End-User Development of Internet of Things Processes in Augmented Reality (Extended Abstract)*

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Abstract: With the increasing number of IoT devices pervading our everyday surroundings there also emerges the desire of interlinking devices and creating processes among them for automation purposes. This "programming" of IoT environments currently requires a high level of technical expertise and abstraction capabilities, which hinders end-users from adapting these new technologies. We present *HoloFlows*–an approach for end-user oriented IoT process development in augmented reality–consisting of a simple modeling language and an intuitive user interface with natural interactions. HoloFlows showed an increased efficiency and user experience as well as steep learning curve for non-experts in a user study and maybe one way of programming the smart home and IoT of the future.

Keywords: Business Processes; Internet of Things; Augmented Reality; End-User Development

1 Introduction and Motivation

The Internet of Things (IoT) increasingly pervades all areas of every day lives. More and more software-controlled and interconnected commodity IoT devices make our homes, offices, factories and hospitals "smart". The programming and linkage of IoT devices in a process-oriented way shows high potential for raising the automation levels and thereby increasing comfort and efficiency in smart spaces [Ja20]. However, IoT devices are usually controlled and managed in isolation of each other, which limits the applicability of Business Process Management (BPM) technology. Moreover, end-users are often overwhelmed when controlling more than one IoT device, especially when it comes to creating automation routines among multiple devices [BV15]. We present the *HoloFlows* approach for enabling the end-user development of processes in IoT by means of augmented reality (AR). *The original article appeared in the Journal on Software and Systems Modeling (SoSyM) [Se21].

2 The HoloFlows Approach

The goal is to provide end-users with means for creating their own simple automation routines in the form of *IoT processes*. Our work consists of the following objectives: 1) create a simple domain-specific language (DSL); 2) visualize physical relations; 3) enable experimentation and feedback; and 4) provide an end-user friendly interface (UI).

DSL: The DSL for IoT processes considers *Sensors* having a *State* and *Actuators* offering *Commands* as first class citizens (cf. Fig. 1a). Different types of *Connections* among these are the basic building blocks for composing IoT processes. We distinguish between the connection types: a) Direct Sensor–Actuator for continuous state transfer; b) Conditional Sensor–Actuator; c) Actuator–Actuator; d) Sensor/Actuator–Gateway–Sensor/Actuator.

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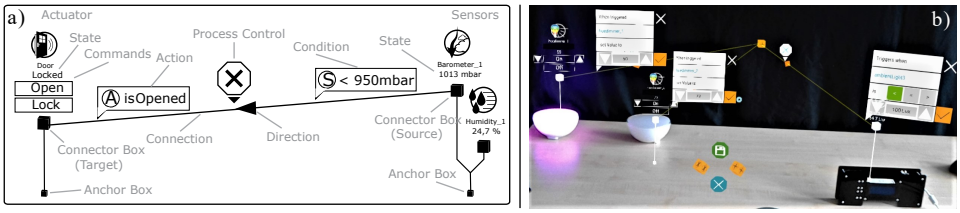

Fig. 1: Elements of the HoloFlows DSL and User Interface (a) with an Example Process in AR (b)

AR-UI: The designed UI projects holographic information above the individual physical IoT devices. It presents the devices' states and enables direct control of their functionality via "airtaps" on virtual buttons. In correspondence with the DSL the user can create the different types of connections by simply "drawing" a virtual wire between the IoT devices that should be part of the process. Depending on the type of connection the user then configures sensor-related conditions and selects the actions to be executed by the actuators (cf. Fig. 1). Once finished, the processes can be directly executed in the IoT environment.

3 Evaluation and Conclusion

We conducted a quantitative study to evaluate the HoloFlows approach. Users were asked to create typical IoT processes of a smart home using HoloFlows and two tools with "classical" desktop-based UIs–namely *Node-RED* for flow-based programming and *Camunda Modeler* for business process-oriented modeling. The comparison of modeling times and TLX scores attests HoloFlows with a high efficiency and relatively low task load, albeit a higher physical effort due to the AR interactions. Using the HoloFlows prototype results in a positive end-user experience achieved by natural interactions in and with the physical smart space.

With HoloFlows we investigated the application and combination of emerging technologies such as IoT and AR with concepts from BPM for process modeling and automation. AR hereby provides a promising new interaction paradigm to facilitate the control and development of IoT devices and processes for end-users as it allows to directly augment the physical world with digital holographic information and means for interaction.

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