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Enabling end users to program for smart environments

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Abstract. In the Internet of Things area, sensor-based smart environments are becoming more and more ubiquitous. Smart environments can support user's cognitive abilities and support them in various tasks e.g. assembling, or cooking. However, programming applications for smart environments still requires a lot of effort as many sensors need to be programmed and synchronized. In this work, we present a novel approach for programming procedures in smart environments through demonstrating a task. We define abstract high-level areas that are triggered by the user while performing a task. According to the triggered areas, projected instructions for performing the task again are automatically created. Those instructions can then be transferred to other users e.g. to learn how to assemble a product or to cook a meal. We present a prototypical implementation of a smart environment using optical sensors and present how it can be used in a smart factory and in a smart kitchen

1 Introduction and Background

In the area of the Internet of Things (IoT), sensors are becoming more and more ubiquitous. As sensors are getting cheaper and need less battery, it is feasible to equip nearly everything with sensors. By equipping sensors with Internet connectivity and therefore connecting sensors to each other, smart environments can be created. These smart environments are finding their way into many areas of people's lives. The measured values of deployed sensors can be used to check the properties of the environment, e.g. the temperature in one's living-room. But more interestingly, the measured values can also be used as an input for automatically triggering context sensitive actions. For example in the living room, the Clapper[1] enables the user to switch the light on and off by just clapping their hands. In more public areas, e.g. in the hallway, motion sensors automatically trigger the lighting when a person is walking by. More recently, sensors and smart home technology are connected to each other to enable controlling systems in one's home from anywhere. Savant[2] for example, enables controlling the heating, light, or electronic devices from anywhere using a smart phone.

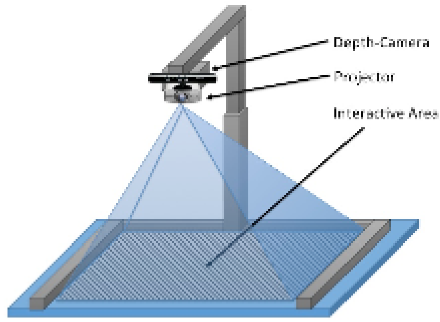

Figure 1: Our prototypical setup uses a depth camera to survey zones and a projector to display feedbacks

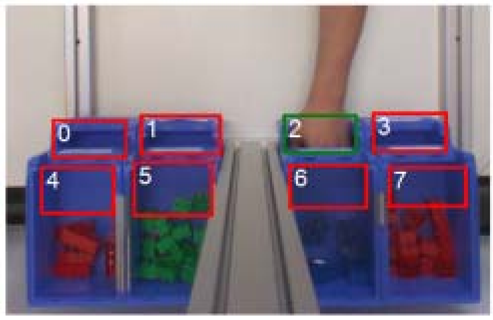

Figure 2: A graphical user interface is used to define interactive zones. (Here in an assembly context)

Interconnecting sensors in smart environments to offer cognitive support for end users was also the topic of many projects. Antifakos et al. [1] proposed to equip assembly parts of an IKEA PAX wardrobe with sensors. They use instrumented tools to infer a user's current action and suggest proactive instructions for assembling. Compared to a printed manual, their sensor-based system can dynamically react upon a user's action as it is aware of all possible assembly orders rather than printing one fixed order. Other projects use camera based approaches to detect movement in important areas e.g. boxes that are holding parts [2]. The camera is connected to a computer system that can react to picking from the box.

In this work, we present an approach for enabling the end user to program instructions for complex procedures using smart environments by just demonstrating the procedure. In our prototypical system, we use a camera-based approach, similar to Bannat et al. [2]. Using this approach, we are able to define high level actions (c.f. [3]) from which instructions can be automatically created.

[1] www.chia.com/index.php/83-other-products/94-the-clapper (last access 01-05-2015)

[2] www.savant.com (last access 01-05-2015)

Our concept enables the user to combine, alter, and transfer created instructions between different users and across smart environments.

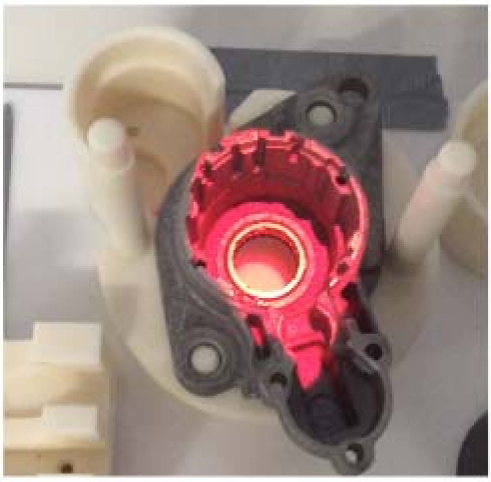

Figure 3: An object needs to be placed at a storing area. The shape and the position of the projected red light indicates the position and orientation of the object.

Figure 4: The area concept is applied to a kitchen scenario. A tool area detects the usage of kitchen tools and a storage area to check what is being cooked.

2 Concept

The main concept of this work is to enable the user to create procedures for smart environments, without having to write code, by just demonstrating a procedure to the system by performing it once. Deployed optical sensors are used to automatically sense performed actions, while they are performed. Later, the system is able to playback the procedure in the order it was performed.

Our prototypical system (also see [4]) consists of a depth camera and a projector that is mounted over the area of application (see Figure 1). In an initial step, the user has to define important areas using a GUI (see Figure 2). The system can distinguish between three types of areas: a movement area, a tool area, and a storing area. In the movement area, the system just detects if somebody entered the area. For example in the kitchen, this can be used for detecting if the user's hand entered a compartment. A tool area is used to mark the regular position of a tool, while a storing area is used to mark an area, where something has to be placed or assembled. For detecting performed activities and creating instructions, we define a high-level representation of performed actions (c.f. [3]). We call this high-level representation a work ow, which consists of a finite number of working steps. Each working step has an initial state and a trigger condition (trigger) for advancing to the next step. A trigger is activated when the action according to the type of the area is performed. A movement area triggers if a movement is detected. A tool area is triggered if a registered tool is taken and put back again, i.e. the tool was used. And a storing area is triggered if an object is correctly placed in the area.

Recording procedures

After defining the important areas, the system is ready to record procedures. Thereby, the instructions for procedures in a smart environment are created using a programming by example approach. The user performs a task the same way he or she would do regularly. While performing the task, the system constructs a workflow from the performed actions. This work ow can be played back afterwards.

Playing back

For visualizing the actions that the user has to perform, the system uses the projector that is mounted next to the depth camera. The visualization for the areas differ for each type of area. The movement area is just highlighted using a green light. Depending on what is highlighted, the user should infer the action that needs to be done. When an item should be used, the item is highlighted with a yellow color. If an object should be placed at the storing area, the target position of the object is highlighted in red. The shape of the projection indicates the orientation and position of the object that is to be placed (see Figure 3).

Areas of Application

We present two different areas of application for our prototype. First, in manual manufacturing to cognitively support workers during assembly. And second, in a smart home environment to support the user with interactive cooking instructions.

Manual Assembly Task

Our setup can be used at an assembly working place to survey the construction and detect user interactions. The system can detect if a worker is picking a part from boxes which hold the spare parts using a movement area. Further, the system can detect if the worker is currently working with a certain tool using a tool area. For determining where the worker is assembling a previously picked part, the system uses a storage area. The interaction with those areas can be recorded and saved in an instruction for the smart environment. Later, the instruction can be played back to show the recorded assembly to an untrained worker.

Interactive Cooking

Another area of application is creating and consuming cooking instructions in a smart environment. There, the environment can also be divided into logical areas (see Figure 4). In our experimental kitchen, we define a tool area, an ingredients area, and a cooking area. A user can, e.g. teach the system how to cook rice. Therefore, the rice needs to be removed from its position on a shelf, which is defined using a movement area (see Figure 5). Then, the rice needs to be put into a pot on the cooking plate, which is implemented as a storage area. The system then saves the meta information into an interactive cooking-instruction, which can be played back. Furthermore, the instruction can be sent to a friend. As the system is using meta information for displaying the feedback, the instruction can be easily integrated into another persons kitchen. There, the rice might be at another position, but the instruction can be adapted by highlighting the persons specific rice area.

Figure 5: A movement area is defined at the regular place of ingredients in a cupboard. Thereby the system knows which ingredients are used.

3 Conclusion & Workshop Contribution

In this paper, we presented an approach for enabling end users to program complex procedures for smart environments. We integrated our camera-based prototype into an assembly scenario, and a smart kitchen scenario. As the instructions created by our prototype are based on abstract zones, they can be recorded at one environment and then easily transferred and played back at another environment. We believe that enabling users to create, share, and alter content for the smart environments, may have a similar impact on the Internet of Things as it had on the Internet in the area of Web 2.0.

We believe that our work can significantly contribute to the workshop as we provide a user-centered approach for enabling end-users to program smart environments. In our presentation, we will present videos showing the full potential of our system. Further, we believe that presenting our project will foster interesting discussions at the workshop.

4 References

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