HoloInteractions: Visualizing Interactions between Autonomous Cognitive Machines

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ABSTRACT

Production processes in factories increasingly involve dynamic interactions between individual manufacturing devices that allow processes to evolve and enable rapid reconfigurations for the mass-customization of products. When participating machines start to be aware of their own functionality, processes can even be dynamically reconfigured at run time. We propose a system that supports operators within such environments by enabling them to directly observe which devices interact with each other and what data is transmitted between them at any given moment, using computer-mediated reality technology. We demonstrate the application of this system in a goal-driven manufacturing use case and discuss its applicability to the monitoring of smart environments in users' homes.

Author Keywords

Augmented Reality, Web of Things, Smart Factories

INTRODUCTION

Driven by the *Industrie 4.0* paradigm, we expect the development and real-world deployment of increasingly dynamic manufacturing processes as one core component of future *smart factories*. In these, humans and machines will collaborate not according to static plans that production engineers produce off-line, but governed by reasoning and planning software that is aware of the capabilities and restrictions of individual agents and able to compose their abilities on-the-fly [6]. This should enable factories to flexibly and transparently adapt to producing a plethora of different product variants, thereby realizing the vision of a world of mass-customized, *lot-size-one* products produced at mass-production prices [5].

While we expect large economic benefits from the creation of these smart factories for both consumers and producers, this development toward more autonomous agents will also raise a number of challenges for workers at these factories that will need to be overcome, including regarding their *health and safety* (e.g., due to devices that behave in hard-to-predict

Figure 1. *HoloInteractions* visualizes Web interactions between industrial equipment in real time on a Microsoft HoloLens device.

ways), helping them to *understand* the deployed system for maintenance and debugging purposes, and for giving them a feeling of *being in control* of dynamic device environments. Another related challenge that we expect to surface in smart home environments is that of privacy: users should know – and be in control of – which (remote) services their smart devices interact with [4].

As ever more smart devices at home and at the workplace will get connected to the Internet of Things, users might easily lose track of interactions between the devices in their environment. Over the next decade, these challenges might – if not properly addressed – hinder the widespread adoption of smart environments despite their favorable economic profile because people could lose trust in the smart things and the remote services these things use: the feeling of not being in control of one's smart environment is not only inconvenient, but was also shown to lower user acceptance [2]; some users even fear a loss of control of their environment [8]. Industry certainly is already aware of this challenge in its manifestations today: *LinkSys*, for instance, has been advertising routers from its *Smart Wi-Fi Router* products range with the slogan "*Do you have a home full of devices that seem to have their own agenda?*"¹

We present the *HoloInteractions* system (see Fig. 1) that puts users in control of their smart environments by visualizing device interactions in-situ in an intuitive and visually appealing way. Aimed at workers in industrial outlets, *HoloInteractions* consists of a logging component that captures Web interactions (i.e., HTTP requests and responses) of smart devices and an Augmented Reality (AR) display on a *Microsoft HoloLens* for the real-time visualization of the captured data. AR device

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¹See <https://www.enervisionmedia.com/words-that-work-well-on-the-web-part-2-sample-successes/>

Figure 2. HoloInteractions AR view: visualization of HTTP messages that are exchanged between the participating devices.

positions in this setup are statically defined but a combination with an object classification system (e.g., Vuforia) is possible for dynamic use cases.

RELATED WORK

Enabling users to remain aware of which devices and services interact in their surroundings is challenging as devices in smart environments form complex networked systems and communication happens invisibly “behind the back” of inhabitants and provided management tools are hard to use for average users [3]. Network management tools were created for industrial environments (in the beginning, exclusively) and also today still focus on giving their users overviews of static network properties, configuration parameters, and consumption/usage metrics; research projects such as NetFlow [7] let users monitor which remote services their networked devices are interacting with. All these tools are usually used via a dashboard interface on fixed computer screens which limits their application in the smart factory scenarios that we target in this paper – *HoloInteractions*, conversely, enables the inspection of network interactions between devices and with remote services by visualizing this information in situ, as a “magic lens” [1] type AR overlay. Furthermore, the logging approach for dynamic network management tools often requires outfitting individual communicating devices with additional sniffing software or even adding additional logging hardware to a system – we mentioned these drawbacks in our own related work: consequently, the *HoloInteractions* system re-uses the logging back end from [4] and enables not only the visualization, but also the visual inspection of transmitted packets’ contents in near real time.

HOLOINTERACTIONS APPLICATION USE CASE

We applied the *HoloInteractions* system in a prototypical manufacturing cell in our laboratory that comprises a *Universal Robots UR5* collaborative robot, a *Siemens S7-300* Programmable Logic Controller (PLC), and a *Microsoft Kinect* device. In our first application use case (see Fig. 2), we connected the *UberManufacturing* reasoning back end [5] with this setup to flexibly control the devices in a goal-driven way. In this rather simple scenario, we issue the goal of having the robot hold the box in mid-air. To accomplish this, the reasoner instructs the Kinect to establish a WebSocket connection and stream the live position of a white box that is located in the robot’s reach (see Fig. 3) to the robot. Subsequently,

Figure 3. HoloInteractions AR view: visualization of a WebSockets connection (blue bubbles) between an MS Kinect device and the UR5 robot.

it instructs the robot to pick up the object at the streamed position.

HoloInteractions visualizes the reasoner back end as a “UFO” device that floats in mid-air in our laboratory and displays its HTTP interactions with the other devices as colored bubbles that move on bezier curves between the objects. In the view shown in Fig. 2, each bubble is labeled with the HTTP method (GET, POST, etc.) for requests and the HTTP response code for responses. The WebSocket stream from the Kinect to the robot is visualized as a “stream” of blue message bubbles that emanate from the Kinect device. Also visible in Fig. 3 is an HTTP PUT request en route to the robot - this is the request that will make the robot move pick up the box.

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