

**PLANT SCANNER:
A HANDHELD PDA USING RFID TAGS FOR CHILD VISITORS TO
THE MICHIGAN 4-H CHILDREN'S GARDEN**

By

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ABSTRACT

PLANT SCANNER: A HANDHELD PDA USING RFID TAGS FOR CHILD VISITORS TO THE MICHIGAN 4-H CHILDREN'S GARDEN

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This thesis project investigates the viability of using interactive handheld and RFID technology in the 4-H Indoor Children's Garden at Michigan State University. The Plant Scanner Project is designed to teach children introductory plant biology and enhance their indoor children's garden experience of exploration. The results from the study suggests that students learn more about plants by using the Plant Scanner, that students use the technology with ease, that students engage with the technology, that the Plant Scanner works better in the outdoor garden, and that learning with the Plant Scanner is enhanced when a plant expert accompanies children.

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CHAPTER 1

INTRODUCTION

Description

Interactive handheld technology is being used in the 4-H Indoor Children's Garden for the first time. The Plant Scanner Project uses a handheld device (PDA) to teach children introductory plant biology and enhance their indoor children's garden experience of exploration. The project bridges the real world (the children's garden) with a virtual world that exists inside the handheld device.

A child walks through the Children's garden with a handheld device and stops in front of a plant- let's say a tomato plant. In front of the tomato plant is a physical sign. If the child waves the handheld in front of the tomato sign, information about the tomato plant appears in the interface. The PDA in this case acts like a 'plant-scanner.' The Plant Scanner helps you 'see' what is not visible. As the child explores the garden she could 'scan' other plants with the plant-scanner. This action would bring up information like the name of the plant and a picture of the plant and other information that may not be visible. For example, she could see a picture of the root that is buried and understand what the root structure is like and what the other plant parts such as stem, leaf, flower, fruit, and seed look like. Pictures of the plant in each of the four seasons can be accessed in the cycle's section. She could also see that the plant is used for beauty, food, medicine, bio-agent, fun, arts and crafts. By interacting with the garden in this way, she

can get a better understanding of the various parts, life cycles, and uses of the particular plant.

The sign next to the plant has an RFID tag and the handheld PDA has an RFID reader, so when the child waves the PDA in front of the sign, data is passed to the PDA. This action makes information appear on the screen. But to the child the act of waving the device in front of the sign brings up the information. These combined technologies create an interactive interface that enables the learner to call up images and text information about various plants; for signs are all over the garden and on each sign there is a tag. The Plant Scanner Project supports learning and adds to the child's experience.

Elementary school students, particularly those in third grade through eighth grade who visit the indoor children's garden at Michigan State University will be using the Plant Scanner Project. The 4-H Children's Garden is a popular destination for local school children, so the project has a large projected audience.

Objectives

The Plant Scanner Project has multiple objectives: to expose young learners to plant biology in a fun and appealing way, to explore ways to best integrate virtual and real experiences, to enhance the Indoor Children's Garden experience for children, to encourage children to explore the garden and learn through technology (garden plus technology is even better than either one alone because technology scaffolds), to interest young learners in the plant biology- life cycles of plants, uses of plants, parts of plants.

Garden visitors and particularly young garden visitors experience the physical reality of the garden but rarely read the existing signs. The Plant Scanner Project will also investigate the viability of using handhelds in the garden, looking at new RFID (Radio Frequency Identification) technologies and their interaction with handheld devices.

CHAPTER 2

LITERATURE REVIEW

Introduction

The Plant Scanner Project involves the use of a handheld device. Interest in handheld technology is growing, especially in museums. Schools are becoming more interested in the technology. Proponents of handheld technology believe that because it is more affordable and more portable than other technologies its' popularity will grow.

What is a PDA?

A handheld or PDA (Personal Digital Assistant) has been described as a “small, low-cost, highly versatile, mobile computer” (Avanzato, n.d., para.1). It has also been described as a “small, handheld device that provides tools to enhance personal productivity” (Deneen, 2001, para.1). PDA's are mainly designed to be Personal Information Managers (PIMs) and usually include calendar, address book, task lists and notes. Most PDA's have a pen-based (stylus) input and usually have handwriting recognition. Some have an inbuilt keyboard or an external keyboard connected to it. Many PDA's are now equipped with wireless connectivity and Bluetooth, while other PDA's come with expansion slots which could host a number of add-ons including GPS and wireless connectivity. The two most popular kinds of PDAs are the Palm OS PDAs and the Microsoft Pocket PC.

How are PDA's being used in museum environment/city guides?

Exploratorium Guidebook project

<http://www.exploratorium.edu/guidebook/>

The Electronic Guidebook Project was created at the Exploratorium in San Francisco in partnership with researchers from Hewlett Packard Labs and The Concord Consortium.

The Electronic Guidebook project investigated “the use of handheld computing devices and wireless networks to support a richer learning experience for science museum visitors” (Exploratorium, n.d., para. 1). The project’s goal was to find out how a “network of mobile devices, wireless networks and web-based content” (Exploratorium, n.d., para. 1) would allow users to “engage in a continuum of activities before, during, and after a museum visit to support a deeper engagement with the exhibits and the ideas they can communicate” (Exploratorium, n.d., para. 1).

The project’s technology enables users to interact with exhibits with a wireless device and have URL’s sent to their PDA. This project made use of a Pi- station (point-of-information station) that included a digital camera, infrared beacon, and RFID transmitter/receiver. The Pi-station is placed next to an exhibit. The users use a handheld device like a PDA to interact with these stations. The infrared beacon sends a URL to the handheld device when it is close to the exhibit. The corresponding webpage is then automatically downloaded from the content server. In this way, text, images video, and

audio are delivered to the PDA. In addition users bookmark the exhibits, take digital pictures with the camera near the exhibit and have a record of their visit. This user information can be stored in a “My Exploratorium” web page that that can be accessed later.

A study led by Sherry Hsi asked teachers, staff, museum members, and teens to describe their experiences after working with the Electronic Guidebook Project. Generally the participant comments were positive. Many commented that the handheld resources helped them “to think about and interact with the exhibits in new ways” (Hsi, 2002, p. 2). None of the participants had problems swiping the RFID devices with the handheld. Although most comments were positive, some participants complained of the heaviness of the handheld and one participant “felt a sense of isolation” and “expressed a concern that the handheld interfered with exhibit” (Hsi, 2002, p. 2).

Tate Museum

<http://www.tate.org.uk/modern/multimediatour/>

The Tate Museum launched a multimedia tour that incorporated wireless technologies and handheld computing in July 2002. The tour allowed visitors to see background information about the exhibits in a variety of different formats on a handheld device. These included still images, videos, and additional context for the exhibits. Visitors could listen to expert audio commentary about works while the works were being highlighted simultaneously on their PDA's. There were interactive screens where the visitor could

respond to the works, answer questions, and create their own sound track about the works.

The tour used a wireless network that pinpointed the visitor's location and sent them relevant information. The information stored on a central server can be limitless and easily updated. Since the tour was connected to a network the museum can broadcast messages to the visitor or send automatic alerts when an event is about to start. The visitor can also have information about a piece of art sent to their home e-mail address.

852 visitors who took the Tate Museum Multimedia tour completed evaluation forms based on their experiences. About 70% of the visitors said they spent more time in the gallery with the multimedia tour than they normally would have. A similar percentage said their visit was improved because of the multimedia tour. In general, older visitors found the tour more difficult to use than younger people.

As long as the message was clear and the device was functioning properly, users did not find multi-tasking between the PDA screen and the artwork to be a problem. Susie Fisher reported, "Visitors can multi track with great ease, even when the input tracks (audio, screen, painting) are not synchronized with one another" (Tate, 2003, p. 2). The multimedia tour made users look at the exhibit longer even though the screen commanded attention. Long messages didn't work, as the average user's attention span for the interactive message was shorter than just an audio tour. The help button helped show users how to use the tour. Text got mixed responses; the more art experienced

people liked the wall label information in their PDA, while others wanted more exciting content.

Invisible ideas

<http://www.invisibleideas.org/>

“Invisible Ideas” is a location aware application that gives users specific information about a site as they stroll along several parks in Boston. It combines GPS technology Macromedia Flash and Pocket PC and is the first application of its kind in the world.

The project consists of 147 art exhibits, each associated with a GPS waypoint (latitude and longitude), scattered over three parks. When the user is within a certain radius of an exhibit, the Invisible Ideas application triggers an event that plays the artist’s content, be it-audio, graphical, or video. The content stops playing when the user is outside the specified radius. As the users are walking, the application saves the users GPS coordinates on a SD (Secure Digital) card on the PDA. When the user returns the PDA to the gallery this SD card is removed and the information is saved to a database. A Flash application then uses this data to draw the users walking path on a scaled map of the parks.

This award-winning project has created a new location-aware technology platform to explore ideas and develop further projects from. SmartWorlds, the technology provider for Invisible Ideas, has received requests from other communities to build similar projects. To SmartWorlds CEO Giuseppe Taibi, Macromedia Flash MX is “the most

flexible and powerful development environment for any device, operating system, browser, or chip set to create applications that integrate seamlessly with GPS technology” (Macromedia, n.d., “The Benefits” section, para. 2).

Handhelds in the Classroom

Eliot Soloway, a researcher at the University of Michigan, argues that handhelds have “emerged as a viable alternative to desktop and laptop computers” (Norris & Soloway, 2003, “Opportunity Knocks” section, para. 1) and will become the “primary computing device for K-12 students” (Norris & Soloway, 2003, “Opportunity Knocks” section, para. 3). Desktops and laptops he argues “are overly complex, burdened with excess functionality.” (Norris & Soloway, 2003, “Opportunity Knocks” section, para. 3) They take away too much time from the teaching of ideas and require too much time to teach the technology. Handhelds, unlike desktops and laptops, are portable so can be taken and used outside the classroom. Portability, accessibility, and cost make Soloway think that schools will move towards handheld technology in the near future.

One scenario offered by Soloway and his colleagues is that of a 5th grade classroom where each of the thirty students had handheld computers. In the first two days of the science unit, the students researched inventors on the Internet. On the third day they used software developed by Soloway’s team to concept map on their handheld. The students also used their handhelds to type in and store notes. Students also sent information to each other thus increasing collaboration in the classroom. This finding, the discovery of increased collaboration with the use of handhelds was also shown in a study done by

researchers at Simon Fraser University and the University of California (Regan & Inkpen, 2001). In their study, children aged 12 to 14 worked collaboratively to explore genetic concepts. Both the Soloway and Fraser studies seem to suggest that handhelds offer affordances, but collaboration is dependent on the design of the learning activity.

Soloway and his fellow researchers at the University of Michigan have conducted multiple studies, most of them qualitative, on the affordances and constraints of handheld technology and the supporting software. In a study with third to ninth graders using handhelds, they found that students were more productive with handhelds, because they produced more documents than the control groups. Students across the grades were also more likely to revisit their notes when using handhelds. Easy accessibility to notes supported this process. Soloway's team concluded from these early studies "the handheld computer will have more of an impact on teaching and learning in K-12 education than the Internet has had" (Norris & Soloway, 2003, "Next Steps" section, para. 1).

Studying handheld computers and its' affects on science learning in four seventh grade classrooms, Soloway's group found that the handheld itself increased student motivation and engagement, while supporting the understanding of scientific ideas. Handhelds fit into the school curriculum because they "are flexible enough to support a range of learning activities and learning styles and they are affordable enough to make it feasible for all students to have a truly personal computing device to support their own learning" (Luchini & Quintana & Soloway, 2004, p. 1).

Literature Review Conclusion

The use of handhelds is increasing in museums. Schools are usually slow in adopting new technologies, but a handheld's lower price and portability may make its' purchase more attractive. Researchers are starting to look closely at how handhelds within a curriculum can promote learning and collaboration. More research needs to follow, so we can begin to better understand how handhelds support learning.

CHAPTER 3

TECHNOLOGY OVERVIEW

Introduction

This project uses a variety of hardware and software technologies. The hardware interface includes the Pocket PC (hp iPAQ h5550), a RFID reader (AWID MPR-1230) plugged into a PC card expansion pack in the Pocket PC and various RFID “tags” (Texas Instruments Vicinity Card Transponders) placed at different parts of the garden.

The software consists of a front-end Flash program and a backend embedded Visual Basic program (eVB) that communicates with the RFID Reader. The eVB program interacts with the RFID reader and transfers tag data to the Flash program with the help of an XMLSocket connection.

The tag is activated by the RFID reader when the user waves the device (the Pocket PC with an RFID reader) over a tag. The RFID reader then reads the tag data with the help of the eVB program and then passes this data to the Flash program through the XMLSocket connection. The Flash program then utilizes this data to display information about the plant. This information includes pictures along with text information about the plant parts, plant life cycle and the plant uses.

Background

In the beginning of this production thesis I consulted with John Turner, a multimedia specialist at the Exploratorium in San Francisco. We discussed several options available to enable interaction with the Pocket PC and the garden and hence make the project location and context aware. Some of the options available were GPS, 802.11 positioning, bar coding, and RFID.

GPS

“GPS is a satellite-based radio navigation system developed and operated by the U.S. Department of Defense (DOD)” (U.S. Coast Guard Navigation Center, n.d.). GPS satellites circle the earth twice each day in a precise orbit and transmit signal information to earth. GPS receivers take this information to calculate the user’s exact location (Garim, n.d.). The location accuracy for most equipment can range between 10 to 100 meters. The military equipment has higher accuracy (up to 1 meter or less). The GPS receivers get information such as the date, time, latitude, longitude, and altitude as string values from the satellites.

The Plant Scanner Project is to be used in the Indoor Children’s Garden that has a small area of less than half an acre. GPS was ruled out since it has an accuracy of about 10 to 100 meters, and it doesn’t work well indoors due to weak satellite signals.

802.11 Positioning

802.11 refers to a family of specifications developed by the IEEE for wireless LAN

technology. 802.11 specifies an over-the-air interface between a wireless client and a base station or between two wireless clients (Webopedia, 2004).

While GPS works outdoors, the satellite signal is not strong enough to work well indoors. New forms of indoor positioning that use 802.11 wireless LAN are appearing in the market. Indoor positioning requires special equipment that interacts with the wireless network. There are no standards for these systems, so most solutions are vendor specific (Geier, 2002, “Proprietary Technologies” section, para. 1).

One such system available is the Ekahau Positioning system (EPE) (Ekahau, n.d), which locates laptops and PDA within 1 meter (3.5 feet) in less than a second (Geier, 2002, “Proprietary Technologies” section, para. 2). The Ekahau system costs about \$2995 to track 5 devices and \$4990 to track 15.

The Ekahau system was launched in July of 2003. With our limited budget, the Ekahau system wasn't the most ideal solution for this project.

Bar coding

A bar code is a pattern of dark bars and white spaces of varying widths that represent numbers letters or symbols. Bar code labels are read with a scanner. The scanner translates the barcode into numbers and letters that are passed to a computer.

The reason I didn't choose barcodes was because I wanted to experiment with more sophisticated RFID technology. There are several advantages to using RFID, which are included in the next section.

RFID

RFID (Radio Frequency Identification) is the technology that uses radio waves to identify people and objects (RFID Journal, n.d.). An RFID system consists of an RFID tag (also known as the transponder) and an RFID reader. The RFID tag consists of a small microchip and an antenna. Data is stored in the tag, usually in the form of a unique serial number. (RFID Journal, n.d.) RFID tags can be either "passive" (no battery) or "active" (battery present). Active tags need a battery and are more expensive (\$10 - \$100) than passive tags and have a read range of several meters (10 to 100 meters). Passive tags don't need a battery and have a read range between 10 mm to about 5 meters. They are cheap, for they start at about \$0.25 (Wikipedia, n.d.). The vast majority of RFID tags are passive in nature. This project uses passive tags.

The RFID reader acts as a transmitter/receiver. The reader transmits an electromagnetic field that "wakes-up" the tag and provides the power required for the tag to operate (Zebra, 2004). The tag then transfers the data to the reader through the antenna. This data is then read by the RFID reader and transferred to the Pocket PC or computer.

Unlike barcodes, RFID tags do not have to be line-of-sight. They only have to be within the reader's radio range. Also unlike barcodes, RFID tags can be read through most

materials. RFID tags are getting smaller and smaller some are 1/3 of a millimeter across (Granneman, 2003, “RFID 101” section, para. 1).

RFID systems use many different frequencies, but generally the most common are low (around 125 KHz), high (13.56 MHz) and ultra-high frequency, or UHF (850-900 MHz). The MPR-1230 spans the high frequency (13.56MHz) (RFID Journal, n.d)

The RFID reader used in this project was the AWID MPR-1230, a popular RFID reader that is designed to slip into any third party handheld, notebook or tablet computers. (see Figure 3.1)



Figure 3. 1 Pocket PC with MPR-1230 RFID Reader

It will read and write most leading smart labels or tags (AWID, 2003). The MPR-1230 reader uses the high frequency spectrum. The read range of the MPR-1230 is about 4 to 5

inches (AWID, 2003). I noticed during testing that the read range reduced to about 2 to 3 inches when the reader was protected by a rugged case.

There are several tags that are compatible with the AWID MPR-1230. I used RFID tags made by Texas Instruments. The tag used in this project is a 13.56.MHz Vicinity Card Transponder (Texas Instruments Radio Frequency Identification Systems, 2002). (see Figure 3.2). It supports the ISO-15693 standard and operates at a frequency of 13.56 MHz. Its' dimensions are 85.6 mm x 54 mm x 0.76mm, and it weighs about 5 grams and has a glossy finish. Its' operating temperature is 25°C to +50°C. It has a data retention capacity of over 10 years. It is relatively cheap, about \$5 per tag. The prices fall when bought in larger quantities.



Figure 3. 2 13.56 MHz Vicinity card Transponder (Texas Instruments)



Figure 3. 3 13.56 MHz Encapsulated Transponder (Texas Instruments)

Another newly available tag that has the same frequency of 13.56MHz and the ISO-15693 standard is the 13.56MHz-encapsulated transponder (Texas Instruments Radio Frequency Identification Systems, 2003). (see Figure 3.3). It is designed to withstand very harsh environments. It is black and about the size of a quarter. Its operating temperature is -25°C to +90°C. It is designed for laundry tracking applications and can

withstand shock and vibration. It could be used in the outdoor garden where there are more variations in temperature.

I decided to go with RFID technology, because the tags could be placed right next to the exhibit (a plant in this case) and would enable a higher level of user interactivity. The RFID tags are low maintenance and relatively cheap.

Embedded Visual Basic and XMLSocket connection

Sophisticated applications for the Pocket PC are usually built using embedded Visual Basic (eVB) or embedded Visual C++ (eVC), since both languages offer deep integration with Windows CE. Both languages facilitate various tasks including file system access and network connectivity (Chia, 2002).

Due to security issues, browsers and their plugins like Flash cannot have the same deep system access as eVB and eVC (Chia, 2002). This means that sophisticated applications can be built that use a rich Flash interface as the front end and eVB or eVC middleware or a backend program.

The Plant Scanner Project requires interaction with the RFID reader, which is inserted into the expansion pack of the Pocket PC. Flash cannot communicate directly with the reader, so instead a backend eVB program communicates with the RFID reader.

The eVB program communicates with the RFID reader and provides functions to read the tag data. This custom program performs functions such as activating and deactivating the RFID reader, setting the reader to read mode, reading tag data when the reader is in an activated state and passing this data to the XMLSocket object.

The XMLsocket object offers a convenient way for bi-directional communication between a Flash and an eVB or eVC program (Chia, 2002). The XMLSocket object creates persistent connections with a socket server, which could be running as a component of an eVB or eVC program. These persistent connections are called sockets. Once the socket is established, data can be sent and received across this channel. The XMLSocket object is intended for XML data, but it can accept plain string data too. The eVB program and XMLSocket connection for this project was written by my friend, Vineet Bansal.

Flash for Pocket PC

Overview

Macromedia Flash allows Flash content to be developed once and deployed across multiple platforms, browsers, and devices. Unlike desktop computers, mobile devices have limited storage capabilities, so Macromedia Flash is an ideal solution, since Flash files are compact and load quickly over low bandwidth connections. In addition, Flash supports scripting capabilities and server-side connectivity to create engaging applications, presentations, and data-driven content.

Pocket PC refers to the class of PDA that runs the Microsoft Pocket PC Operating system. The current version is Pocket PC 2003. There are “over 35 different manufacturers of Pocket PC, devices ranging from consumer to enterprise to ruggedized” (Macromedia, 2003).

For a list of all the Pocket PC devices the Pocket PC OS see:

<http://www.microsoft.com/windowsmobile/pocketpc/>

The Pocket PC devices can have different specifications, but most of them share the following characteristics: an Intel processor, 32-128 MB of RAM, 240x320 resolution, 64k color screen, built-in expansion slot for CompactFlash, SD, and MMC (Watrall & Herber, 2003, p. 764).

The device used for this project is the HP iPAQ pocket PC h-5550. Its’ specifications are: 400 MHz Intel Xscale technology-based processor, 128 MB RAM, 240x320 resolution, 64 k color screen, integrated wireless, and Bluetooth. A PC card expansion pack plus was also purchased to house the RFID reader and the extended battery. The extended battery can increase the battery life of the pocket PC by 135% - 150% (HP, 2004).

Fonts for Flash

The screen size in a PDA (240x320) is relatively small, so smaller font sizes were required. Text in Flash, by default, is anti-aliased. This anti-aliased text becomes blurry

and difficult to read at smaller sizes. A solution to this is to use pixel fonts or optimize the text using Alias Text (Watrall & Herber, 2003, p. 770).

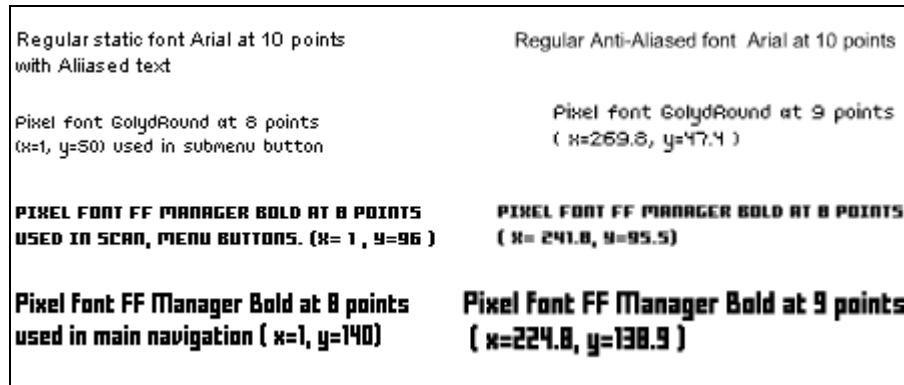


Figure 3. 4 Fonts for Flash

Using Pixel Fonts:

Pixel fonts are designed to be viewed at small point sizes and are not anti-aliased. The fonts use pixels to create each character (Watrall & Herber, 2003, p. 770), so they remain crisp and legible irrespective of screen size and resolution. However there are some things to be considered while using pixel fonts (see Figure 3.4). Pixel fonts need to be in increments of 8 (8,16,32) or as specified by the font creator. They need to be placed at whole X and Y coordinates, 10 instead of 10.5 (Watrall & Herber, 2003, p. 770).

This can be done using the Property Inspector (Window>Properties) or the Info panel (Window>Design Panels>Info). If input or dynamic fonts are being used, then fonts need to be embedded or else they will default to the Pocket PC system fonts (Watrall & Herber, 2003, p. 770). Pixel fonts don't usually come with Flash and need to be purchased separately. Some pixel fonts are available at www.fontsforflash.com and www.miniml.com.

Optimizing Small Fonts:

One of the new features of Flash MX 2004 and Flash MX 2004 professional is that it supports the Alias Text feature (see Figure 3.4). This feature makes small-sized text more readable, for it aligns the text outlines along pixel boundaries. The text does not need to be aligned on whole X or Y coordinates. Also there is no need to purchase fonts, as this feature works on all fonts installed on the machine.

However some things need to be considered while aliasing text with the Alias Text feature. If the user has Flash Player 7, then the Aliased text feature works with static, dynamic, and input text. But if the user has Flash Player 6, then this feature only works with static text. At the time of creating this project, the latest version of the Flash player available for the Pocket PC was version 6.

The Aliased Text feature does not improve the readability of text less than 8 points. In the case of some fonts, using type styles like italic or bold can reduce the readability of the Aliased text at small sizes. Sans serif text, such as Verdana or Arial, appears clearer at small sizes than serif text.

Sound

For Pocket PCs the less sound the better, because sound takes up precious processing power. However this project was built for children, so in order to make the project interactive and fun for children, sound effects for buttons and scanning were added. MP3

compression with a bit rate of 16kbps and quality of ‘fast’ was used. It is important to test sound on the Pocket PC, since it might sound differently on a desktop. The speakers in a Pocket PC aren’t very powerful, so sound effects need to be tested for audibility on a Pocket PC, as they are sometimes difficult to hear.

Buttons

Buttons in Flash should be designed differently for the Pocket PC. There is no mouse in the Pocket PC, so there is no mouse pointer. When the user interacts with a Pocket PC, a tap on the screen is a mouse click. A button “rollover” state should not be used as the rollover state might remain after the tap (Macromedia, 2003).



Figure 3. 5 Main Menu buttons (Parts has been tapped on)



Figure 3. 6 Sub Menu buttons (Leaf has been tapped on)

The button’s hit area should be made large enough for a quick stylus tap or for the user to tap with a finger (see Figure 3.5 and Figure 3.6).

XML in Flash

XML is Extensible Markup Language. It is becoming the standard of exchange of structured data for most Internet applications. Just like HTML, XML uses tags to mark up or specify text. While in HTML tags are predefined in XML, the tags are not predefined (e.g. <plant>Tomato</plant>). XML specifies the structure of the information not the way it is displayed, so the same XML can be reused for different applications. Every XML tag is called a node that could have attributes. A node that is inside another node is called a child node. The XML document has a hierarchical tree structure.

When an XML file is loaded into Flash, an object model is created that allows the data to be manipulated and easily extracted (Tupper, 2002). XML is a good option for loading large amounts of external data.

Optimization

Pocket PC devices still don't measure up to desktop or laptop computers in terms of performance. Content therefore needs to be optimized to work better on a Pocket PC.

A higher frame rate means a larger file size. A larger file size puts more strain on the processor. Due to hardware limitations on the Pocket PC, adequate playback can be achieved at a frame rate between 12 and 15 fps (Watrall & Herber, 2003, p. 765). The current project uses a frame rate of 12 fps.

Flash uses vectors to display content. In the case of a Pocket PC, using vectors can strain the processor. The more the vector curves are manipulated, the more processing power is required (Macromedia, 2003). It is better to use bitmap images instead of vectors while creating animations in a Pocket PC. The sliding scan door in the current project is a bitmap image. For better performance it is better to limit animation while creating content for a Pocket PC.

It is a good practice to load external files like JPG and SWF into the Flash movie, as this minimizes the file size of the Flash content and provides more easily updateable content for the user. All the plant images in this project are stored in an external folder and imported when needed into the Flash program using the “loadMovie” command.

Screen Size and FlashPack

Drawbacks of using the PIE (Pocket Internet Explorer):

A majority of Pocket PC devices including the one used for this project have a screen size of 240x320. By default if one wants to display an SWF file on a Pocket PC one will have to embed the SWF file in an html page and use PIE (Pocket Internet Explorer) to view this page. The drawback to this method is that there are two areas in the Pocket PC 2002 UI that cannot be utilized for content (see Figure 3.7).

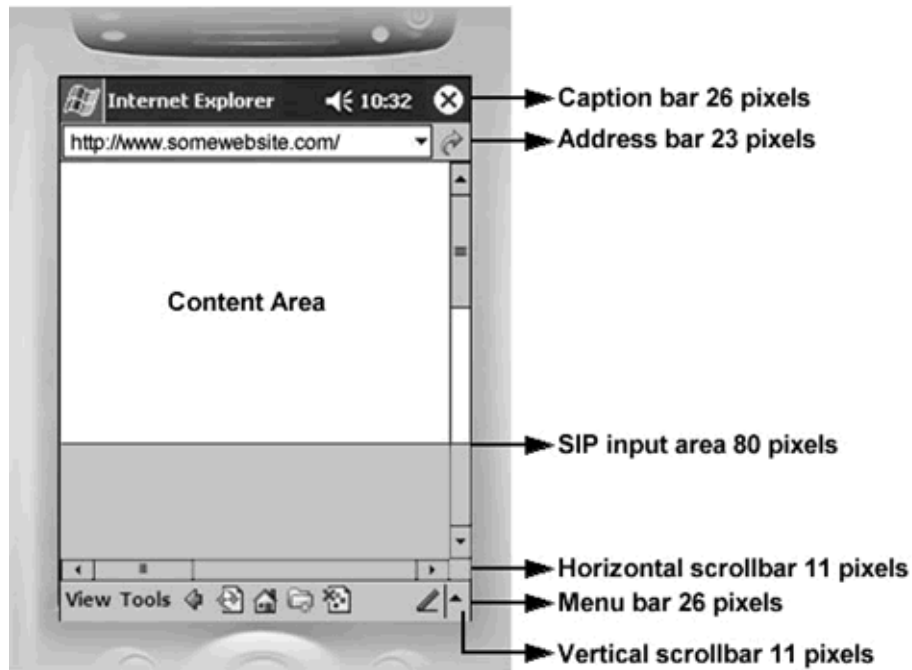


Figure 3. 7 Screen Size in Pocket Internet Explorer (PIE)

These are the caption bar at the top of the screen and the menu bar at the bottom of the screen. These bars remove 26 pixels each off the vertical resolution. Therefore, in order to design content for a Pocket Internet Explorer that fits on one page, the page size cannot exceed 240x263. Because of a scroll bug in the PIE, one cannot use the full 268-pixel height. After the page height exceeds 263 pixels the vertical scroll bar appears. This reduces the screen width to 229 pixels. Switching off the address bar can provide an additional 23 pixels, but since turning it off is optional one can't design the page to use that space. An additional 11 vertical pixels can be lost if the Flash movie requires a horizontal scroll bar.

If one wants the user to enter text information, an additional 80 vertical pixels are lost, so that the screen can accommodate the SIP area (Soft Input Panel). This is the area that has

the keyboard and block recognizer. Generally content is sized at 230x250, so that it appears without scrollbars when the address bar is turned off.

FlashPack:

It is possible to view full screen Flash content in a Pocket PC and avoid being limited by the size constraints of the PIE. One method is to use the Macromedia Flash Standalone Player (SAP). The SAP is a client-side application installed in the Pocket PC that allows the developer to create Flash projectors that run on the Pocket PC. The disadvantage is that it costs \$499 per year to license the SAP. This license needs to be renewed yearly. Another method to avoid the issues associated with the PIE is to use third party programs that create full screen stand-alone executable files. (.exe)



Figure 3. 8 FlashPack Screen Shot

One such third party program that was used in this project is called FlashPack (see Figure 3.8), a product created by HandSmart (<http://www.handsmart.com>). FlashPack allows the developer to easily create full-screen stand-alone executable files from SWF files. It is relatively cheap, about \$89.95 for the standard edition. However FlashPack requires the device to already have Flash Player for the Pocket PC (not the stand-alone player). The Flash player is freely available at the Macromedia website.

Setting Screen Size:

There are two ways to set the screen size when creating a full screen Flash movie for the Pocket PC. One way is to manually set the movie size to 240 x 320. First create a new Flash movie by choosing File> New. Select the flash Document option. Once the new file is open, go to Modify> Document. Then set the width to 240 and the height to 320.

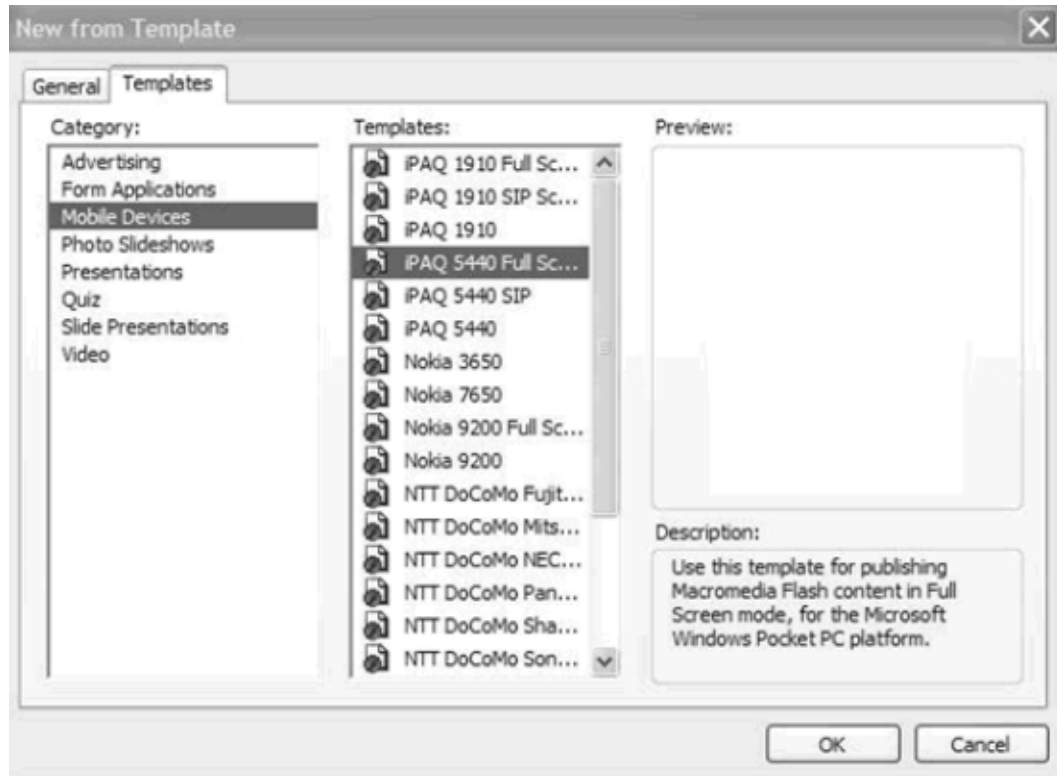


Figure 3. 9 New from Template Screen Shot

Another method is to use templates (see Figure 3.9). Macromedia Flash MX professional 2004 comes with a series of templates for mobile devices. To set the screen size of the Flash movie using the template, go to File > New. Click on the Templates tab. Choose Mobile Devices from the list. Select the template that matches your Pocket PC. In the case of this project I chose the iPAQ 5440 full screen template.

CHAPTER 4

PRODUCTION PROCESS

User Interface

The interface for this project was designed with the same color scheme as the 4-H Garden's website. The limited screen size (240x320 pixels) imposed several restrictions while designing the interface.

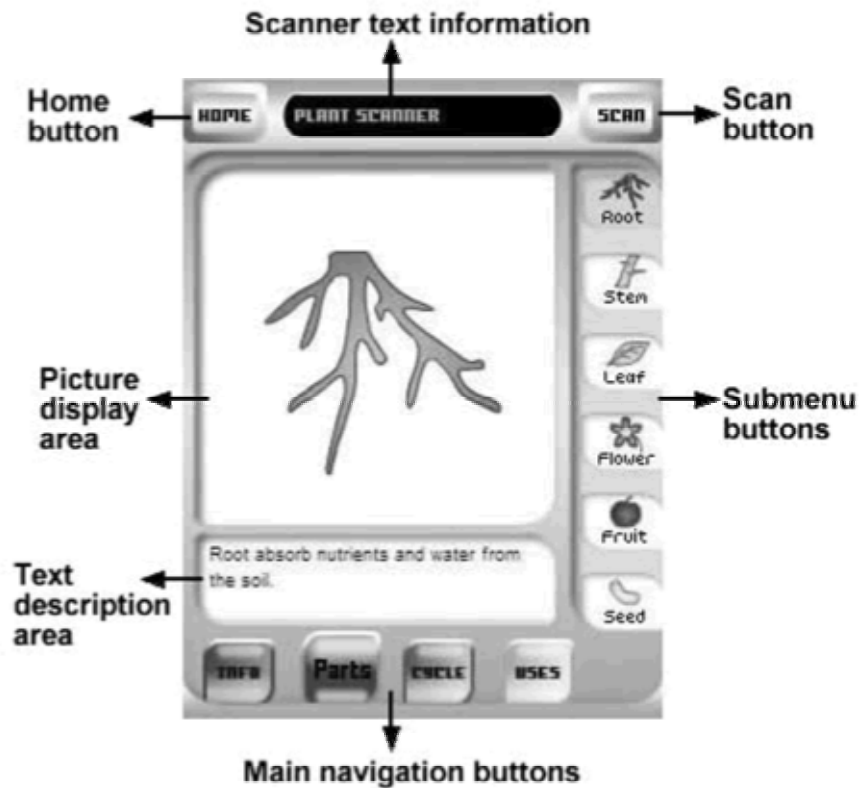


Figure 4.1 User Interface

I kept the layout fairly simple (see Figure 4.1). The scan button and the home button were placed on the top and a small text box was placed between them. This text box provides

scanner status information. The main body of the interface has four areas. The picture display area displays the image. Right below the picture display area is the text description area where text description related to the image is displayed. Below the text description area there are four main navigation buttons-Info, Parts, Cycle, and Uses. Clicking on these main navigation buttons changes the submenu that appears on the right-hand side of the interface. The submenu buttons contain an icon and text to indicate what they signify. Images in the picture display area are changed by clicking on the submenu buttons.

EVB Program and XML socket connection

Clicking on the eVB program initializes the Plant Scanner. This activates the scanner and brings up the Flash user interface. The XMLSocket connection is established and the Flash user interface is ready to use. When the scan button in the user interface is clicked, the reader is in read mode. If there is a tag within its' read range, the tag data is read and transferred to the Flash program via the XMLSocket connection.

XML Data

The data present in a tag is a unique serial number. The reader reads this data and passes it to the Flash program. The Flash program contains a look-up table that associates each serial number with an XML file. This XML file contains data about the plant. The XML file is parsed by the Flash program and utilized to display information.

Snippet of the XML data:

```
<parts>  
<root img="file:///imgs/marigoldroot.jpg" description="This is a marigold root."/>  
<stem img="file:///imgs/marigoldstem.jpg" description="This is a marigold stem."/>  
</parts>
```

One thing to note while using FlashPack to access other files is that FlashPack does not accept relative paths while loading external file. It needs the absolute path e.g. <file:///imgs/marigold.jpg> instead of imgs/marigold.jpg.

Working

The Flash program is designed to make the whole scanning process fun and interactive for children. When the user presses the scan button the scanner is “activated.” When this scanner is activated the act of waving it in front of an RFID tag triggers a scan event.

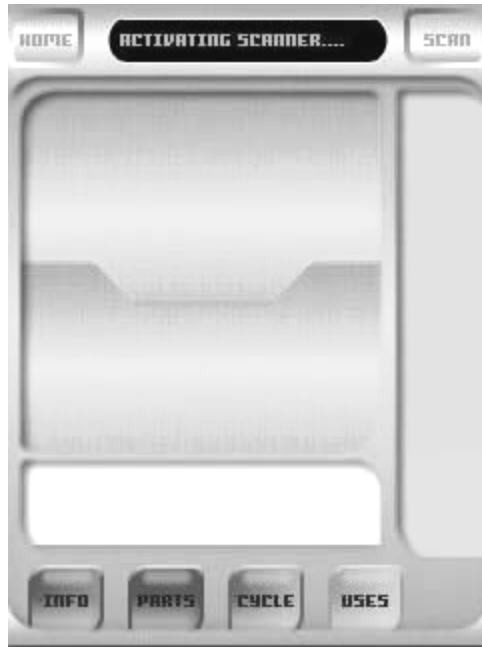


Figure 4. 2 Scan door closed



Figure 4. 3 Scan door opening

When there is a scan event, sliding doors cover the picture display area and sound effects are audible (see Figure 4.2 and Figure 4.3). The text box at the top provides feedback to the user like the various steps that are being taken to scan and download information.

When this process is completed, the sliding doors open to reveal a picture of the plant that has just been scanned along with general information about the plant. The name of the plant remains in the text box at the top.

This general 'Info' includes the name of the plant, its' scientific name, and some other information. The user can view more information about the plant by using the four main navigation buttons below the text description box. Pressing the 'Parts' button reveals a set of buttons on the right hand side. By pressing these 'Parts' submenu buttons, the user can view images of the various plant parts, which include the root, stem, leaf, flower,

fruit, and seed in the picture display area. Corresponding text description is available in the text description area. Similarly by clicking the 'Cycle' button, the user can view what the plant looks like in spring, summer, fall, and winter. By pressing the 'Uses' button, the user can view what that particular plant is used for. For this project we have broadly categorized uses as beauty, food, bio-agent, medicine, arts and crafts, and fun.

The menu buttons are highlighted to indicate what section the user is seeing. Every time the user wants to scan a new plant, she has to press the scan button and then wave the device over a tag.

CHAPTER 5

STUDY

Method

This study took place in the 4-H Children's Indoor and Outdoor Garden at Michigan State University. An eleven-year old boy, an eleven-year old girl, and an eight-year old girl participated in the study. The two girls had never used a PDA before. The boy had used a PDA before. Norm Lownds, the Children's Garden curator, accompanied the group through the garden. The participants were observed using the Plant Scanner for approximately 20 minutes.

RFID tags were placed on sticks, which were placed next to three plants, marigolds, tomatoes, and pansies. The marigolds were blooming. The tomatoes were not. Since the pansies were not in the Indoor garden, we decided to put the pansy tag in the Outdoor garden. The PDA was placed inside a rugged case. This cover also protected the RFID reader. The plastic screen cover was removed since the screen was warped, which made it difficult to see the interface.

Introduction to Study

The children were told that they were going to test a new product in the Outdoor and Indoor gardens. They were told that there were blank tags in the gardens and that they should wave the scanner over the top of the tag. The students were asked to think aloud,

as they went as a group around the garden. They were told to take turns using the device. Norm said that they could explore the Plant Scanner project first before scanning a tag.

During the introduction the children seemed interested in the device. After being given the tool, the two eleven-year olds focused intently on the scanning device. The father of the two girls was interested and soon came over and looked at the device. When the father came over, the younger sister was standing away from the two eleven year olds. Her father told the eight year old that, “she should be watching too.”

Sam looked comfortable holding and using the Plant Scanner. He pressed the parts button, clicked on roots, then flower, then seeds, and then clicked on the cycle button. He then clicked on each season. Later he went to the plant Uses section. Sam clicked on all the buttons. Jill stood beside Sam and looked at the Plant Scanner too. They both liked the smiley face in the Uses section. Sam said that he wanted to look at the actual plants.

Jill was the next to hold the device. She quickly clicked around the interface in a linear order. She didn't read the text. Sue was the last to test out the plant scanner. Compared to Jill and Sam, she spent less time with the scanner.

Inside the Indoor Garden

Norm led the group to the marigold plant. Sam held the Plant Scanner and waved it in front of the plant. Nothing happened. I asked Sam if he could figure out what he needed to do before he waved the device. Sam looked at the interface for an instant and said,

“press the scan button.” He then pressed the scan button and heard beeping. At this point Sam bent down and waved the scanner across the RFID tag. The two sisters did not gather around Sam when he stood up. I asked Sam if the picture in the scanner matched the plant in the garden. Sam replied yes. Sam was able to provide the name of the plant when prompted.

After clicking through the interface, Sam handed the scanner to Jill. At this point, Norm and Sam started talking about a tall flowering plant nearby in the garden.

Jill clicked quickly on all the parts buttons and then went to the seasons. I asked her what plant information was available. She said parts, cycles, and uses. I asked her if she had noticed that the text information kept changing. She said that she hadn't and then began to look again at the text descriptions.

Norm asked them to look for other plants with tags but soon directed them to the tomato plant. Sam gave the PDA to Jill who then successfully scanned the plant without being given any instructions. Jill looked through the interface quickly and in linear order. She went to the uses section button and noticed that nothing was there, became confused, then clicked on the parts button and looked at all the parts again.

Jill then gave the scanner to her sister. Sue initially moved from parts to cycles and then to the uses but didn't click on the sub-menus. Sue pressed a few buttons and soon lost interest.

Norm asked the children if they knew all about the tomato plant. Sam then looked back at the interface.

The two older children were holding the stylus like a pencil, while Sue held it in a closed fist. Despite these differences, all three were able to easily maneuver around the interface with the stylus. Both the eleven years olds looked very relaxed using the scanner.

In the Outdoor Garden

An RFID tag was placed beside the pansy plants in the outdoor garden. Sam scanned the Pansy plant without any instructions. Norm asked Sam if he noticed what the text said in the start screen. Sam read the description and said that pansies don't do very well in hot weather. Norm asked the group when they thought the pansies had been planted. Pointing to the pansies, Norm said that they had been planted last October, and that they were in bad shape because it had been hot recently.

Because it was raining, Norm suggested that we go under the tent and work with the scanner. The scanner, at this point, was already loaded with the pansy plant information. Sam, with scanner in hand, sat down and began clicking through the environment. He rested the scanner on his knee. Sam read the descriptions of the pansies. After clicking on the description of the pansy in the fall, Sam paused and had the other girls look at the little pansy. The girls smiled and said it looked like a mushroom. Sam then looked at the picture of the pansy fruit. I asked him if he had ever seen a pansy fruit before, and he

replied that he didn't know that pansies had fruit. Norm said that they did and that he would go and see if there were any fruit on the pansies in the garden. Sam got up to go with Norm, but Norm told him that he must wait until the others were ready. Sam continued to look at the pansy information and laughed after reading that pansies were able to "live through winter, even in Michigan." Sam was working primarily alone during this time. He later handed the Plant Scanner to Jill.

Jill looked at the Pansy uses and then went to the first button, beauty. Norm told the group that the pansy picture for beauty was taken right where we were sitting. Jill went to Pansy-food and saw a muffin. Sam said yum. Because both Sam and Jill had been through the garden chef program earlier that day, they knew that pansies could be eaten. Jill didn't think that pansies tasted very good. The two sisters began using the interface together. Jill went to pansy fun and read the text, 'can you see a face.' Norm asked her if she could see the face. She and Sam said they could see the face and Jill pointed to the picture on the screen. Jill gave the scanner to her younger sister, but Sue was content to hand it back to her and watch.

I asked the group if the pansy fruit was like the marigold fruit. They didn't remember so Norm went back to retrieve the RFID tag for the marigold plant.

Norm returned with the tag, and Sam scanned it. Sam went to the uses and then to marigold fun. He read that the marigolds have fun names. He said he didn't know that marigolds have other names. He read the name French vanilla and thought that

information was cool. Sam asked Jill if she knew they had other names. She said that she thought they were only called marigolds. Norm asked Sam if he knew what the names refer to. Sam thought they probably refer to their smell. Norm said that the names probably refer to the color, but it would be a good idea to check on that. Norm asked the group if they knew what French vanilla ice cream looked like. Sam said it was like a cream. Norm said that the names probably did not refer to the smell, since all marigold smelled alike.

Then Sam looked at the parts. Sam said that the marigold roots looked strange and clumpy. I asked him if he had seen other roots like that. Sam said he hadn't. I told him that its' strange appearance was probably was due to the attached mud.

Sam looked at the stem and asked whose finger had been photographed. Sam liked the color shades and said that the striped look of the stem was cool. He then looked at the leaves image, and even turned the Plant Scanner horizontal to take a closer look. He then looked at the marigold fruit image and said that he hadn't seen anything like that before. Sam then went to flowers section and read that the flowers had a variety of colors. A creamy white flower was mentioned in the text. He said that flower was probably the French Vanilla variety. Sam thought the marigold seeds were cool. He handed the Plant Scanner to Jill.

Jill looked at the Marigold uses. Jill thought it was interesting that the marigolds kept the bugs away. Sam too thought it was cool that marigold kept bugs away.

After asking them questions about the Plant Scanner program (see exit interview), the kids were interested in going back and looking at the fruit of the pansies. Kneeling down, Norm opened one of the pansy fruits that still had seeds. All three children became very interested. Sam picked up another fruit to see for himself. The group then wanted to see marigold fruit; we went to the marigold plants. Norm opened marigold fruits to show the seeds. All three kids held out their hands, all wanting to hold the seeds. Norm said that each plant has many flowers. . He counted the number of flowers on the plant. The plant had more than 25 flowers. Norm then said that there were many seeds in each flower. Norm pointed to a huge marigold that had even more seeds than the smaller one they had just opened. Norm placed marigold seeds in Sam and Sue's hands. Sam said that he wanted to take the seeds home with him.

Exit Interview

How would you use the plant scanner?

- For science projects, to learn more about plant parts, to find out a plant's uses

Did you like the colors?

- All the kids said yes.

What did you like about the plant scanner?

- Jill said that she liked the uses section the best. She said she didn't know that marigolds kept bugs away.

Did you like the Pictures?

- All the kids said yes.

What were interesting thing about Pansies?

- They didn't know they had fruit.
- They knew that pansies could be eaten.

What were interesting thing about Marigolds?

- They didn't know marigolds kept bugs away.
- They didn't know that marigolds had different names.
- They thought the seeds were cool.
- Sam thought the stem was cool too.

Was the scanner fun to use?

- All three said yes.

Was the text easy to read? Was the text was clear?

- All three said yes.

Was the scanner easy to use?

- They said it was easy to use.

Where else could use it?

- They said they would use it in school for science projects.

Suggestions?

They wanted more of the “interesting text.” Sam mentioned that the text for marigolds was interesting and gave information of various colors of marigolds, but in other places the text was not informative. One example that Sam gave was the text belonging to the marigold seed.

Analysis

The study suggests that when there are more than two people in a group, the Plant Scanner Project works better outdoors. The Outdoor Garden promotes more collaborative activity with groups of three because it offers room for the children to walk around, and stand beside one another when working with the Plant Scanner. In the Outdoor Garden, the children were more likely to show one another something they found interesting. Outdoors the children could also scan a plant and then sit down and navigate slowly around the interface. The children were more likely to read more and ask more questions when they were sitting down. Because the Indoor Garden is in a more confined space, the group of three had difficulties sharing the Plant Scanner. Indoors the children were navigating more hurriedly and not reading the text. The study suggests that because of the Indoor Garden’s limited space, it might be better for groups of three or more to use the Plant Scanner in the Outdoor Garden.

The children had no difficulties holding the Plant Scanner and using the stylus. Even the eight year old did not have difficulty using the Plant Scanner. The scanner was not dropped or put down on the ground at any point during the study. The children did feel more comfortable using the Scanner when they were sitting on the ground.

The children navigated through the interface with little or no instruction. They more or less tended to follow a linear pattern of navigation. More time was spent with images that had more descriptive text. 'Interesting' text descriptions, like pansies surviving the Michigan winter for example, were more likely to be shared. They all enjoyed the sounds and the graphics in the interface. There were no technical difficulties during the study. The images and text came up quickly. The sound effects were audible.

The scanner worked well because of Norm's guidance and expertise. Norm asked key questions which motivated the children to look at more information on the Plant Scanner and led to interesting discussions. His prompting questions helped the children think more deeply about plant biology. The mix of virtual and real was effective. The children were able to see certain plant parts in the device and then actually look back at the physical plant to observe even more closely. The children enjoyed this process.

Games and learning scholars are concluding as they study games and learning that a digital game in isolation will not have nearly so powerful a learning impact as a game preceded by and/or followed up by guided interpretation and group activities to reinforce and highlight learning content. Technology plus a guide/teacher/coach can go beyond the

impact of technology alone (Jenkins & Squire, 2003). The guide can pick up on individual child interests, or events of the moment, to encourage further exploration and wonder. The Michigan 4-H Children's Garden guides field trips throughout the year. Based on this limited but promising user observation, the plant scanner facilitates interest and inquiry into unseen dimensions of a plant which is normally visible at one point in its life cycle. The presence of an involved guide combined with the plant scanner heightens child interest, involvement, and learning from the experience.

Other issues

The scan range is reduced when the protective cover for the reader is put in place. When the reader is held parallel to the tag the read range is about 3 to 4 inches. When the scanner is held perpendicular to the tag the read range is even less about 1 to 2 inches. Without the protective cover the read range is about 5 to 6 inches.

CHAPTER 6

FUTURE

Future Implications for the Plant Scanner Project

The current project uses data stored locally. A future modification of the project could be to have the data on a server and data access through a wireless network. The PDA being used for this project already has an in-built wireless card. If there is a strong wireless signal in the garden, then data for a potentially unlimited number of plants can be viewed in the plant scanner without worrying about storage space. The XML file contains the file name of the image and its' location, so the XML file could be easily modified to contain the URL of the images. In addition, the XML file itself could be stored on the server making the system truly dynamic. It could then be possible to easily add more and more plants without modifying the Flash program.

Some extra features like what insects are harmful to the plant in question, what are favorable growth conditions, plant problems, comparisons between plants, and plant growth rate could be added to the Plant Scanner Project.

Future studies should look more closely at individual differences and ways to use the Plant Scanner to promote collaborative learning. It would be useful to work with classroom teachers and experts in the 4-H Garden on ways that the project could be integrated into science curricula. A potentially useful feature could be the ability for users

to save certain information to a server, which they could access later, or beam information to other plant scanner users in the garden.

High school students who attend 4-H Garden summer programs could be enlisted to gather content and lead tours through the Children's Garden. It would also be interesting to find ways to integrate the Plant Scanner with other 4-H Garden activities like Plant Problems and with online activities at the 4-H Garden website.

Future implications for other Handheld Projects

The use of RFID tags, or location sensitive equipment, can enhance tours that are normally guided. Technologies like GPS and similar positioning systems or RFID tags could be used as city guides, park guides, and museum guides. In the future the devices will be smaller. Already cell phones are equipped with more functionality and this will only improve. It is likely that in the future users will have one device that will integrate various technologies, which serve all their mobile needs. I expect that these devices will be smaller, less expensive, and more powerful.

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