

Embedded Interaction 2008

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6 March 2009

version 1.0

Abstract

In this document we report on research done in the field of Embedded Interaction as well as events at which the public was exposed to this research. We also report on the dissemination of the research results, being mostly at conferences and the resultant conference proceedings.

Key words

tangible user interface, HCD, rope pulling, GameBlocks, RockBlocks, embedded interaction, robot.

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Scope

This document reports on the activities of the Embedded Interaction research group at the CSIR Meraka Institute and funded by the South African Department of Science and Technology for the financial year ending March 2009.

Introduction

The Embedded Interaction research group's primary interest is the interaction between people and technology.

Of specific interest to the group is the development of alternative interaction mechanisms for illeterates (not able to read/write) to make use of Information and Communication Technologies (ICT's). An alternative interaction mechanism which has received most of the group's attention is that of using Tangible User Interfaces (TUI's) for computer programming. TUI's can potentially replace the keyboard, mouse and computer screen as interfaces when simple computer applications are required.

Other areas where the research group has made a contribution in the 2008 financial year are those of Human Capital Development and Public Understanding of Science and Technology.

Public understanding of science and technology

The research group has participated in a number of initiatives to promote science and technology among school children.

- ***SciFest Africa***

Workshops arranged by the Embedded Interaction research group were held in Grahamstown. Here, thousands of learners, students and educators from around the country participated in the 13th annual SciFest Africa during the period 16 - 22 April 2008. The interactive workshops, designed to be of special interest to children, entailed the use of RockBlocks for controlling a motorised car, and the use of the internet in conducting a real-time intercontinental rope pulling contest between South African children and children in the city of Joensuu, Finland. The Minister of Science and Technology, Dr Mosibudi Mangena, attended the opening ceremony in Grahamstown.

- ***Giyani science centre***

On 16 May 2008 the Scientia site received 150 scholars from the Giyani area in the Limpopo province. The visit was arranged in collaboration with the Giyani Science Centre. An interactive workshop on programming using the RockBlocks tangible user interface was given. The principles of operation were explained and the children given an opportunity to control a motorised car using RockBlocks.

- ***DoC career guidance week***

On 30 and 31 July 2008, an interactive exhibition of RockBlocks was held in Hatfield, Pretoria. The visitors were given an opportunity to control a motorised car by constructing a programme sequence using RockBlocks.

- ***National science week***

GameBlocks was presented to thousands of learners, educators and the general public.

Dissemination of research results

Research results were presented at six conferences [1][2][3][4][5][6] where the contributions were peer-reviewed and the results published ISBN-assigned proceedings. One presentation [7] was made at a conference with no peer-review process or with published proceedings. The following are summaries of the peer-reviewed results presented.

- ***Visual perception skills testing: preliminary results***

A more comprehensive presentation on these research results was presented at *TEI: Tangible and Embedded Interaction* [1].

Good visual perception skills are important in the effective manipulation of Tangible User Interfaces. This paper reports on the application of a test set we have developed specifically to quantify the visual perception skills of children when matching a physical object to its flat representation on paper. A pilot evaluation, with two groups of children from differing socio-economic backgrounds, was conducted to quantify their ability to make the mental transformation from tangible objects to the drawings that represent those objects. Our test instrument is described.

Township schools in South Africa do not provide children with good visualization skills. Visualization skills are required to successfully use portable Tangible User Interfaces (TUI's) like RockBlocks and GameBlocks when constructing Tangible Programme sequences. We devised a test set to compare the visualization skills of children from affluent suburban areas to that of children from townships. The specific visualization skill tested is a child's ability to map a 3D object to its 2D representation. We piloted the test set at two schools in South Africa. Both schools practice the Montessori Method of early childhood schooling. School A is situated in an affluent suburb in the city of Pretoria. School B serves a township and is located approximately 70 km distant from School A. The ages of the subjects varied between five and six years.

In South Africa there is a significant difference in the daily activities of children from differing socio- economic backgrounds. Typically, children attending School A interact mostly with electronic technology and books, both presenting information in a 2D format. In contrast, children from School B interact mostly with 3D environments by playing outdoors and climbing trees. This pilot study indicates that there is a difference between the initial visualization abilities of the two tested groups. However, this difference diminished as the tests progressed. A possible explanation is that children from School B became accustomed to the 2D representations, and children from School A became over-confident and less meticulous. It can be expected that differing visual perception skills will manifest as differing performance levels when children participate in Tangible Programming Environments. A solution could be the development of TUI's that are not sensitive to varying levels of visual perception skills. Further tests are planned to affirm the findings of this pilot.

- ***A low-cost, low-energy tangible programming system for computer illiterates in developing regions***

A more comprehensive presentation on these research results was presented at *TEDC: Technology for Innovation and Education in Developing Countries* [2].

We present a low-cost, low-energy technology design that addresses the lack of readily available functional computers for the vast number of computer-illiterate people in developing countries. The tangible programming language presented is an alternative entry point into the field of Information Technology. We conclude with a list of further work needed.

The majority of residents in developing countries do not have access to a working computer. Neither is a large number of this majority fully literate, having limited reading and writing skills. On-going attempts by local governments and funding agencies have not yet been able to fully overcome the computer illiteracy situation in developing countries. In an attempt to improve this situation, relief programmes supply computing infrastructure to schools, or community centres, and provide training. But this model is not always effective. As an example of this, consider the trained personnel who soon leave the training centre for more profitable employment in private practice, leaving no expertise behind to assist the local population. Another potential problem is the lack of technical support for repair of the sophisticated computers. The well-meaning suppliers of the equipment are not always aware of the lack of resident technical support when they return to their industrialised countries. In both of these examples, these once well-equipped training centres go into disrepair and are eventually no longer functional. The goal of these training centres is to increase the number of information-technology- (IT) literate citizens as it is believed that the modern economy is based on IT. In contrast to the provision of high-end

technologies to these training centres, we propose a novel, alternative means of introducing illiterates to IT. Other methods have previously been reported. If we acknowledge the high level of illiteracy in developing countries, it serves little purpose to introduce large numbers of sophisticated personal computers to these areas. An alternative approach is to first develop, in the illiterate population, the cognitive process of logical thinking required in the IT field. Having developed this ability, the illiterate person has a tool for potentially controlling a number of objects in the immediate surroundings. If so desired, this person is ready to receive training using the traditional personal computer and subsequently become integrated in the IT mainstream. Our approach makes use of symbols and physical artefacts to compile a sequence of actions, and is an extension of GameBlocks. Two groups of the general population who will benefit the most from this technology are the young children and the elderly. It can be argued that both of these groups are typically illiterate and do not possess the fine motor skills of a healthy young adult, making the use of large and tangible input devices a strong contender as a replacement for a keyboard. The population group that fits between these age extremes typically does not have these problems and is not the target group of the research reported on in this paper.

The technology we present is simple, requires little energy to operate, can be modified, is open-sourced, and can be interfaced to various output devices. Our research contribution with this paper is our motivation for using a tangible programming environment in developing regions. We also give a description of one implementation of a tangible programming environment.

We have presented an alternative programming environment which addresses a number of problems in the developing world. The problems include the low level of IT literacy, the lack of IT maintenance infrastructure, and limited motor skills in some cases. The presented system can provide an alternative entry point into the field of IT, aimed at the computer illiterates of developing countries. We concluded by briefly introducing two areas in which the system may be improved to make it better suited for developing regions.

- ***Towards an affordable alternative educational video game input device***

A more comprehensive presentation on these research results was presented at *IST-Africa* [3].

Abstract: We present the prototype design results of an alternative physical educational video gaming input device. The device elicits increased physical activity from the players as compared to the compact gaming controller. Complicated and expensive alternative input devices are available, but remain unaffordable for developing countries. We propose a design that is more suitable for local manufacture in developing countries. In addition, we are concerned about the social isolation experienced by gamers. To address this, we project the gaming area onto the floor in front of players and the spectators. This is to encourage co-located collaboration and increased social interaction between players and the spectators. Four players take positions around the projected rectangular image. Angle sensors attached to each player's elbows serve as game inputs. As an educational component, the game incorporates the graphical display of dynamic vectors. We present an overview of the educational gaming software developed, the mechanical design implemented, the advantages and limitations of our input device, together with recommendations for future development.

In our research we want to know whether a) an affordable interface can be built that requires increased physical activity by the player, b) young children can be exposed to vector algebra in such a way that is not intimidating and also fun for them, a concept that has been called technology enhanced natural learning, and c) a gaming environment could be developed that will increase social interaction among the players and also with spectators.

Computer games with their small user interfaces have been criticized for the lack of physical activity on the part of the player, and for the player's social isolation during play. In an attempt to encourage whole-body interaction, a number of game system designers have incorporated accelerometers or web cameras to track game player's movements. These remain mostly unaffordable for children in developing countries. Most video game manufacturers are not progressive in their game interfacing mechanisms, having retained the small hand-held controller with multiple tiny buttons ("twitch-controllers"). We are of the opinion that these, at best, provide exercise for the fingers. Prevalent generic physical user interfaces are limited and typically consist of the mouse, keyboard and computer screen. These interfaces restrict the wide range of kinaesthesia that the human body is capable of, being reduced to slight wrist movements, clicking and typing. The use of bodily and special interfaces provide for increased immersive and compelling interfaces.

All existing camera-based body-driven game systems are intended for single players only. Real body-driven multi-player games have received little or no attention. Increasing physical activity such as body movement improves the important actions of real-world perception, experience, and interaction.

Still, social bonding amongst computer game players are far from the level experienced in a sports game, and the physical exercise remains limited. We attempted to use the children's built-in abilities, as opposed to their trained computer skills as required by so many educational software programmes. Most commonly, a child uses a palm-sized controller to interact with a game. The child also views the game on a screen, which limits eye movement to a few arc-degrees. The game is mostly played in solitude, sometimes with another player. Seldom do more than two players physically interact during play. Physical activity is mostly limited to the fingers, and the player is usually in a seated position. Using the setup we describe in this paper, the number of co-located players is increased to four, spectators have increased visual access to the gaming display, and physical activity by both spectators and players is increased. Our input device can be constructed using equipment available at a FabLab. FabLabs allow users to build just about anything from inexpensive and readily available materials. There are currently four established in South Africa, with at least ten being envisaged. Children in developing countries are the primary intended beneficiaries of this research. Children in developed countries where obesity seems to prevail may also benefit from this research.

Our work is based on the basic computer game of Pong. Just as 'Hello World' is typically the first programme a programmer trying out a new programming language would write, so is Pong the first game a programmer would typically write. Because we are investigating various ways the whole player's body can be used in playing the game, the name 'BodyPingPong' was decided on.

We implemented a game where the paddles are moved East-West depending on the angle at which the players held their elbows. We would like to revisit the alternative option of rather controlling the paddle angles with the inputs received from the elbow sensors, as opposed to controlling the lateral positions of the paddles.

We developed the game and interfaces as open-content. The source code is freely available for download and modification.

Because our research investigated a number of aspects, not only tracking mechanisms, we opted for a wired interface. Some optical tracking systems, that do not use markers, are susceptible to line-of-sight obscuration. In contrast, a tethered interface has the advantage that spectators do not have to stay out of a camera's field-of-view. A tethered interface also reduces the computational load of the software significantly, allowing more complex games to be played with the same computer processing power.

Future games should preferably include player collaboration to accomplish a pre-determined task. This could enhance social interaction, a dimension missing from the majority of current computer-based games. Our system does not fully utilise the 3-dimensional movement the human body is capable of. Adding additional sensors to the body could exploit these movements.

Wireless data transmission (either infra-red or radio) could alleviate some of the problems experienced due to the tethered interface.

The sensor mounting mechanism may be improved by incorporation of the sensors into a jacket, to be worn over the player's own clothes.

The East-West velocity vector magnitude could be made to vary, depending whether the direction, before intersection, of the ball and paddles were coincident. If the directions were coincident, the ball velocity vector magnitude would increase by a fixed amount. If they were in opposite directions, the velocity vector magnitude would be decreased by the same fixed amount, but never to less than a certain minimum amount.

We hope that the system described in this paper would be the beginnings of future affordable body-driven gaming systems that encourage social communication and player coordination skills development.

- ***Hand-crafted physical syntax elements for illiterate children: initial concepts***

A more comprehensive presentation on these research results was presented at *IDC: Interaction Design for Children* [4].

We present two technology-augmented physical materials that illiterate coders can sculpt for use as physical syntax elements in a tangible early programming learning environment. Two physical coding sequences are given. We conclude with the listing of further work required.

There have been many attempts to make computer programming accessible to more people. Our research is aimed at introducing illiterate (a narrow definition of non-literacy) children to the topic of programming. Our physical syntax, although simple, has the benefit of eliminating syntax errors such as those encountered in most text-based or icon-based programming environments. Manipulating physical objects to form a sequence of steps does not require the user to operate a computer nor the ability to read. It has been reported that the computer screen limits the human experience. In contrast, using physical objects broadens the human experience over that offered by the two-dimensional world of computer keyboard, mouse and screen. Although we live in a three-dimensional world, current computer interaction

technologies limit us to two-dimensional interaction. We are interested in the user's innate ability as well as already-learned skills to express abstract concepts by manipulating real-world objects. The contributions of this work are the initial concept designs for end-user-crafted physical programming syntax elements for use by illiterate users.

A fifth magnetic sensor can be added in the centre of the sensor slab. This would allow for either one or two magnets to be embedded in the inserted artefact, doubling the usable function encoding space from four to eight. Alternatively, the increased coding space could be used to assign properties to the coding objects, such as speed in the case of the clay car. We would also like to investigate, with children as design partners, the use of other materials as input artefacts, such as wood and paper.

We have given the potential benefits of using custom hand-crafted physical syntax objects to introduce illiterate people to the abstract thinking required for computer programming. Examples of objects given include the use of soft stone and clay.

- ***Providing disabled persons in developing countries access to computer games through a novel gaming input device***

A more comprehensive presentation on these research results was presented at *Artabilitation* [5].

A novel input device for use with a personal computer by persons with physical disabilities who would otherwise not be able to enjoy computer gaming is presented. This device is simple to manufacture and low cost. We describe the constituent parts of this device. A collaboration gaming application especially designed for this input device is given in brief.

This paper's contribution is the description of an input device suitable for use by people with gross motor skill problems. The device can be manufactured at low cost. A superficial survey of available personal computer (PC) input devices for the disabled will show that these are mostly well designed, but expensive. In developed countries where state subsidies reduce the financial burden for the disabled, this is less of a problem. However, in developing countries such subsidies either do not exist, or are minimal. The input device we present in this paper is simple to manufacture. It is quite feasible for the local community handy-man to construct it from a variety of materials. These materials include sheets of ply-wood or acrylic. A modified commercial joystick, magnets, and magnetic sensors are the main components of our input device (SlideStick). The magnets and magnetic sensors are commonly used as intrusion sensors in homes and offices, making them readily-available items. Electrical contacts of the magnetic switches are wired in parallel to the joystick switches. The stick usually used when manipulating the commercial joystick can optionally be removed, resulting in an improved compact unit.

We have presented an alternative input device which is suitable for use by people with certain disabilities. The input device can be manufactured by adapting commercial gaming joysticks. The required adaptation is simple and can be accomplished by an able-bodied person with limited technical experience. The high volume at which commercial joysticks are manufactured, and the subsequent relatively low cost compared to other custom-built aids, makes this device a viable alternative to commercial aids. By virtue of its large range of movement and low resolution, the SlideStick controller may be an ideal input device for people with fine

motor control challenges. Our tests indicate that the input device can be manipulated by either the player's hand or the foot, making it potentially useful to people with physical disabilities.

We have developed this input device and the associated software as a concept demonstrator. The software still lacks in several areas and future versions of the software will have the capability to use suitable bitmaps of the user's own choice as well as the ability to print and save coloured images. SlideStick was developed with the specific purpose of testing the viability of a low-cost, community-manufactured input device, together with custom-developed software, for use by people in developing countries. As such the SlideStick emulates the sequential pressing of five buttons on a joystick and no other joystick functionality. SlideStick in its current form is not meant as a replacement for a commercial joystick but rather offers an alternative input mechanism for custom-designed applications. Informal evaluations of SlideStick with the custom-developed gaming application indicate that the emulation of the joystick's "hat" switch would result in a better system. This option would open up other possibilities with existing commercial games – such as changing the player's point-of-view and movement in a game. Our informal tests with mentally handicapped adults indicate that the interface device should be simplified, perhaps only using two input positions instead of the current five positions. Formal tests are needed with the mentally- and physically disabled communities to properly evaluate the value which this input device can provide to these target groups.

- ***Quantifying the visual perception skills of pre-school testees using a novel tangible electronic test instrument***

A more comprehensive presentation on these research results was presented at the *CSIR biennial conference* [6].

Earlier studies discovered that South African testees from community schools do not have the required skills to participate in tertiary education and also lack many of the basic skills to compete successfully in certain sectors of society. These children were found to be less proficient in visualisation skills than their suburban counterparts. A new study was undertaken to ascertain whether there is any difference in cognitive skills, particularly visual perception, between pre-school children from the different socio-economic backgrounds (township and suburban). We state and elaborate on the reasons for choosing this specific age group. The ultimate aim of the study was to ascertain the age at which cognitive skill levels of these groups begin to differ and to develop intervention tools in the form of Tangible User Interfaces (TUI) to assist in enhancing the skills of the less advantaged children so that they can meaningfully participate in their own education. In this study we designed and evaluated an assessment instrument that directly measures pre-school children's visual perception skills that form part of literacy skills, as defined in the Persona Object Model in order to provide information that could contribute to the design of appropriate game-based learning tools. Consequently, an electronic game-based tangible assessment tool, which measures the children's visual perception skills, was developed. This testing instrument was designed to take into account the limited cognitive- and fine-motor skills of the targeted age group. A number of tangible user interfaces were developed to address these limitations. We explain how the information and communications technology (ICT) used in the design of the test instrument allows for the automatic capture of the test data. The various design iterations of the test instrument are explained and motivated, which include the choice of microprocessor technologies and the invention of various custom designed TUIs. The paper also describes the abilities and issues that were identified during other practical intervention sessions held with pre-school children. Therefore, the paper reports on the design, testing and

use of this instrument, in order to quantify the visual perception skills of pre-school testees. We conclude with recommendations for further development of the assessment tool.

The findings of this preliminary study illustrate that for testees to be able to programme properly using the RockBlocks, they need to have good understanding of direction and visual perception skills. It was however discovered that these skills were not so well developed in the preschoolers. This was seen when many preschoolers, particularly those from School B, could not match the 3D rocks to 2D objects. It had previously been contended that rural and township testees performed poorly because of the poor quality of education they received and their poor home economic status. In this particular case we have two pre-school groups in environments that use the same international schooling system and the testees are of the same age. However, we found that the preschoolers who came from the townships and whose first language is not English performed badly compared to their more affluent counterparts attending School A. The results are similar to those attained by Grade 11 and 12 scholars and university students who came from similar demographics, as reported in another study. A prior thesis concluded that township and rural schools do not provide children with good visualisation skills. This has now also been observed in five- and six year olds. Testees from School B struggled to match the directions of rocks with arrows drawn on paper. This we conclude was because most of these School B testees did not comprehend the relationship an arrow has with direction. For example, some interpreted the tail of the arrow as indicating the direction. Some of them tried to explain the meaning of the arrow in relation to the arrows often found in traffic light clusters. Unfortunately, these young testees had not yet mastered language sufficiently. This made it difficult for them to verbalise their thoughts properly. Still these testees also insisted in communicating in English, a language that was still mostly foreign to them. As for programming using RockBlocks, we found that the performance gap was narrower between the schools than in changing the 3D to 2D objects and both groups performed equally well. Once the testees understood the meanings of the arrows and how directions are determined, their performance improved. This includes testees from School B. Programming activity results of the School B testees show a dramatic improvement when compared to the task results of converting 3D objects to 2D objects.

We have described an electronic system to aid in testing the visual perception skills of pre-school children. The iterations through which the system has evolved were given, each iteration reducing the cost of the tangible user interface. However, a component of the system that has not received sufficient attention to reduce its cost significantly is the output device. The current output device is made from a commercial toy designed in Europe to what is arguably a too high standard for the local need in a developing country, resulting in system costs that are potentially unaffordable to those in need of an evaluation system. In our tests with pre-school children, we have identified a problem with the mechanical design of the programming user interface: placing the rocks properly onto the tray is a problem. One solution could be the addition of keying mechanism to automatically align the wood-mounted rock with the wooden reader-tray. Test results show that, whether testees come from the poor townships or from the rich suburban areas, it is easier for them to programme with RockBlocks if their visual skills have been developed appropriately. The study found that, regardless of the background of testees, RockBlocks is potentially a tool for measuring visual perception skills among pre-school children. Finally and more importantly, because of the small sample of testees who participated in the test (visual ability test) there is a need for more research to be carried out. For conclusive findings on the visual abilities of pre-school learners more

schools across the socio-economic spectrum of the country need to participate in the subsequent study.

Other notable activities

- ***Data-encoding invention disclosure***

An invention on data-encoding using reconfigurable spatially distributed static magnetic fields was disclosed to the CSIR.

The technology provides a contact-less, zero-bandwidth, means of encoding data and can be used in a user-interface that utilises physical tangible artefacts as opposed to buttons.

The competitive advantage of this innovation over existing systems is its low cost and simplicity. It uses re-configurable static magnetic fields to function, as opposed to RFID or optical mechanisms. Essentially, magnets can be cheaper than switches, can withstand physical abuse because it can be embedded under the surface of an object. It is resistant to water, and electro-magnetic pulses. It is also well suited for tangible user interfaces.

- ***Intercontinental rope pulling***

This project was executed in conjunction with the University of Joensuu, Finland. Its aim was to demonstrate physical interaction between two parties who are physically distant, but still connected via the internet. Two teams, based in South Africa and Finland respectively, pulled on two ropes with the relative forces displayed at the venues in real-time. Scores of SciFest-Africa and SciFest-Finland spectators witnessed the event.

- ***Universal remote controller***

In an attempt to make the current GameBlocks and RockBlocks compatible with diverse devices, development of a universal remote controller was initiated. The first version of this infra-red controller has successfully been tested with a robot designed and manufactured by WowWee electronics.

- ***Clicker***

This design project is aimed at empowering disadvantaged children, specifically children finding themselves in refugee camps. It is sound activated, responding to pre-configured sound sequences. A child can either use a simple mechanical 'clicker', or produce the sounds by pushing the tongue against the roof of the mouth and then releasing the tongue to produce an oral 'click' sound. By producing sound sequences similar to Morse code, various attached devices could conceivably be activated.

Both desktop and embedded options have been investigated as solution to this design challenge. An embedded solution using a low cost micro controller is currently being pursued.

HCD

A number of activities have been undertaken to promote human capital development in the research group.

- ***In-service-training***

A number of undergraduate students from the Tshwane University of Technology (TUT) joined the research group for periods of between six and 12 months. This provided the students an opportunity to gain in-service-training as required by TUT as a prerequisite for graduation.

- ***Book proposal review***

Morgan Kaufmann Publishers approached the author to provide feedback and an endorsement on a book proposal entitled "On the Move: Children and Mobile Technology". The book is edited by Alison Druin, an expert in the field of user interface design.

- ***PhD proposal review***

The author was invited, and subsequently participated, as a critical reviewer in the PhD proposal defence of Adele Botha. The working title of the PhD proposal is "Towards a Mobile Learning Environment for South Africa: A Development Research Perspective".

- ***Advisory committee member***

The author was invited, and served, as a member of the advisory committee to the Tshwane University of Technology's engineering department.

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