digital representation in VR. In particular, we were interested in how public spaces influence these interactions. As a preliminary outcome in this direction, we present a simple application called *BuildingBlocks*, which allows any member of the public to assemble a work order for a robot with almost no instruction. This application was tested anecdotally during an industry fair with 235 active participants.

ACM Classification Keywords

H.5.1. Information interfaces and presentation (e.g. HCI): Multimedia information systems: Artificial, augmented, and virtual realities.

Author Keywords

Virtual Reality; Public; Robots; Programming.

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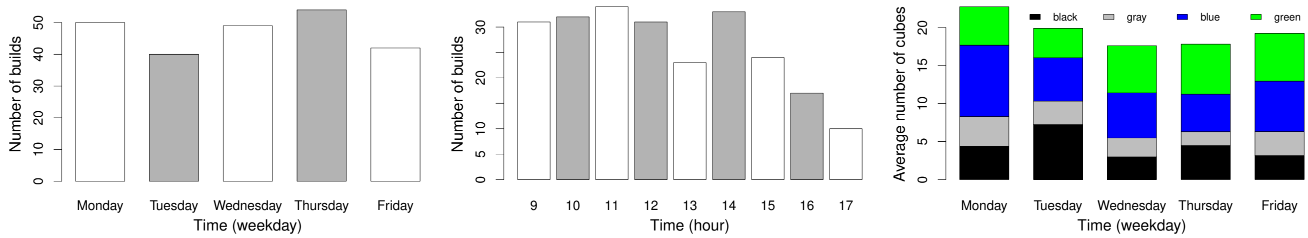
INTRODUCTION

With recent advances in Virtual Reality (VR) technology, users can experience highly immersive virtual environments. Visualizing and manipulating abstract representations of complex special relationships and constraints is possible in such immersions. Interacting with robot programs, especially in industrial settings, but also in households and public scenarios, exhibits exactly these complexities. Traditionally, highly trained experts are needed to overcome these complexities with imperative programming interfaces used in current off-the-shelf industrial robots.

We are especially interested in lowering the barrier of entry to meaningful interactions with robot programming. While other approaches exist, e.g. using natural language dialogue systems [2], these usually imply a direct co-location and/or co-operation with the robot. This is not usually given when programming industrial robots, where tasks executed by the robots are often dangerous for humans, e.g. welding. When physical interaction is required for robot programming, using "teaching" interfaces that leverage compliance of modern robots for example, these tasks can not be performed during the programming phase, raising the possibility for expensive iterations on the program should the first execution fail.

VR approaches allow novel ways to interact with robots, no matter if they are close or remote. Such approaches have been known for some time [1], but only recent advances in VR technology allow realistic scenarios. In our system, a virtual 3D representation of the task at hand and the robot,



(a) **Number of builds (by weekday).** (b) **Number of builds (by hour).** (c) **Arranged cubes per build.**

Figure 2: **Number of builds and interaction with VR application.** ***Best seen in colors.***

a "digital twin", is used to interact with and parameterize the robot program in VR. This proved to be a very quick interaction style, especially for spatial parameters, perfectly suited for non-expert members of the public. Turn-around is quick enough to allow a large number of people to experience this interaction approach.

Apart from the technical aspects of the implementation, we were curious in how far people would accept to wear VR glasses in a public crowded place to try out programming of robots. During an anecdotal test of our VR-based programming interaction approach at Hannover Messe in March 2018 with over 200000 visitors and over 5000 exhibitions running on 5 days[1]. We encouraged visitors to try out the system.

SYSTEM SETUP AND IMPLEMENTATION

In our demonstration during the industrial fair, we set up a prototype system using VR glasses and an industrial robot arm. The example task implemented in this prototype was to build a 3D voxel-based picture with the robot up to three layers high. As a conservative measure, we disallowed placing a second and third layer of voxels during the first four days of the five-day fair. This restriction was lifted on the fifth day.

The robot was placed in an enclosure for security reasons, mainly because of the rather large speed. Also, this prevented visitors from disturbing the real build area. The cubes were 3D-printed to ensure highly precise dimensions. A construction from aluminium extrusions was built, including a dedicated VR area, which allowed for stable placement of the required tracking hardware. The needed cables for the VR glasses were fastened on top of the construction so they would not interfere with the visitor.

In the virtual world, we set up the same construction with the corresponding pillars as of the real world construction, easing orientation when transitioning between VR and reality. Behind the visitor, we set up a virtual TV-screen that was connected to a camera focused on the visitor. The user was able to use this TV as a window to the real world. In front of the user, we set up a virtual table for placing the voxels and thus interact with and parameterize the robot program. The interface required only one controller, so one hand remained free for taking off the VR glasses if necessary.

[1] http://www.hannovermesse.de/en/exhibition/facts-figure, last retrieved July 11, 2018

Using the VR controller, the user could place and delete voxels of four different colors (Figure 1b). The interface allowed placing voxels in a grid of 25x10x3 (width, depth, height). Once the visitor was ready, the program was sent to the robot. Finally, the synthesized program was executed by the robot, building the voxel-based picture in reality (Figure 1c).

The VR interface was realized with Unity and SteamVR using HTC Vive VR glasses. The robot program was synthesized on a system running ROS and a custom interface to a Universal Robots UR5 with a vacuum gripper by Schmalz.

INTERACTION IN PUBLIC SPACES

Overall, we had 235 visitors distributed over five days who all agreed to use the Virtual Reality glasses and to select cubes. The average number of stones that are placed is 19.43. Several visitors tested the system just by placing a few cubes in the corners or somewhere else to see the functionality of the exhibition. Some visitors constructed pictures, patterns or letters and used, therefore, more cubes. The average number of cubes placed per weekday can be seen in Figure 2c. The usage over weekday and time can be seen in Figure 2a - 2b. Interestingly, we observed that bystanders were more likely to interact with the robot arm themselves when visitors were already trying it out. After we observed this effect, we were able to engage more people by demonstrating our VR application.

CONCLUSION

In this work, we explore how users interact with a robot arm and its programming by using a digital representation in VR. In particular, we were interested in how public spaces influence these interactions. As a preliminary outcome in this direction, we present a simple application called *BuildingBlocks*, which allows any member of the public to assemble a work order for a robot with almost no instruction.

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