CodeCubes - Playing with Cubes and Learning to Code

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Abstract. We present the concept, design and first prototype of CodeCubes, a hybrid interface that combines physical paper cubes with Augmented Reality (AR) for promoting computational thinking. Additionally, we reflect on the potential of combining digital games with new interaction paradigms in the context of the classroom for introducing students to programming concepts in a playful, engaging way, this way promoting student's interest and engagement for STEAM (Science, Technology, Engineering, Art and Math).

Keywords: Tangible interfaces · Interaction · Co-learning
Augmented Reality · Computational thinking

1 Introduction

In recent years the video/digital games industry has grown exponentially playing an increasingly important role in entertainment. A few successful video games have even been adapted and released as films, e.g., Tomb Raider or Resident Evil. At the same time there is also a trend for integrating real and virtual environments (augmented and virtual reality) using optical sensors (present in mobile technologies) and the convergence of several gaming platforms, allied to a new type of interaction, based on gestures. The enormous success of digital or video games lead to a new learning approach [1], named Game Based Learning (GBL) in which games are used to motivate and involve the students with the learning subject [2], as is the case of Serious Games (SG). A more recent trend considers that the students can create their own games and by doing so developing problem solving as well as programming skills.

In this paper we present CodeCubes, a hybrid interface for learning basic programming concepts. The combination of physical and virtual objects aims at assessing the impact that the addition of a tangible component to a digital game can have in the teaching/learning process, as well as at investigating whether a hybrid interface motivates the students to collaboratively solve problems. The development of CodeCubes is being carried out with two classes of 8th graders following a Design Based Research methodology [3]. Following this methodology, we have carried out several

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design sessions with the students in which we have tried out different possibilities for the design of the interface. After several iterations where we imagined different forms, materials and objects we decided to use physical paper cubes as interface for learning basic coding. Paper cubes are easy to craft and handle and provide a good metaphor for representing data.

In the following section we discuss relevant work in this area.

2 Related Work

There are various kits and digital platforms for children and young adults that aim at promoting the development of logical reasoning and programming skills. These tools have been developed both in commercial and academic contexts and can be classified in three main groups: (i) physical (all the components are tangible), (ii) virtual (all the components are virtual e.g., PC and/or mobile-device based applications without physical components), (iii) hybrid (combining physical and virtual components) [4].

An aspect that is particularly important specially for children is the kind of interaction supported by the materials. This is, the physical or the virtual features of an interface, strongly influence the way children perceive and use it [4]. Previous research has shown that tangible interfaces are especially adequate for supporting and promoting collaboration [5, 6]. Some authors consider that hybrid interfaces that combine physical and graphical elements are also advantageous as they allow changing between two interaction modalities. Here the tangible component can be used for exploration whereas the graphical component can be used for rapid prototyping [7].

In line with this last approach CodeCubes combines Augmented Reality (AR) with physical blocks for promoting the learning of basic programming concepts. Some relevant examples of interfaces that use AR to promote computational thinking are the AR Scratch [8], Code Bits [9], AR-Maze [10] or Paper Cubes [11].

The AR Scratch is an extension that adds an Augmented Reality functionality to the Scratch programming environment, displaying virtual objects on a real-world space seen through a camera, where the virtual world can be controlled by physical markers. The AR-Maze, is a tangible programming tool for children, that uses physical programming blocks and mixes virtual and real elements. Children can create their own programs by manipulating the programming blocks and debug or execute the code with a mobile device. Code Bits is a tangible paper kit that students can use to create programs. The code is then processed in the Code Bits mobile application. Paper Cubes aims at teaching basic computational skills as well as more advanced programming skills in the field of Artificial Intelligence (AI) or Machine Learning (ML) using AR. Cubely [12], is an immersive Virtual Reality (VR) programming environment in which novice programmers solve programming puzzles within a virtual world.

CodeCubes combines affordances from Paper Cubes (the physical paper cubes) and from Code Bits, however CodeCubes allows users to program and process the code on the virtual environment without having to change environments like in Code Bits. In the following section we present the CodeCubes interface.

3 CodeCubes

CodeCubes builds on the Classic Maze game [13], in which the users use visual programming blocks that they can drag and drop to program and overcome various challenges. However, instead of using virtual programming blocks e.g. as in the Scratch platform (see Fig. 1, top), CodeCubes uses physical paper cubes that can be easily crafted by the users and serve as interface to manipulate the virtual elements (see Fig. 1, bottom).

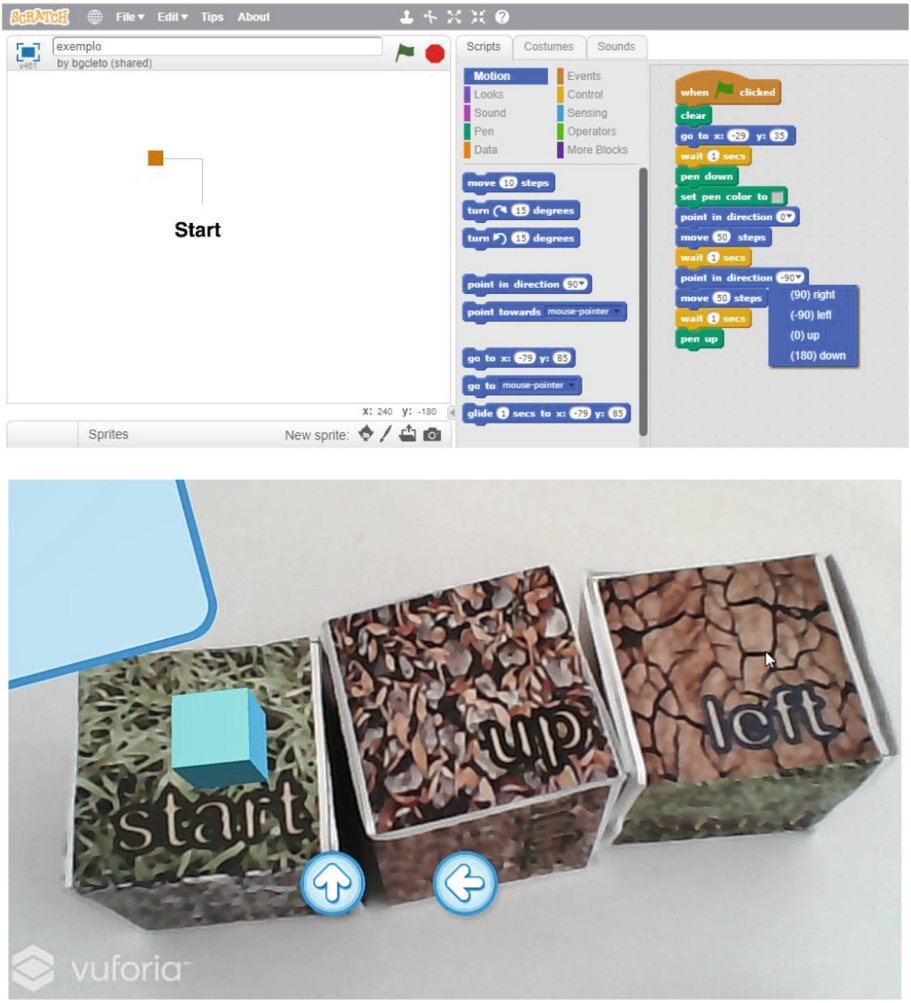

Fig. 1. The scratch programming environment (top), the CodeCubes environment (bottom)

CodeCubes was developed in the Unity 2017.4.0f1 (64-bit) game engine [14] and the Vuforia AR platform [15], which allows the virtual simulation of the tangible programming cubes. Each face of the cubes has an AR marker that represents one of the basic programming instructions: start, forward, right, left, back and end. To improve the detection of the physical cubes and to minimize possible recognition errors, mainly in poor light conditions, the markers present text labels and patterns.

CodeCubes presents the users a labyrinth with various paths along which there are cubes and pyramids scattered. The application allows the users to create their own labyrinths, which they can print on an A4 sheet of paper. The printed labyrinth displays the area for placing and moving the physical cubes.

To start the game, the users show the face with the start marker of a physical cube to the camera. Once the camera detects the start marker a 3D virtual cube appears over the physical paper cube. The users can visualize both the virtual cube and the path that they need to program with the physical cubes to follow a certain route. After programming the virtual cube using the physical programming blocks, by clicking the play button, the user visualizes the programmed actions (see Fig. 2). This is the virtual cube moves along the programmed path.

Fig. 2. Interface and game interaction

To fulfil the game the user needs to program the virtual cube to follow a certain path in order to pick the different cubes and pyramids that are scattered over the play surface. When the users are successful they can start creating buildings, e.g., by pilling up cubes and pyramids on the play field (see Fig. 3). The aim of the game is to create different building constructions, resulting in a small town at the end of the game. To achieve this, the users use the physical paper cubes to program the path of the virtual cube. As previously referred each face of the cubes has an AR marker that represents

one of the basic programming instructions: start, forward, right, left, back and end. In order to program a sequence of actions that the virtual cube must follow, the user places each paper cube in front of the camera of a mobile device showing the respective face, and then hits the play button to execute the programmed actions.

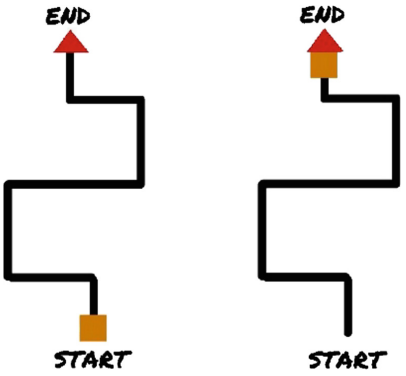

Fig. 3. Example of a path to be programmed

The goal of the game is that the students collaboratively create their own labyrinths as well as different building construction. A possible scenario could be building constructions with different heights (pilling up different number of cubes) and using the pyramids for building the roof or even incorporate them on the buildings.

4 Conclusion and Future Work

In this paper we have presented CodeCubes, a hybrid interface for collaboratively learn basic programming concepts. The combination of physical and virtual elements aims at supporting and promoting social interactions between the students themselves as well as between the teachers and the students. Therefore, potentially increasing students learning motivation and achievements. CodeCubes, is still in an early development stage, in the next design iterations we will explore together with the students the inclusion of different construction elements that the users can use to create their buildings in a more creative way. Another thought is to enable the users to create their own physical markers and the physical objects to manipulate the virtual game content. The resulting upgraded prototype will be tested in the classroom environment to investigate the impact that the addition of a tangible component to a digital game can have in the teaching/learning process as well as the extent to which it promotes collaborative problem solving.

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