Teachers' feedback on the end-user development of tangible systems

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Abstract

This paper presents an approach for involving teachers as end-users in the development of tangible systems for the classroom. The approach makes use of a series of building blocks, a web tool to visually specify and generate XML files, as well as a piece of software automatically generating running applications from these specification files on a tangible tabletop. In October 2016, we have organised a workshop where 37 teachers created new tangible learning activities with the provided tools. In this paper we present the results from a questionnaire we distributed to these teachers, focussing on the usability of the web platform and the utility of the tools for their classroom.

1   Introduction

Tangible Tabletop Interfaces (TTIs) provide several affordances that we can exploit as part of a classroom activity. In particular, TTIs support co-location, multiple users, hands-on-activities, and multiple modes of communication (Dillenbourg and Evans, 2011). Previous work report on how tangible systems could effectively support learners in exploring a complex phenomenon (e.g. Price et al., 2009, Zufferey et al. 2009).

Developing tangible systems is a highly multidisciplinary task, requiring the expertise from software engineers, usability experts, graphic and product designers, as well as domain experts. To take in account the requirements from these various fields, developers of tangible systems commonly tackle the design process in an iterative way, making use of prototypes that are progressively evaluated and refined with the help of the different parties. End-User Development (EUD) investigates suitable methods and tools with the aim to empower end-users in developing their own programmes (Lieberman et al., 2006). One of the reasons of applying EUD is to reduce the number of iterations and the overall length of the development by better involving domain experts in the process to answer their needs more quickly.

To date, only few works have investigated EUD approaches for programming tangible systems. The TAC paradigm (Shaer and Jacob, 2009) proposes high-level constructs to

specify tangible interfaces as part of its design and implementation. The approach is akin to model-based development, consisting in a visual specification technique, an XML compliant language, as well as a tool that semi-automatically translates the specification into a running programme. To the knowledge of the authors, there is no previous work that has investigated the use of EUD approaches for developing tangible systems for the classroom.

In this paper we describe the first version of our EUD approach that we develop in an iterative way with the aim to support teachers in programming TTI based applications for the classroom. We report on how we have tested the approach during a workshop with 37 teachers in October 2016. Based on the results, we discuss advantages and remaining impediments of the approach.

2   Our approach

In our EUD approach, we rely on the concept of Microworlds. A Microworld is generally understood as a computational environment that embodies or instantiates a mathematical or scientific subdomain. The central objects and relations of this subdomain are provided as an interactive representation, accessible to new learners (Edwards, 1991).

Figure 1 illustrates the different steps of our approach, as well as the related representations of a scenario. By means of the web-based authoring tool called Microworld Creator (MC), the teacher creates a visual specification of a scenario. Based on the inputs, the tool automatically generates a XML file. This specification file is then interpreted by COPSE (Maquil et al., 2017) with the aim to automatically instantiate a running application.
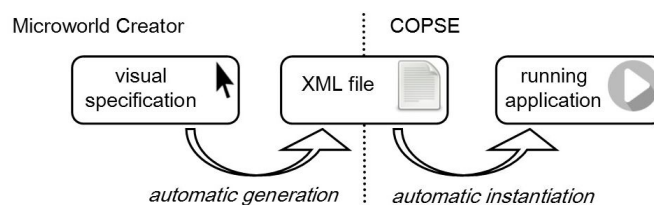

Figure 1: The different steps and objects of our EUD approach

While COPSE and the related building blocks have already been described elsewhere (Maquil et al., 2017), this paper describes the EUD approach in its entire form and reports on the teachers' feedback.

2.1   COPSE and its building blocks

There are three types of building blocks in COPSE, which can be defined as XML (Maquil et al., 2017): (1) widgets, (2) equations, and (3) scenes. Widgets represent the objects to be manipulated in a Microworld. Conceptually, widgets are separated into two categories: those

that associate a value to a variable on placement (on/off behaviour) and those that modify their variables on rotations (dial behaviour, increasing a value from a minimum to a maximum). Each widget has a handle (the physical object), variable (holding the current value of the widget), and coronas (localised feedback displayed around the handles such as text or images). Equations provide the underlying model of the scenario. They make use of the previously defined variables, as well as mathematical expressions and operators. For instance, a scenario about a windmill is defined with the widgets wind force (0 to 50km), temperature (-50 to 50°C), blades (1 to 4) and height (0 to 10m). An equation to calculate the energy is then: energy = (wind force/3.6) ^{3} * blades/3.

The feedback to be interpreted in the scenario is provided by several scenes, providing visualisations of the current state of the Microworld displayed on the overall tabletop surface. Scenes react to variables through a condition with a mathematical expression determining whether a scene should be activated. This approach allows the user to define interaction concepts through defining visual reactions (change of background or corona) based on the rotation or placement of widgets.

2.2 Microworld Creator

The Microworld Creator (MC)1 was designed to have a front-end for users who have no experience in programming. It is based on node.js and deployed on the internet.

After the user is logged-in he/she arrives on an overview page that is the central point to access own or shared scenarios. Shared scenarios can be used as they are or can be duplicated to modify them to the user's own needs.
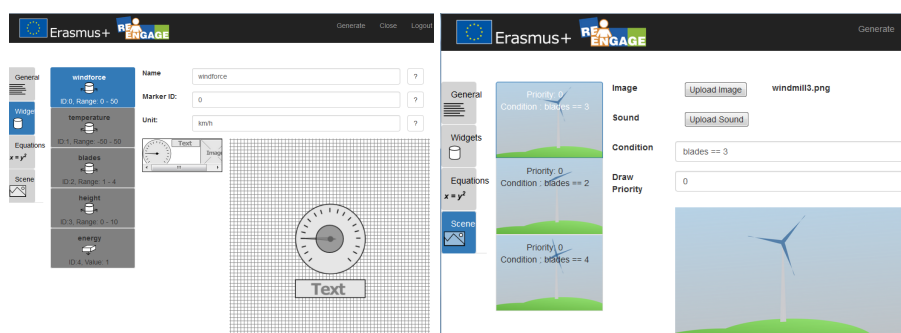

Figure 2: The MC provides means to visually specify scenarios: by defining widgets (left) and scenes (right).

The creation of a new Microworld is designed as a four steps process. After (1) adding a **name and some description and tags**, the user (2) **defines the widgets** (rotating or placement) available in the Microworld (see Figure 2 left). Coronas of widgets can be added

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[1] http://creator.reengage-learning.eu

by drag and drop. They can be decorated with static text or the value of the widget. If the widget defines a unit, it is displayed next to the value. Alternatively, values can be displayed with a gauge that is drawn around the tangible, or images showing parameters graphically. The images can be linked to a condition. The equation system can read and write the values of a widget. To (3) **model the Microworld one or more equations can be defined** by relying on the widget names defined in the previous step. The equations can be described by a simple mathematical formula or with JavaScript code. This enables the user to also use complex mathematical operators and conditions. The last step is to (4) **define the scenes** (see Figure 2 right). These can be the background, a semi-transparent overlay or a sound file. The scene is only shown when a condition is true, e.g. when the solution for a task is found.

As soon as all information is provided, the corresponding XML file is generated directly from the web platform. The user is prompted to save the file on the hard disk, and can then launch it with COPSE.

3   Teachers' feedback

To evaluate the MC, we will apply a combination of several methods: a questionnaire, interviews and observation on the field. On this paper we focus on the first results obtained by the questionnaire. During a one day workshop of the ERASMUS+ KA2 project ReEngage dedicated to share new pedagogical tools and practices, we presented the TTI and the MC to participants, mainly teachers interested in new pedagogical tools from Malta, Luxembourg, Belgium, Spain and Latvia who teach very different matters including STEM, Social Sciences, History. For most of them, it was their first contact with TTIs. The evaluation's objective was to validate the interest of the teachers for the TTI and particularly for the MC tool, and to identify the main ways of improvement for a second version of the MC.

In small groups of 3 to 6 people, teachers had the instructions to design a Microworld scenario on the tabletop thanks to the MC. At the end of the workshop, we distributed a questionnaire about the MC and the proposed teaching approach. The questionnaire contained two parts: first, what are the worst and best experiences with the MC, based on the critical incidents technique (ISO/TR 16982); second, what are the main benefits and disadvantages of using tangible systems in classrooms. Results are presented in Table 1.

From the 37 participants, 20 teachers returned the questionnaire (N:20). They generally declare that they intend to use the MC to design scenarios for their classrooms (80%). The main difficulty cited about the MC is the complexity of using equations. For instance, p14 declares "The understanding of the equations and how to write them: mathematically or logically [was my worst experience of the MC]". The positive aspects noted by users about the MC were the creative aspect for teachers, the ease of use and the fun and attractiveness for students.

The main disadvantages of TTIs in classrooms are the time needed to design a new scenario and the expensive price of a TTI.

Category	Subject	Occur-rence
Positive aspects about the MC	Creativity for teachers (design of scenario, equations and widgets)	5
	Easy to use	3
	Fun and attractiveness for students	2
	Propose another approach more suitable for certain students	1
	Visualisation of the consequences and impacts thanks to the link between inputs and outputs	1
	Offers a lot of possibilities	1
Difficulties about the MC	The use formulas frighten some of them and is judged complicated	10
	A lack of training on TTI and MC	5
	The distinction between inputs and outputs was not clear	2
	The time taken to build the widgets	1
	Some small bugs	1
Benefits of TTIs in classroom	Give another pedagogical approach that makes things more concrete with hands-on interactions and very visual feedback	11
	Motivating for students	4
	It's easy to learn how to use it	2
	It includes students well	1
Disadvantages of TTIs in classrooms	Time needed to design a new scenario is judged too long	13
	The price is judged too expensive	2
	Only small groups of students can interact at the same time	2
	Limits of TTIs	1

Table 1: Results of the questionnaire (N:20).

The main benefit of TTIs in classroom is that they support an alternative pedagogical approach that makes things more concrete with hands-on interactions and very visual feedback like noted by p22 "Different lesson than exposition/traditional method", p1 "The students see a different teaching method and they can experience a subject in a new way, using their hands to actively participate and create", p5 "Make things concrete" and p14 "It's hands on". In this way, it motivates students like noted by p4 "The student will be more motivated, and they would understand better". Tangible systems, through their collaborative aspect also include students well.

4   Discussion

Based on the results of the questionnaire, teachers are positive about their intend to use the MC for creating own scenario for their classrooms (80%). For them, the main advantage of this technology is that it allows them to teach differently than the conventional way. It allows them to better include students, with visual feedback and a hands-on experience, which is attractive to students and helps them to understand complex problems. Also the creation of

their own scenarios was perceived as a creative, enjoyable process, with the MC being easy to use. Some impediments have to be raised to promote the development of tangible systems in classroom. First, the price of such equipment is still too high. This problem will most certainly vanish in the future as the price of IT equipment decreases constantly, especially through larger production volumes. A second impediment is that, for some teachers, learning how to use the MC and defining their own scenario is too time-consuming. This might be addressed in the next iteration by simplifying the definition of equations that underlie the Microworld, notably by proposing a more graphical approach to input the equations in a more transparent way. But also by providing additional guidance and support, such as a library of shared scenarios which can be used as templates to be adapted by the teachers. In the meantime, 14 of such scenarios are already available in the MC.

In regards of the teachers' feedbacks, the developed tooling answers to our goal to give teachers the means to develop themselves another variant of teaching and learning activities, more inclusive, more embodying and fun.

In future work, improvements in regards of the users' feedback will be integrated in a new version, including the correction of bugs, help and more shared scenarios. After that, a study on the field will be conducted with teachers to evaluate the MC, but also to observe their use of tangible systems in classrooms.

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