SMARTPADS - ENCOURAGING CHILDREN'S PHYSICAL ACTIVITY USING A MULTIMEDIA EDUTAINMENT SYSTEM

by

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A thesis submitted to the
Faculty of Graduate and Postdoctoral Studies in partial fulfillment of the
requirements for the degree of Master in Electrical Engineering

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Abstract

This thesis presents an exercise-based edutainment system intended for children. It is designed to enhance their cognitive development by encouraging movement in a fun way. The main idea behind the system is that children will have fun constructing a physical, tangible user interface. In addition, they will learn how to spell many words that represent objects and entities by stepping on a collection of coloured pads and receiving responses through a set of multimedia outputs related to these entities. For this purpose we have designed and implemented a tangible user interface that facilitates interaction with the system. This tangible user interface is called "SmartPads" and is composed of coloured tiles that can be physically connected to each other to form any shape. The pads are mapped onto a computer screen in real-time. A user interacts with the interface by stepping on the pads. We have incorporated two games that allow children of different ages to benefit from the system's functionalities and encourage them to interact with it. This thesis provides detailed information about the proposed system and its related components, discusses the design and development of the two games, and measures the system's performance when used by the children.

Acknowledgements

It is a pleasure to thank those who made this thesis possible. First and foremost I would like to thank my supervisor Professor Abdulmotaleb El-Saddik for his support and guidance throughout this degree. I am indebted to my closest colleague, Ali Karime, for his constant cooperation and innovative ideas. His role in the final product is considerable. I would also like to thank Hussein Al Osman for his valuable comments and assistance throughout this research, and also thank all my friends and fellow DISCOVER Lab students for their suggestions and constructive discussions.

I would like to thank my family, my wife Bushra and my sons Ali and Mustafa, whose patience, kindness, encouragement, and endless support allowed me to complete this degree.

Moreover, I would like to acknowledge the fruitful collaboration with Prof. Jihad M. Alja'am from Qatar University.

Lastly, this study could not have been possible without God. Thank you.

This project is sponsored by Qatar National Research Fund – QNRF, NPRP 09 - 052 - 5 – 003.

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List of Abbreviations

3D: Three dimensional

API: Application Programming Interface

CST: Connection Status Tree

LED: Light-emitting Diode

GND: Ground

GUI: Graphical User Interface

ID: Identifier

FSR: Force Sensitive Resistor

PC: Personal Computer

RGB: Red, Green, and Blue

TUI: Tangible User Interface

TV: Television

UART: Universal Asynchronous Receiver Transmitter

UI: User Interface

USB: Universal Serial Bus

Vcc: Integrated circuit power supply pin

VE: Virtual Environment

VR: Virtual Reality

Chapter 1

Introduction

Edutainment is a term coined to describe the merger of education and entertainment such as video games. It is known for its learning and cognitive benefits for children, however, adding a physical aspect could make it even more beneficial. When physical activity is combined with video games, it is called exergaming. In this thesis, we present a system that combines aspects of both paradigms. This chapter provides some background on both edutainment and exergaming, followed by a look at the current problems encountered in existing related systems. We then describe our contribution, and finally, outline the content of the remaining chapters.

1.1 Background and Motivation

Edutainment: The term edutainment is defined in many ways. White [1], for example, defines edutainment as a multimedia-related term for a computer interface that is used in both education and entertainment. The American Heritage Dictionary defines edutainment as "the act of learning through a medium that both educates and entertains". Maushak *et al.* [2] defines edutainment as the manipulation of entertainment for educational purposes, specifically video games. Rapeepisarn *et al.* [3] states that edutainment is the act of learning heavily through a combination of many media (television programs, video games, films, music, multimedia, websites and computer software).

The idea of using entertainment for the purpose of education is not a new one. It is an important form of education that has been used by many education systems to improve the cognitive skills of children [4, 5]. In fact, according to [6], researchers have been interested in developing children's games for the purpose of education since the 1990s. The reason behind this interest is multi-faceted. To begin with, Hogle's [7] review of the benefits of using games as cognitive tools shows that they increase interest, motivation, and retention. Furthermore, [8, 9] also point out that these games improve higher order thinking and reasoning skills, and Stone [10] asserts that edutainment helps students so that they become more involved in the subject they are learning and even wish to continue practicing after the session is over. As a result, there has been a tremendous demand for developing efficient systems that promote learning through playing in an intuitive manner [11, 12, 13, and 14].

Exergaming: With the popularity of video games, children are becoming more inclined to spend long hours in front of a screen. This extended playing time has caused them to lead inactive lifestyles, and thus created several social, mental, and physical problems for the players [15, 16, and 17]. Since these video games have become an intrinsic part of many children's everyday activities, persuading the children to quit the gaming activity is impractical. In response, researchers have attempted to enhance video games by supplementing them with a physical dimension. This is usually done by replacing the traditional input interfaces like mice, keyboards, and joysticks with new interfaces that promote physical activity. As such, exergaming is thought to be a suitable solution for reducing obesity in children [18]. Exergames aim to overcome the lack of enthusiasm for exercising by combining it with a gaming element.

Most existing work has approached the topic of edutainment by developing computer games, like painting for example, as well as learning games [19]. Other works have designed systems and tools for interactive storytelling [20, 21]. These systems are more focused on stimulating discussions and sharing ideas among children [21, 22] and do not pay much attention to the users' physical activity.

On the other hand, the main shortcoming of most of the existing exergaming systems is the fact that they focus mainly on improving the physical health of the users without taking the educational aspect into consideration [23]. For instance, with Wii Sports from Nintendo children can play tennis, boxing, baseball, and other games by simply waving the controller [24]. The Eye Toy gaming series [25] from PlayStation 2 also interprets the user's body movements that tracked by a camera into actions. These are great physical activities, but they lack in terms of educational content.

Through the investigation of existing edutainment and exergaming systems, we have been motivated to design a multimedia system that promotes the overall wellbeing of children by combining aspects of both the exergaming and edutainment fields.

1.2 Existing Problems

There are various problems with existing systems that differ from one system to the next depending on their functionalities and the goals they accomplish. The following is the summary of these problems:

- **Entertainment vs. Education:** Many systems have focused more on entertainment than education. For instance, systems in [26] and [27] focused on the level of fun without taking cognitive development into consideration.

- **Functionality vs. Price:** Some systems, such as [21, 28 and 29], had to be equipped with expensive components in order to add more functionalities. This made it unaffordable for many people because the price of the tool increased significantly.

- **Special System Requirements:** Some systems require a special environment like a cave or the wall in [30]. Such systems generally could not be used in homes. Requirements like these have restricted people from using these systems and made them only suitable for experimental purposes.

- **Deficiency in Interactivity:** Many of the software based edutainment systems require children to be sitting in front of a display for long periods of time. The lack of interactivity among children and between the child and the system has pushed researchers to turn the spotlight onto the negative health, mental, and physical effects for children that use such systems.

- **Static Tangible User Interface (TUI):** Most of the existing edutainment and exergaming systems' tangible user interfaces are static, which means that their shape is fixed and cannot be changed. Hence, these kinds of interfaces can become boring with time.

1.3 Objective and Contribution

The objective of this research is to bring about a rare intersection between the edutainment and exergaming paradigms by making use of an intuitive tangible user interface that can be customized by the end user.

The following points summarize the contributions in this thesis:

- Analyze the requirement of the children's exercise-based edutainment system and design and development of a microprocessor-controlled, tangible user interface called "SmartPads". These pads can be connected to form any shape and communicate with the computer using RS-485 communication technology.

- Design and development of an exercise-based edutainment system that uses SmartPads as a physical tangible user interface and enhances children's learning and cognitive development while remaining fun and encouraging interaction with the system and other peers.

- Integrate multiple multimedia output modalities, such as text, images, and audio, in order to enrich the child's learning and entertainment experience.

1.4 Publications Resulting From This Research

The following paper has been published and is directly related to the thesis topic:

> A. Karime, B. Hafidh, A. Khaldi, and A. El-Saddik, "MeMaPads: Enhancing Children's Well-being through a Physically Interactive Memory and Math Game", *IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*, Graz, Austria, 2012.

1.5 Thesis Organization

The remainder of this thesis is organized as follows:

Chapter 2 presents an overview of background literature for different works in the domains of edutainment and exergaming as well as some of the smart TUIs. When applicable, there is discussion about the drawbacks and suitability of the systems for children. It also provides a comparison table that summarizes the most important characteristics of these systems that are relevant to our proposed system.

Chapter 3 discusses the proposed system and elaborates on the different aspects of the design. This chapter focuses mainly on the real-time recognition of the tangible user interface and the interaction between this interface and the computer software module.

Chapter 4 discusses the implementation of the system. It also discusses the technology that was used in developing the system and explains the implemented Graphical User Interface (GUI).

Chapter 5 presents the evaluation of the system. It details the different test cases that were performed and focuses on the evaluations of system usability and user studies.

Finally, in chapter 6 we summarize our work, present our conclusion, and propose potential future work.

Chapter 2

Related Work

There have been many efforts in the fields of edutainment and exergaming aimed at promoting both learning and physical activities while playing. In this chapter we review the basic concepts and functionalities of the various edutainment and exergaming machines. We also present some edutainment and exergaming systems that currently exist in the commercial market. A comparative study is then drawn between the different approaches stated in these works and our proposed system.

2.1 Edutainment and exergaming through tangible interface devices

In this section, we review different edutainment and exergaming systems that use TUI to either interact with the computer as an input device or as both an input and output device.

2.1.1 Magic Stick

The Magic Stick is an RFID-based TUI that aims to help children over the age of one learn about new objects and entities by providing their names associated with different images [31]. The RFID is used for object identification and is placed on the tip of the stick in order to detect the tags located on different objects. The communication between the stick and the computer is done using Bluetooth technology. Children's interactions have been tested in two scenarios. In the first scenario, the mother of a two-year-old child was provided with a tagged image book containing different pictures, and she was asked to help her child use the Magic Stick. The second test took place in a laboratory with preschoolers who were invited to play a game with a number of RFID-tagged dolls of different types, such as animals and birds. In both scenarios, children were encouraged to tap on the tagged objects to accomplish a certain goal in the game. The system provided educational media in response, such as the objects' names and a set of images for those particular objects (Figure 2.1).

Figure 2.1 The Children solving the game using the Magic Stick [31].

The system was highly appreciated by parents and teachers for its learning benefits; however, it did not really help encourage physical activity.

2.1.2 ActiveCube

ActiveCube [32] is a device that allows a user to interact with a 3D environment by using a set of rigid cubes with a bi-directional user interface to construct a structure that is recognized by the computer in real time. A 3D structure that corresponds to the physical structure of the cubes can be seamlessly constructed in the application. Each cube is equipped with a microcontroller, which is used to communicate between the cubes and the computer and can also control input or output devices integrated in each box, such as sensors or actuators/displays, to execute actions or show simulated results. Examples of these devices are motors, buzzers, lights, and vibrators. Children and adults can use the system by retrieving 3D shape models. Another 3D application that makes use of this tangible interface is called a story-telling system, an interactive system for stimulating children's creativity and imagination intuitively. First, users construct a shape using ActiveCube, which is displayed for them to play with in virtual space. The constructed structure is recognized by the computer in real-time, and a set of closely matching 3D models are retrieved from a database. At that point, one of the candidate models can be selected by the user, and the computer starts the virtual play mode. The child can play in the virtual space while holding the constructed shape (see Figure 2.2).

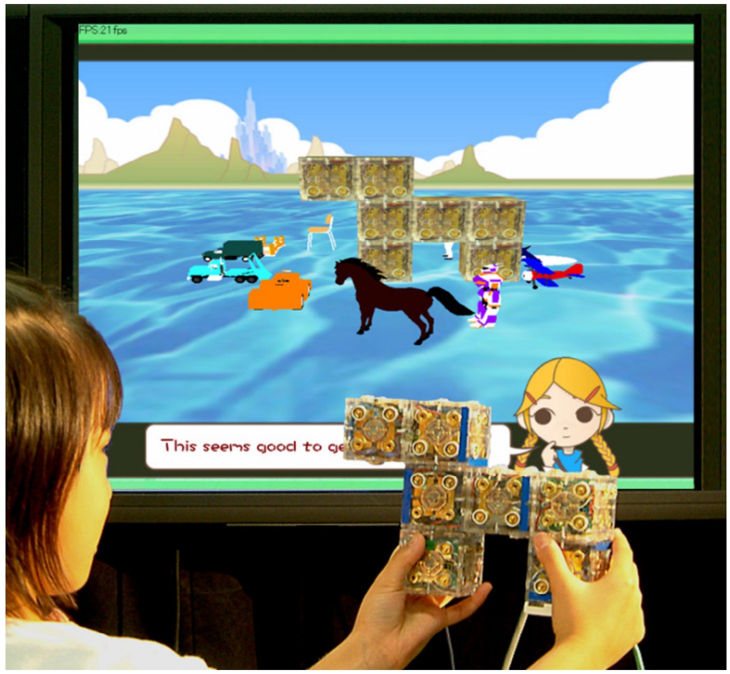
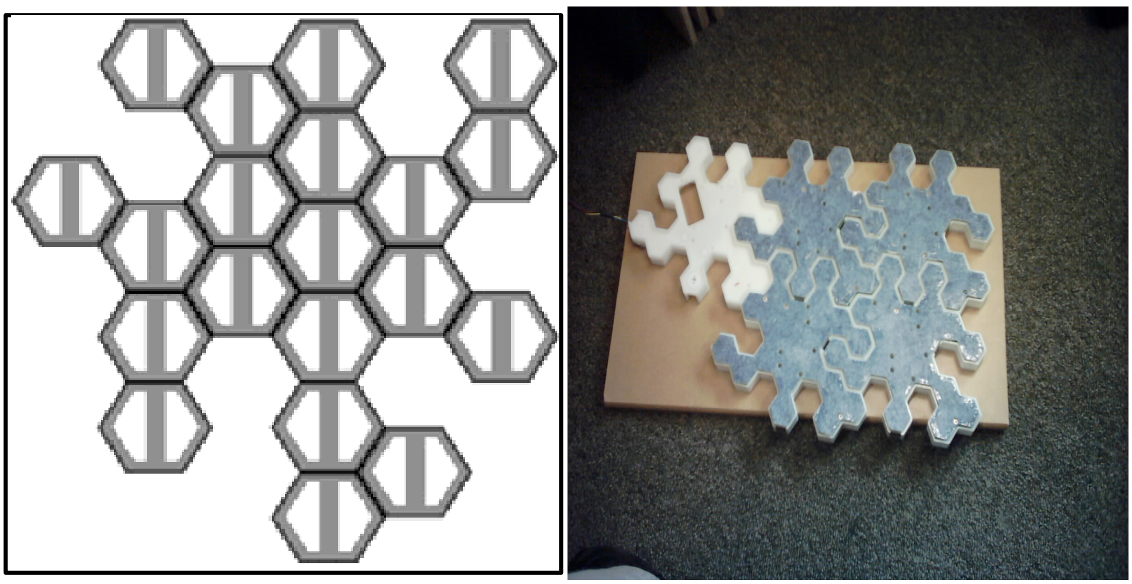


Figure 2.2 Shape selection for several candidate models [32].

2.1.3 Z-Tiles

Richardson *et al.* [33] have presented a new interactive floorspace used as an input interface for generating music from the movements of dancers or for controlling computer games. The floorspace consists of modular nodes (Z-tiles) connected together to create a variable size and shape, pressure-sensitive area integrated into an interactive environment. The main application of the system is as an interactive dance floor with performance requirements, such as sensing resolution and response time to stimuli, a sensitive measurement in real-time. Each node has twenty force-sensitive resistors (FSRs) as demonstrated in Figure 2.3a. The unique shape of the nodes allows them to be interlocked with each other in a regular pattern (Figure 2.3b). Data reading and communication among tiles by means of a Universal Asynchronous Receiver/Transmitter (UART) is controlled by five microcontrollers per node. One microcontroller has been used for the tile pressure sensor readings and the other four handle the communication among the tiles. There are many applications for the system. Children can interact with the system by generating music from their movements on the Z-tiles. The author has also used the tiles as input devices for controlling computer games, like controlling the movement of a hovercraft in a racing game in a virtual reality (VR) application.



(a) (b)

Figure 2.3 (a) The Z-Tile shape; (b) prototype tiles in a small Z-Tiles floorspace [33].

Here, the authors focused mainly on providing a fun environment for the children. Consequently, the system did not include any educational content.

2.1.4 Playware-Playground

Another work that shares common functionalities with [33] is Playware-Playground [34]. The main difference between the two works is that Z-tiles are input-only devices, whereas Playware tiles serve as both input and output devices. Playware is a building-block concept based upon principles from robotics and embodied artificial intelligence for creating a kind of playground that allows the implementation of outdoor games that demand physical activity by the end users. A set of tangible tiles was developed to function as building blocks. They contain processors, sensors, actuators, and communication capabilities. There is an FSR inside each tile to act as an input device. The output device of the system is composed of 18 LEDs (9 blue and 9 red) integrated in each tile in the first version of the system. In version 2, lights that can display 8 different colours in addition to audio output are used. Every time a user jumps over the tile, the LEDs switch from blue to red or from red to blue. The microcontroller in each tile can communicate with the four neighboring tiles and control the games as well. The tiles can be arranged into different physical arrangements. One tile is known as the master tile and should be included in the tile set so that different games may be uploaded.

Figure 2.4 Children playing physical games on the tangible tiles [34].

Several games, such as Color Race and Ping Pong, have been implemented by constructing different patterns with the tiles. Some of the games need the master tile as the first tile in the constructed shape. In the Color Race game, children compete against each other by first choosing a colour (either blue or red) and then jumping quickly over the tiles so that they turn into their colour. In the Ping Pong game, a red arrow moves around the tile set randomly, and when it gets to one side of the tile configuration, the child has to return the arrow to his/her opponent by jumping quickly over the arrow tile. The arrow can only move to a connected neighbour. Figure 2.4 shows children playing games on the tangible tiles. The

Playware tiles are considered as input and output interfaces at the same time, and all the designed games use the speakers and LEDs. In our system, however, computer games have been developed as the output when interacting with the tiles instead of using the tiles as output devices, which makes our implementation less expensive.

2.1.5 Breakout for Two

Breakout for Two [28] is a system in which two players can play soccer together and at the same time, even if they are in two different locations around the world. Each player's location is provided by three cameras; one provides the video-conference to the other player, and the other two cameras track the ball. Those three cameras, in addition to an audio connection, enable the players to interact with each other in real time. Figure 2.5 demonstrates the system setup. Both of the players kick a ball against a local physical wall that represents the boundary between the players over which they can communicate. The players, however, feel like they are separated by only a glass window. Eight semi-transparent blocks are displayed via the video stream. These virtual blocks are shared between the players and appear on each player's wall. The player is awarded a point when she/he successfully breaks a block by hitting it three times. The requirements of this game (multiple cameras and reliable network in each player's location) make its performance unpredictable due to the variation of delays that are inherent in existing networks.

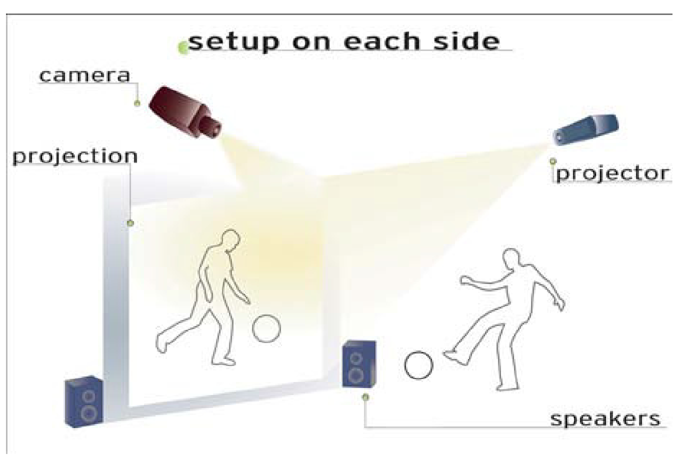


Figure 2.5 The Breakout for Two system setup on each side [28]

2.1.6 Learn-Pads

Learn-Pads [35] is a math-based exergaming and edutainment system aiming to improve the math skills of children (ages 7 and up) while they are playing. The system consists of 4 square pads as a tangible user interface. They have integrated pressure sensors, and work with an arithmetic video game running on a computer. The children simply jumps on two of the four pads alternatively N times to answer some basic arithmetic operations (addition and multiplication), where N is the answer to the arithmetic operation, as shown in Figure 2.6. The child has to jump over a third pad in order to indicate to the system his/her final answer. In order to display a new arithmetic operation, the child needs to step on the fourth pad. With every step, the child can hear a verbal spelling of the number he/she has reached. In addition, the game is accompanied with music and verbal feedback regarding the validity of the child's answer.

Figure 2.6 A child playing with Learn-Pads [35].

Although the system creates an atmosphere of fun among the children and engages them in a physically active learning exercise, it can become repetitive with time due to the static shape of the tangible user interface. This drawback, however, has been overcome in our system by designing a flexible tangible user interface that allows the child to organize the tiles into different physical arrangements.

2.1.7 MeMaPads Game

Another example of a foot pad interface is the MeMaPads game [36]. MeMaPads is a multimedia exergaming system that promotes learning. It consists of a mat with a set of square pads that children have to step on to interact with the game. An FSR sensor is embedded in each pad in order to interact with two software games; a memory game and a math game. In the memory game, matching pairs of pictures need to be uncovered by the children from among a set of hidden images. Every step on a pad reveals an associated picture. A verbal and written spelling of the entity is presented with each picture when displayed on the screen in order to enrich the vocabulary of the child. In the math game, children improve their math skills by answering some basic arithmetic questions, such as addition, subtraction and multiplication, by stepping on two random pads that generate two random numbers and a random arithmetic operation. The system then displays a matrix of numbers that contains one correct answer. The child then has to step on the pad that corresponds to the right answer. Figure 2.7 shows a participant playing with MeMaPads.

Figure 2.7 A participant playing with the MeMaPads memory game [36].

2.2 Commercial systems

There are many exergaming and educational tools for children that have already been commercialized and become very popular. The price of these tools also ranges from as low as few dollars to as high as hundreds of dollars depending on the capabilities they provide. Here we will review three of these tools.

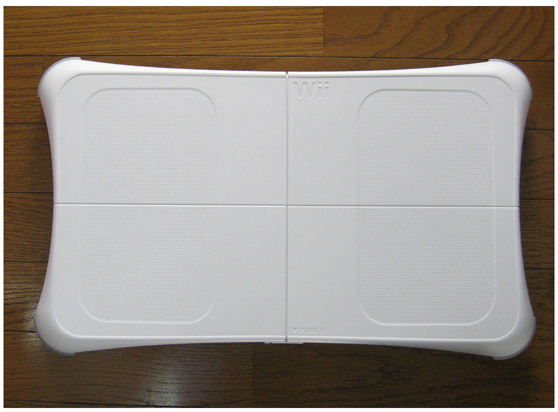
2.2.1 Smart Fit Park

Smart Fit is a TV-interactive commercial system that is aimed at children between the ages of 2 and 6 [37]. It has learning games at multiple levels, which encourages users to stay active as they learn. Smart Fit is a mat with multiple integrated pressure sensors and buttons as shown in Figure 2.8. It enables children to walk, run, and jump during interactive activities. The mat is plugged into the TV through the audio/video cable. The children can play educational games like letter identification, addition and subtraction, and spelling while performing motor skill activities.

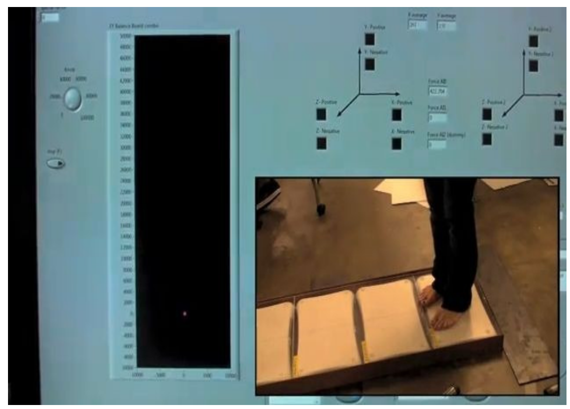
Figure 2.8 The Smart Fit Park [37].

2.2.2 The Wii Balance Board

Another commercial foot-operated game is the Wii Balance Board bundled with the Wii Fit software, which was released by Nintendo in 2007 [38]. The balance board input interface device, shown in Figure 2.9a, is a plastic panel containing four pressure sensors. The measured pressure values are communicated to the host PC via Bluetooth. This board is designed originally to measure the centre of balance and weight of the user on the board. The Wii Fit software features four categories of activity to choose from: strength training, aerobics, yoga, and balance games like soccer heading, ski jump, and balance bubble. Several boards can be linked together to form the so called Equilibrator [39] to help physically-challenged children between the ages of 6 and 18 learn balance skills. The system incorporates five linked Wii Balance Boards to form a straight runway along the floor as shown in figure 2.9b. These boards interact with the host PC by running a custom-designed video game called "Kill Monsters". Children using the system are able to play the game by successfully performing exercises in order to build their balance skills.



(a)



(b)

Figure 2.9 (a) The Wii Balance Board [38], (b) The Equilibrator (5 linked Wii Balance Boards) [39]

2.2.3 Dance Dance Revolution

Another prevalent tool is the commercialized Dance Dance Revolution (DDR) from Konami [40]. In DDR, one arrow pointing in each of four directions - forward, back, left, and right - scroll up the screen in various sequences and combinations. The player must step on the corresponding arrows on four tiles on the floor in time with the arrows on the screen (Figure 2.10).

Figure 2.10 The DDR game console.

DDR provides some health benefits by promoting a serious level of exercise. In addition, it is a social game and promotes lots of fun. On the other hand, this game can cause some lower-body problems such as pain in joints, knees, and balls of the feet [41]. Moreover, the game yields almost no cognitive benefits to its players.

2.3 Summary and Comparison

Based on the above review of the existing literature and systems, we compare six distinct and important aspects and show how the different works address each one. This information is displayed in Table 2.1 and includes our own system in the comparison. The aspects being compared are:

a) Type of interaction interface: Devices that might be necessary in order for the user to interact with the system.
b) Education goals: Learning objectives the system aims to achieve.
c) Type of physical activity: Type of motor movement the system promotes.
d) Age range: Recommended children's age range.
e) Whether the tangible user interface of the system has a static or dynamic shape or geometry.

f) Output modality: The nature of the output(s) projected to the user.

Related work	Type of interaction interface	Education goals	Type of physical activity	Age range (Years)	Does TUI have a dynamic shape?	Output modality
Magic Stick [31]	RFID Stick	Learn about new objects	N/A	1 and up	No	Audio, animation, images, text
ActiveCube [32]	Smart cubes	Learning how to assemble real and virtual objects	N/A	4 and up	Yes	3D graphics
Z-Tile [33]	Smart tiles	N/A	Movement of dancers	N/A	Yes	Audio, animation
Playware Playground [34]	Smart tiles	N/A	Jumping	7 and up	Yes	Audio, LED light on the same tile
Breakout for Two [28]	N/A	N/A	Kicking a ball	12 and up	No	Video, audio
Learn-Pads [35]	4 foot pads	Arithmetic operations	Jogging, jumping	7 and up	No	Audio, graphics, text
MeMaPads [36]	Mat with 16 pads	Memory game, arithmetic operations	Jumping	4 and up	No	Audio, still images, animation, text
Smart Fit Park [37]	Pads	Letter identification, addition, subtraction, spelling	Walking, jumping	2-6	No	Animation, audio, text
Wii Balance Board [38]	Board with 4 foot pads	N/A	Jumping, balancing	6 and up	No	Animation, audio, text
DDR [40]	4 foot pads	N/A	Jumping, kneeling	10 and up	No	Lights, audio
Our System	SmartPads	Assembling, memory, spelling	Jumping	5 and up	Yes	Audio, animation, still images, text

Table 2.1 A summary of the related work and how it compares to our own system.

Chapter 3

Proposed Approach

This chapter discusses the requirements for our proposed system along with the overall architecture and the different modules associated with it.

3.1 Requirements of the Proposed System

This section discusses the set of requirements for our proposed system based on the objectives stated in section 1.3 and in light of the related work presented in Chapter 2. We identify the characteristics that we feel would make the system educational while promoting physical activity and entertainment. In our opinion, the following are the most important requirements for accomplishing our goals:

- **Interactivity:** [42] has pointed out that watching the TV or computer screen by children for many hours a day increases the chance of childhood obesity. Moreover, research has revealed that negative physical, social, and mental impacts have been linked to prolonged computer usage by kids [43, 44, 45, and 46]. In order to be healthy and productive, children need physical activity and social interaction [51]. Hence, our system should encourage children to be involved in a dynamic play environment and encourage them to engage in discussions and cooperatively play games.

- **Dynamicity and flexibility:** The goal when designing a physical user interface for children is to make it enjoyable and easy to use and play. However, fixed patterns of physical movements can become boring with time. For this reason our system should adopt a dynamic and flexible physical user interface so that the child has the ability to use their imagination and change the interface pattern to one of his/her choice.

- **Multimedia outputs:** Research indicates that using various types of media such as, text, audio, and images has a great effect in improving learning skills [47]. Based on this fact, our system should provide more than one kind of output medium in order to pique the interest of children.

3.2 System Overview

The main idea of the proposed system is to allow the child to construct his/her own physical interface to the gaming system in order to interact with a computer game. To do this we developed a padding system that allows the child to configure the pads in whatever shape they find suitable and engaging. These pads (or tiles) are mapped on the computer screen in real-time. This user interface is composed of a set of "SmartPads", where each pad has its own microprocessor integrated with a pressure sensor. The SmartPads are connected together to form a physical interface that can interact with various computer games. To demonstrate the system's functionality, we developed two custom games suitable for children: the memory game and the words game.

The remainder of this chapter is organized as follows: Section 3.3 presents the overall system architecture and discusses its various modules, Section 3.4 discusses the interaction support of the proposed system, Section 3.5 illustrates the concept of the SmartPads and the real-time structure recognition. Finally Section 3.6 details the two games associated with the system.

3.3 Overall System's Architecture

In this section, we provide an overview of the overall system structure. Figure 3.1 shows the architecture of the overall system including associated modules, which includes four parts:

A padding system, a repeater, a computer interface, and a multimedia output. The padding system represents a set of connected SmartPads (nodes) used as a physical input interface to the system. The repeater collects the data coming from the nodes. The data includes information about which node is added or removed or which pad has been stepped on. The repeater passes this information to the computer system, which in turn maps the nodes on the screen in real-time and runs the associated games with the aid of the multimedia output devices. The following are the modules used in the proposed system:

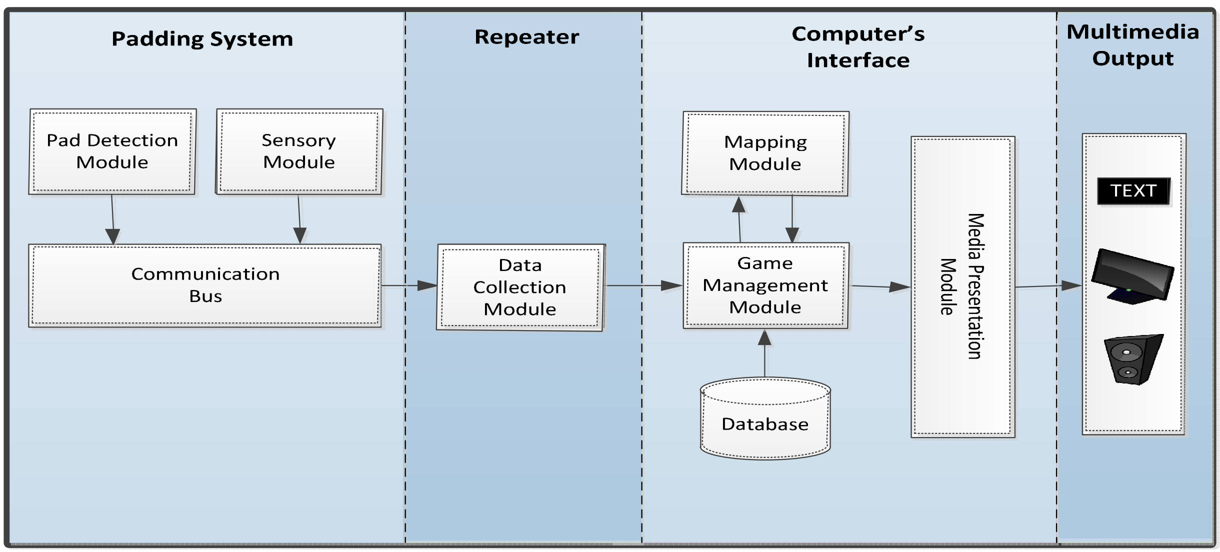


Figure 3.1 The overall system's architecture.

3.3.1 Pad Detection Module

This module is responsible for detecting when a new node is physically connected to or disconnected from the node cluster. Usually this module is activated when the user first sets up the user interface by combining the nodes in their selected pattern before he/she plays a game. A unique identification number is assigned to each node (padID). A sideID is also assigned to each side of the pad to identify the connected side. In the case of adding a new node to the system, the module broadcasts a connectivity message that includes both the padID and the sideID of both nodes being connected. Figure 3.2 demonstrates an example of a new node being connected to a node structure. The module broadcasts the padID and the sideID of the inactive node (Node 4), as well as the padID and the sideID of the active node (Node 2) through the serial bus. On the other hand, when a node is removed from the combination, the module responds by broadcasting only the pad and side IDs of the node whose state has been changed (i.e., the side from which a neighbour node has been disconnected). By referring to the same example in Figure 3.2, if Node 4 is disconnected, the module broadcasts the padID and sideID from Node 2. The connectivity information is communicated to the host computer via the repeater.

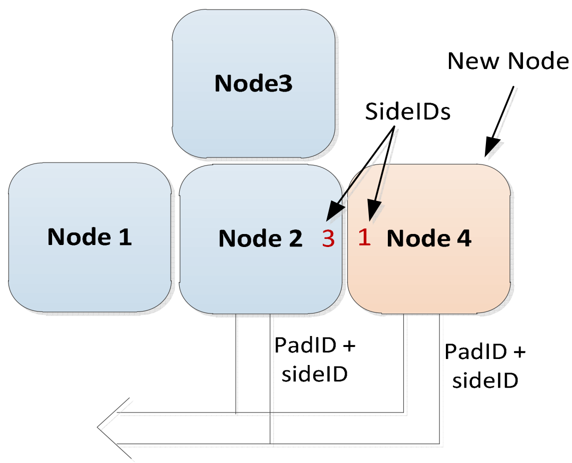


Figure 3.2 Example of node connection and disconnection.

3.3.2 Sensory Module

This module is activated when the user steps on a pad during game play. The duties performed by this module can be divided into three main tasks (see Figure 3.3):

1. Performing the analog to digital conversions of the signal received from the pressure sensors.

2. Making decisions on whether the value detected from a pressure sensor can be actually be considered a user step. We have determined a pressure threshold level above which a captured value can be considered as a valid step. This threshold was obtained from preliminary tests that were conducted with children in order to determine the minimum pressure value of a child's step.

3. Broadcasting the padID info of the pad being stepped on.

Similarly to the Pad Detection Module, the sensors' data are communicated to the host computer through the repeater.

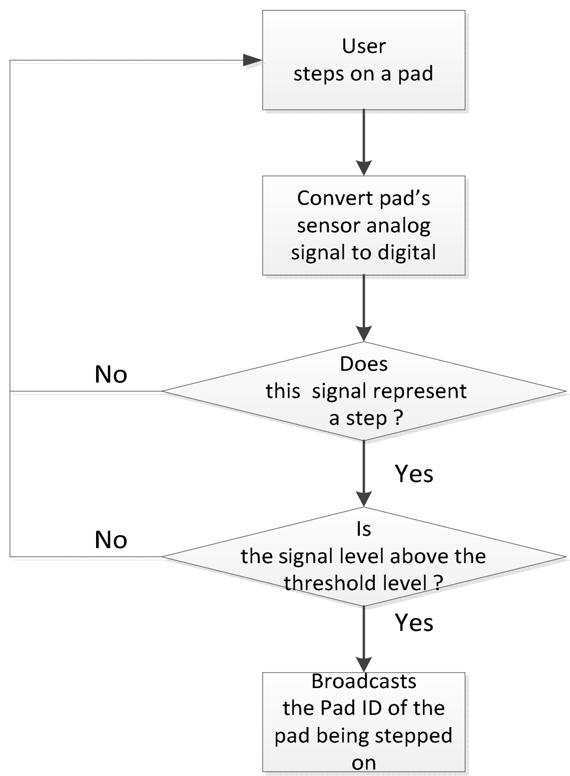


Figure 3.3 Sensory Module workflow.

3.3.3 Communication Bus

The Communication Bus is responsible for providing the necessary communication among the hardware components of the system. The medium of communication among the nodes is the (RS485), which is a serial method of communication. The bus passes the data received from the Pad Detection and Sensory modules to the Data Collection Module. Figure 3.4 demonstrates how the information is transferred among the nodes through the communication bus.

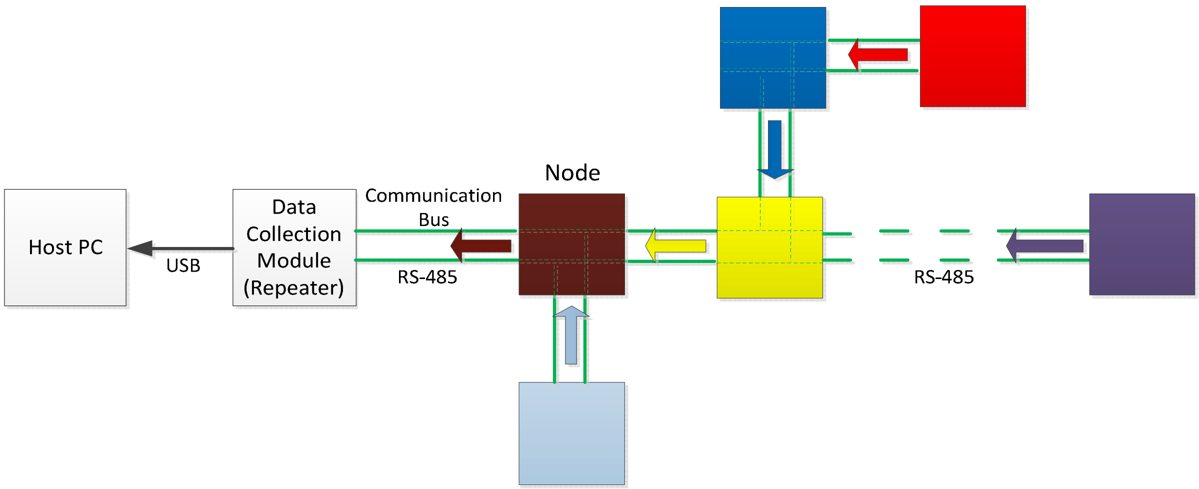


Figure 3.4 The Communication Bus.

3.3.4 Data Collection Module

The Data Collection Module provides the necessary translation between the hardware and software. It performs two tasks: firstly, it acts as a communication adapter by converting RS-485 to RS-232 so that the SmartPads interface can be connected to a computer through a standard USB port, and secondly, it collects the data received from the Pad Detection and Sensor modules and passes them to the Game Management Module.

3.3.5 Game Management Module

The Game Management Module controls both the mapping logic of the physical pad environment as well as within the accompanying games. This occurs upon receiving the pertaining information about the nodes. Such information includes the status of nodes being connected/disconnected, the ID of the node being stepped on, the location of the pads' images in the game, and the game's pictures in the database.

Figure 3.5 demonstrates the workflow of the tasks performed by this mechanism. It is clear that upon receiving the data from the Data Collection Module, the Game Manager first counts the number of nodes that have sent the data. If the information comes from a single node, it analyzes the data and decides whether it comes from the Sensory or Pad Detection

Module. However, if the information comes from more than one node, that means the information must come from the Pad Detection Module. If the information comes from the Pad Detection Module, this information is passed to the Mapping Module to map the physically connected or disconnected node on the screen. If the information received comes from the Sensory Module, it will take the appropriate action within the running game.

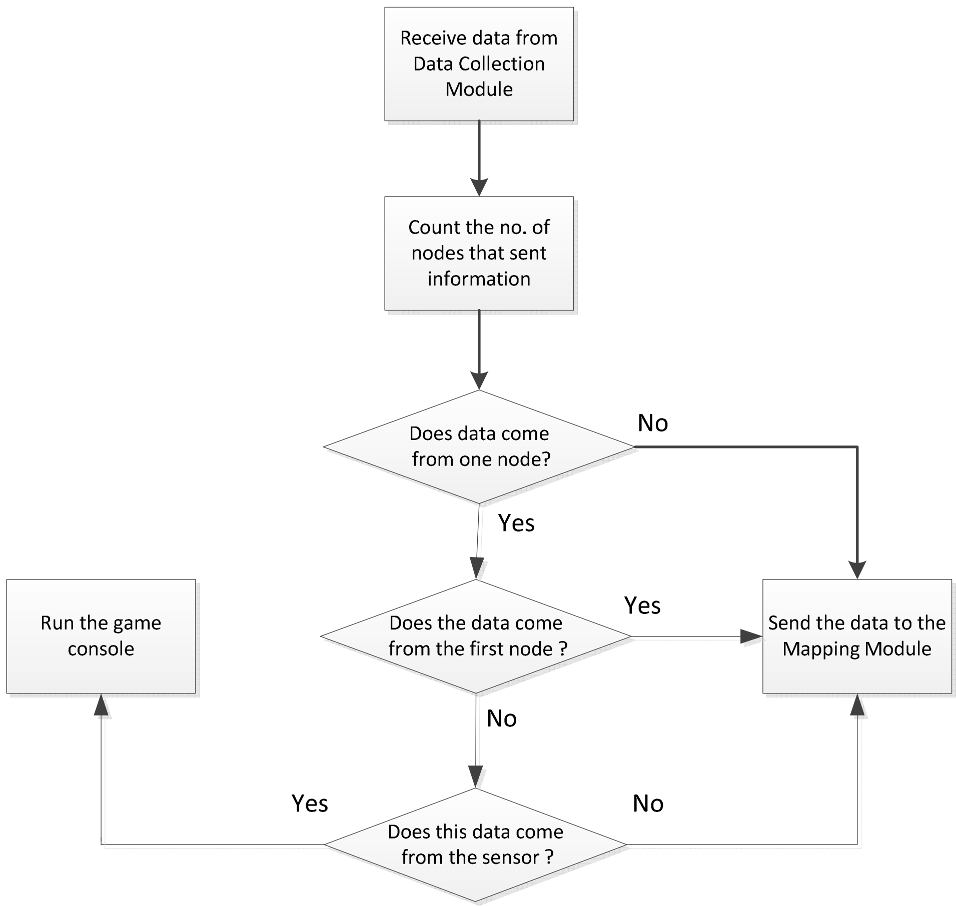


Figure 3.5 Game Management Module workflow when receiving data from Data Collection Module.

The Game Management Module also receives data from the Mapping Module. This information represents the position of a removed or added node. Upon receiving this information, this module passes the data to the Presentation Module in order to visually update the mapped nodes by adding or removing the picture of the node to or from the screen.

3.3.6 Mapping Module

This module performs the mapping of the physical nodes onto the computer screen. Upon receiving the data from the Game Management Module, this module performs the following tasks:

1. Analyzes the received data and decides whether it is for connecting a new node to the collection or for disconnecting an existing node.
2. Finds which of the information is for the active node by comparing the received information with the information stored in a structure called the Connection Status Tree (CST) [32]. This tree stores the padIDs of the active nodes.
3. Calculates the position and the colour of the added or removed node.
4. Updates the CST.
5. Passes the calculated position and colour information to the Game Management Module, which in turn passes them to the Presentation Module to update the node pictures on the screen.

Figure 3.6 demonstrates the workflow of the Mapping Module. It is clear from the figure that when adding or removing nodes, the CST array has to be updated.

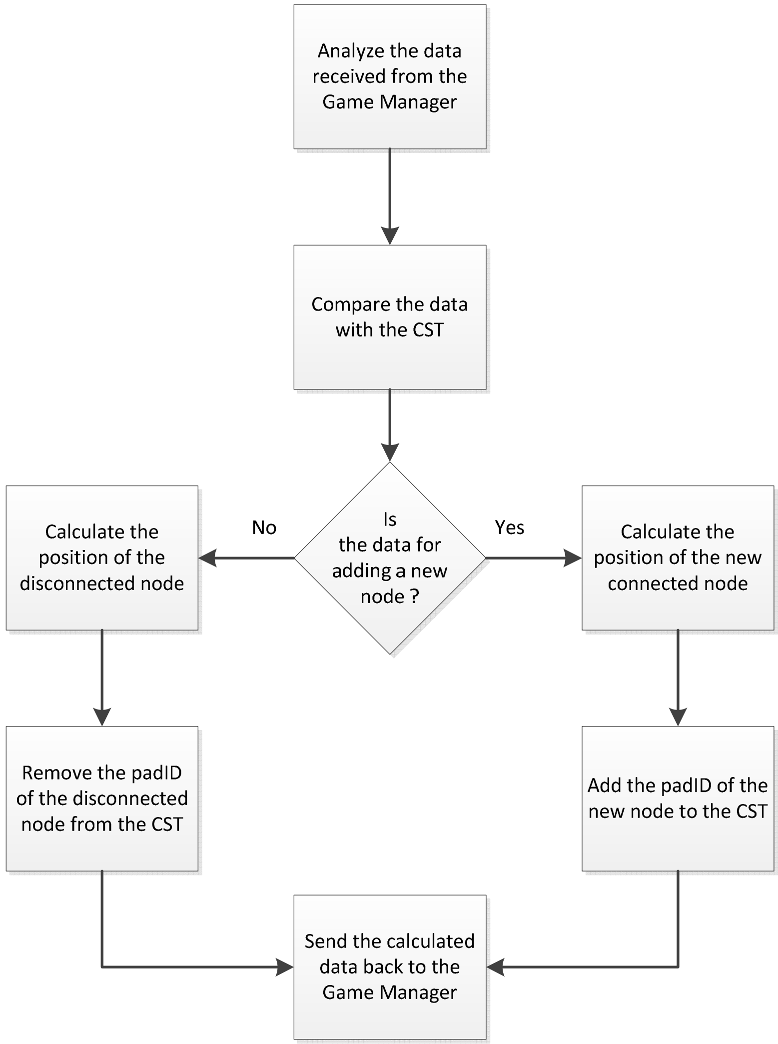


Figure 3.6 The Mapping Module workflow.

3.3.7 Media Presentation Module

The Media Presentation Module properly displays media, such as images, audio, or text depending on the game scenario, upon receiving the necessary commands from the Game Management module. These commands are processed by the Presentation Module to update the mapped nodes onto the screen or display pictures, text, or audio for the running game.

3.4 Interaction Support

Our proposed system provides a mechanism to enhance the interaction model so that the child is not sitting in front of the computer screen using traditional static interfaces like a mouse, keyboard, or gamepad. The system offers an interaction model that makes use of a dynamic tangible interface (SmartPads). The child interacts with the system during both the setup and game play phases. This method of interaction also achieves a continuous movement of the child around the game interface. In addition, the child can modify the shape of the interface during game play by adding or removing pads.

3.5 The SmartPads Design

In this section we provide details about the SmartPads design and explain how the host PC recognizes them in real-time.

3.5.1 SmartPads Hardware Design

The SmartPads system has been developed based on the techniques used in the smart input interface such as in [32, 33, and 34]. Each node is equipped with a microcontroller for the detection and communication among the nodes. The connected nodes compose a network bus made up of RS-485 components. Communication between the nodes and the host PC is achieved by connecting a repeater in the middle that translates RS-485 to USB as was shown in Figure 3.4.

Six communication lines are required on each of the node's sides to communicate between the other nodes. In Figure 3.7, six contact terminals are connected in each side. Two of them are for supplying the neighbour node with DC power (Vcc and GND) and two are for the serial bus (A and B) for communicating the nodes with the repeater. The last two are the input line and another Vcc line. The input terminal is used in order to recognize when there is a connection or disconnection of a neighbour node. The other Vcc terminal represents an output terminal and is always connected to the input terminal of the neighbour node to supply the connect/disconnect signal to it.

Each pad module also contains a pressure sensor. This sensor is used for gaming purposes, and it will be discussed in Section 3.6.

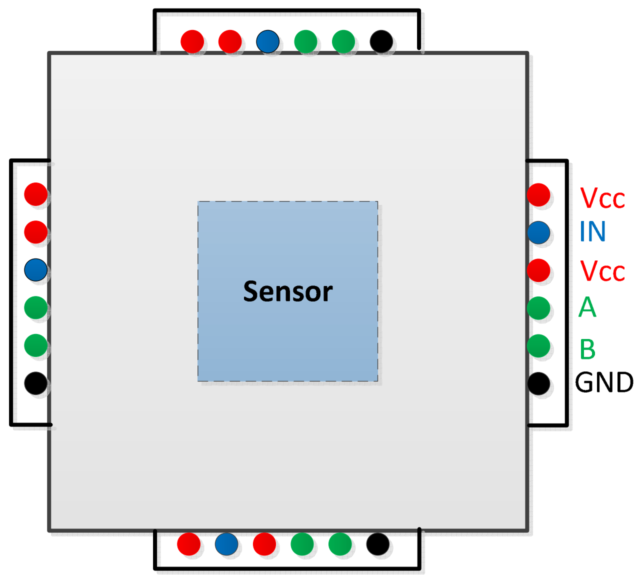


Figure 3.7 The SmartPad contact terminals

3.5.2 Real-Time Recognition

When a new node (inactive) is connected to the active nodes, it is supplied with power (Vcc) which allows the new node to broadcast its padID and the connected sideID. The newly connected side is recognized by the active node when its Vcc output connects to the input terminal of the active node. At this time, the active node broadcasts its padID and connected sideID. Upon receiving this information, the host PC maps the physically connected node into the virtual environment and updates the Connection Status Tree (CST) which organizes the connection status of the nodes. In the case of disconnecting a node from the network, its active neighbour node broadcasts its own padID and disconnected sideID; the host PC recognizes the disconnection and again updates the virtual nodes and the CST.

3.6 System Games

Since each pad is equipped with a microcontroller, it is possible to affix them with sensory devices that can be used to control a game. Two games (the memory game and the words game) have been designed using SmartPads integrated with pressure sensors to test the performance and functionality of the proposed system.

3.6.1 The Memory Game

In the memory game, the user is required to find matching pairs of pictures among a set of images. Unlike traditional memory games that are played with a mouse, the proposed system uses a set of pads integrated with sensors that the user has to step onto in order to interact with the game. Every step on a pad reveals an associated picture shown on the corresponding mapped pad on the screen. The system's media content can be customized by parents or guardians to suit the child's learning needs, thereby enhancing his or her cognitive development. The game includes images that aim to expand children's knowledge by introducing them to animals, birds, and many other different entities. In addition, every picture displayed is associated with a verbal and written spelling of the name of the entity being shown. Such functionalities can enrich the vocabulary of the children, consolidate their current knowledge of objects they might already know, and widen their boundaries of learning by showing new objects and shapes they might not have seen before. Consequently, the system resolves the learning deficiency of traditional memory games which seek to develop solely the memorization capabilities of the children without giving any information about the entities shown in the game.

Game Scenarios: The game can be played by one child or a group of children collaborating to find the match among the hidden pictures. First of all, the child or children must build their tangible user interface by connecting the pads, and the system responds by mapping those pads on the computer screen in real-time. We have incorporated customization functionalities into the game to allow guardians to be involved in their children’s learning. For instance, we allow them to choose from the various picture sets included in the database.

One proposed method for playing the game would be for the child to play alone while the teacher records the number of guesses and the time it take to complete the game. A second method is to divide a group or class into smaller groups that collaborate to find the matches. Since each child has different memorization abilities, the system enables guardians or teachers to increase or decrease the number of pads used as a physical interface, and consequently, the number of pictures associated in the game. Figure 3.8 presents the GUI interface of the memory game.

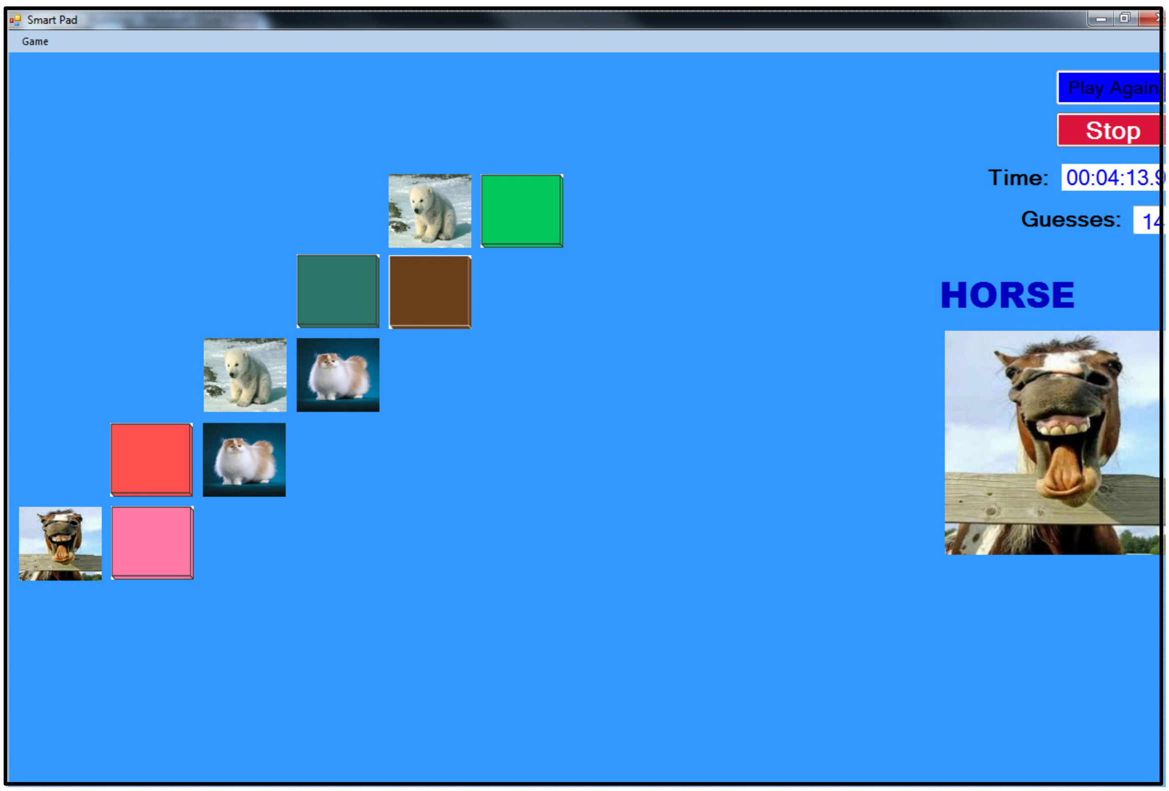


Figure 3.8 The memory game interface.

3.6.2 The Words Game

This game aims to teach reading and writing skills to children who are at earlier stages of learning. Children can write a word with the pads and get a corresponding picture, and audio and textual description. First, the word appears on the screen for a short period of time. Thereafter, the system displays a set of random letters on the mapped pads. The player has to step on the tiles in order to spell the word depicted by the image. Figure 3.9 presents a screen shot of the words game.

Game Scenarios: Like in the memory game, first the children can combine any number of pads together in a pattern of their choice in order to build their tangible user interface. After that, one child or more can either write by him/herself or collaborate in writing a selected word. The game has different word categories that the guardian can select for the children. Some of the categories are animal names, transportation, fruit, colours, and so forth. In addition, every word displayed is verbally pronounced and graphically depicted by a representative picture. As in the memory game, in order to enhance the interaction and competition among children, the game calculates the time elapsed to spell the different words, and it also provides sound effects to encourage the child when stepping on the correct pads.

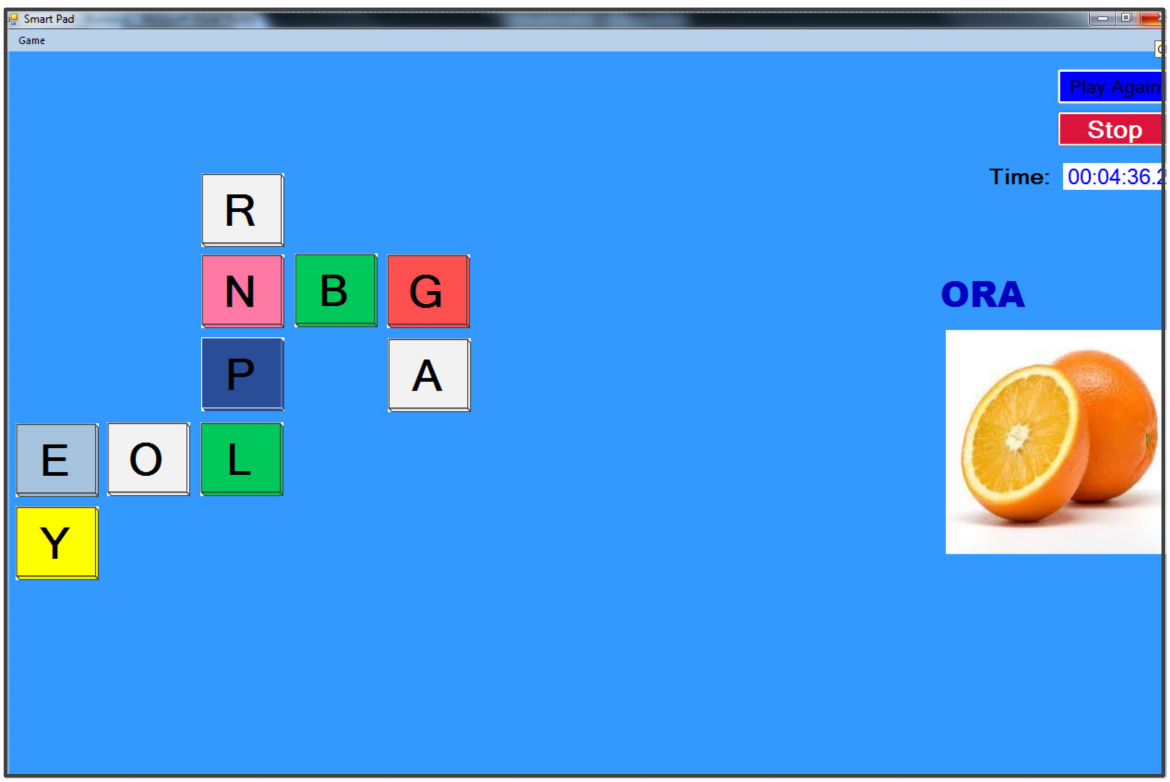


Figure 3.9 The words game interface.

3.7 Summary

In this chapter, we have discussed the overall system architecture with the different incorporated modules. Moreover, we have defined and demonstrated how to meet our requirements. In addition, we have given an overview of the two associated games that suit these requirements.

Chapter 4

Implementation

In this chapter we discuss the components and interaction diagram of the developed prototype, describe the devices used, and discuss the graphical user interface of our proposed system.

4.1 Components and Interaction Diagram

This section explains the structural design of the SmartPads System. Figure 4.1 shows the software components diagram, which illustrates the components associated with the system architecture discussed in section 3.3.

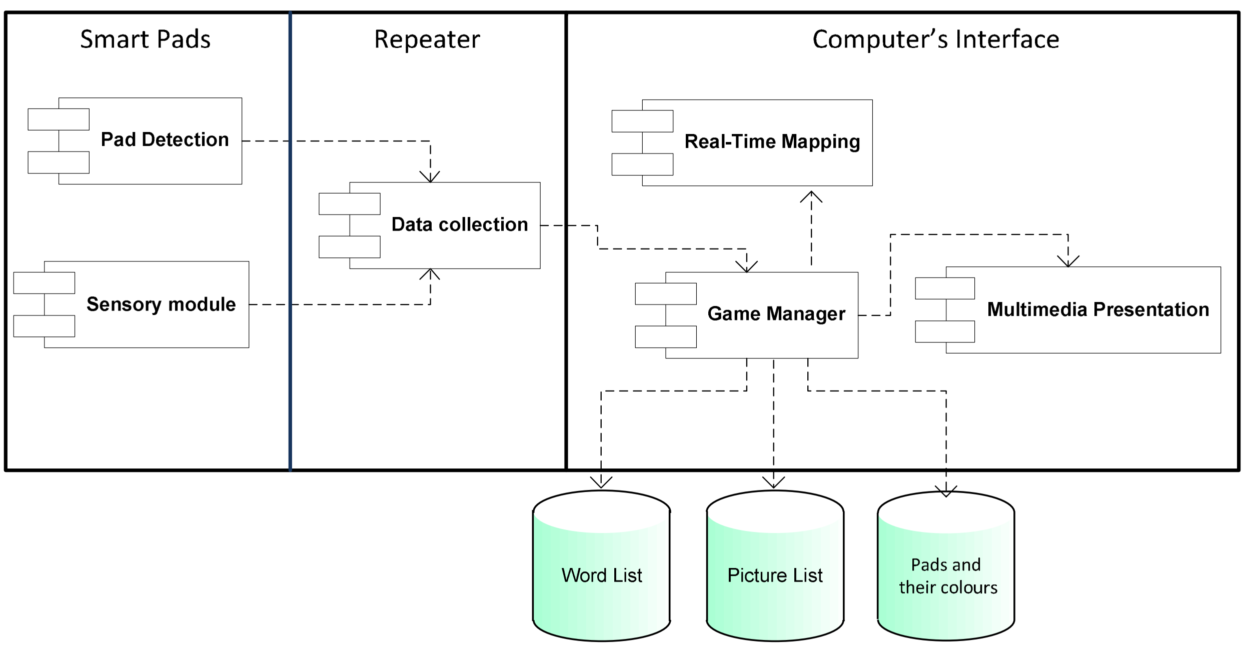


Figure 4.1 The component diagram of the SmartPads system.

Figure 4.2 presents the interaction diagram for the SmartPads system. The system starts running when a pad is physically connected to the assembly, disconnected, or stepped onto. The padID and sideID of the corresponding pad or pads are sent to the Data Collector, which passes the data to the Game Manager. The Game Manager analyzes the data and sends it to the Mapping component in the case of adding or removing pads. Alternatively, the running game is updated if sensor data is received. The Mapping component calculates the pad position, updates the CST, and sends the calculated pad position back to the Game Management component in order to update the mapped pads on the screen with the aid of the Multimedia Presentation component.

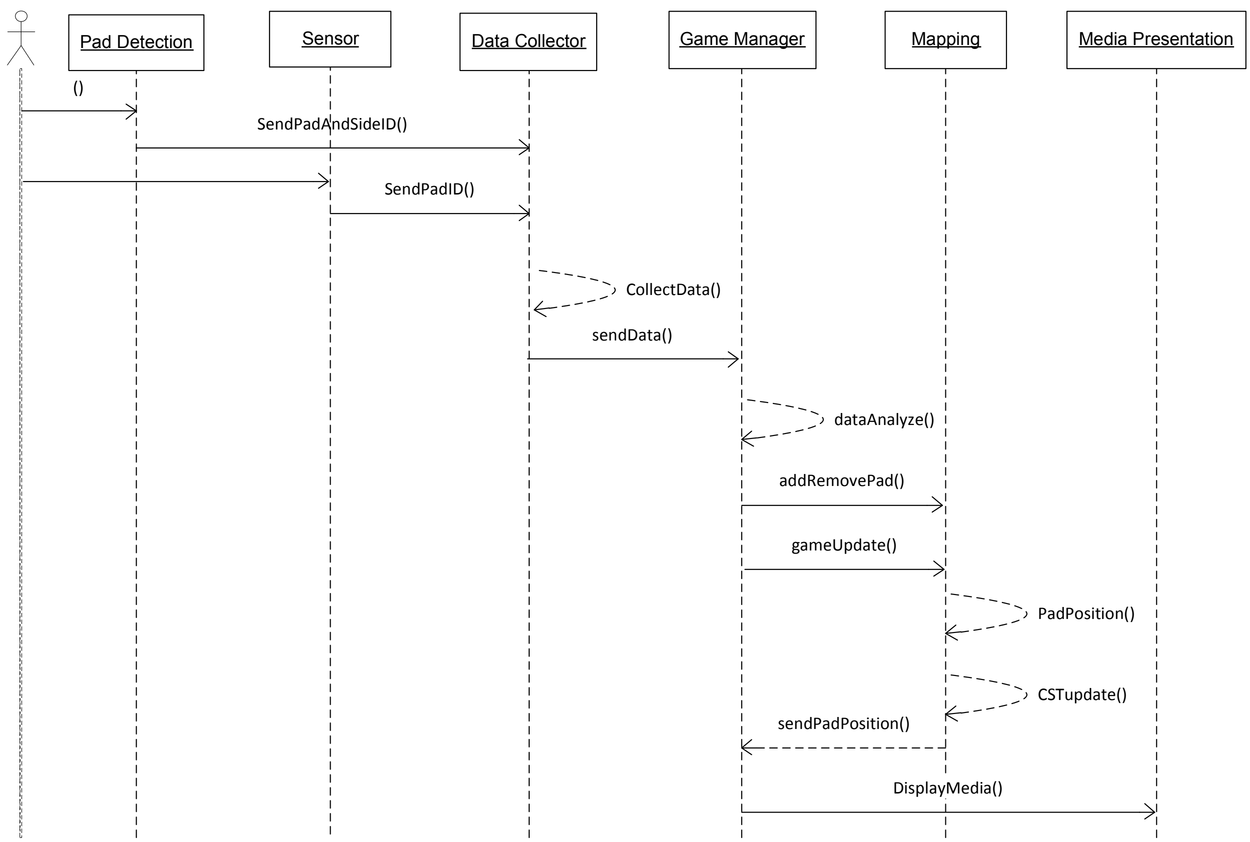
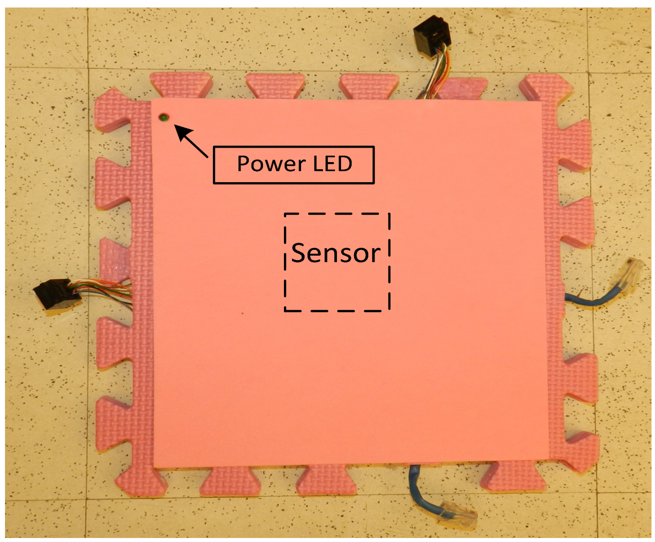


Figure 4.2 The SmartPads interaction diagram.

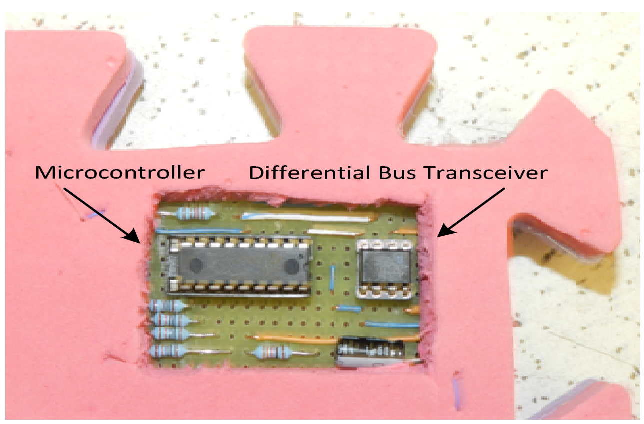
4.2 The Tangible User interface

This section details the specifications of the different devices used to develop the system.

SmartPad Elements: The actual design of the SmartPads is presented in Figure 4.3. Each pad has an integrated Picaxe-18M2 microcontroller with 16 configurable I/O ports. The "2400, N, 8, 1" (Baud rate, Parity, Data bits, Stop bits) protocol is used in Picaxe serial communication. This baud speed is quite slow by modern standards but is quite sufficient for our system design. The microcontroller is attached with a differential bus transceiver (SN75176) for serial data communication. The reason for using a Picaxe microcontroller is because of its small size, low cost, and programming simplicity.



(a)



(b)

Figure 4.3 The SmartPad prototype (a) top view, (b) bottom view.

A 1.75x1.5” square FSR sensor is embedded in each pad. This sensor is located in the centre of the pad surface and is protected by the 2 mm layer of foam material that covers the surface of each tile. Each side of the pad has a male or female RJ45 connector with 6 lines. The connectors are arranged in the pattern shown in Figure 4.3a and are used to connect the pads to each other. The +5V power is supplied to the pads from the host PC serial interface (USB) through the data collector, as will be discussed later in this section. The attached LED is for power IN indication. The SmartPad components are inserted in between two 12x12" square foam layers as shown in Figure 4.3b.

Figure 4.4 demonstrates the schematic diagram of the SmartPad circuit. The Left, Up, Right, and Down are four inputs for detecting in which side of the pad a neighbour pad is connected. The Sensor input is connected to the FSR sensor and to GND. The default value of the input voltage to the microcontroller input pin (B0) is almost 0V. Once a user steps on the pad, the FSR resistance decreases so that an input greater than 0V is detected by the microcontroller, which compares this voltage with the stored threshold value and decides whether it is a valid step or not. The SN 75176 is a differential bus transceiver device, and it is connected here as a transmitter. A and B are output terminals connected to the serial bus in order to link the pad with the Data Collector.

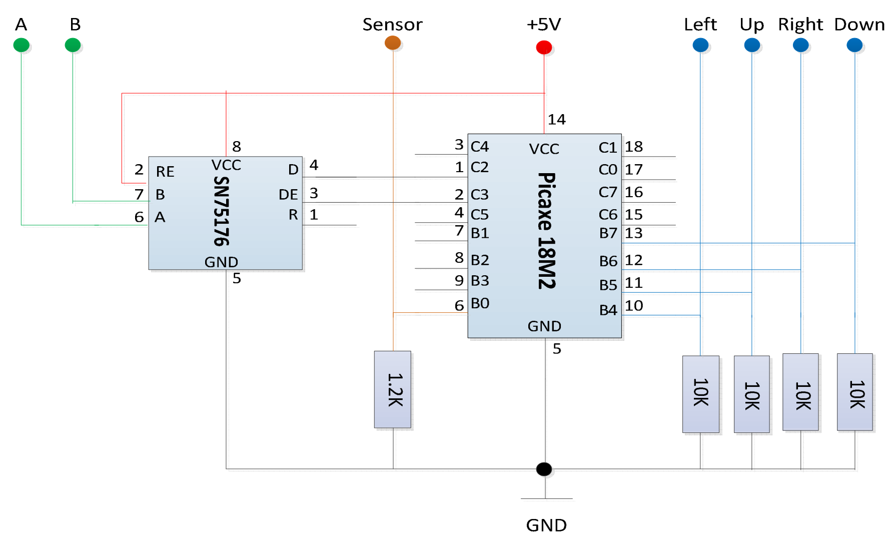


Figure 4.4 SmartPad schematic diagram.

Data Collector (Repeater): An ATmega 168 microcontroller on an "Arduino Uno" board is used to perform all the necessary communication between the pads and the host PC. This communication is achieved by translating RS-485 to USB as shown in Figure 4.5. The microcontroller is attached to a differential bus transceiver (SN75176) that is used to receive data from the pads through the serial bus. The host PC supplies both the Data Collector and the pad circuits with a Vcc power through the USB port.

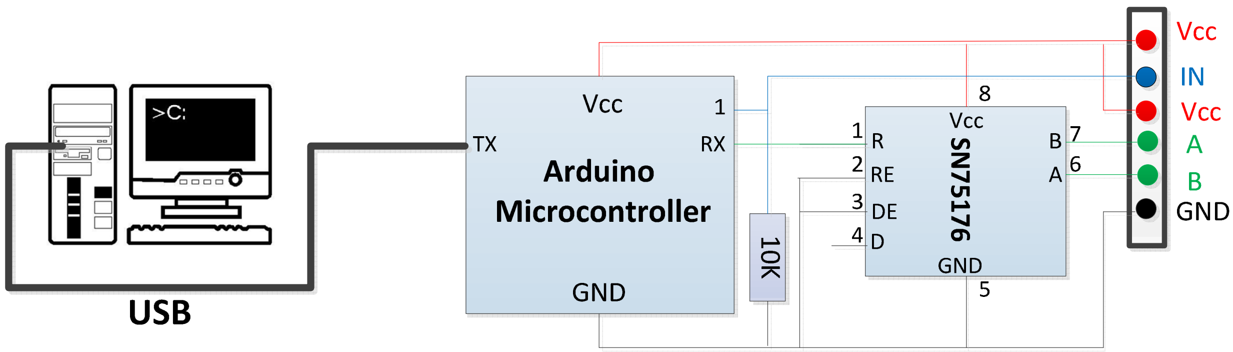
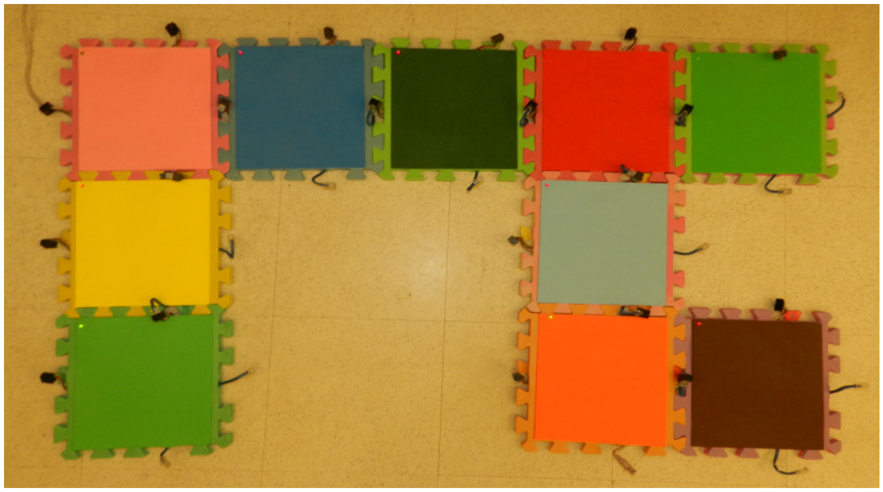


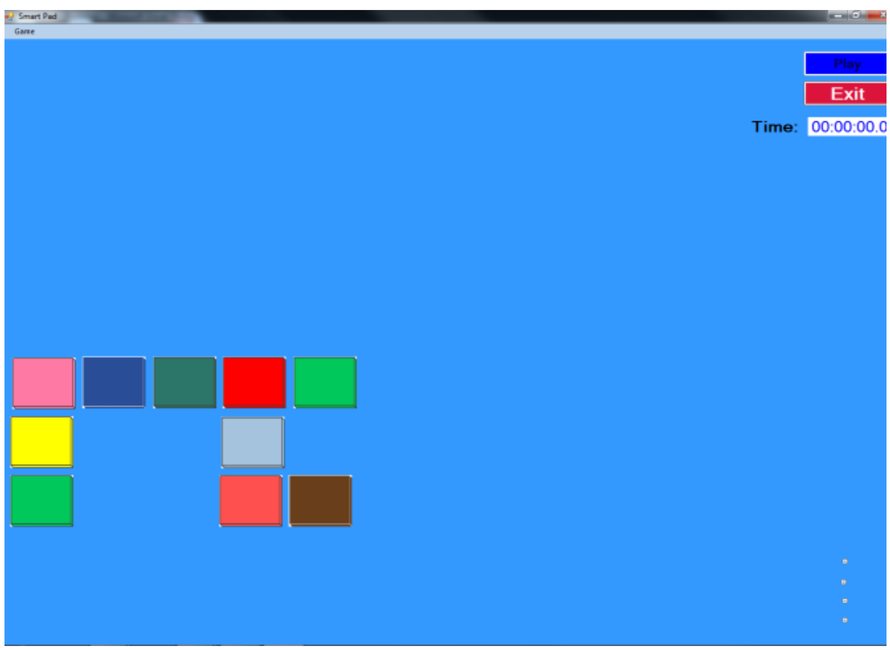
Figure 4.5 The Data Collector design.

The Tangible user Interface (TUI): The designed tangible user interface consists of a number of SmartPads that can be physically assembled into many different arrangements; an example is shown in Figure 4.6a. Although our current prototype includes only a relatively small number of SmartPads (10), there is nothing in our design that precludes the possibility of large collections of up to 32 pads. This limitation comes from the characteristics of the differential bus transceiver chip. However, this number, can be increased up to 128 by adding a termination resistor at both ends of the serial bus.

In order to interact with a corresponding computer game, the user steps on these pads. The number of incorporated pads is not fixed. It is variable and can be chosen by guardians or teachers depending on their children's learning capabilities and the amount of physical activity desired. Each pad's pressure sensor allows the system to identify the pads being used. The pads are mapped on the screen in the same pattern that they are organized in the floor. By doing so, the user will have a screen view of the position of the coloured pads he /she will be stepping on while playing the game. Figure 4.6a presents 10 SmartPads organized in a selected pattern. This pattern is normally set up by the child who plays the game. The pads are virtually mapped on the GUI interface screen in real time as shown in figure 4.6b.



(a)



(b)

Figure 4.6 Ten SmartPads (a) physically connected, and (b) virtually mapped on the computer screen in real time.

Software Module: The proposed system software has been implemented using Visual Studio 2008 (C# language) on a Windows 7 platform. The Microsoft Speech Engine was used for the verbal spellings and feedback messages.

4.3 Games Interface

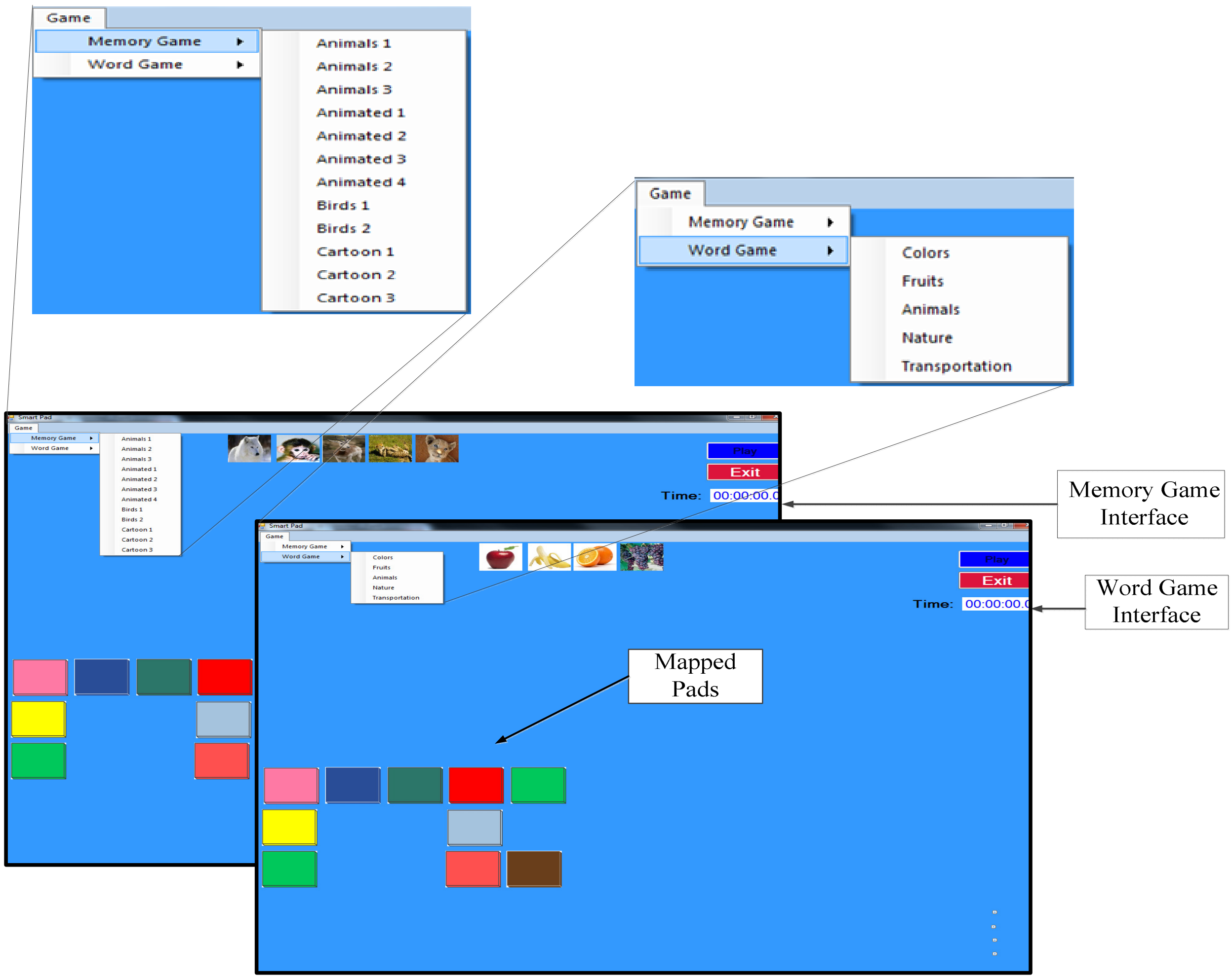


Figure 4.7 System graphical user interface.

One of the important design aspects of the system is the GUI. A single GUI was designed to map the physically connected pads into a virtual environment in real-time and to run two different games: the memory and words games. Figure 4.7 demonstrates the GUI used in our proposed system. As can be seen from the figure, the type of game can be selected through the menu tab located in the upper left corner of the interface. The GUI can also facilitate personalization for the parents by allowing them to add/remove pictures and select the picture and words set.

Chapter 5

Performance Evaluation

In this chapter we present the evaluation of the proposed system. In particular, we evaluate the system based on the two games presented in section 3.6. The two games are intended for both home use and classroom use in schools. The games can be single or multi-player. The evaluation was performed by considering two categories of children, each with a different age range. The first category was composed of children who suffered from various degrees of developmental delay, while the second category consisted of children with no developmental delay. Accordingly, in section 5.1 we evaluate the memory game with children with varying levels of developmental delays, and in section 5.2 we test our words game with mentally healthy children. Both boys and girls participated in the evaluations, however, gender-specific factors were not considered because of the limited number of children.

5.1 The Memory Game Evaluation

5.1.1 Experimental Setup

To evaluate the memory game, the system was set up in the classrooms of children with developmental delays at Shafallah Center in Qatar. The Center is a non-profit, private institution, focusing on special education, therapeutic, and health care support services for children with disabilities from birth to adulthood [48]. For media display and sound, a projector and a large speaker were connected to the laptop where the system's software was running. The media was projected against a white wall in the classroom and the pads or tiles were placed on the floor in front of the wall.

5.1.2 Experimental Procedure

We conducted qualitative evaluations for 3 groups of 5 to 6 children between the ages 8 and 16. The classrooms were classified according to their degree of mental disabilities as follows:

Classroom 1: Group of 5 students with severe disability.

Classroom 2: Group of 6 students with moderate disability.

Classroom 3: Group of 6 students with mild disability.

The evaluations were conducted in 5 scheduled sessions for each group (a total of 15 sessions). Every test session lasted approximately 90 minutes and was videotaped for further analysis.

Before starting the first session, it was necessary to explain to the children how the SmartPads worked and how they were physically connected together and mapped onto the screen in real time. The teachers were also shown how to use these pads as an input interface, along with the different functionalities of the GUI. For the pads setup, the teachers suggested that they connect the pads instead of the children since it would be difficult for the children to do so. Each teacher first demonstrated to their group of children how to play the memory game.

5.1.3 Test Objectives

The teachers of classrooms 1 and 2 suggested that their children would benefit more from using 4, 6, or 8 pads instead of 10. Each child in the group was asked to play the game individually and also asked to choose which picture set he/she wanted to see on the screen. Testing with the memory game had the following objectives:

a) To observe children's interactions with the system.

b) To test the pads-screen coordination for the children.

c) To observe any improvement in the children's ability to play the game.

5.1.4 Results

Children's Interaction: Students grasped the idea of the SmartPads very quickly after one short demo. Each child was happy when he/she matched the pictures, and the students were excited as they gathered around the tiles helping their peers find the match by pointing at the tile that they thought revealed the matching picture. Moreover, because the game GUI interface counts the elapsed time for each session, children were competing against each other. Each child tried to finish the game with less time. The number of guesses and the time elapsed for each session has been recorded for each child. Table 5.1 presents just the results obtained at the end of the first and last session for the three groups. The reason why some children completed the session faster than others was due to their older age or lesser degree of disability.

Child No.	Classroom 1				Classroom 2				Classroom 3			
	Age	No. of Pads	1st Session	Last Session	Age	No. of Pads	1st Session	Last Session	Age	No. of Pads	1st Session	Last Session
1	8	4	0:55	0:42	14	6	4:27	3:32	15	10	5:47	5:12
2	8	4	1:11	1:10	14	6	6:00	5:01	16	10	2:40	2:01
3	9	4	0:52	0:33	14	6	6:23	5:12	16	10	7:17	5:59
4	9	4	0:59	1:01	14	6	1:42	1:17	16	10	4:16	3:58
5	10	4	0:45	0:34	14	6	2:15	1:44	16	10	3:49	3:11
6					14	6	2:32	2:13	16	10	1:11	1:06

Table 5.1 Elapsed time (m:ss) for each child to complete the game for their first and last sessions.

Figure 5.1 shows a chart for the five sessions, indicating the means and standard deviations for the time required for the children to complete the game. From the chart, we can conclude that the skills of the children improved with time, and thus predicts a likely opportunity for cognitive enhancement over the long term, provided that the game is practiced regularly.

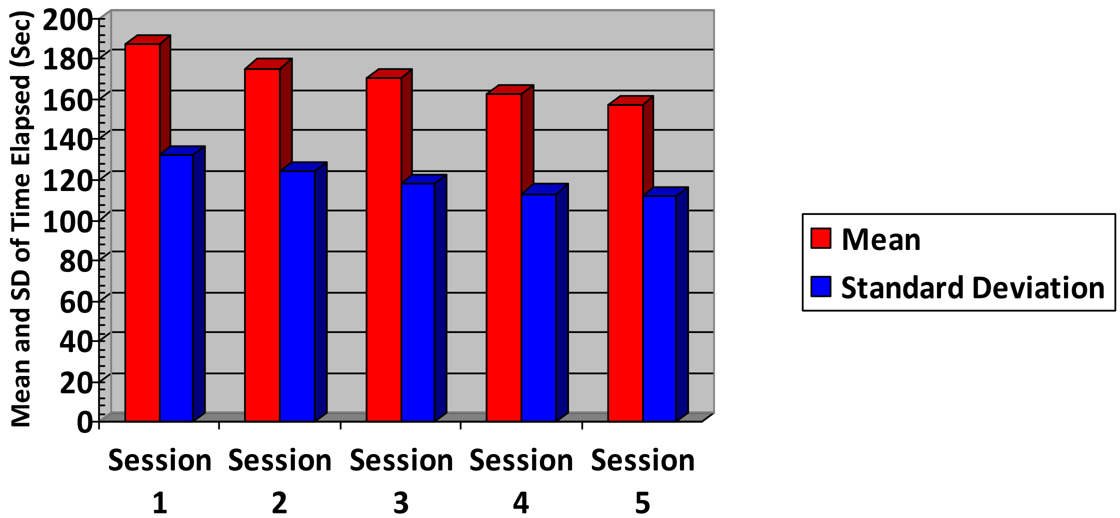


Figure 5.1 The mean times and standard deviations (SD) for the students to complete the memory game.

Pads-Screen Coordination: Even though the 10 prototype pads have different colours and are mapped on the screen with respect to those colours, some children were confused between the tile location on the floor and that on the screen. In order to better analyze these coordination issues, we noted the number of times that the children confused the locations of the pads in the physical and virtual environments over the 5 sessions. Figure 5.2 shows a chart that indicates the average number of times children were confused between the physical and virtual pad locations. As can be seen from the chart, eventually this confusion became less pronounced as the children became familiar with the game.

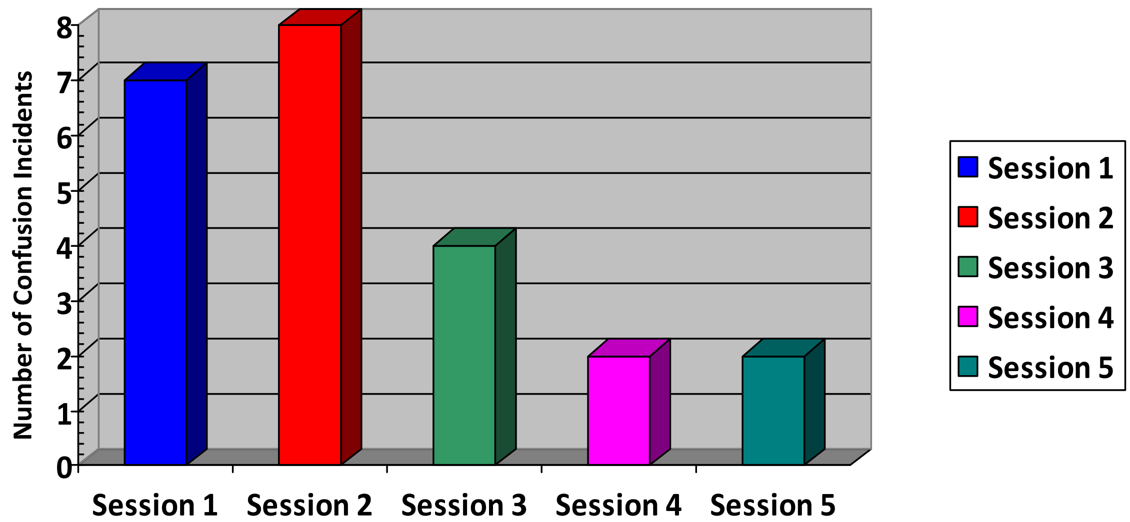


Figure 5.2 The average number of incidents there was confusion between the physical and virtual pad locations during 5 sessions.

System issues: Two issues were observed during the testing of the system in the three classrooms:

1) The pressure sensor location should be optimized for better detection. Some children needed to step on the tile more than one time in order to get a response because they had not stepped on the exact location of the sensor. To overcome this issue, the sensor could be located in a raised area on top of the tile service.

2) Some of the children tried stepping on two different tiles at the same time in order to find a match, but the system was designed to respond to one tile at a time, so only one tile was triggered.

Teacher comments and recommendations:

- The teachers showed appreciation for the system, and they would be interested in having such a tool in their classroom.

- One teacher recommended changing the game theme for the group with a severe level of disability. She suggested showing all the pictures on the screen instead of hiding. Just matching the exposed pictures on the screen would be enough of a cognitive exercise for beginners with severe developmental delays.

- One teacher realized that sometimes children were distracted while stepping and looking at the pictures on the wall at the same time; however, she added that this issue should be eliminated after few sessions.

5.2 The Words Game Evaluation

We also tested the words game with a group of mentally healthy children between the ages of 5 and 8. The game evaluation was divided into two parts:

1. The setup of the tangible user interface.
2. The interaction through playing the game by using both the tangible user interface and a mouse.

5.2.1 Experimental Setup

The evaluation started by having 3 families bring their children to a house to test the game in a group setting. A laptop was connected to a large screen TV for running the system software and displaying the appropriate media output. The reason behind inviting all the children at once is that, as [50] suggests, "Children naturally gather in groups, especially to play games". As described in [49, 50], when using computers, children enjoy collaboration with others.

5.2.2 Experimental Procedure

The experiments were conducted in 3 different sessions within a 2 week period. Each session lasted between 1 and 2 hours, and the sessions were videotaped. The interactions between the children and the system and between the children themselves were later observed and analyzed.

On the first day of the experiment, a short demo session was presented. This was to show how to assemble the 10 prototype pads together in order to build the input interface and to show how the pads are mapped in the virtual environment in real-time. The demo also included instructions on how to play the game. The importance of stepping on the pads one at a time was stressed because the system will not respond otherwise.

5.2.3 Test Objectives

Children were given the opportunity to assemble the whole 10 pad system in a shape of their choice in order to build the input user interface and play the game either collaboratively (2 children write one word together) or individually (one word for each child). They were also asked to play the game by using a mouse instead of the pads. The objectives of the experiment were the following:

a) Test the difficulty of assembling and connecting the physical pads together.

b) Observe children's interactions among each other using both kinds of interfaces (the physical pads and the mouse) by analyzing their discussions and queries.

5.2.4 Results

Pads Setup: Children were excited when they were physically connecting the prototype pads together, and every child wanted to build her or his own interface shape in order to play the game. Figure 5.3 shows a child connecting the last pad, while Figure 5.4 shows two children helping each other to set up the pads. The children were especially fascinated by how their pad design was instantly mapped onto the TV screen.

Figure 5.3 A child connecting the pads.

Figure 5.4 Two children helping each other set up the pads.

On the other hand, the system did have some issues. In particular, since this system is a prototype, some of the children, particularly the 5-year old, faced some difficulties connecting the pads together because of the less than ideal choice of connectors. During the 3 experimental sessions, the children connected a total of 60 pads. They had succeeded to correctly connect the pads on the first attempt 47 times, on the second attempt 11 times, and on the third attempt 3 times. Nobody actually required more than 3 attempts in order to connect the pads successfully. Figure 5.5 summarizes the aforementioned numbers. Since the children were able to connect the pads successfully 78% of the time without the need to reconnect them, in our opinion the SmartPads performed fairly well, even though the selected connectors were not ideal. However, a better choice of connectors could have produced better results.

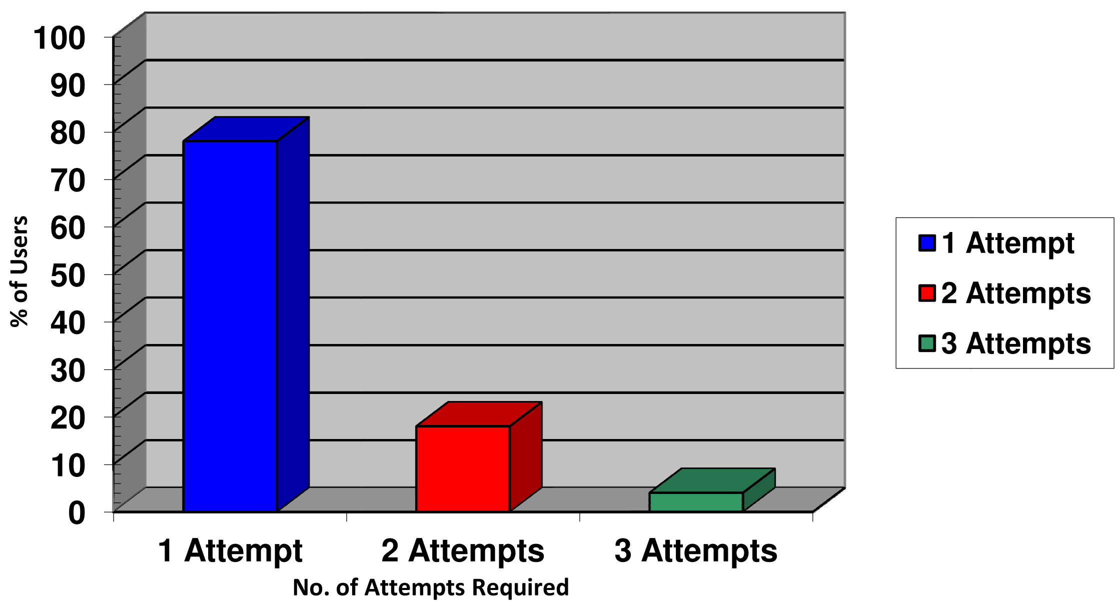


Figure 5.5 Success rate of each of the three attempts for pads connection.

Writing: The words that the children wrote varied in theme, like animals, fruit, colours, nature, and transportation. In one example, Zaineb wrote “TRAIN”, while Abdullah wrote his favorite colour, “GREEN”. Figure 5.6 shows Zaineb trying to write the word “TRAIN”, while Figure 5.7 shows Abdullah was thinking about whether the word “GREEN” has one or two Es before getting the right answer from his peer.

Figure 5.6 Zainab trying to write the word "TRAIN".

Figure 5.7 Abdullah was confused about whether there should be 1 or 2 Es in the word “GREEN”.

Interaction with the game using the mouse: In order to evaluate the interaction between the children and the system without using the pads, children had the opportunity to play the game in the last session using the mouse as an input interface as shown in Figure 5.8 At the end of the session, the children were asked to fill in a questionnaire to test the game's usability for each kind of interface. Children were asked to paste a sticker on a picture of the interface they liked to use better. All participants pasted the stickers on the pads interface picture. This result gives the overwhelming impression that children prefer to use a tangible interface instead of traditional interfaces.

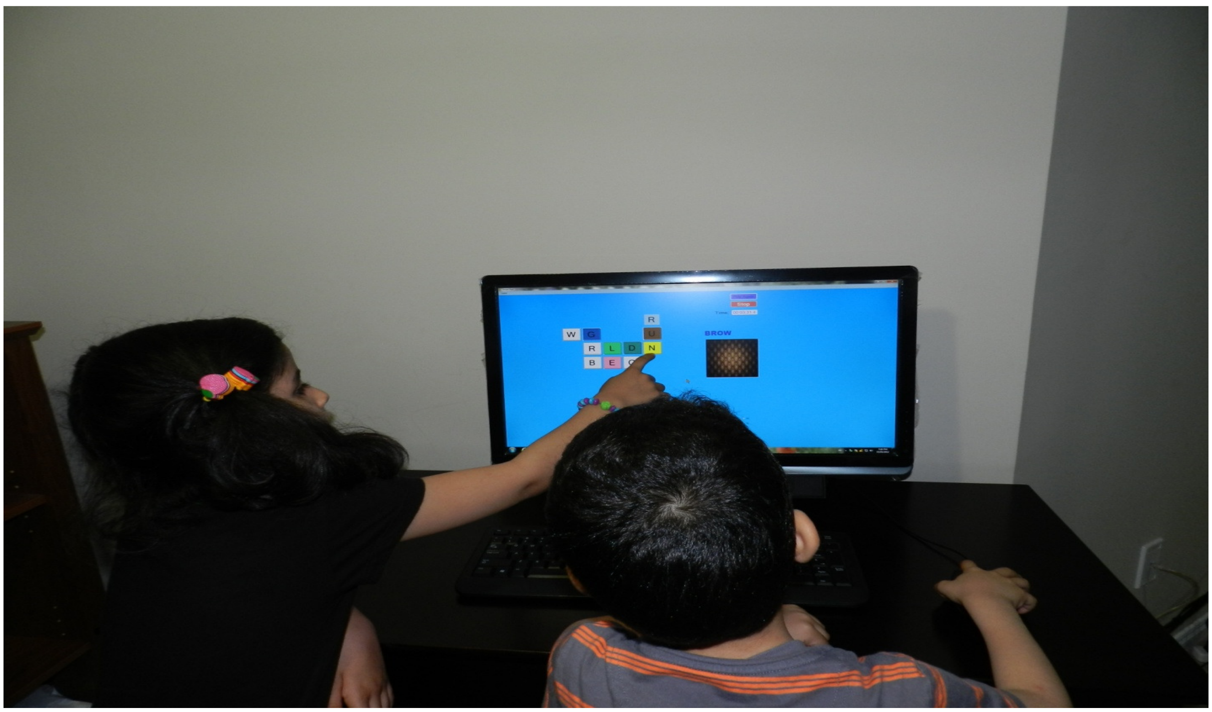


Figure 5.8 Peers helping each other in writing the word “BROWN” using the mouse interface.

Interaction among children: Children helped each other in solving the games by sharing ideas and through verbal discussion. For example, when writing the word "RABBIT", one child told her peer that the word "RABBIT" has 2 Bs, not only one. Another child told his peer "can I write the next word alone and then you can write the next after", the other child replied "ok". This demonstrates that the game is capable of getting the children to interact with each other while playing.

What did children ask?: At the beginning, and before they had seen the demo, the children were confused about the fact that the tiles can write letters on the screen. The children asked each other and myself many questions regarding the pads. Eventually, the confusion was eliminated after they had seen the demo, and they started selecting the word categories from the menu tab. For example, one child asked if it is possible to write the word "KANGAROO", and she added that it was because the shape of the pads combination was like a kangaroo. Another child asked if she could write the word "PURPLE" because she did not find her favorite colour in the colours list. Some pictures also pushed the children to pose more questions. For instance, when the word "RAT" and its picture were displayed on the screen, a child asked "Why it is called 'rat', and not 'mouse'?" Another child replied, "It is different, it is bigger than the mouse." One other child asked his friend the following question: "Why the computer chooses the words, why not us? I need to write the words I like." She replied "If you write the words you like, you will not learn new words".

5.3 Summary

This chapter presented the evaluation of our proposed edutainment and exergaming system by evaluating the SmartPads. The evaluation sessions were done at either a home or a school with children between the ages of 5 and 16. The results highlight the strengths and weaknesses of the SmartPads system. These results may be taken into consideration when further developing the prototype.

Chapter 6

Conclusion and Future Work

This thesis presented our exercise-based edutainment system that was designed to educate children in a simple and entertaining manner. Interaction between the children and the system is done through the use of an intuitive tangible user interface called SmartPads that can be customized by the end user.

The system allows children to construct the pads into any physical arrangement as a tangible user interface. The arrangement is based on their choice and imagination. The system also allows them to write words, match pictures, and get responses as an appropriate set of media such as images, text, and audio. The system incorporates two different games: the memory game and the words game. They are intended to promote learning and physical movement while having fun. The system has been evaluated in both home and school environments with mentally healthy children as well with children with developmental delays, all between the ages of 5 and 16.

The memory game was evaluated in a school setting. Since the children in the school have special needs, it was hard for them to construct the pads shape by themselves; hence, we could not evaluate the degree of difficulty in assembling the pads to construct the physical user interface with this group. In addition, some students were confused between the tile location on the floor and that on the screen, especially during the early sessions, but this factor was gradually eliminated as the results indicate. However, this issue could be dealt with by adding a light on the pad that turns off once a tile is out of play, or integrating a small LCD screen on one corner of every tile as an output device and replacement for the computer screen. We have observed that children were excited during the sessions and really enjoyed playing. In addition, as was suggested by some teachers, we intend to incorporate more than one language when it comes to reading the object names.

The words game was evaluated with children in a home setting. Children physically constructed the SmartPads shapes in a pattern of their own choice in order to build the input user interface. The observation we have made during pad setup and during time playing the game have shown that children really enjoyed interacting with the system. This became obvious from their writings, conversations, and discussions. In addition, this game created an atmosphere of collaboration among children. They collaborated in finding the correct letters of a particular word that the system had asked them to write. On the other hand, some children had some difficulty in connecting the pads together because of the less than ideal choice of connectors. They had succeeded to correctly connect 78% of the pads on the first attempt, 18% on the second attempt, and 4% on the third attempt. These results, in our opinion, indicate that SmartPads performed fairly well. However, a better choice of connectors could have produced better results. In addition, as was suggested by some teachers and parents, we intended to associate more games such as math game for teaching children the basic arithmetic operations.

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