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MathMazing: 3D gesture recognition exergame for arithmetic skills

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Abstract: We have developed a 3D gesture-recognition based animation game, called MathMazing, for teaching arithmetic to primary school students. MathMazing requires application of not only Logic and Kinesthetic skills but also addresses spatial skills. It is created using an open source 3D animation and game logic tool called Blender. The gestures are captured using Microsoft Kinect and imported into Blender through FAAST, a gesture-interpretation tool. Preliminary experiments and interviews with primary school students show that they enjoyed the active learning environment in MathMazing. They were motivated by its interaction mode, beyond that of conventional computer-games, for sustained interest in arithmetic. We are in process of conducting more rigorous experiments to assess the usability and learning outcome of Mathmazing.

Keywords: Arithmetic drill, gesture based educational games, exergaming, multiple intelligences, Blender game engine.

Introduction

Fluency in the basic arithmetic skills of addition, subtraction, multiplication and division helps students in acquiring higher level math skills (Ke, 2008, LaBerge & Samuels, 1974). Fluency in math can be achieved by drill and practice as it helps students in automatic retrieval (Dehaene, 1997, Wong & Evans, 2007).

Computer games that have math drill significantly enhance students' positive attitudes toward math learning (Ke, 2008). Students prefer computer based drill and practice over conventional paper-pencil drill (Yurdabakan & Uzunkavak, 2008). The aspects of computer based practice like: multiple practice opportunities, randomized item generation, immediate feedback and automated scoring encourage students to practice more. Additionally, students enjoy the challenges to reach high scores and eagerly spend time on computer-based math drill (Nguyen, et al., 2006).

On the other hand, spending time on playing computer games leads to sedentary lifestyle habits, with associated health issues (Dietz & Gortmaker, 1993). Hence it is desirable to incorporate physical activity into computer games. Exergaming (exercise and gaming) is a new form of gaming that requires players to perform physical activities in order to play a game. One of the definitions which we use in this paper is, “combination of exercise and video games” (Bogost, 2007). With exergaming, the mind focuses on the action displayed and the exercise "just happens" while the player is having fun.

Gesture-based interaction devices, such as WII, Nintendo, X Box and Kinect, are more exciting than conventional interaction devices like keyboard, mouse and joystick. Use of gesture-based interaction devices for educational purposes has a positive impact not only on children's learning but also on their enjoyment in physical activities (Alharthi, et al., 2012)

In addition, gesture-based games induce students to apply a number of the nine abilities corresponding to multiple intelligences (Gardner. H., 1983). These games typically address the Logical and Kinesthetic abilities. For example, Learn pads (Karime A. et al., 2011) is a math problem-solving game that uses a set of footpads as the interaction device. Students have to solve the problem (logical) and jump on the footpads to reach the answer (kinesthetic). Since, computer games are also useful to develop spatial ability (Dondlinger. M. J., 2007) it would be interesting to add visual aspects too.

We have developed a 3D gesture-recognition based animation game, called MathMazing, for teaching basic arithmetic to primary school students. MathMazing requires application of not only Logic and Kinesthetic abilities but also addresses spatial abilities. MathMazing combines the advantages of math games and exergames. It is a single player, gesture controlled mathematical maze. Players need to solve the mathematical equation (logic), locate the path to the correct answer (spatial) and perform gestures to steer the onscreen character to the correct answer (kinesthetic).

Figure 1 summarizes the workflow of MathMazing. The player's gestures (1) are captured using Microsoft Kinect (2) and converted into signals (3). The signals are interpreted using FAAST (4) and converted to key press events (5). These events are imported into Blender game logic (6) and shown as player movement on the screen (7). The player can now decide the next step based on this visual feedback. Preliminary experiments and interviews with primary school students show that they enjoyed the active learning environment in MathMazing. They were motivated by its interaction mode, beyond that of conventional computer-games, for sustained interest in arithmetic.

In Section 1, we present the overview of MathMazing, followed by its implementation details in Section 2. In Section 3, we present the experiment, followed by results and analysis in Section 4.

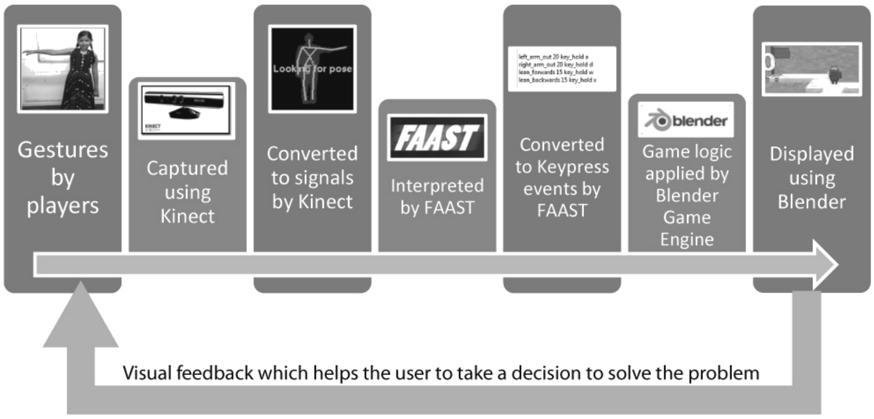

Figure 1: Flow diagram of MathMazing

1. Overview of MathMazing

MathMazing is a single player, multi-level, gesture-controlled mathematical maze. At each level, the player has to solve a randomly generated arithmetic equation. Three answer choices are displayed at three different end-points of the maze, one of which is the correct answer. Users can see the instructions for 'How to play' at the start of the game. The player has to navigate through the maze to the correct answer, using gestures. These gestures include some simple actions like bending forward/backward to make the 3D character move forward/backward, or raising your left/right hand up to move the player left/right.

1.1 Game Play

As shown in Figure 2, the game starts with an equation displayed on the screen. A timer starts the countdown simultaneously. Users see a 3D floating maze with three end-points, corresponding to the three choices for the answers of the equation. A 3D character, representing the player, is shown at the bottom of the screen. The steps for the player are as follows:

1. Solve the equation and get the answer for it.
2. Locate the answer from the three choices displayed on the screen.
3. Find the shortest correct path to reach the answer through the maze.
4. Steer the onscreen 3D character to the answer, by performing relevant gestures in front of Kinect (which is connected to the computer).

The player has to make gestures to guide the 3D character along the path leading to the correct answer. If the player makes a wrong gesture, gets to the wrong answer, or runs out of time, the 3D character falls into the water, and the level has to be restarted.

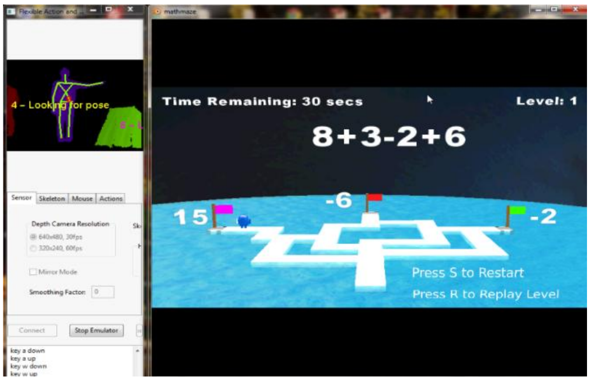

Figure 2: Screenshot showing the actual game in progress

If the player gets to the correct answer successfully, he/she can either replay the level or move to the next level. Complexity of the equations increases with levels. Time available reduces with each higher level, thereby training the player to calculate faster.

1.2 Benefits of MathMazing

As mentioned earlier, MathMazing requires application of not only Logic and Kinesthetic abilities but also addresses Spatial abilities. Logical ability is inductive and deductive logic, numeration, and abstract patterns. Kinesthetic ability is about potential of using one's whole body or parts of the body to solve problems. Spatial ability is about forming and manipulating a mental model (Ho¨ysniemi, 2006). Table 1 shows the four stages of playing MathMazing and the respective abilities addressed.

Table 1: Multiple intelligences required to be applied in MathMazing

Stages of playing MathMazing	Abilities Addressed
Solve the equation	Logical
Locate the answer	Logical+Spatial
Find the shortest correct path	Spatial
Steer to the destination using gestures	Spatial+Kinesthetic

2. MathMazing implementation

2.1 Scope

MathMazing targets the development of basic arithmetic skills that require the appropriate application of the BODMAS theorem. It focuses on Logical, Spatial and Kinesthetic abilities. Development of higher-level math skills or other abilities are beyond the scope.

2.2 System architecture

Figure 3 depicts the basic architecture of MathMazing. It has five main modules: Input, Interpretation, Visual imagery, Game logic and Output. The details of the modules and the rationale for the choice of hardware and the software used in the system architecture are given in the following subsections.

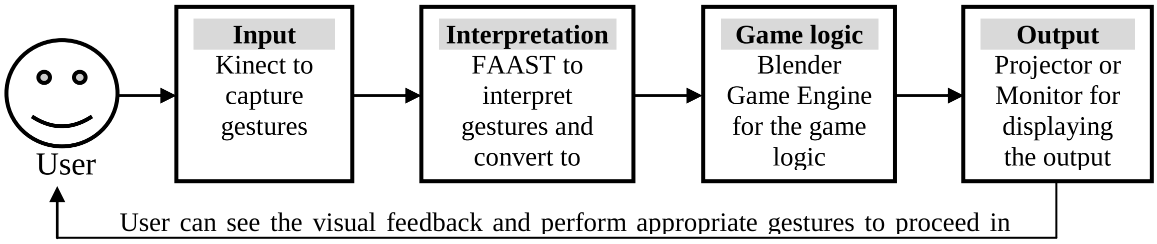

Figure 3: System architecture of MathMazing

2.2.1 Input module

This module captures the gestures performed by the player and sends it to the computer. It is done using **Microsoft Kinect.** Kinect is a motion sensing input device from Microsoft. The reason to select this device was that it has RGB camera, depth sensor and multi-array microphone. These features provide full-body 3D motion capture, facial recognition and voice recognition capabilities, which were necessary for the game play.

2.2.2 Interpretation module

This module interprets the data captured by the input device (Kinect) converts it to keypress events and then passes it to the game logic module. We used FAAST **(**Flexible Action and Articulated Skeleton Toolkit), to facilitate this integration, as it is an open source middleware (other SDKs like Kinect were not open source at the time of this decision). It is also compatible with a variety of gesture recognition tools to emulate keyboard input triggered by body posture and specific gestures. This feature allows the programmer to add custom body-based control mechanisms to existing off-the-shelf games that do not provide official support for depth sensors. In MathMazing, Kinect sends the gesture data like ‘bend forward’. FAAST interprets it, and then converts into key press event like ‘up arrow key press’ for the game logic module.

2.2.3 Game logic module

This module implements the game logic. This is done using Blender Game Engine (BGE), a component of Blender 3D (an open source 3D content creation suite). The decision of using Blender was taken since it is open source, and has modeling and game engine is integrated.

The imagery required for the game was created in the modeling component of Blender (version 2.49). In MathMazing, the screen shows a maze like structure floating on water. The viewers can see the waves in the water and the splash if the character falls into it (See Figure 1). Other artifacts like 3D character, numerals for the display and three waving flags shown at the ends of the maze were also created. Blender 3D production methodology (Dere. S. et al., 2010) of modeling, texturing and lighting was followed to create these models. Modeling was created using few polygons, to facilitate smooth motion display of the game. Same strategy was followed for texturing and lighting.

The game logic was created using BGE. It is a python based programming tool for creating interactive 3D games. It uses a combination of ‘sensors’, ‘controllers’, and ‘actuators’ to control the movement. A Sensor will detect some form of input. This input could be anything from a keypress, a joystick button, or a mouse click. Controllers link Sensors to Actuators and allow for some more complex control over how sensor and actuators interact with each other. An Actuator will actually carry out an action within the game. It controls the motion of the object, which includes moving an object within a scene, playing an animation, or playing a sound effect.

BGE provides options to the programmer to choose the inputs as sensors. These sensors are then connected to the appropriate controllers. The different controllers are then connected to the respective actuators. (See Figure 4).

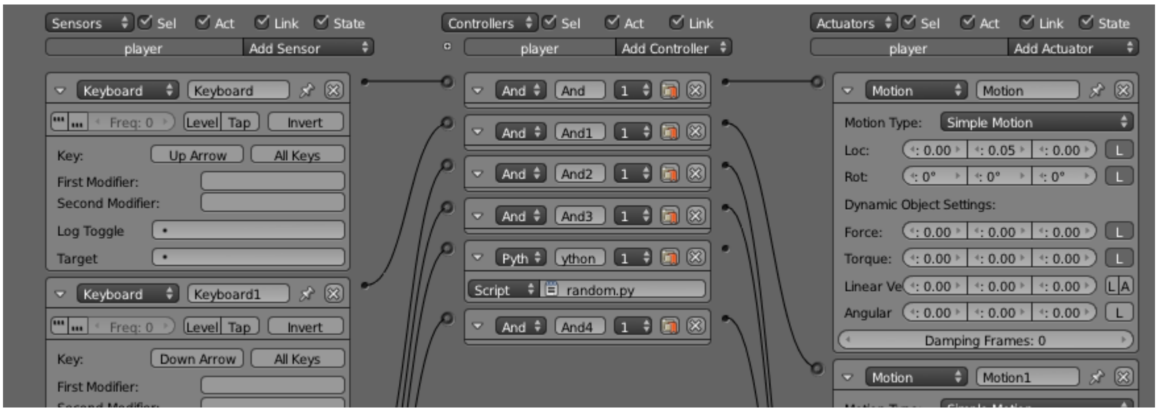

Figure 4: Settings in Blender Game Engine

2.2.4 Output module

This module provides visual feedback to the player. It consists of a display device like a projector or a monitor. Having solved the equation, the player has to perform gestures to make onscreen characters move to the right answer.

3. Experiment

3.1 *Objective of the experiment*

The game development is in its preliminary stage, so we have not performed rigorous experiments to test its effectiveness in terms of achievement of the students in arithmetic. We have tested for some components of usability as defined in the research like learnability (degree of ease for the first time users), efficiency (after they have interacted once, how quickly can they perform) and satisfaction (whether the interaction was pleasant?) (Nielsen, 2003 and Shneiderman, 1980).

3.2 *Sample*

Four students were selected using a convenient sampling method. These were from the age group between 9-12 yrs. There were two boys and two girls in the group. All the students had prior exposure to computer enabled gaming for approximately two years.

3.3 *Tools*

Since the sample was small (n=4) we used a mixed method. In addition to administering a 14-item usability scale, we also conducted interviews of the participants. We recorded the time log of the students' game play and noted observations about their interactions during the game play.

3.4 *Procedure*

In the beginning all the students (players) were briefed about the game, verbally and also by showing a live demo by one of the researchers. Later, each player was given 15 minutes to play the game. While the player was interacting with the game, one of the researchers maintained a time log of the interaction. Another researcher noted down the observations of the interaction. After the game play, the player was given the 14-item usability survey. Finally, the third researcher conducted a interview of the player to augment and crosscheck the survey data.

4. Results and Analysis

Table 2 shows responses of the students to 4 key items in the usability survey.

Table 2: Responses to key items in the usability survey

Item	Yes	No
Do you feel more confident of solving Math after playing MathMazing?	4	0
Do you enjoy the game more because the player moves as you move?	4	0
Would you prefer to not have the maze and directly select the right answer?	1	3
If this game required keyboard input, would you play this game frequently?	0	4

Table 3 shows the average time taken by the students for the various stages of the game, for their first and last attempts.

Table 3: Average time taken for various actions

Action	1. Solve the equation	2. Locate and Steer to the answer
Average time for First attempt (seconds)	22.01s	26s
Average time for Last attempt (seconds)	9.25s	14.75s
Percentage of improvement	**57.95%**	**43.27%**

As can be seen from Table 2, the students not only found MathMazing enjoyable (item 2) but also showed a marked preference for its gesture-based interaction mode (item 4). This shows that MathMazing not only makes arithmetic drill enjoyable to students but also induces them to perform physical activities.

As can be seen from Table 3, there was a reduction in the time required by the students to not only calculate the correct answer (column 2) but also navigate to it (column 3). This validates our assumption that MathMazing could be used to enhance Logical, Kinesthetic and Spatial abilities.

During the interviews, a student said that Math was one subject he always feared but his enjoyment of the game helped him to overcome the fear. Students also mentioned that they liked the interaction (Kinect) and the game play. They said that if the interactions were using keyboard and mouse then, they would not have played the game so long.

We are aware that the sample size for the experiments is too small, therefore we are in the process of carrying out more experiments regarding the usability and effectiveness of MathMazing. We feel that gesture-based games involving a combination of kinesthetic and spatial components could be designed for other subjects also.

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