Tangible User Interface for Children – An Overview

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Abstract

This paper concerns the Tangible technologies in children's learning environment. As part of the wider body of developing technology known as 'Ubiquitous Computing', tangible technologies have drawn the attention of some researchers in the recent years. This paper begins with a review of some of the Tangible User Interfaces (TUIs) for assisting children's learning, followed by examining how tangible technologies may be beneficial to children's learning. Finally, summary and implications for future research are highlighted at the end of the paper.

1 Introduction

We are born able to manipulate objects tangibly with little cognitive effort. But unfortunately, most interfaces have relied on a limited variety of physical objects and a limited range of our abilities; it blocks many of our natural abilities and forces complexity upon us.

Here is an example: young children can build complex shapes using physical building blocks, sand or snow. However, few adult computer users can design even relatively simple 3D structures using Computer Aided Design (CAD) software. The reason is the lack of an interface that can fully exploit human spatiality, our innate ability to act in physical space and to interact with physical objects (Sharlin and Watson 2004). Arguably, many classic computer interactions offer very limited stimuli, little freedom to behave and low ecological validity (that is, little relevance to normal, everyday human behaviour in the real world).

It is commonly believed that physical action is important in learning, and tangible objects are thought to provide different kinds of opportunities for reasoning about the world. Designing TUI for children's learning has its practical and scientific relevance.

Tangible User Interfaces (TUIs) can be employed to improve existing learning tasks. Also it is can be an alternative to GUI to allow direct manipulations: children will be able to control the system and navigate through info by selecting and positioning physical objects not just representations. Last but not least, TUIs can be used for Computer Supported Collaborated Work (CSCW) to encourage collaboration between groups of children. The research can improve the scientific understanding of the new interactions for all users.

What is required for this new technology? Druin et al. (1999), pointed out that what children want in technology are: control, social experiences and expressive tool. The technology should support their curiosities, their love of repetition and their need for control (Druin and Solomon 1996). When we design a TUI, we should consider all these factors and include them into our design.

This research project will involves designing and evaluating of children's TUI. Children are involved in the design process. There can be several sets of trials and iterations before the final prototype.

1.1 The recent research trend, Ubiquitous Computing

Ubiquitous computing names the third wave in computing, beginning just now. First were mainframes, each shared by lots of people. Now we are in the personal computing era, person and machine interact across the desktop. Next comes Ubiquitous Computing, also know as Pervasive Computing which is "the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user" (Weiser 1993). Due to its invisibility it also referred as "the disappearing computer". Ubiquitous computing is an integration of human factors, computer science, engineering, and social sciences.

Work on ubiquitous computing is still at an early phase. Most work in the recent years is concentrating on the mobile infrastructure for wireless networking. There are three challenges: new wireless technology to achieve the high bandwidth required; new network protocols for handling machine mobility and remote window over a network problem in window systems. (Weiser 1993)

An article 'Completed control?' highlighted that it may not be too long before we are controlling lights and other household items using a handheld computer with low cost single chip solutions. (New Electronics on Campus, summer 2004) This is exciting news, because how far we can go in ubiquitous computing largely depends on the new technologies like this and the cost of them.

1.2 A introduction to TUI

Fitzmaurice was the first to distinguish TUIs from other interfaces – though he called them "graspable" user interfaces (Fitzmaurice 1996). Fitzmaurice defined a graspable user interface as: "a physical handle to a virtual function where the physical handle serves as a dedicated functional manipulator". Ullmer and Ishii, from the Tangible Media Group at the MIT Media Lab, define TUIs as "devices that give physical form to digital information, employing physical artefacts as representations and controls of the computational data" (Ullmer and Ishii 2000).

The term 'Tangibles' refers specifically to the physical elements of tangible interfaces, and to their role in physically representing digital information. This term has the advantage of brevity and specificity to the TUI context.

Tangible User Interface provides physical form to digital information and computation, facilitating the direct manipulation of bits. TUI designers are looking for a seamless coupling between physicality and virtuality. Tangible Interfaces will make bits accessible through: augmented physical surfaces (e.g. walls, desktops, ceilings, windows), graspable objects (e.g. building blocks, models, instruments) and ambient media (e.g. light, sound, airflow, water-flow, kinetic sculpture) within physical environments. TUI support collaboration more than one user interacting with environment, also the physical models in TUI offer the user an intuitive understanding of complex structures. The potential users of TUI can be people who are not always sitting at a computer and people who do things better with their hands and objects.

1.3 Children's learning environment

"Computer access will penetrate all groups in society…Machines that fit the human environment…using a computer as refreshing as taking a walk in the woods." (Weiser 1991) The Weiser's futuristic vision has not been totally realised yet, but it is true that technology is now increasingly embedded in our everyday lives: computers and networks are encouraged in schools by government and in fact wildly applied among schools. Also children are taken out of the schools to the museums; some of the museums have computer environment especially multimedia exhibitions. On this side, for example, the University of Limerick has done some research on augmented artefacts and ambient media for enhancing the museums visiting experience (Ferris et al. 2004).

When children come back home, some of them still have the chance to use the PC and the network to access the information online. The Science Museum in London (http://www.sciencemuseum.org.uk/) not only has some exhibitions linked with the school visit and the National Curriculum in their museum, they also include these exhibitions on their interactive website. Their 'do-it-yourself exhibits' (http://www.sciencemuseum.org.uk/on-line/launchpad/4XX.asp) are based on the gallery's most popular interactives and can be used at home or at school.

Although school children have some degrees of freedom on where and in which way to learn, all school related learning activities have to follow the National Curriculum (http://www.nc.uk.net/home.html). Potentially, the fixed nature of the National Curriculum can impose severe limitation on the design; the design has to focus on section(s) of the curriculum.

2 Tangible interfaces for assisting learning

Historically children have played with physical objects to learn a variety of skill, a tangible interface (TUI) therefore would appear as a "natural" form to them.

In the University of Limerick museum projects (Ferris et al. 2004), 'Everyday technology' such as paper, books and other physical displays has been augmented digitally. In Figure 1, as the user turns the page to reveal the marker they see an image overlaid onto the page of the book. The exhibitions like this create a unique museum visiting environment. It may appear to children 'Magical', interesting and unforgettable experience.

Figure 1. The antique desk with projection on the book.

"I/O Brush" is a drawing tool, children can move the brush over any physical surface and pick up colours and textures and then draw with them on canvas (Ryokai et al. 2004). I/O Brush is in a regular physical form of paintbrush but has a small video camera with lights and touch sensors embedded inside. Outside of the drawing canvas, the brush can pick up colour, texture, and movement of a brushed surface. On the canvas, artists can draw with the special "ink" they just picked up from their immediate environment (Figure 2.). This is TUI is 'Edutainment': a game-like educational environment, it is fun to children. In children's learning experience, fun is a very important factor and they learn from playing.

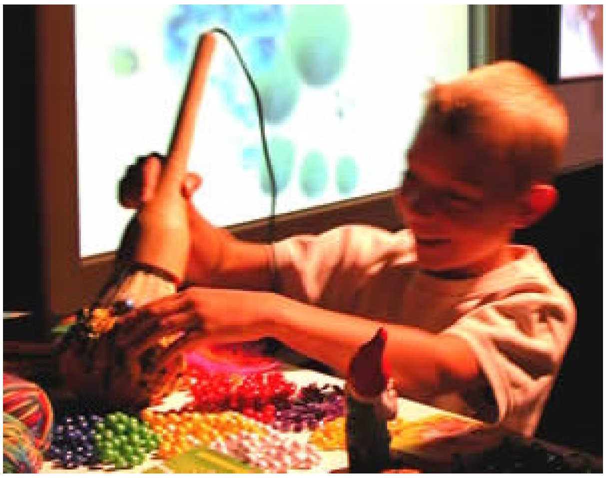

Figure 2. The I/O Brush.

"Teaching Rhetorical Skills with Tangible User Interface" (Stringer and Toye 2004) is an application which uses a large screen graphical user interface (GUI) and a tangible user interface (TUI) to teach children important rhetorical skills, it is shown in Figure 3. The image on the left shows the TUI and on the right is the GUI screen shoot. The five large coloured physical blocks represent the sections of the argument which match the GUI on the right. The small physical blocks represent the statements which support the argument. The participants were encouraged to work together: deciding which statement for which section, and then the statement blocks were put on the corresponding sections. This learning TUI is augmented with the RFID readers and tags which enable the system detects the statements for the each section. The research has closely followed the National Curriculum and was carried out in the schools.

Figure 3: Teaching Rhetorical Skills with Tangible User Interface.

"Tango (Tag Added learNinG Objects, in Japanese Tango means language)" system (Ogata and Akamatsu 2004) is a ubiquitous computing environment for computer-assisted language learning (CALL). (Figure 4) The user holds a PDA with a RFID reader module attached wandering around the room. The room is an augmented environment with tagged objects. When the user gets close to any object and stops, certain information will be shown the screen. The user has to know the words and understand the questions to be able to carry out a series of tasks. The similar ubiquitous learning system can be applied in treasure-hunt type interactive museum learning.

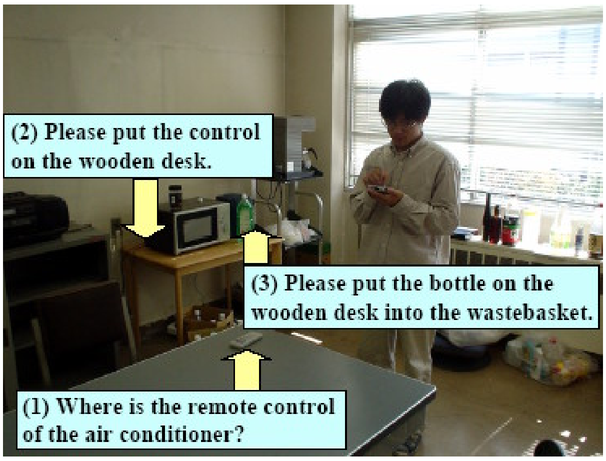

Figure 4: Usage example of TANGO.

Very interestingly, many researchers involved cube in their tangible interface design, because some 3D shape like cube can cluster similar functions to the same physical object and potentially reduce the number of physical objects needed in a workspace at a given time. Lancaster University 'Cubicle', tangible cuboid interface(Laerhoven et al. 2003), which is a multifaceted, multi-sensory wireless tangible input device. User is able to touch or grasp and being perceived through sense of touch, it is also a haptic interfaces. ActiveCube (Kitamura et al. 2001) is a spatial 3D TUI for structural input, enabling real-time, interactive, step-by-step, geometry sampling of a 3D structure.

Sony (http://www.sony.net/Fun/SonyDesign/2003/BlockJam/future.html) also developed cube based system to implement multimodal interactions.

2.1 Tangible technologies

Like most of the Ubiquitous Computing, tangible technologies require mobile computing and wireless technologies. The wireless technologies available include Bluetooth, wireless LAN, RFID identifier tags and readers, RF networking, Infrared beacons, Ultrasound. Sensors, sound and vision tracking are also normally applied in Tangible technologies. The following table summaries some of the technologies:

The technology	Specification & Cost	Comments
Sensors: Force/Pressure Sensor, light sensor, speed sensor, motion sensor, temperature sensor, pressure sensor	Need to work with a Digitizer and a computer Around £5.00, can be more expensive	Generally cheap. Detect motion, light, speed and pressure etc…Very useful in TUI design. Haptic UI Work with other technology
Barcodes	Reader and Barcodes stickers	Cheap and easy implement. Representation of commodity? The 2-D and line of sight limitations
Radio Frequency Identification (RFID)	The price varies according to the functionality: Omron V720 Gate Reader $14,990 PhidgetRFID kit CND 90.00	Passive and semi-passive tags require little or no power on the transmitters. Easy to attach the tags to items. Work with a powered reader (or more) and some RFID tags.
Bluetooth	Around 10 meters working distance	Forming a local wireless network, do not require line of sight
Infra-red(IR)		Not expensive. Limited bandwidth Forming a point to point network link, data transfer, requires line of sight
Wireless LAN		Mature technology, the cost is acceptable. Provides flexibility and seamless integration
Sound & Vision tracking Computer vision	Need audio and video capture device and certain algorithm to process the information	Act as ambient media, vision reflects on augmented physical surfaces. Need specific software support

In addition, the increasing accessibility of PDAs makes it feasible to consider more mobile and ubiquitous use of sensor-based systems: during the last decade there has been an enormous development in mobile communication. Cellular phones have become mass-market commodities and are now converging with the PC and Internet technologies to bring us low-price, hand-held units with PC-functionality in combination with mobile Internet. The deployment of third-generation systems for mobile communication (3G), starting throughout Europe, together with demands from both service providers and the consumers will soon lead to affordable PDAs which give approximately the same functionality and bandwidth as today's standard PC with a modem-based Internet connection.

3 How tangible technologies may benefit children’s learning

Tangible technologies can benefit children’s learning from many ways:

TUI requires little time to learn how to use the interface

TUI is a natural interface which requires little cognitive effort to learn, therefore children can concentrate more on the task rather than how to use the computer or software.

TUI offers user an alternative way of interaction and control of the computing environment

TUI can offer a variety of interactions, it allows user to solve problems with concrete physical objects and physical action when they fail using more abstract representations and complex syntax, therefore TUI can empower children with the control of the computing environment;

they will feel and "own" the environment and will be actively engaged and not lose their interest easily.

TUI supports 'Trial-And-Error' activity

TUI gives continuous presentation of the object of interest. It uses rapid incremental and reversible actions whose impact on the object of interest is immediately visible.

TUI supports more than one user

The advantage of using a TUI is that it is no longer restricted to a single user, children can sit down and collaborate with their friends face to face in an entirely natural way. It can provide children with a social experience. Also research shows that children are more productive when they cooperate, therefore compared to a single child a group of children may be able to do a task more efficiently and benefit more from the experience

Also from psychologist and educationist point of view (O'Malley and Fraser 2004), tangibles are beneficial for learning because: physical action is important in learning; concrete objects are important in learning; physical materials give rise to mental images which can then guide and constrain future problem solving in the absence of the physical materials; learners can abstract symbolic relations from a variety of concrete instances; and physical objects that are familiar are more easily understood by children than more symbolic entities.

4 Introduction of the research

The increasing accessibility of PDAs makes it feasible to consider more mobile and ubiquitous use of sensor-based systems. PDA as a mediator between RFID tags and smart artefacts, making the use of RFID tags seamless and intuitive, and supporting applications in everyday objects in the school or in artefacts in the museum environment.

The objectives for this research are:

- Develop an object based interface using RFID tags for children
- Develop a physical query language (PQL) to describe how users use the objects to perform queries and otherwise interact with information.
- Investigate common TUIs for both class and museum
- Compare the efficiency of traditional interface and TUI
- Design the evaluations methods for TUIs, new forms of evaluation are sought to reflect the potential of tangible technologies for learning.

Beyond this research, it can be extended to do with children with special educational needs, emotional and behavioural difficulties, visually impaired and so on… to see whether tangibles offer a more engaging interaction process than traditional text based interfaces.

5 Conclusions

Tangible Interface is a natural interface, it is a more explorative, expressive and collaborative technology compare to others. TUIs have greater potential, if there is enough technology support. In many ways, TUI can be beneficial to children's learning. Research in a relatively new area raises more questions than it answers, and this work is no exception. There is a multitude of applications in the general area of Ubiquitous Computing and Tangible User Interface to be discovered.

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