An Embodied Interface for Teaching Computational Thinking

Judith Good, Pablo Romero, Benedict du Boulay, Henry Reid, Katherine Howland
IDEAs Laboratory
University of Sussex, Department of Informatics
Brighton BN1 9QH
J.Good@sussex.ac.uk
+44 (0)1273 873 228

Judy Robertson
Mathematical and Computer Sciences
Heriot-Watt University
Edinburgh EH14 4AS, UK
Judy.Robertson@hw.ac.uk
+44 (0)131 451 8223

ABSTRACT
We describe an innovative educational system designed to, firstly, motivate young people to engage with computational concepts and secondly, provide them with tools to do so in an embodied manner. The interface is designed as a "magic mirror" in which users can, through augmented reality technology, take on the role of a character and control the character's movements via their own movements. They are able to record movements, and using a Wii Remote as a mouse and pointing device, organise these movements into sequences. We are now working on ways in which the recorded movements can be manipulated in ways that foster computational thinking.

Author Keywords
Embodied interfaces, augmented reality, computational thinking.

ACM Classification Keywords
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *graphical user interfaces, input devices and strategies, user-centered design.*

INTRODUCTION
Computational thinking can be defined as a way of "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" [11]. These fundamental concepts, such as abstraction, decomposition, heuristic reasoning, planning and scheduling, amongst others, can be applied across a wide range of disciplines in a way that allows for new advances in many fields. Computational thinking extends from such subjects as statistics, biology and chemistry, to sports and entertainment. In fact, Wing postulates that computational thinking is crucial for everyone, and should be considered as a basic skill to be taught to children along with reading, writing and arithmetic.

There is a compelling case to be made for the importance of computational thinking, given the pervasiveness of computers in almost all disciplines and in a wide variety of both work and leisure situations. However, as seductive as the idea of computational thinking may appear to those within the field of computer science, the problem remains of how to motivate young people to engage with computational thinking, and to see its relevance. There are a number of different initiatives which, although they don't address computational thinking explicitly, aim to make computer programming more engaging and relevant, for example, Alice [3], and Scratch [8].

Our approach to fostering computational thinking is three-fold: firstly, by providing an innovative, embodied interface to students in the form of a "magic mirror" (described in detail below), we aim to leverage their enthusiasm to engage in this new form of interaction. Secondly, by providing activities which are novel and engaging, and which allow for students to learn and practice computational thinking skills, we aim to sustain their motivation. Finally, by linking these activities to diverse areas in the curriculum, such as English, history, drama or dance, we aim to embody the belief that computational thinking does indeed span the curriculum, and can be applicable in a number of areas.

In the following sections, we provide an overview of the STAGE implementation, and describe an interaction with the prototype. We go on to discuss initial user testing of the prototype, and conclude with a description of further work.

STAGE PROTOTYPE IMPLEMENTATION
Our aim with the STAGE prototype is to develop a system which is both innovative and yet affordable, a prime consideration if it is to be used in actual classrooms.

The prototype combines components already available in today's classrooms (e.g. a computer, an interactive whiteboard), with elements that are either free or low-cost (e.g. augmented reality tags, which can be printed off on a standard black and white printer, a Wii Remote, a Wii sensor bar, and a webcam).

Figure 1 provides an overview of the STAGE prototype. From a hardware perspective, the prototype requires a computer and monitor (Figure 1 shows a large screen, although a desktop monitor or interactive whiteboard could equally be used).

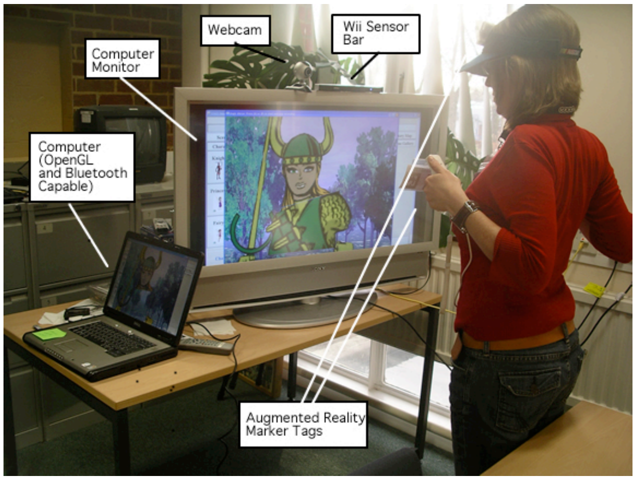

Figure 1. The STAGE prototype

Interaction with the prototype takes place via a Wii Remote, which is used as a mouse and pointing device. This device is detected using a Wii sensor bar mounted on the screen. Finally, the prototype uses Augmented Reality (AR) which allows virtual objects to appear alongside real world objects in a video display. The AR system used is described in [6] and [7], whilst [1] and [2] give a wider background on AR research. The prototype requires either a video camera or a web cam (as in Figure 1), along with AR marker tags which are worn on the user's head, body and hands (see Figure 2).

Figure 2. User wearing Augmented Reality Tags

INTERACTING WITH STAGE

In order to interact with the STAGE prototype, the user first needs to don the augmented reality tags (as shown in Figure 2), set up a web camera, and launch the STAGE application. The user starts by choosing a character (as shown in Figure 3), a background, and then launches the Magic Mirror by clicking on the appropriate button.

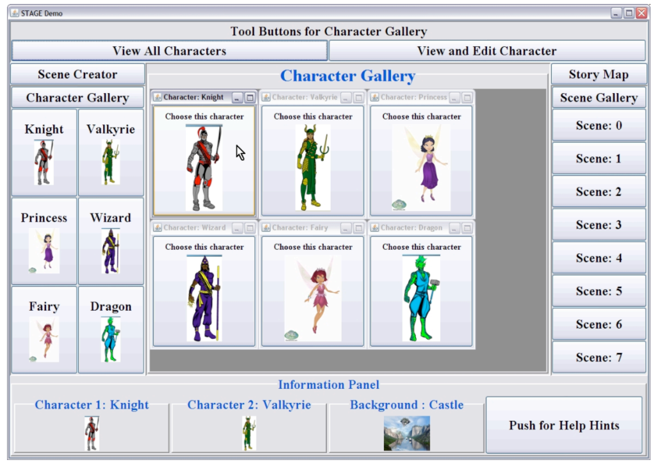

Figure 3. The STAGE interface

The user will then see herself as the chosen character on the screen, as in Figure 1.

Interaction with the STAGE prototype operates on two levels. Interface navigation takes place using a Wii Remote. Users can control the cursor and click on interface buttons by pointing the Wii Remote at the screen. Once the magic mirror is launched, the webcam (or video camera) is used to detect the augmented reality marker tags being worn by the user, and uses these to render the character previously chosen by the user. As the user moves, the change in position of the tags is detected, and the character on screen moves in synchrony with the user.

When using the magic mirror, users are able to record these sequences of character actions. Rather than a simple recording of a scene akin to a video recording, STAGE records the positional data of the trajectories of each AR paper marker. Thus, the movements recorded effectively form representations which can be manipulated in different ways. For example, once movements are recorded, users can insert a new background, or instantiate the movements of the recorded character to a new character, thus supporting the re-use of movement sequences. Work on the movement editor is currently focusing on allowing users to cut, copy and link scenes so as to create, say, a simple story.

The proposed approach therefore comprises two parts, a platform for developing applications (the Stage Platform), and the actual applications that will run on the platform. The platform will include the magic mirror to record movements and an editor to manipulate them. The applications developed for the platform could be environments to create simulations, video games, authoring environments for creating free-form, playful applications or game authoring environments, among others. We are particularly interested in the latter two environments as they allow plenty of scope for imaginative play within the authoring (construction) process. The following section provides an example of how such applications could work in a classroom context, and how they relate to fostering computational thinking across the curriculum.

AN EXAMPLE SCENARIO

Dance Along: The students from year 7 are looking at the Maori people in history and the dance teacher has linked the class activities to this topic by practicing the Haka dance. A small group of students in this class (Caitlin, Camila and Jon), who are looking at design abstraction and modularisation in ICT, are interested in creating a dance mat-like game to help the rest of the children learn the Haka. They use the Dance Along game authoring environment to recreate one of these dances and then dance along to it. First, they act and record a basic sequence of dance moves using the magic mirror. Then they edit these dance moves (figuring out the global design of the choreography, creating and assigning characters to dance moves, connecting and duplicating the dance moves), interacting with the moves editor concurrently, each using a Wii remote control to create a complex dance with 40 characters. Finally they invoke a built-in functionality for giving feedback and producing a score for players (this works by comparing the trajectories of players dancing along with those of the programmed characters). Then they invite Chloe, who is also in year 7, to see the movie of the dance and then dance along to it. Chloe chooses the character she wants to be and then dances in front of the magic mirror as if she were that character. When the dance finishes she looks at her score and watches the movie of her dancing as the character and realises that she didn't do that badly in the Haka. Chloe is so impressed by the game that she asks Caitlin, Camila and Jon to teach her how to use the Dance Along environment to create her own dance games. They show her how to record scenes and how to design a choreography by manipulating dance moves, stressing that some of the key concepts are designing the dance in a modular way, understanding the difference between the abstract library of moves and their concrete instantiations and assigning parameters to moves.

The scenario illustrates the main characteristics of our approach, an embodied style of interaction [5], fostering computational thinking skills by an active process of construction (not only of a piece of software but also of a plan of action and strategies) [9, 10] and the mediating aspect of the environment to provoke collaborative encounters [4].

The specific computational thinking skills which are being fostered in this scenario include abstraction and modularisation, working with and differentiating between abstract entities (classes) and their instantiations (objects), and handling parameters.

Within the scenario, abstraction and modularisation are needed in order to create the global design of the choreography from basic move sequences. Abstract entity creation is performed by acting and recording basic moves. Instantiating these moves to concrete scenes is necessary to create the complex dance of 40 characters. This process requires a clear differentiation between the abstract library of moves (the classes) and their associated concrete scenes (the objects). Finally, assigning characters to dance moves is an example of passing parameters (the characters) to the abstract entities (the basic moves) in order to create concrete instances.

INITIAL USER TESTING

In order to test both the usability and motivational potential of STAGE, we carried out an initial consultation with a group of teachers, followed by classroom sessions in a local school. In both cases, feedback was very positive.

Our teacher consultation was organised as a one hour session with primary and secondary school teachers, and consisted of an initial explanation of the project, a demonstration of STAGE, and a presentation of some scenarios of use, followed by questions and comments. Feedback on these workshops focused on technical and usability issues, and the educational potential of the tool. An important technical issue highlighted was the frequent flickering of the images presented in the Magic Mirror. A usability concern was the need to ensure a seamless integration between the recording and editing processes.

Topics related to the educational potential of the tool included the timeliness of the approach, given the increasing importance of ICT in the curriculum, and the importance of collaboration and of physical activity. Some of the possible applications discussed were as a tool for storytelling (especially for younger children), as support for counselling and intervention strategies (children might feel more disposed to act and talk about their problems if they do not identify themselves with the displayed characters) and in subjects such as drama, English and dance.

Finally, teachers were very enthusiastic about the potential of STAGE, and were keen collaborate in its evaluation in classroom settings.

The school visit consisted of two classroom sessions, one with a group of 8 young people in Year 8 (ages 12-13) and the second with a group of 11 young people in Year 10 (ages 14-15). Although STAGE is designed for the younger age group, we felt it would also be useful to obtain feedback from this slightly older group. The first group of pupils was exceptionally enthusiastic about trying out STAGE. While testing the prototype, they explored the different functionalities and used multiple characters and backgrounds. The second group of pupils was initially less enthusiastic about STAGE, and quick to point out the current hardware and software limitations, such as the flickering. However, they did enjoy using it, and all but one said they would want to use it in the classroom.

Comments and suggestions were aimed at extending STAGE and adding functionality, for example, the ability to import characters, and to design one's own character. Doing so may also engage the older age group more fully, as current characters are quite cartoon-like, and aimed at the younger audience.

Although it is too early to draw any solid conclusions, the evaluation seems to indicate that, at least in its present state, STAGE has the potential to engage and motivate children of the target age range, and could perhaps be extended to older audiences.

ONGOING AND FUTURE WORK

Current and future work can be divided into further tool development, evaluation and dissemination. Further tool development comprises the full implementation of the recording facility, the movement editor and the development of at least two applications for the platform.

In terms of tool development, the next phase of work will focus on the movement editor, and will allow for more complex manipulations of movements. For example, the user will be able to duplicate movements, speed them up, play them backwards, and combine them to create composite movements, e.g. by overlaying sequences of movements. In this way, the recorded scenes can effectively be used as animation libraries.

The design and implementation of the movement editor will need to consider issues related to the anatomical plausibility of movements and recorded sequences. For example, when appending two animation sequences, the editor should adjust the resulting sequence in such a way that there is a smooth transition from the finishing point of the first animation to the starting point of the second.

Another important part of further tool development is to address the frequent flickering of images. This is a problem related to the use of Augmented Reality technology. The camera is sometimes unable to read the marker tags, which causes the image on the screen to disappear for an instant. One way to avoid this problem is for the system to hold the same image on display if a new one is not provided (i.e., if the camera could not read the marker tags). Although this approach would create 'holes' in the path of the marker tags, this missing information can be regenerated using simple interpolation techniques.

Regarding the development of applications, the project includes the development of a series (at least two) authoring environments related to subjects such as drama, English or dance, for example. The platform, although innovative and appealing, does not currently comprise sufficient authoring functionality. Ideally, the developed authoring environments should provide enough support for young people to create powerful applications in specific curricular areas while at the same time leaving enough room for a sense of challenge and the chance to be creative.

The evaluation will comprise evaluation of the platform as well as of the developed authoring environments. The platform evaluation will focus mainly on usability issues while that of the authoring environments will take educational aspects into account.

Finally, dissemination will be an important part of future project activities. We will actively encourage other research groups to consider the Stage Platform as the standard tool to build applications using embodied interaction.

REFERENCES

[1] R. Azuma. A Survey of Augmented Reality. In *Presence: Teleoperators and Virtual Environments* 6, 4, 355-385, 1997.

[2] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, B. MacIntyre. Recent Advances in Augmented Reality. *IEEE Computer Graphics and Applications* 21, 6, 34-47, 2001.

[3] W. Dann, S, Cooper, R. Pausch. *Learning to program with Alice*. Prentice Hall, New Jersey, 2005.

[4] C. Crook. *Computers and the Collaborative Experience of Learning*. Routledge, London, 1994.

[5] P. Dourish. *Where the Action is: The Foundations of Embodied Interaction*. MIT Press, London, England, 2001.

[6] M. Fiala. *ARTag, an improved marker system based on artoolkit*. NRC/ERB-1111 NRC 47166, National Research Council Canada, July 2004.

[7] M. Fiala, ARTag, a Fiducial Marker System Using Digital Techniques. Proceedings of the 2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05) - Volume 2, p.590-596, June 20-26, 2005.

[8] J. Maloney, L. Burd, Y. Kafai, N. Rusk, B. Silverman, and M. Resnick. Scratch: A Sneak Preview. *Second International Conference on Creating, Connecting, and Collaborating through Computing*, pages 104–109, Kyoto, Japan, 2004.

[9] S. Papert. *Mindstorms: Children, Computers, and Powerful Ideas*. Basic Books, New York, 1980.

[10] S. Papert. *The Connected Family: Bridging the Digital Generation Gap*. Longstreet Press, Atlanta, Georgia, 1996.

[11] J. M. Wing. Computational thinking. *Communications of the ACM*, 49(3):33–35, 2006.