# An End-User Development Approach for Crafting Smart Interactive Experiences

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## Abstract
Despite the advantages that Internet of Things (IoT) technology offers, there are still important issues to be solved to increase its practical impact. The opportunities offered by IoT can be amplified if new approaches, based on high-level abstractions and adequate interaction paradigms, are conceived to involve directly non-technical users in configuring the behavior of their smart objects. In this paper, we present our End-User Development approach, which we would like to discuss at the workshop together with the challenges our future research implies.

## Author Keywords
Internet of Things; Smart Object Modelling; Smart Visit Experience; Cultural Heritage.

## ACM Classification Keywords
**Software and its engineering~Integrated and visual development environments** • *Software and its engineering~Visual languages*.

## Introduction and Motivation
Smart objects are increasingly pervading the environments we live in. If enabled to exploit the abundance of resources (object functionality, produced data, related applications), end users could compose the “behavior” of the surrounding environment to accommodate their everyday needs. However, programming the behavior of smart objects is currently

a prerogative reserved for professional developers, as it requires the use of scripting languages and tools that can also vary depending on the underlying hardware. Furthermore, the available objects often expose very specific functionalities that do not result in useful services able to accommodate users' needs.

In order to directly involve non-technical users in configuring the behavior of their smart objects, new approaches, based on high-level abstractions and adequate interaction paradigms, have to be conceived. Our research capitalizes on years of experience on End-User Development (EUD), a discipline that encompasses methods, techniques, tools, and methodologies to allow professionals of a given domain to master domains in which they are not professionals [1-4]. In the IoT context, we developed EFESTO-5W, a platform implementing an EUD approach to customize and synchronize the behavior of resources, like smart objects and Web services, through Event-Condition-Actions (ECA) rules [5]. With respect to other Task-Automation Systems (TASs) (see, for example, those in [6]), whose adopted graphical notations often do not match the mental model of most users [7], EFESTO-5W promotes a richer set of high-level abstractions and operators to define rules and a visual notation that, despite the intrinsic complexity related to managing events and actions, is affordable even by non-programmers.

TASs are typically conceived as general purpose systems, but their generality often implies a scarce adoption by specific communities of end users [8]. EFESTO-5W is also general purpose but can be customized to several application domains. Our position, which also derives from observing people adopting our EUD tools during field studies, is that these disadvantages occur because the proposed platforms are too "general", claiming that one single design might satisfy the requirements of many domains. For example, in Cultural Heritage (CH), guides and curators are non-professional in Computer Science who might create objects that visitors of CH sites can bring with themselves, touch and manipulate for experiencing the site by receiving personalized information. However, by observing CH experts engaged in the definition of smart objects behavior, we realized that, even without being required to write any code, it is still difficult for them to manage technical concepts. We, therefore, propose higher-level abstractions to allow end users themselves (i.e., CH experts in the case study proposed in this paper) to define custom properties to characterize the semantics of smart objects, thus helping them to make sense of the available smart devices and digital resources and facilitate the definition of their cross interactions. These features have been implemented in EFESTO-SE, an extension of EFESTO-5W, which was evaluated involving 14 professional cultural-heritage guides who were asked to create an interactive visit experience. The study showed that our hypotheses on extending the semantics of smart objects by means of custom attributes were valid with respect to the expectations of CH stakeholders. We are further exploring and verifying this aspect in some recently undertaken research activities. In particular, we are interested in evaluating if our proposal can stimulate the creativity of CH stakeholder as smart-experience designers: the hypothesis is that if the smart objects make evident the relationship they have with the content, CH professionals can better identify how to adopt such devices to convey the CH-site content to visitors.

This paper is organized as follows. The next section describes, with the help of a usage scenario, the challenges of defining a smart interactive experience and how our approach addresses them. The last section concludes the paper and suggests some research issues that would matter to further discuss at the workshop.

## Smart Experiences in the CH domain

Even in the CH domain, IoT research has primarily focused on technical features, e.g., how to program networks of sensors and actuators and how to ensure their interoperability [9-12]. Very few approaches try to facilitate the configuration of smart objects and their advantage is limited to programming single objects that the visitors bring across the CH site to receive personalized content when they reach hot spots [13]. It is still hard for CH experts (e.g., site curators and professional guides) to synchronize the behavior of multiple devices in order to create smart visit experiences where different sensors and actuators, installed in the environment or embedded in tangible objects manipulated by visitors, actively react to some detected events.

In our ongoing research, we are investigating how non-technical users, like CH guides, can personalize the behavior of smart objects in order to customize visit experiences depending on their skills and capabilities, as well as on the needs of specific visitors. To understand how ECA rules can be exploited to define smart visit experiences, let us consider the scenario described in the following section.

*A usage scenario*

Molly is the CH guide of the archaeological park of Egnathia, an ancient Roman city in Southern Italy. After the outdoor visit through the ruins, where Molly explains the history of the city and illustrates the function of every place in the park, the visit continues in the park museum. Molly engages visitors in playing a serious game in the "smart" rooms of the museum. Here, display cases containing ancient objects are instrumented with sensors able to detect NFC coins[1] provided to each visitor before the game starts. During the game, Molly asks different questions and, accordingly, sets the sensors of the display cases in different modalities by means of an app installed on her smartphone. For example, she sets the "Age" modality and asks visitors to find the display cases where Roman objects are shown. The visitors move through the museum, identify the cases matching Molly's request and touch them with their coin. If they are successful, the light inside cases turns green and the visitor's current score is increased. Then, Molly asks other questions and sets the display cases in the corresponding modality, thus the game continues. The synchronizations between cases and NFC coins are established by the guide using our platform through the creation of ECA rules.

*Defining the smart visit experience*

From the previous scenario, it is evident that the personalization of a smart visit experience might not be limited to a trivial synchronization of smart objects, but it might also require creating digital narratives threads that professionals themselves need to put in context with respect to the CH-site content. Driven by these emerging requirements, we introduce the notion of *custom attributes*, as a means to characterize smart objects not only by native events and actions (as conceived in many IoT platforms) but also by properties

[1] Near-field communication device, resembling an ancient Roman coin, used for identifying each visitor.

that the domain experts (i.e., the designers of the smart experience) can define to assign semantics to the objects. Such semantics empowers and simplifies the creation of ECA rules, as it can exploit an enriched vocabulary based on user-defined terms. Visual mechanisms also simplify the creation of custom attributes and their association to smart objects.

To understand some of the advantages of custom attributes, let us go back to the above scenario. Since the CH guide needs to define, for each display case, couplings with the NFC coins, she has to create a rule for each coupling. In addition, such rules refer to technical terminology (e.g., the NFC-coin code) that does not correspond to the language adopted by the domain experts. Figure 1 illustrates an example of ECA rule that defines the synchronization between a single case (i.e. case 3) and a specific coin. Thus, Molly has to replicate this rule for coupling all the other cases and coins.

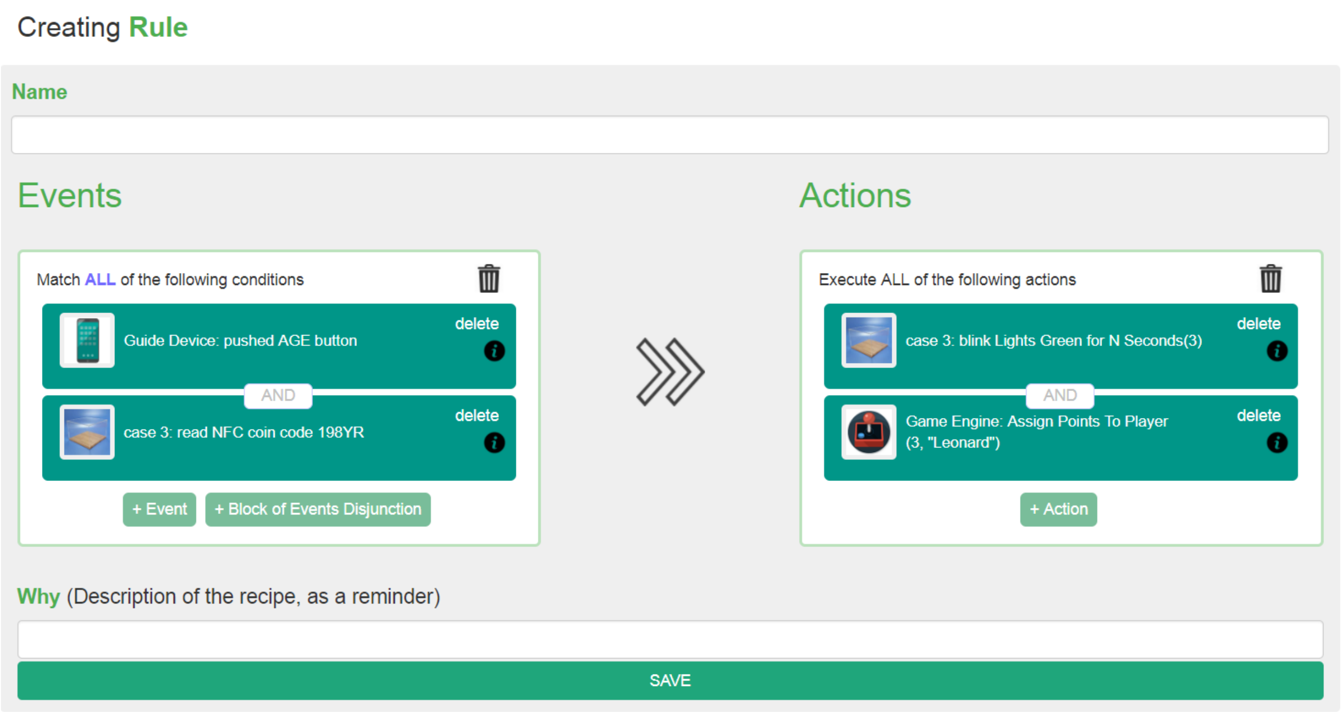


Figure 1. Example of ECA rule determining the behavior of a single case and coin.

In our proposal, before creating ECA rules, Molly interacts with a visual tool offered by our platform, which allows her to assign *custom attributes* to each case by manipulating widget interfaces, without the need of coding. Custom attributes can be seen as conceptual tools that can allow designers to characterize the basic elements of a smart experience (i.e., smart objects and rules) with a semantics related to the content to be conveyed during the smart experience.

In the example of Figure 2, she defines and assigns the attributes *Age*, representing the age of the artifacts contained by the cases, *Points*, representing the number of points the visitor gains if the answer is correct, *Blinking time*, indicating for how many seconds the case has to blink. From now on, the creation of ECA rules can exploit this terminology (see for example Figure 3). In addition, more general rules, i.e., parametric, can be created. In Molly's scenario, she does not need to define a multitude of very similar rules for coupling every single case and coin, since they are all encompassed by the single rule shown in Figure 3.

*Evaluation with CH Guides*

We recruited 14 professional guides (5 female) aged between 18 and 50 ($\bar{x}$ = 37.9, SD = 8.2), operating in different museums, archaeological sites and natural parks in Southern Italy. The guides, who participated individually and underwent the same procedure, were required to design a smart visit experience.

We collected different qualitative data. All the interactions were audio-video recorded by using an external camera. To evaluate user satisfaction, a questionnaire with 23 statements was administered at the end of the study. The first statement was the Net Promoter Score (NPS) question [14], typically used to measure, on a scale between 0 and 10, how likely users would recommend the product to a friend or a colleague. The NPS score is equal to 57, i.e., excellent; it indicates an attitude towards suggesting this system to other CH guides. This encouraging result is also confirmed by the analysis of the SUS questions, which gave us detailed indications about the perceived system usability and learnability. The SUS global score was 81.1/100 (SD = 14.1), which is higher than the average SUS scores (69.5) computed based on one thousand studies reported in [15].

The thematic analysis carried out on the transcribed data, triangulated with the questionnaire results, allowed us to identify important themes, also highlighting the presence of some usability issues to be addressed. We summarize them in the following section, since we are confident that they would enable further discussion at the workshop.

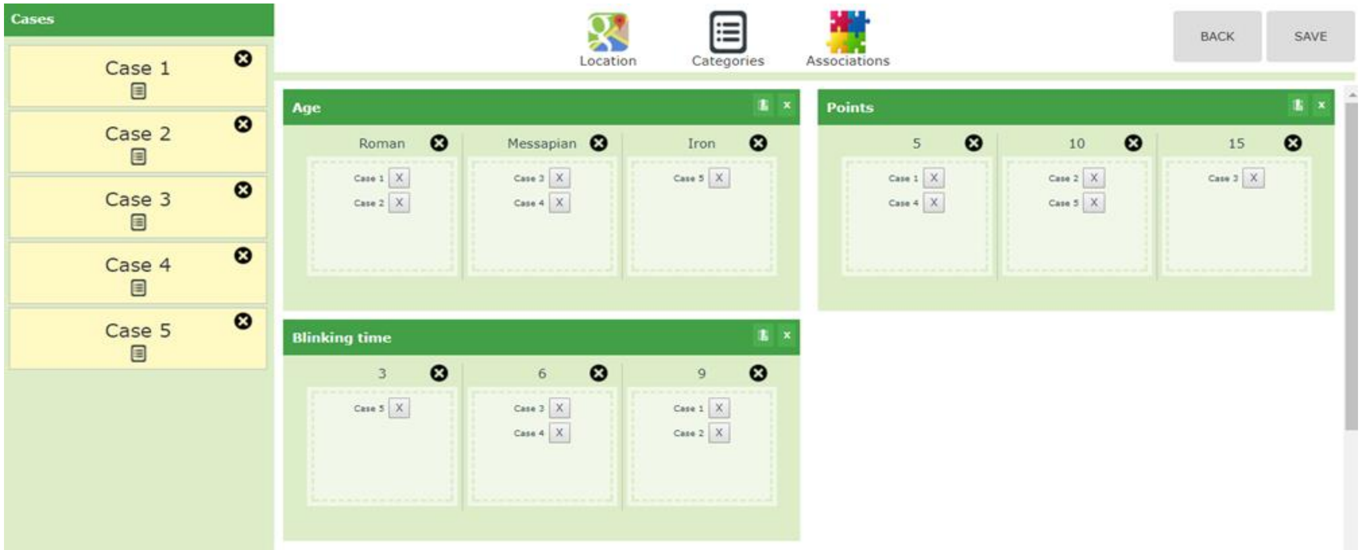


Figure 2. Platform tool for defining and assigning custom attributes.

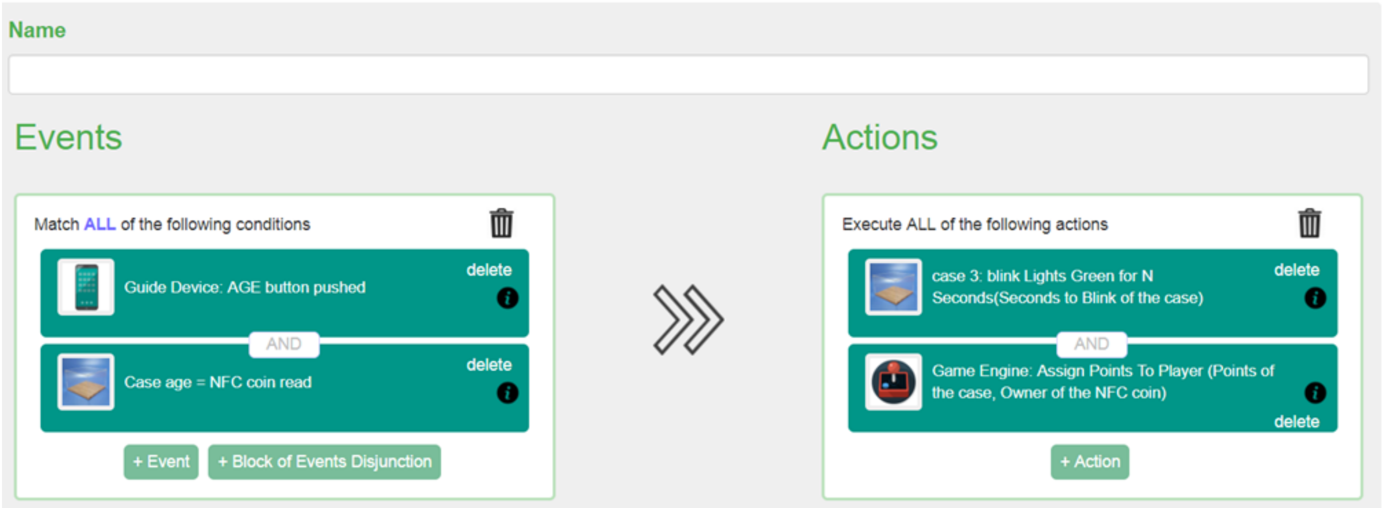


Figure 3. A single rule determining the behavior of multiple cases and coins.

## Discussion and conclusions

This article has presented our perspective on the EUD of smart experiences. The work described here provides the first results of a larger research that aims to promote smart objects as components of a smart experience that can bring with themselves evident connections with the semantics of content for which they facilitate the access. We showed how we extended and customized a generic composition paradigm, initially conceived for the EUD of IoT systems, to respond to the need of exploiting IoT to mediate narrative and content-appropriation goals for interactive visits to CH sites. However, some challenges are still open. We summarize them in the following with the aim of stimulating discussion among the workshop participants. Even though the reported aspects emerged from the application of our EUD paradigm to the CH domain, we believe they can be of general validity and should be taken into account when defining EUD frameworks for IoT also in other domains.

**Constraining the flow of design activities.** Based on the observed problems and participants' suggestions, we believe that our environment for the creation of smart experiences should be redesigned to provide a robust guidance to users. For example, a wizard procedure can guide users in configuring an initial, limited core set of smart objects, together with their CAs and basic ECA rules controlling them. Later, users can freely continue expanding this core set until obtaining the final and complete smart experience.

**Simplifying the paradigm for CA definition.** As emerged from triangulating questionnaire results with users' comments, CA definition resulted more difficult than ECA rules creation. Other metaphors for the property assignment, than the one we implemented in EFESTO-SE, could be perceived as more usable. For example, one participant suggested a spreadsheet-based solution: users could use a tabular format in which they allocate smart objects in rows, CA names in columns, and then specify CA values in cells located at the intersection between rows and columns. The tabular format was also adopted in the elicitation study by the CH guides to specify CAs and their values.

**Stimulating creativity in smart-experience design.** Another important aspect in smart-experience design is the adoption of paradigms that can stimulate creativity. The evaluation study demonstrated that EFESTO-SE has a potential in supporting the design of smart experiences. However, discussions with participants revealed that there is still room for improvements.

**Supporting and fostering technical skills growth.** Another aspect emerged during the discussion with the CH experts regards the customization activities that go beyond the smart-object programming supported by EFESTO-SE. Indeed, 6 out of 14 participants stated that, after a certain period of EFESTO-SE usage, they would like to be supported in extending the smart object capabilities by integrating new sensors and actuators, avoiding to involve every time IT experts. Even if this activity seems an aspect that only technicians can accomplish, today there are hardware and software solutions that satisfy this goal. For example, *mCookies*[2] is an alternative to Arduino that can support people who have an interest in the "Do It Yourself" paradigm for electronics. It consists of a set

2 http://microduinoinc.com/products/mcookie/

of magnetic, color-coded modules, which can be staked in a LEGO fashion.

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