Designing HumanS-Centered Interactive Systems on Top of the Industrial Internet of Things

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Abstract
The main challenge involved by the raise of autonomous systems in industrial setups is the articulation of human and automated works. In order to let human co-workers collaborate with these systems, new kinds of user interfaces need to be designed. In this paper, we introduce the systems' architecture we consider the most adapted to answer durably to this stake. We also describe our contribution to this field as well as remaining challenges to be addressed for an effective implementation.

Author Keywords
Industrial Internet of Things; Interactive systems; Software architecture; Distributed systems.

ACM Classification Keywords
H.3.4 [Systems and Software]: Distributed systems; H.5.2 [User Interfaces]: Standardization; Natural language; Input devices

Introduction
The ongoing digital transformation of the industry involves new design challenges for interactive systems. Indeed, the diversity and number of connected devices and autonomous systems make factories more complex systems than ever before. In the same way, the richness of potential mediums to interact with this Industrial Internet of Things

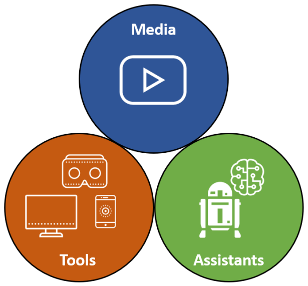

Figure 1: This image shows the three paradigms of interaction which can be used to classify interactive systems.

(VR, AR or Virtual Assistants) is growing ever faster. In this context, designing effective and sustainable interactive systems is a challenging issue. These systems must at the same time address a real need for articulation between automated work and human work, and provide workers with consolidated data from IIoT to improve their decisions. Finally, they must be adaptable enough to get through the constant evolution of the IIoT and of interaction devices.

In this paper, we argue for a modular architecture of interactive systems which separates the different paradigms of interaction, as well as for the creation of generic exchange standards for the communication between those paradigms. Finally, after a brief presentation of our contributions to this field, we discuss the remaining challenges for an industrial implementation of our proposition.

Interactive systems

Three paradigms have been proposed in order to classify interactive systems (Figure 1). In [2] Beaudouin-Lafon gives us a definition for those paradigms. The 'computer-as-a-tool' paradigm groups all the systems designed to extend the user's capabilities. 'Computer-as-a-media' rallies the digital media which support the communication between humans. Finally, the 'computer-as-an-assistant' paradigm gathers the intelligent systems which interact with humans.

If a solution to a real need obviously requires the integration of more than one paradigm (For example a digital media at least requires a tool to let humans visualize it), we believe that these paradigms should be separated in different sub-systems in the final implementation. Thus, a tool (e.g. a device) could be replaced by another without impacting the whole system. In the same way it would make it possible to add new sub-systems, like virtual assistants, to existing interactive systems. The requirement to reach such a modularity in interactive systems is to create exchange standards for the communication between the different kinds of interactive systems [3, 4].

Connecting interactive systems to the IIOT

Regarding the continuous evolution of interaction mediums and the progressive integration of connected and autonomous systems to the factories, we argue that the previously discussed modularity of interactive systems is a requirement for the deployment of sustainable interactive systems connected to the IIoT. If we apply the previously presented interaction paradigms' separation to the interactions between interactive systems, IIoT and human workers, it results in the interaction schema presented Figure 2.

- The human co-workers can interact physically with the factory, through a virtual assistant, or through a media using interaction devices.
- The interfaces of the factory's connected objects are available to media and virtual assistants through a dedicated API.
- Information about the connected objects or about autonomous systems' activities can be obtained through the same API.
- Exchange standards are required to let the different interaction sub-systems communicate.

There are three challenges in the implementation of this theoretical model. First, we need generic exchange standards for the communication between interactive systems. This is indeed required to be able to replace a sub-system without impacting the rest of the solution. Second, if the modular architecture simplifies the design of solutions, we need to create development tools to facilitate the design and connection of multiple interaction systems. Third, we need to adapt existing user-centered design methods to ensure shorter iterations [4]. In the next section, we present some researches and development projects we are working on in order to solve these issues.

Our contribution

UMI3D: A generic exchange standard for the communication between interaction devices and 3D media

This is a model allowing the communication between multiple devices connected to a 3D environment running on a dedicated server or a computer [3]. This permits the connected devices to interact with this environment thanks to their own specificities and without the need to adapt the server application. An interaction-based abstraction layer allows us to bind any device to this application. Consequently, the complexity and the necessary time of the application's development are decreased, by only changing the server application features [4].

Virtual Assistants Factory

We are currently working on two key aspects of the virtual assistant we need for the system. The first one is a factory that allows us to create bots on demand, configure them, train them and make them interact with other systems. The chatbots can be connected to each other on the fly to create a complex virtual assistant capable of handling various complex topics while remaining simple to maintain. The second one is context. All chatbots must have access to contextual information about the user and the environment. This is crucial to make the interactions with the assistants more relevant and less distracting.

Data as a Service

One of the goals of this project is to simplify the aggregation and analysis of data from different connected systems. The solution consists in a platform dedicated to the automatic generation of faster and more economical Cloud-based data structures in accordance with the form of the data. Thus, it is an adapted tool to analyze and consolidate IIoT data to feed a media.

Normalized IoT API

This project has for purpose the automatic discovery of sensors in an environment and their configuration. This makes it possible to dynamically read the data of the sensors and to control the actuators, whatever the network on which it dialogues (Wi-Fi, Bluetooth, ZWAVE, LPWAN, ...) and whatever their geographical situation. Furthermore, this API's interface assembles all the considered IoT's interfaces to ease their handling.

Remaining challenges

Finding generic standards for the tool-assistant and media-assistant communication

Language is one of the most effective forms of communication for human interactions. Therefore one of the challenges of creating virtual assistant is the reproduction of human language and its characteristics by artificial agents, in order to make interactions between humans and machines more efficient [1]. However, there is still no form of communication identified as the most powerful between an assistant and a media or an assistant and a device.

Building models for the individual's and group's contexts in a multi-systems setup

The management of these systems requires the knowledge of the state of them all. Consequently, it is crucial to find a shared data model to represent the status of all these systems. Then it would be possible to determine and to deal with a global context be the use of these representations. One of the possibilities of this purpose is the management by a virtual assistant of a set of applications available in a specific area.

Creating analytics to test and classify the interaction mediums' usages in an IIoT setup

Our third ambition consists in collecting amounts of data resulting from user experiments through diversified systems and interactions for dealing with the same situation. The main objectives reside in associating each system with the interactions that seem to be adapted to it and in analyzing how easily an ordinary user handles the devices. This is why the central requirement dwells in setting methods to aggregate the diverse data from the Interactive Systems and IIoT and in the establishment of quality metrics.

Conclusion

In this paper we have proposed a modular architecture for interactive systems that should, in our opinion, be adapted to build user interfaces for the Industrial Internet of Things. We have also argued that the implementation of our proposal requires the definition of generic interfaces between the different kinds of interactive systems (tools, media, and virtual assistants). Finally, we have introduced our past and current work on this field, as well as the challenges that remain to be addressed.

In closing, we would add that the decrease in development time, and the increase of sustainability, of the interactive systems is a major challenge to strengthen the place of human work in the Industrial Internet of Things. By making our interactive systems easily adaptable to new technologies, we will give more time for designers to build systems that take advantage of the collaboration between autonomous systems and human workers rather than replace them.

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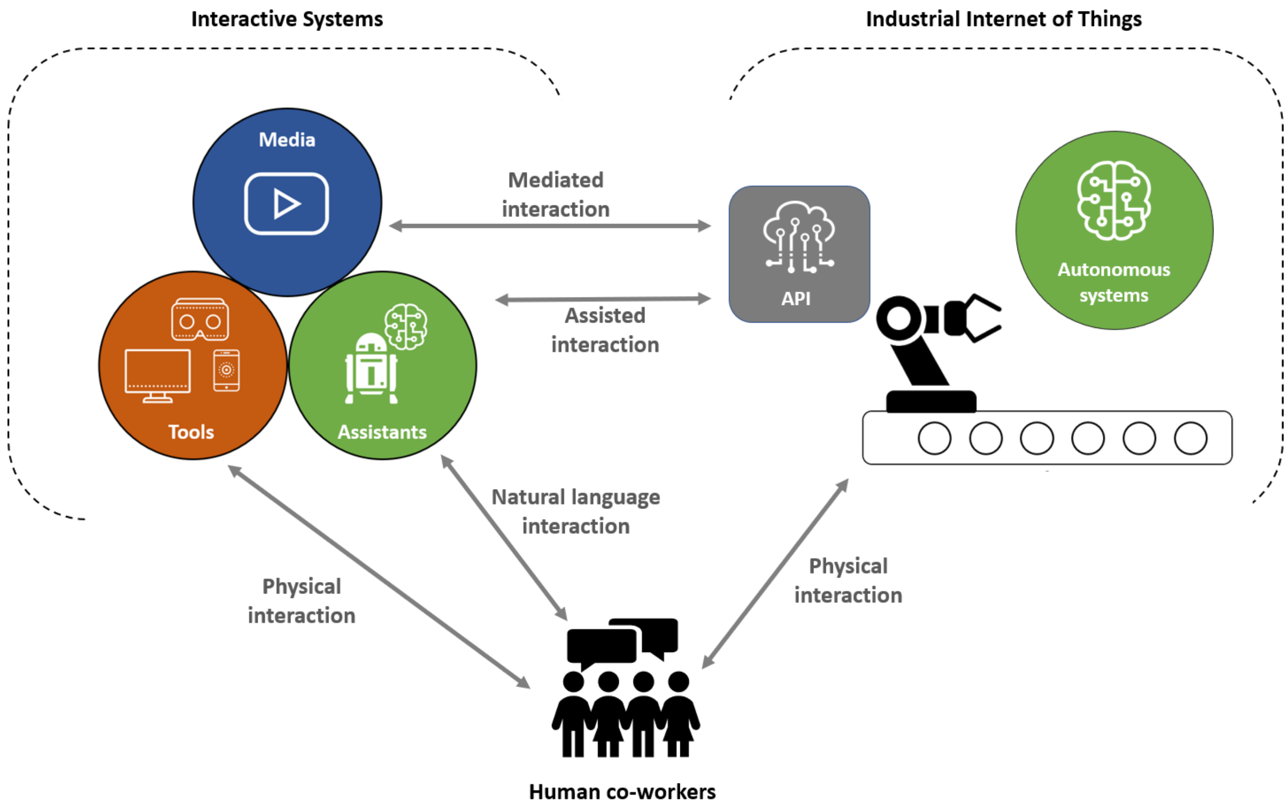

Figure 2: This image illustrates the software architecture we recommend for the design of modular interaction systems on top of the Industrial Internet of Things. Each item of this figure should, in our opinion, be developed separately from the others as a sub-system, and generic exchange standards should allow the communication between these sub-systems.