Final Year Project Report

Using RFID to Remember

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BA/BSc (hons) in Computer Science

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Abstract

RFID has proved to be a useful technology, becoming more common with development of applications that benefit people in everyday useful ways. This project demonstrates the use of this technology to aid human memory, specifically to help people find lost items. Losing a wallet or a mobile phone is a common occurrence for most people, and a system such as this could be beneficial. The system consists of an RFID component which identifies user interactions with objects. This data is used to help people locate lost items through interacting with a lost and found application, which is based on human readable cues. For example, 'The user last took their wallet out of their bag at 12:00 along with their car keys'. The cues are constructed based on interactions with such objects. Users view these cues through a web page and also receive alerts on potentially lost items through a built in system display.

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Chapter 1: **Introduction**

This report describes the development of the ReFInDer system, which helps users to find lost items, such as a phone or wallet. It is based on RFID technology, which is used to record user interactions with these items. RFID is a way of wirelessly identifying objects, consisting of a reader and tags. When an item is tagged, it can be uniquely identified when it comes into range of the reader. Using these records of user interactions with items, an Aide Memoire can be developed. This takes the form of a web site where users can obtain information about their interactions with a lost item and aid them in remembering where they may have lost it.

ReFInDer consists of of a mobile component and a website. The mobile component consists of the RFID reader connected to a portable micro-sized computer, which has an extremely small form factor. This gathers information about users' interactions such as when they had certain items and what locations and people they have come in contact with. The static component consists of a server and lost and found website. The data gathered by the micro-computer is wirelessly transmitted to the server, stored in a database, and presented to the user through the website. The mobile component also incorporates an LCD screen, facilitating an additional user interface. In addition to the implementation steps given by the project specification an additional means of gathering information about a users' activities was explored using Bluetooth.

This report presents a detailed overview of the goals, design and outcome of the system implementation. It includes a full description of the system design and construction leading to system evaluations and conclusions. Chapter 2 discusses background research relevant to the project. The papers presented are relevant to the technologies being used and provide useful insight into related fields of research involving these technologies. The background research also gives further insight into the applicability or usefulness of RFID for the proposed system design, and explores the concepts and goals of this project. Chapter 3 gives a detailed description of ReFInDer's implementation. This includes the system's design with regards to the hardware being used and the system's form factor. This chapter also includes descriptions of ReFInDer's data processing techniques and overviews of the software technologies being used. Chapter 4 describes how the system is evaluated and tested. This includes the results of these tests and the conclusions which can be drawn from them. Chapter 5 presents the final conclusions of this work based upon the overall evaluations and performance of the system. The applicability of this system for its intended purpose are discussed and the future research potential for this technology is explored.

1.1 Project Specification

The following is the original specification for this project:

Title: Using RFID to Remember

Lecturer: Lorcan Coyle and Aaron Quigley

Description: Associating interactions between users and artefacts in their everyday surroundings could be a useful way of helping people remember where they left them. When people cannot find something, simple cues like ‘you left your keys on the dresser table’, or ‘i saw you take your wallet with your mobile phone’ are naturally helpful. This project seeks to record a person’s interactions with everyday items and generate useful cues to the user when they lose something.

This project builds on an earlier ODCSSS summer school project, where an RFID reader is embedded in a glove and RFID tags are attached to kitchen implements. The reader can see when the user interacts with any item that has an attached tag and know what that item is.

The earlier project recorded interactions with the kitchen implements and used them to detect when the user was completing a routine task (e.g., making a cup of tea). This project would have access to the outputs of that project and one of the challenges of this project would be to understand, reuse, and extend the earlier work.

Mandatory: Software must be built to recognise a human user’s interactions with everyday objects. These objects would be attached with RFID tags and the user will interact with them using the rfid glove.

The software must be capable of giving useful (if simple) cues to remind the user where lost items are, e.g. ‘you interacted with your mobile phone at 2:01pm, 32 seconds after you interacted with your car keys and 21 seconds before you interacted with your wallet’

Discretionary: A useful way for the software to communicate with the user should be developed - this might be through a lost-and-found web page, or a display attached to the glove.

Exceptional: More complex, human readable cues should be developed, e.g., ‘you last had your mobile just after 2pm; you were also using your car keys and wallet at that time’.

Chapter 2: **Background Research**

2.1 Introduction

This chapter presents an overview of background research relevant to the project. In this chapter previous research involving RFID technology is discussed. The literature also explores a number of relevant concepts such as ubiquitous computing and wearable technology. These papers give a positive insight into different implementations of the proposed technologies, leading to some important conclusions on the application of RFID technology in this project.

2.2 An Introduction to RFID Technology

RFID is a technique for wirelessly identifying objects, which has become increasingly recognised for its many potential mainstream applications and uses. Examples include retail security systems and inventory management. The increase in the use of RFID is due mainly to lower cost of RFID components and the large amount of potential applications of RFID technology. Also RFID tags are available that do not require batteries. Recent research into the applicability of RFID include short range mobile phone communication, and anti counterfeit cryptography and authentication techniques [1, 4]. There are various types of RFID available, suited to different types applications. From the highest level RFID can be divided into two classes, active and passive [1]. The difference between them is based on the technique in which the tags are powered. Figure 2.1 shows the RFID reader used in this system and an example tag.

2.2.1 Passive RFID

The RFID method used in the ReFInDer system is known as passive RFID [1]. This is opposed to active RFID where the tags contain their own power source. As these tags are much larger and will eventually require maintenance such as battery replacement passive RFID is the ideal choice. In this technique tags are powered by the reader using a method known as electromagnetic induction, essentially building a charge from the readers magnetic field. Once powered the tag can transmit its unique hexadecimal ID. Passive RFID tags are much smaller and flexible, thus more suitable for placing them on common items. They are unobtrusive and could, for example, be placed inside the battery cover of a phone. This proves consistent with the projects main goals.

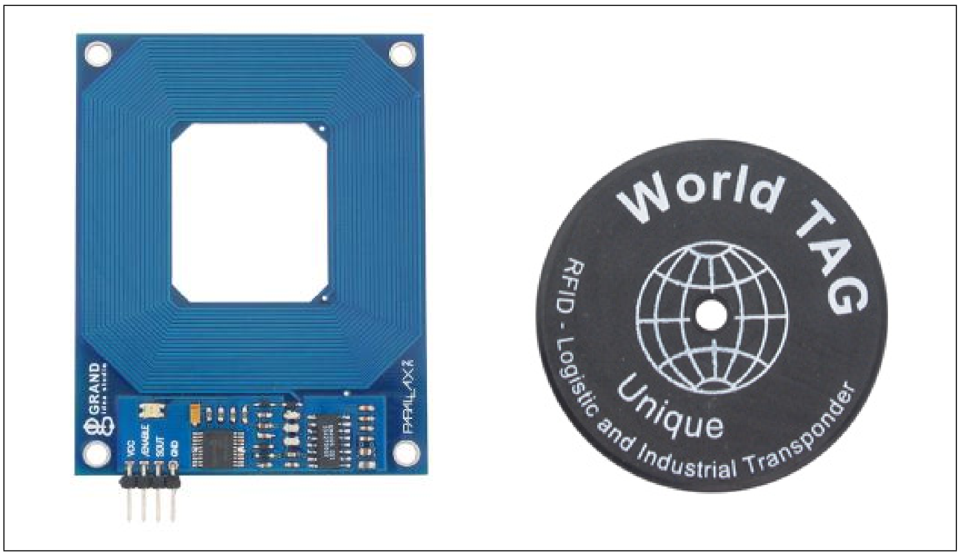

Figure 2.1: [14] RFID reader and Tag

2.3 The Computer for the 21st Century

Mark Weiser's seminal paper on ubiquitous computing proposes the concept of 'embodied virtuality' [11]. He describes how in today's world information is everywhere in our environment, so much so that we do not even notice it. Technology is also a common element in our environment but it has yet to reach its full potential. He conceives a system in which computers cover free surface spaces in our surroundings, connected through an invisible network, and become part of our normal environment. One is surrounded by technology, but it vanishes into the background so as its presence is not noted. Such a system has countless applications. This is similar to the ideas of Dey et al. [15] in which the concept of technology integrating and blended seamlessly into our environment is explored. Weiser's proposed system identifies people through badges, for example, and adjusts the environment based on the individual. A person enters a room and their calls and messages are automatically transferred to them through the environment. When a person enters their place of work they are identified, at which point their office logs them in and displays documents and files, or perhaps starts to make coffee, before they have even arrived. An important point the author raises is that such complex systems do not require the use of complex artificial intelligence techniques. All these systems can simply be derived from knowing basic information about a persons' activities [11]. This project proposes a similar concept. From knowing simple information about a user's interactions with objects, a more complex and useful application can be derived.

2.4 Chatchayanuson's Kitchen Tracker

Chatchayanuson et al.'s Kitchen Tracker system proposes to aid people with grocery shopping [5]. The system consists of stationary RFID readers in a kitchen and tags placed on key grocery items within it. As items are removed from the kitchen, i.e., used or thrown away, the RFID readers are used to identify these items. This data is used to assist in grocery shopping indicating key items that are needed in the kitchen through real time synchronisation with a phone or PDA. These implementations are based on smart home concepts [5]. The system is an integrated and useful system contained within a home environment, assisting in every day tasks without being obtrusive to a person's life. An important point raised by this implementation is that such technologies should be unobtrusive and blend naturally into our environment.

2.5 Ubiquitous Memories

Kawamura et al.'s Ubiquitous Memories is an innovative system designed to augment human memory through interaction with objects, and explores the area of wearable computing [6]. From a hardware perspective the system consists of a head mounted display over the left eye for displaying video to the user. This eyepiece also incorporates a camera to record users activities and experiences. There is an RFID reader on one wrist to read tagged objects. These are both connected to a remote control for the system which connects to a hip-mounted wearable computer. This is shown in figure 2.2. This computer connects wirelessly to a LAN. The system records the users experiences and activities and passes them to a server to be stored in a video database. Objects related to specific events are RFID tagged. When a tag is read the system replays a video related to that object, mimicking the behavior of human memory. When people touch objects they often recall associated memories [6].

The system was tested using memory and recall techniques using different memory aids, one of which being the Ubiquitous Memories system. This determines the effectiveness of the system in aiding human memory and also offers insight into alternative ways of achieving this. The system is compared to other methods, in this case memory recall techniques that do not involve technology. Instead of simply rating the system performance based solely on testing it for what it is designed for, it is compared to these other methods which are designed to achieve the same goal. This knowledge could be potentially used to refine or augment the system in the future. It is this authors opinion that, like the kitchen tracker system and Weiser's concepts [5, 11], it is important to point out that such a system needs to be unobtrusive and feel natural in our environment. This is particularly relevant for wearable computing in which the user is often in direct physical contact or in possession of the technology while they undertake everyday tasks.

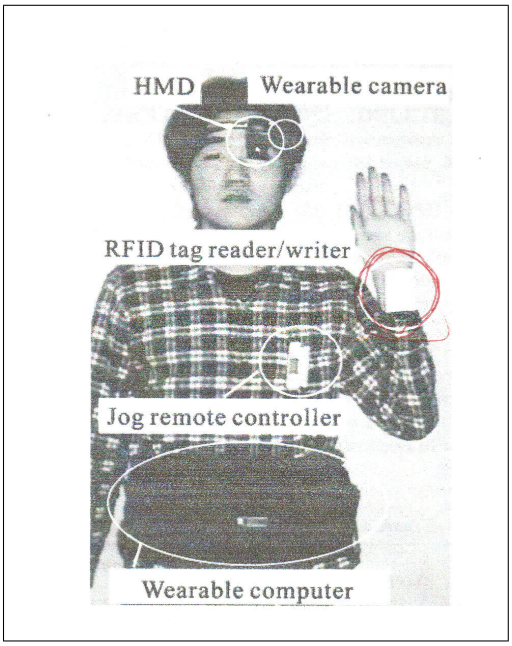

Figure 2.2: [6] 'Ubiquitous Memories' system

2.6 Schmidt and Gellersen's RFID glove

Like the Ubiquitous Memories system, Schmidt and Gellersen's RFID glove explores the area of wearable computing [6, 10] . In this area there is often difficulty in providing computer input if systems carry high cognitive loads or performance problems in their deployment. They explore human computer interaction using an RFID based system in an attempt to overcome the inherent shortcomings of wearable computing. The main concept is based on implicit human computer interaction. Implicit interaction is described as actions which are not primarily intended to be used as computer input but can still be used as such in some useful way. This is very relevant in this proposed project and similar to weiser's concepts [11], where computer inputs are used to create a useful application. Their implementation consists of a glove with an integrated RFID reader. The reader is connected through a serial connection to a wearable computer. RFID tag IDs are mapped to a specific URL which increases a counter. Each time an object is identified its corresponding counter is increased. Their test system did not have a specific task it was simply used to explore the use of RFID in wearable computing and if it has potential future applications.

They conclude that such an implementation effectively overcomes the traditional problems associated with user input in wearable computing, and propose that such a system would form a sound base for implementing practical applications of the technology [10]. Their work indicates how RFID can overcome high cognitive loads which are typical of wearable technology, where the technology does not require a user's attention or interaction in order to gather useful computer input and data.

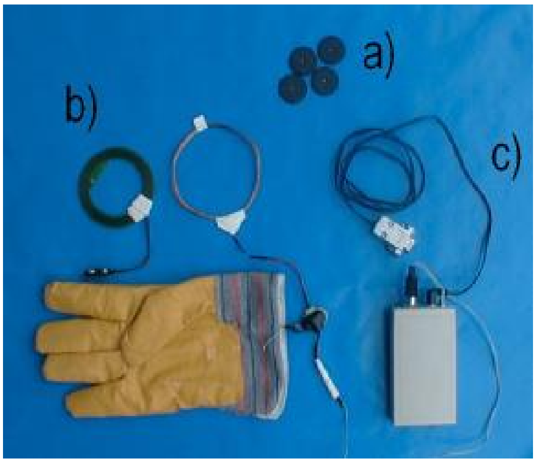

Figure 2.3: [10] RFID glove components: a) RFID Tags, b) Reader Coils, c) Wearable Tag Reader

2.7 Intel's iGlove

In building useful applications with RFID technology a technique is required in order to allow the computer to correctly interpret its inputs. Intel Seattle's iGlove research project explored the concept of recognising and interpreting an individuals activities from large sets of possibly related RFID readings [2]. Like Schmidt and Gellersen, their system prototype was an RFID enabled glove with the antenna located in the palm. This is connected to a reader with radio capabilities for communicating with a computer. The glove components are all housed in a plastic box on the outer side of the glove, which overall makes the system compact and unobtrusive, which can be seen in figure 2.4.

One difficulty their system faced was interpreting ‘variety’, for example the same task could be completed in different ways or in a different order of steps. This would give various combinations of data inputs leading to the difficulty of interpreting them correctly. The proposed solution was to represent tasks in a sequence, or probable sequence, of the objects used, which resulted in a high level of system accuracy and performance. This is shown by their systems ability to correctly identify various tasks being undertaken by the user [2]. This project’s proposed system also gathers large amounts of data which and similarly to this project may present inherant difficulties in interpreting it correctly, which will need consideration in the systems data processing techniques.

Figure 2.4: /citeintel Intel’s ‘iGlove‘

2.8 Lustig’s RFID glove

Lustig and Coyle developed a similar RFID glove system following Intel’s work on the iGlove [2], designed to identify specific tasks carried out by a user [8, 9]. A glove design was implemented with an RFID reader built into the palm, as shown in figure 2.5. This was connected to a micro-computer with wireless capabilities. The micro-computer can connect wirelessly to a server which in turn can update a database of tag reads and pass this information to a web page. The system is designed to recognise individual tasks by associating each one with a number of relevant tags. This work extends this research building upon the work already achieved while focusing on a related but different goal. Although this project utilised some similar technologies, such as an RFID reader and micro-computer, the ReFInDer is a very different implementation and different application, specifically a lost and found application. It also explored a technique of gathering more data inputs via Bluetooth technology, and more advanced user interaction, achieved through an LCD display. Having said this it has proven useful to take into account the results and findings of their work. It was found that a glove implementation was considerably restrictive to the user, which does not conform to the principles of ubiquitous and wearable computing, which are some of the main goals of this project. This was considered a strong motivation for a new proposed form factor.

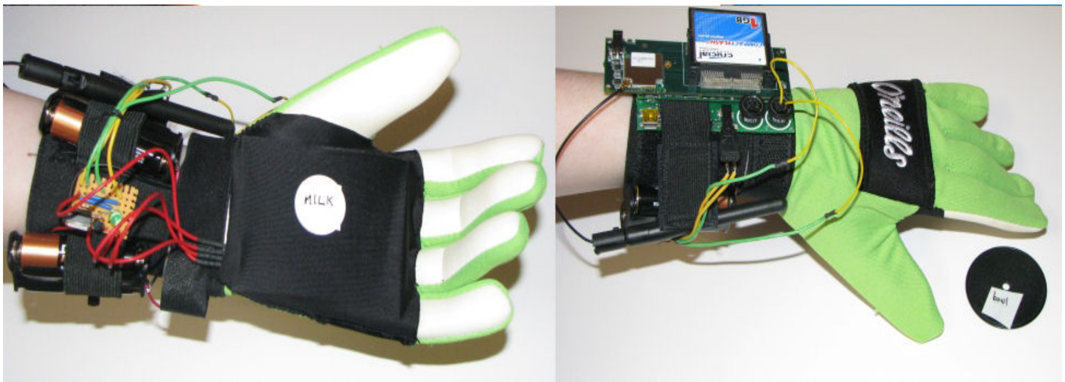

Figure 2.5: [8] Lustig and Coyle's RFID glove

2.9 Activity Recognition

Logan et al. explored the abilities of different sensing equipment [12]. This research involved the use of intel's previous research on the iGlove and their later work on the iBracelet [2, 3]. The test system was based on a house equipped with over 900 sensor inputs, such as RFID tags, current and water flow sensors, and infrared motion detectors. The concept is also similar Lustig and Coyle's RFID glove, in that it uses sensor input to recognise human interactions and activities in a home environment [8]. In this evaluation the effectiveness of the sensor types is discussed. In the case of RFID, the user was equipped with an RFID bracelet for reading tags in the environment, sending tag reads wirelessly to a database. The results of the experiment showed that RFID performed quite poorly. It was found that this was due to the reader detecting very few of the objects being touched. There were various reasons for this, such as opposite hands being used to interact with objects, and temporary removal of the bracelet for hygiene reasons. This raises a conflicting point to the other implementations, that RFID may not necessarily be useful in some instances. For example if a person is washing dishes they cannot have electronic equipment attached to their hands [12].

2.10 Recognising Assembly Tasks

Ward et al. explored the concept of activity recognition and ubiquitous computing [13]. Mobile workers, such as maintenance personnel, often face difficulties in accessing useful information relevant to their task. For example a person may need to access a PDA to bring up schematics which requires complete physical and mental attention. The proposed concept involves identifying users' activities and automatically displaying task relevant data through a head mounted display. This involves both sound and accelerometer sensors, for gesture identification, to gather data and use different algorithmic methods to identify individual tasks. The arm mounted sensors are shown in figure 2.6. One problem with this, similar to that of Logan et al., involves non relevant activities [12]. For example, while a user undertakes a task they may momentarily break from this, perhaps to take something from their pocket. Their system was tested on a 'mock' scenario where a user constructs a simple item from wood. Although their results were promising they conclude that their approach would be more applicable in a home environment, especially with regards to sound identification. They propose to explore other sensor and algorithmic methods, one of which being RFID, to improve the performance of the system [13].

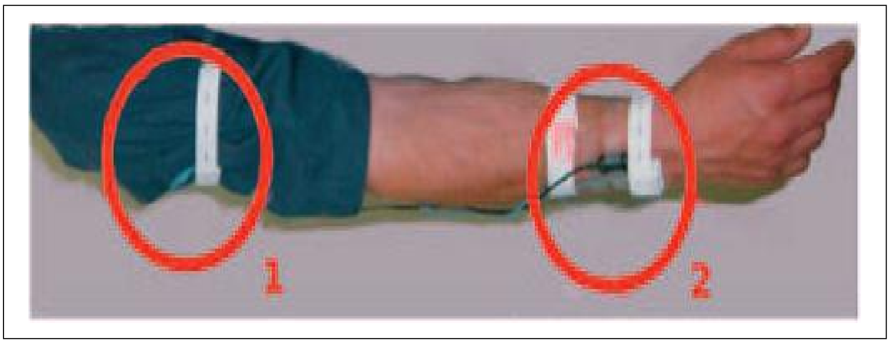

Figure 2.6: [13] Arm mounted microphones and accelerometers

2.11 Conclusions

Much of this previous work in RFID applications offers some important guidance and insight for this project. One important point raised by many of the discussed research papers is that such systems need to be unobtrusive, feel natural to a user, and blend naturally into our environment. Ubiquitous Memories and Chatchayanuson et al.'s kitchen tracker are good examples of this, as well as the important concept of ubiquitous computing [5, 6]. Weiser raises another important point which is relevant to this project's system. From simply knowing some basic information, such as where you where at certain time, a more complicated and useful application can be derived, in this case a memory aid [11].

There are often many problems facing the concept of wearable computing systems, as discussed by Schmidt and Gellerson, such as problems with performance. While this is true, it is suggested RFID offers a sound base for implementing practical applications of these technologies and overcoming such associated problems [10]. In conflict to this, Logan et al. suggested that RFID may not be useful in some instances, however their evaluation involved recognition of many, very complex user activities, over a long period of time [12]. In the instances of low performance involving RFID it seems, in this author's opinion, that the reasons for this could have been taken into account or avoided through revising and augmenting activity recognition and sensor techniques of the system. The application in this case is also quite different to that of this proposed project. Identifying a large number of complex tasks as a user undertakes their everyday home activities involves a high number of random factors, such as spontaneously switching between tasks. In the proposed system items are static in a certain sense, where an item is placed in a pocket within very close proximity to the reader. The possibility of not reading an item in this form factor is low in most cases, as discussed in section 4.3. It can be concluded that with this systems form factor and design, RFID technology proves very effective.

Lustig and Coyle found their RFID system to be very restrictive [8]. This project will explore an alternative form factor in order to overcome these disadvantages. This project will use some of the proven hardware and technologies as Lustig and Coyle's earlier work, such as the micro-computer and RFID reader, but with a different implementation and application. Their system followed the work of Intel in using RFID to identify user's activities, whereas this project proposes to gather data on a user's interactions with objects. It also takes into account more useful information, such as location and interactions with other people. Interaction between user's and the system is augmented using a built in LCD screen to display relevant information.

Chapter 3: **System Implementation**

3.1 Introduction

Chapter2 gave an overview of the applicability and suitability of RFID technology to the areas of wearable and ubiquitous computing. It also highlighted its ability to overcome the shortcomings inherent to these fields, leading to the conclusion that RFID is a suitable technology for building the ReFInDer system. This chapter describes how RFID technology is used and presents a detailed overview of the ReFInDer system's design. This includes the systems form factor and the types of hardware used. The system's data processing techniques are discussed with descriptions of how data is gathered, stored, and used in the application.

3.2 Problem Analysis

There are two main components required in the ReFInDer system. A mobile component which is carried by the user and a web based lost and found application. The mobile component is necessary to gather information about a user's interactions with items. It requires the ability to process and wirelessly transmit this recorded data. The form factor of this component must be one which is portable and capable of performing its task with minimum user interaction. The web based component requires a means of receiving and storing recorded data. An application is needed to retrieve this information and make it accessable to the user. This application takes the form of the lost and found website and provides a user interface to the system.

3.3 System Form Factor

The initial concept and form factor of the mobile component was an RFID enabled glove, inspired by the work of Lustig and Coyle [8]. The major downfall of their system was the inherent restrictiveness of the glove's design 2.8. Also their system was based upon a very different application, recognising user activities where a glove design is more suitable for this task. It is also the opinion of this author that an RFID enabled glove design is very obtrusive to a user's everyday activities, and is not consistent with the ideals of technology blending naturally into our environment. Another consideration in the design of the systems form factor arised from the initial protoype evaluation. The form factor was influenced by the inherent limitations of the RFID readers range. This is discussed further in section 4.2. For these reasons a different system form factor was developed for ReFInDer. A box was designed using a 3D printer to house the mini computer. This box along with the RFID reader are held within a small pouch. This pouch is carried easily within a pocket or a bag. Due to the limited capacity of pockets and bags the reader will be constantly in close proximity to tagged items. This goal of this is to overcome the issue of the readers range. This is discussed further in section 4.3

Figure 3.1: System Form Factor

3.4 Hardware Design

There are a number of key hardware components required for the ReFInDer system. The mobile component of ReFInDer consists of an RFID reader connected to a Gumstix computer. The Gumstix is a mini computer running a Linux operating system [1]. The Gumstix is expanded with wireless capabilities, two serial connections, and has an integrated Bluetooth module. The Gumstix facilitates the necessary data processing and wireless transmition of recorded data required by the mobile component. To connect the reader to the Gumstix a small circuit is constructed which regulates a 5v power supply for the reader and relays tag reads to the Gumstix through its second serial port. Figure **??** shows the schematic for this circuit. Figure 3.3 shows the circuit and the RFID reader connected to the Gumstix.

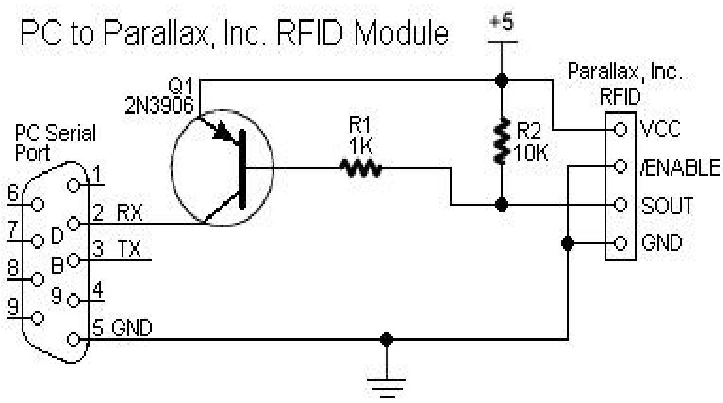

Figure 3.2: Serial to RFID reader circuit schematic [a]

[a]More information on schematics can be found here: http://forums.parallax.com/forums/default.aspx?f=21&m=180521

Once a tag ID has been read and received by the Gumstix it is transmitted wirelessly to a server and stored in a database. The function of the server is to process tag read data and

[1]Gumstix information can be found here: www.gumstix.com

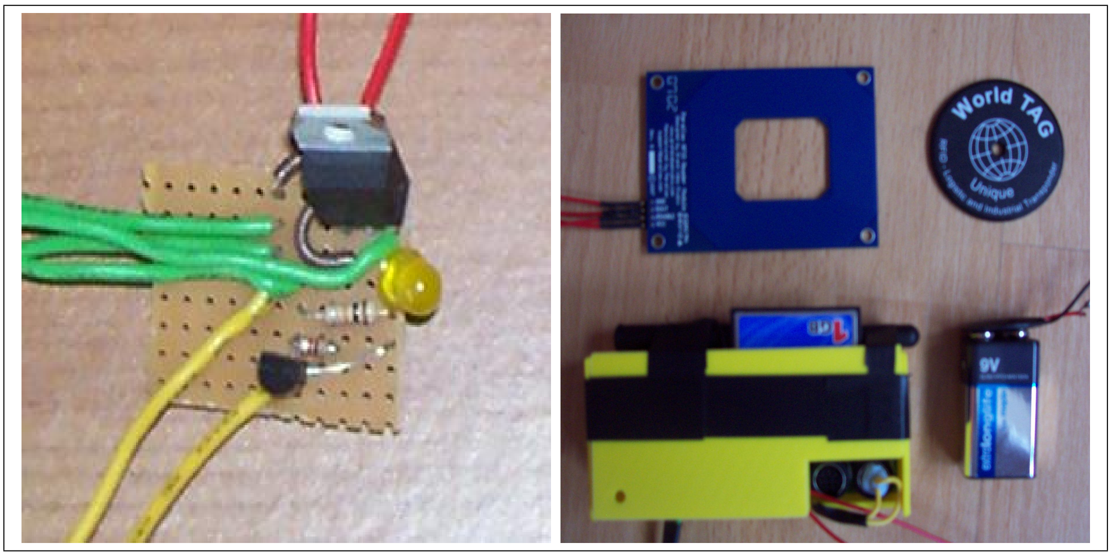

Figure 3.3: RFID reader connected to Gumstix

present it in an online lost and found system. The server runs on a laptop connected to a router which has been configured to allow port forwarding to the static IP address of the laptop. This means the Gumstix can be configured to connect to the router and use it to transmit data to the server.

An alternate method of gathering information about a users activities was explored using Bluetooth, which could potentially be used to augment the systems current functionality. However the technology proved inefective. See appendix B for a discussion of this.

Connected to the Gumstix is a 32 character LCD screen. The purpose of this is to enhance the user to system interaction. The LCD connects to the Gumstix's first serial port which transmits data to the screen through a second circuit. This second circuit also regulates a 5v power supply. Figure **??** shows the schematic for this circuit. Based on objects that have been identified by the RFID reader, the LCD continues to display the last time the user had certain items. Although this information is not as detailed as that presented through the lost and found website, it offers the user assistance in situations where a computer is unavailable. Figure 3.4 shows the system architecture.

3.5 Data Processing

The server setup used in this project is known as Linux Apache MySQL PHP (LAMP). The LAMP server system consists of a number of open source software technologies which are commonly used together in server applications. It consists of an Apache server [2], MySQL [3] for managing databases, and PHP [4] scripting language used for server side data processing in dynamic web pages. These technologies are running on a Linux operating system. The LAMP system was chosen as it encapsulates the required software technologies for the lost and found application. MySQL facilitates the storage and retrieval of data recorded by the mobile component. The Apache server hosts the webpages which are written using PHP. PHP allows interaction with the MySQL database, such as storing and retrieving data, and

[2]Apache website: http://www.apache.org/
[3]MySQL website: www.mysql.com
[4]PHP website: http://www.php.net/

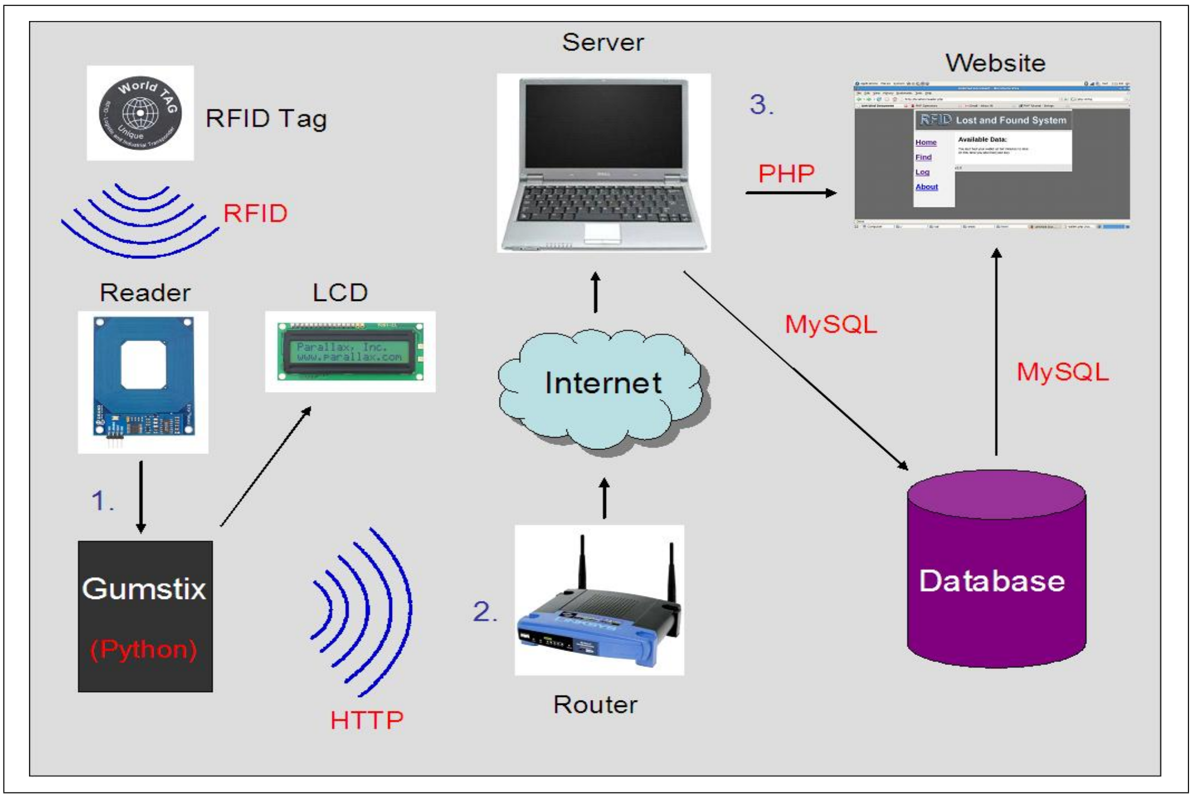

Figure 3.4: System Architecture: 1) Gumstix connected to RFID reader and LCD, 2) Router wirelessly receives data from Gumstix, 3) Laptop server hosting database and Lost and Found website

processes this information displaying it to the user through the website. See figure 3.6 for a data flow diagram.

When the Gumstix is powered and boots up, it runs a Python script and C program. The C program connects to the serial port and reads in data from the RFID reader. The Python script is responsible for transmitting tag IDs to the server and displaying information on the LCD screen. When a tagged object is read by the RFID reader, its ID is passed through the serial port and passed to the Python script which interacts with a PHP page running on the server. When a tag is read, its ID is transmitted wirelessly via the router to the PHP page takes in the tag ID as a GET variable. This ID is stored in a database using MySQL queries embedded within the PHP page. Each ID is given a time stamp when it is stored, consisting of the current time and date, and is checked against a second database. The second database stores all tag ID's recognised by the system and what item the ID corresponds to. When a tag ID is stored this information is used to determine which item the ID corresponds to.

Each time a tag ID is read, the Python program stores the last occurance of the item. Each time an object is identified its time stamp is updated, so that the system records when you last had that object. Using this information, the Python script sends this data to the LCD screen and displays it in the form of simple cue's.

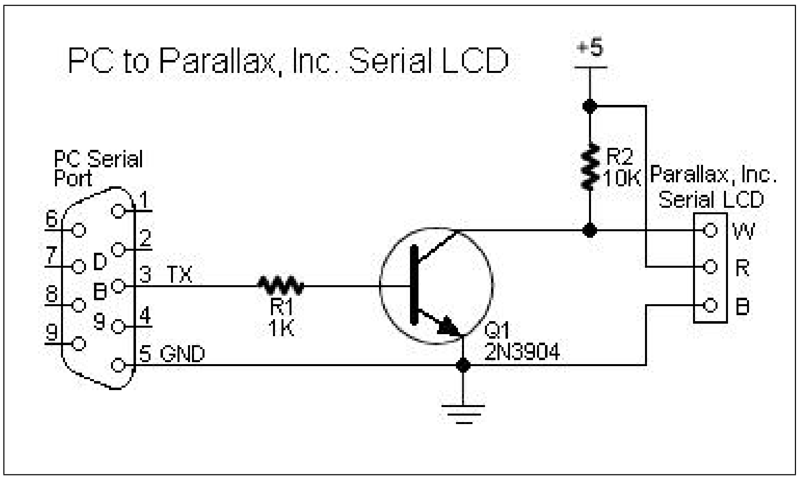

Figure 3.5: Serial to LCD circuit schematic [a]

[a]More information on schematics can be found here: http://forums.parallax.com/forums/default.aspx?f=21&m=180521

3.6 User Interfaces

With RFID data stored, a PHP website can incorporate this as part of the lost and found application. When a user loses an item they simply logon to this website and select the item they are looking for. Using PHP with MySQL the website can retrieve relevant information from the database. This data is presented to the user aiding them in remembering when and where they last had the item. One of the goals for this system is to return this information in the form of human readable cues, or in such a way that is as close as possible to human readable language. For example, You last had your wallet at two o clock.' At this time you were also interacting with your keys. This is achieved within the PHP pages, formatting and filtering data, and displaying relevant information in the form of the human readable cues. The aim of using human readable cues is to create an application which people can easily relate to. It is the opinion of this author that a person can better relate to natural human language rather than lists of data consisting of dates, times and IDs. This however may not always be true. The effectiveness of each technique is discussed in chapter 4. Based on the information obtained from these evaluations the lost and found application presents data in both forms. Figure 3.7 shows a screen shot from the web site.

The second means of presenting useful information to the user is through the LCD screen built into the mobile component. The LCD continues to display the last time you had certain items. Due to the LCD's limited screen space, consisting of 32 characters, the cues are simpler than those found on the lost and found website, for example, 'Last had phone @ 17:38, 17/04/2008'. However the presented information still facilitates user assistance in the situation where a computer is unavailable.

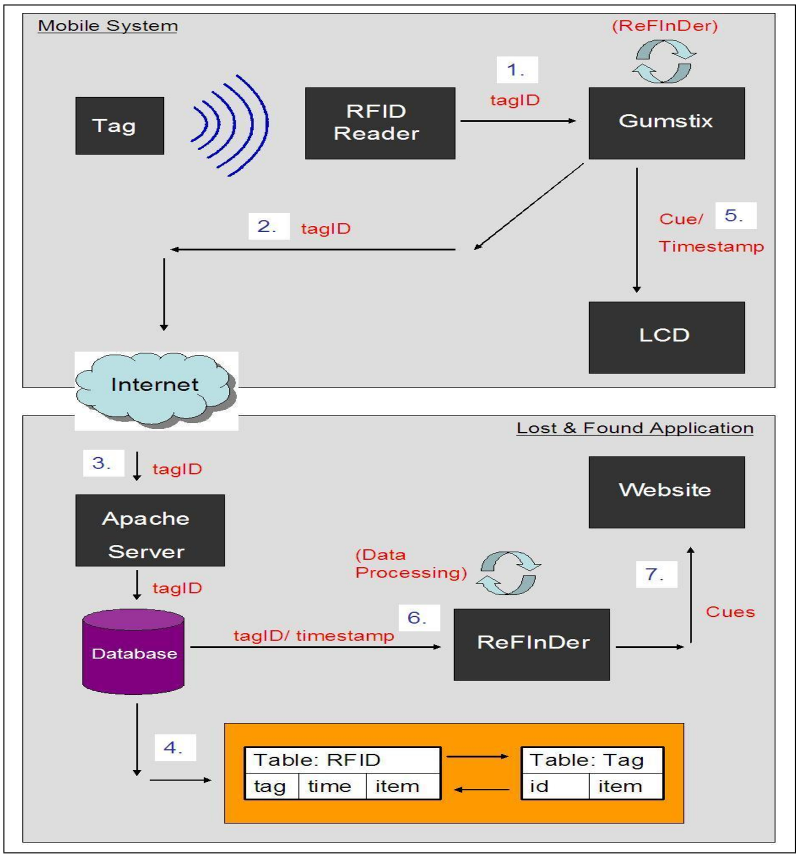

Figure 3.6: Data Flow Diagram

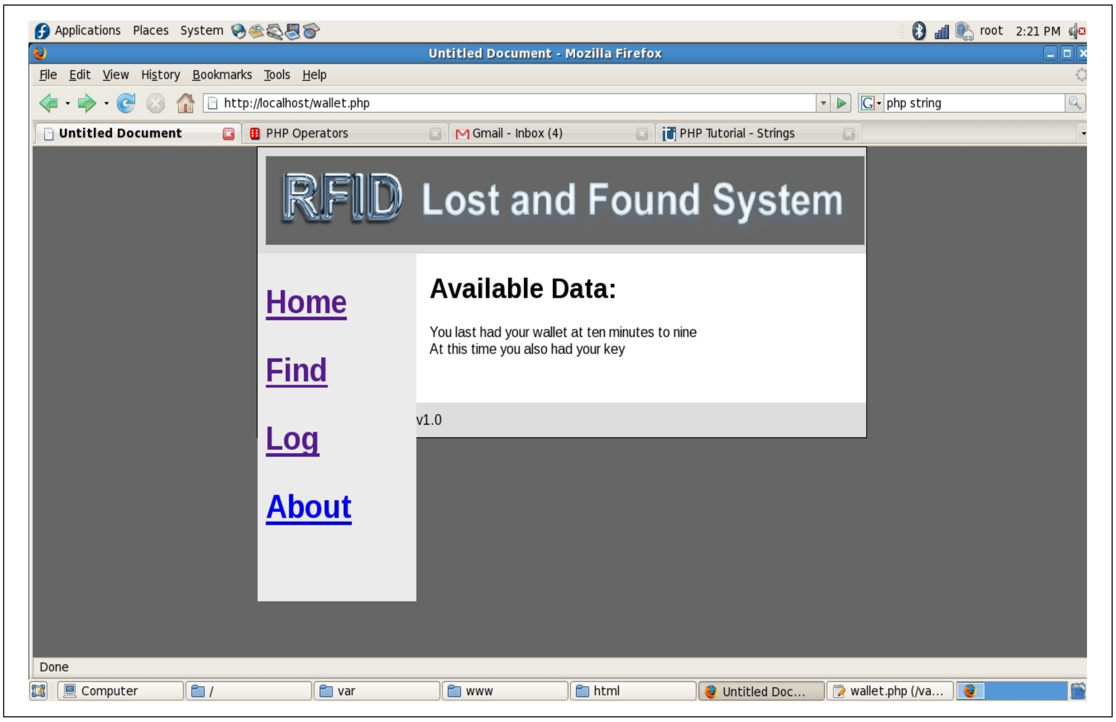

Figure 3.7: Lost and Found website [Note: will be updated]

Chapter 4: **System Testing and Evaluation**

4.1 Introduction

The ideal evaluation for the ReFInDer system would be a longitudinal study. This would involve a user trial in which a person uses the system for a long period of time and the system's performance is evaluated over this period. Due to the fact that ReFInDer is currently a proof of concept prototype, which can only be self powered for short periods of time from 9v batteries. For any effective long term evaluation the system must be kept plugged into the mains, which is completely impractical for a full user trial. Also due to the fact that there is currently only one prototype and a lack of resources to effectively carry out such a trial, the next best and logical evaluation process has been taken. Individual testing has been undertaken in each of the ReFInDer system's key components.

4.2 RFID Prototype

Early system testing began with a working prototype implementing the RFID component. This consisted of the RFID reader connected to the Gumstix, setup of the LAMP server, and implementation of a simple lost and found website. This prototype was designed to evaluate a number of key components of the system. The circuit built for relaying tag IDs to the Gumstix serial port included an LED, which was used to indicate when tags were being read successfully. To ensure tag read data was being transferred successfully to the server a simple test page was setup, which retrieved the contents of the database and displayed it on screen. The evaluation consisted of placing a single tag near the RFID reader and moving it slowly closer along a ruler. This was tested using the front, back, and four sides of the reader. The goal of this was to determine if items could be identified with their ID successfully transmitted to the database. The ruler was used to evaluate the range limitations of the reader, indicating at what distances tags could be accuratly read. Figure 4.1 shows a photo of the evaluation and the php test page.

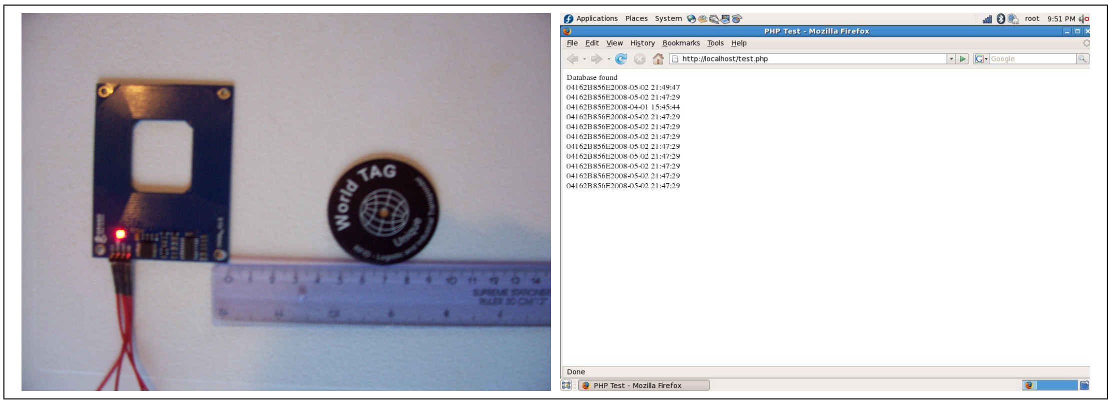

Figure 4.1: RFID Prototype Evaluation

4.2.1 Results

From this evaluation it was found that the RFID reader had a range of only 4 mm from any of the four sides. From the front and back of the reader results were the same with an average range of 2.6cm based on 20 measurements for each side. This indicates that the reader has a very limited range. However it was found that once a tag is within this range it is accurately identified. Viewing the test page, which displayed the contents of the database, indicated that once an ID is read, it is always transmitted and stored correctly in the database. This indicates that the hardware setup and data processing techniques are sound, however the readers range needed to be considered.

4.3 System Form Factor

The goal of the systems form factor is to create a system which is small, compact and easily carried by the user. The second factor in its design was the address the issue of the readers range. A small pouch design can be placed within a pocket or bag along with other items. Due to the relatively small space of pockets and bags, items are in close proximity to each other at all times. The aim of this test was to determine if this can overcome the readers limitations.

Although the system is very compact and portable it is necessary to highlight that it is a *proof of concept*. If such a system was designed and built commercially it would be considerably smaller and lighter. For example the Gumstix computer is much more powerful than is necessary for the data processing involved in the system. The circuits involved for connecting components could be constructed using printed circuit boards which would also be considerably smaller in size. The weight of the form factor is mainly due to the two 9v batteries it contains. Again a commercially built system could feature a smaller and lower weight battery.

This evaluation involved placing the pouch inside the pocket of a bag and a jacket. Tagged objects were placed in the pocket with the pouch in different combinations and positions in order to determine if they could be identified successfully. The RFID reader is positioned at the back of the pouch, as seen in figure 3.1. For this reason it was necessary to evaluate its effectiveness at reading tags from both the front and back of the pouch. In the evaluation the pouch was tested 20 times for each side.

4.3.1 Results

The results of the form factor evaluation were promising but also highlighted a potential weakness in its design. When placed in a pocket, ReFInDer successfully identified tagged items 18 out of 20 tests as long as the reader was facing towards them. If the pouch was positioned the wrong way around it was found that the system could almost never successfully identify tagged items, with only 1 of 20 tests identifying a tagged item. These results indicate that the form factor is effective when used in a specific way, however if the pouch was placed in a pocket incorrectly it is very inaccurate.

To evaluate the form factor it was placed in both a bag and a jacket pocket. The bag provided ample space to fit the ReFInDer system along with a number of items however when placed in a jacket pocket the extra space was limited. It was not possible to comfortably fit more than one or two small tagged item in the pocket with the pocuh.

4.4 Human Readable Cues

To evaluate the human readable cues a survey was created to gather feedback on which technique people consider more effective, the human readable cues or raw data consisting of date and time stamps. This was issued to 13 third year computer science students who had no direct association with the project. See appendix A for the survey.

4.4.1 Results

The results from the survey showed much similarity in peoples' opinions of each data representation. Strong conclusions could therefore be drawn from the results and were used to influence how data is presented on the lost and found website. In the survey basic cues consisted of lists of time stamps and the corresponding item that you had at this time, e.g., '2008-04-01 16:51:31: key'. The survey indicated a number of advantages and disadvantages with this data representation. 12 out of 13 participants considered there to be disadvantages with this representation. Responses included: *'This could be seen as too much effort to decipher', 'It's not very easy to understand', 'Slightly difficult to read since it's just a list of numbers', 'Could take a while to interpret and draw conclusions', 'It's a lot of data. Some users might feel this is overwhelming', 'Hard to read for someone not used to it', 'From a user point of view, I would rather see a simple line of text than read lines of date/time/item', 'It's long and not very personal'.* Of the 12 participants who considered there to be disadvantages of this format, 10 out of 12 considered this format difficult to read or time consuming to interpret the results. Advantages were offered in 12 out of 13 participants. Responses included, *'The sequence of events is easy to see', 'Could be used to map patterns to the usual places where you keep something', 'Gives all the information', 'Precise', 'It shows multiple interactions with one item', 'You can see more information'.* Of these 12 participants 6 considered this representation more precise or informative, 5 of the 12 participants felt more detailed information about a user's activities could be derived.

With regards to the more human readable cues, participants were again asked the advantages and disadvantages of this format. An example of this format is, 'You last had your wallet at ten minutes to four. At this time you also had your keys and phone'. Of the 13 participants 11 considered there to be disadvantages, this included, *'Not as precise', 'Doesn't show surrounding events', 'Not very precise, can seem vague', 'Not as much times shown', 'Lacks the amount of information provided in A'.* The advantages of this format were found to be very similar. Responses included, *'Much more straightforward, easier to obtain required info', 'Much easier to read than A', 'B has a personal touch, it would be a lot easier to read', 'Very basic, straightforward, easy to understand'.* 12 out of 13 participants felt there was advantages of this format.

Participants were also asked to compare each format to the other, and if they considered one more advantageous to the other. In 7 out of 13 cases participants considered there to be advantages to both formats, with no strong advantage of one format over the other. Out of 13 responses, 3 people considered basic cues more advantageous and 3 preferred the human readable cues. Some insightful responses included, 'Overall, I think B is more advantageous to a random person, also it is not as overwhelming', *'B would be better to introduce to individuals who are not technofiles and are wary of using new technology', 'B would be easier* *to understand until you're used to the layout of A', 'Presenting both representations would be helpful. If B is not enough information, A could be looked at'.*

Overall participants considered the basic cues to be more difficult to read and time consuming to interpret. They are however more precise and offer more detailed information. The more human readable cues were considered easy to read but not as precise and detailed. Initially this author considered the more human readable cues to be more suitable and effective in this type of system. The results, however indicate that there are no strong advantages of this. Each representation of the data offered conflicting advantages and disadvantages over the other. For example basic cues are more precise and the human readable cues are less precise. Some interesting comments suggested that the human readable cues would also be more suitable to people who are not used to technology. The results also suggested that if a person was comfortable with interpreting the detailed information in the basic cues, they could derive more information, such as more effectively tracking their movements. With each format offering its own advantages it was chosen to incorporate both into the lost and found website. As there can be different types of people, those comfortable with using technology and those who are not, the application can offer benefits to a wider audience of users.

The last survey question was intended to gather any comments or suggestions participants may have. Six participants offered suggestions. One participant suggested, 'Colour code each item to make A easier to read at a glance'. This is a potential solution to make the detailed basic cues easier to read and interpret. From an implementation point of view this is a simple task and has been included as part of the final website design and how it displays data. Other responses from this question offered some valid and useful ways that could potentially augment the ReFInDer systems functionality. These are discussed further in section 5.2.

Chapter 5: **Conclusions and Future Work**

5.1 Conclusions

The primary goal of this project was to design a memory aid system using RFID technology and to determine its effectiveness in this task. An important component of the system was the ability to identify objects. The initial system prototype was a basic version of the system which was designed to test the effectiveness of RFID technology for identifying items. The RFID reader was found to be accurate at identifying tagged objects which suggests that it is a useful and effective technology for implementing such a system. While the effectiveness of reading tags was found to be very accurate the reader did have a limited range. This influenced the systems form factor and how the system was used.

The evaluation of the systems form factor indicated that it was effective when used in a specific way. If the front side of the pouch is facing towards tagged items, however, the system becomes very inacurrate. This suggests that the approach taken in designing the form factor is sound however modifications are required to overcome potential shortcomings, and improve overall system accurracy. This evaluation also found that the form factor was not practical to use in a jacket packet. This would indicate that the form factor is too large to be used in this way. While it is important for such a system to be compact the tested implementation is a *proof of concept* and is considerably larger and heavier than would be required in a commercially designed version. For this reason the form factors size is not considered as a strong influencing factor in the evaluation of the system.

The results of the cue evaluation survey highlighted some important issues with the human readable cues. It was found that the human readable cues were easy to read and the user can get useful information very quickly. However it was also found that they lacked a certain level of detail. The basic cues consisting of time stamps and corresponding items presented in a list. Survey participants considered this format harder to read, however it is much more precise and could be used to derive more information about their activities. Based upon the findings that there are benefits of representing information in different ways it is concluded that the lost and found application should present information in both formats. This offers benefits for different types of users. The findings of the survey suggest that the human readable cues are more suited to people who may not be comfortable with using technology.

- Im finding this section hard, i think it will come to me closer to completion ;-)

5.2 Future Work

The built in LCD screen of the ReFInDer's mobile component is a means of improving user and system interaction, offering an alternate means of giving information to the user. The information displayed by the screen is simple due to the screens limited space. Future improvements to this includes more detailed information being displayed to the user. This could perhaps be achieved using a larger screen or by a means of scrolling text across the current screen. Currently users do not have any control over what information is displayed to them through the built in display. Future enhancments to the ReFInDer system could include incorporating control buttons into the mobile component.

This work explored an alternative means of gathering information about a user's activities using Bluetooth. By representing people based upon their mobile phone Bluetooth ID the system could keep track of people the user came into contact with. The motivation for this was to increase the amount of information recorded by the system thus increasing the amount of useful information given to the user. By giving a user more information about their activities, the system could potentially be more effective at aiding a person's memory. Although difficulties arose in its implementation, this author considers this a viable solution for future improvements to the ReFInDer system. It could be successfully implemented using a stable Gumstix software revision with correctly functioning wireless and Bluetooth capabilities. This revision would also need to satisfy the Gumstix's limited memory constraints.

A longitudinal study would be the ideal method of evaluating ReFInDer. This would involve a full user trial of the system. Due to a lack of available resources and other factors, undertaking such an evaluation was not possible. Future evaluations would need to include such a user trial to properly determine ReFInDers applicability and performance in everyday situations.

Evaluations indicated that the form factor is effective but modifications are necessary to overcome a potential shortcoming. Item identification is very effective from the back side of the pouch where the RFID reader is located, but is very limited from the front side of the pouch. A possible solution to this would involve incorporating a second RFID reader positioned at the front of the pouch. This would overcome the necessity to have the pouch positioned or used in a specific way.

In the cue evaluations survey, participants were asked if they had any further comments and suggestions. There are some notable results from this question offering some valid potential improvements for ReFInDer. *'A could be used to map patterns to the usual places where you keep something'.* In this comment A refers to the basic cues which are made up of lists of time stamps and their corresponding item, e.g., '2008-04-11 04:50:03: phone'. This comment suggests using the recorded times and comparing them to where you would normally keep an item at that time. This idea has merit and would perhaps be useful for items such as keys that are kept in a specific location when you are at home, for example. However it is this authors opinion that people do not often keep items in specific locations, especially when not at home. An alternate solution would be to compare the recorded time stamps with where you are at certain times. For example, if you work between 09:00 and 17:00 during the day and the system records that you last had your wallet at 15:43, the system could suggest that you may have left your wallet in work.

Another reply to this question was, *'A voice interaction with B would be cool, especially to, perhaps, older people'.* In this case B refers to the more human readable form of the cues, such as 'You last had your wallet at ten minutes to four. At this time you also had your keys and phone'. This suggestion could be a potentially useful way of improving the system's user interface. Older people may be somewhat uncomfortable with using technology however the Lost and Found application is currently very simple to use, with easy website navigation where users simply click on what item they are looking for. For this reason voice recognition could be considered unnecessary functionality. Perhaps a future survey evaluation would provide more insight into this.

Appendix A: **Cue Evaluation Survey**

A.1 Introduction

The purpose of this survey was to evaluate the the human readable cue's. The survey presents two formats for representing the information gathered by ReFInDer. The survey was designed to determine the advantages and disadvantages of each data representation, if people preferred one format to the other, and for what reasons.

A.1.1 Survey

"Using RFID to remember": Human readable cues evaluation

The purpose of this project is to create a memory aid, which helps people find lost items. It does this by gathering information about a person's interactions with items. It records when people were interacting with such items and stores this information. This information is used by a website. When a user loses something they log into this website where they are presented with this information. This information is displayed in the form of readable cues. An example of a readable cue would be: "You last had your watch at 16:45".

Below are two ways of representing the cues, A and B.

A: Basic cues

2008-04-01 15:45:43: phone	2008-04-01 16:51:31: key
2008-04-01 15:45:44: phone	2008-04-01 16:51:32: key
2008-04-01 15:45:48: phone	2008-04-01 16:51:33: key
2008-04-01 16:06:37: phone	2008-04-01 16:55:27: phone
2008-04-01 16:06:38: phone	2008-04-01 16:55:31: phone
2008-04-01 16:18:15: key	2008-04-01 16:55:32: phone
2008-04-01 16:18:16: key	2008-04-01 16:55:32: phone
2008-04-01 16:18:16: key	2008-04-02 12:34:14: key
2008-04-01 16:18:17: key	2008-04-03 10:10:31: key
2008-04-01 16:18:19: key	2008-04-03 10:10:32: key
2008-04-01 16:18:20: key	2008-04-03 10:10:32: key
2008-04-01 16:18:20: key	2008-04-03 10:10:37: phone
2008-04-01 16:34:24: wallet	2008-04-03 10:10:37: phone
2008-04-01 16:34:25: wallet	2008-04-03 10:10:38: phone
2008-04-01 16:34:25: wallet	2008-04-03 10:10:39: phone
2008-04-01 16:34:26: wallet	2008-04-10 20:57:50: key
2008-04-01 16:34:27: wallet	2008-04-10 21:11:20: phone
2008-04-01 16:34:28: wallet	2008-04-10 21:11:56: wallet
2008-04-01 16:34:29: wallet	2008-04-12 03:50:12: wallet

B: Human readable cues

1: You last had your wallet at ten minutes to four. At this time you also had your keys and phone.

2: You last had your keys just after seven on May 3rd.

3: You last had your keys at quarter to five last Tuesday.

Q1: What would you consider are the advantages and disadvantages of the way data is represented in A?

Q2: What would you consider are the advantages and disadvantages of the way data is represented in B?

Q3: From the two data representations what would you consider the relative benefits of A vs. B? For example are there advantages of using one method over the other?

Q4: Do you have any further comments or suggestions?

Appendix B: **Bluetooth**

After the main components of ReFInDer had been implemented the Gumstix was looked at in more detail. It contains an integrated Bluetooth module which could be used to explore an alternative means of gathering information about a users activities. It was poropoosed that this could potentially be used to identify people the user has come into contact with based upon their Bluetooth phone ID. From an implementation point of view this would involve modifying the Python script responsible for transmitting RFID tag IDs to also scan for Bluetooth devices and transmit their unique ID using the same technique. To achieve this Python requires a Bluetooth API which allow it to utilise the Gumstix's Bluetooth capabilities. The Gumstix does not include this functionality as default which meant it was necessary to add new software to the Gumstix.

To add new software to a Gumstix a special program is required called Buildroot [1]. Buildroot is not Gumstix specific software and is used to generate root filesystems for Linux systems. In the case of Gumstixs, Buildroot allows you to select packages or software that you want to run on the Gumstix, such as programming languages like Python. Once desired packages have been selected with Buildroot it compiles and creates a filesystem for the Gumstix which contains all the chosen software and functionality. This filesystem can then be flashed or copied to the Gumstix.

To facilitate the Bluetooth functionality a package named PyBluez was required [2]. The Buildroot process was very time consuming, taking approximately three hours to build a revision and flash it to the Gumstix over a serial cable. Difficulties arose once the filesystem had been flashed to the Gumstix. There are many revisions or versions of Buildroot, at the time of this writing there are currently 1602 revisions, most of which are not stable and contain bugs. This means certain functionality will not work in all revisions. For example one revision may have Bluetooth support but its wireless capabilities will not work correctly. It was essential for the ReFInDer system to have wireless capabilities for transmitting data. Experementing with different revisions of Buildroot failed to result in a stable version that offered both wireless and Bluetooth support. Due to the sheer number of revisions and lack of available information on stable versions, coupled with the lengthy build process for each tested Buildroot revision, experimenting with random selections was not a viable solution. Attempts were made to take a revision of Buildroot with wireless functionality and replace its Bluetooth packages with those from a revision that had working Bluetooth support, however this was unsuccessful. The issue of unstable Buildroot revisions is a well known issue, with much discussion in related forums and blogs, however there has currently not been any viable solution to the problem [3] [4] [5].

A second difficulty with Buildroot was the size of the generated filesystem and the Gumstix memory constraints. The Gumstix has two memory types, RAM and flash memory. The flash memory is 16mb, and stores the Linux filesystem. The filesystem generated by Buildroot must be less than this. Experimenting with newer versions of the Buildroot generated filesystems which were far too large to use. This appeared to be due to an increase in Buildroots core components.

[1] Buildroot information can be found here: http://buildroot.uclibc.org/

[2] PyBluez information can be found here: http://org.csail.mit.edu/pybluez/

[3] Gumstix Forum Discussions: http://www.nabble.com/forum/Search.jtp?forum=22543&local=y&query=stable+buildroot

[4] Gumstix Mailing List Archive: http://article.gmane.org/gmane.linux.distributions.gumstix.general/30503/match=stable+b

[5] UCD 3rd year blog: http://hindenstix.blogspot.com/2008/04/09-frustrated-flashing.html

Although augmenting the ReFInDer systems data gathering techniques and functionality using Bluetooth is a valid approach the technology proved somewhat ineffective in this case.

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