Using Colocation to Support Human Memory

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ABSTRACT
The progress of health care in the western world has been marked by an increase in life expectancy. Advances in life expectancy have meant that more people are living with acute health problems, many of which are related to impairment of memory. This paper describes a pair of scenarios that use RFID to assist people who may suffer from memory defects to extend their capability for independent living. We present our implementation of an RFID glove, describe its operation, and show how it enables the application scenarios.

1. INTRODUCTION
Increasing global life expectancies has opened up new issues for society. Many people, faced with the reality of living longer, wish to maintain their accustomed level of independence as they age. The problem is that the health care that allows them to live longer has not managed to conquer many age-related ailments. As a result, there is a need to balance the desire to live independently with the facts of deteriorating health. This paper describes an approach that have the potential to help achieve that balance.

The impetus behind this work are the demographic changes that are a result of the improved health care. On a local level, the 2002 Irish census showed 11.13% of the population are over 65; figures published by the Office for National Statistics in the UK indicate that the equivalent figure was 15.96% of the population in 2003. Many of these people live alone: 28.5% of the over-65s in the 2002 Irish figures. This aging is not an isolated phenomenon, and is reflected throughout the developed world [15].

From a technological point of view, the computing power present in the average home is staggering compared with 50 years ago. How to harness this technological power to assist independent living is a challenge which has been addressed via approaches ranging from the full instrumentation of smart homes [17], to the more individually targeted life-logging and review [8, 5].

Much research on *aides-mémoire* for sufferers of memory loss has been conducted. Oriani *et al.* demonstrate the advantages that electronic memory aids (EMAs) have, as well as the motivation for their use by Alzheimer's patients [13]. Hart *et al.* explore the use of EMAs for a different population, that of people recovering from traumatic head injuries [7]. These studies both comment on the need to reduce the barrier of use of electronic devices. If a prospective user needs to remember complicated procedures or receive specialised training to use the device, they are less likely to want one.

RFID is a commercially available technology, and has proven to be useful in real life applications. Our investigation into the application of RFID to this area indicates that it significantly reduces the complexity of operation exposed to the user since the system makes its observations based on normal every-day activities of the user. Additionally, the user retains ownership of the gathered information – there is no need for it to leave the home.

2. RFID AND COLOCATION
Radio Frequency Identification (RFID) technology has been around since 1948 and has become an integral part of many business processes [11]. On a personal scale, RFID badges are prevalent in many environments (for example, [6]). These types of badges lead to a common scenario, in which the RFID tag is mobile and uniquely identifies an individual, while the associated reader(s) are stationary (for example, [6, 1]). Our application proposes to reverse this structure, and use a mobile reader – which is associated with a unique user – with multiple tags which are relatively immobile.

Our environment is populated with RFID-tagged artifacts. These passive RFID tags uniquely identify each artifact; as the user comes into contact with them the system records the interaction. We have developed an *RFID glove* to gather this information and transmit it to a database. The glove is

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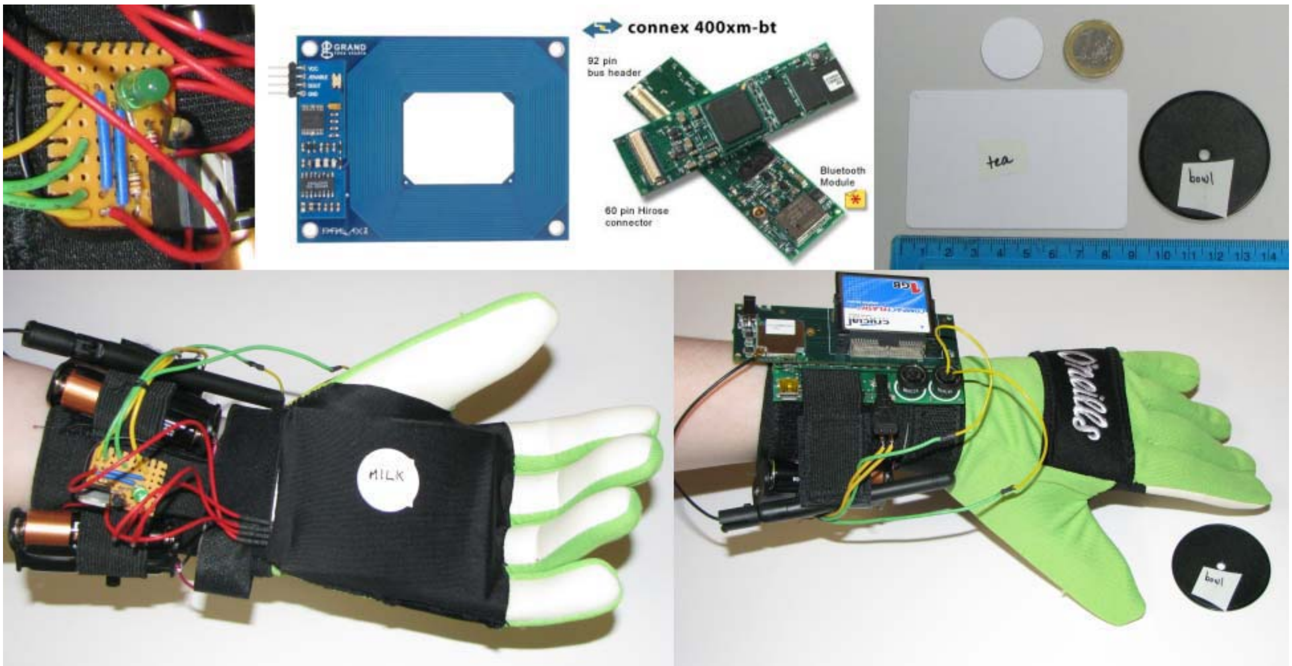

Figure 1: The RFID glove. Clockwise from top left: the circuitry connecting the RFID reader to the Gumstix; the portable RFID reader; the Gumstix motherboard; three types of RFID tags; the front view of the glove – the circuitry and batteries are visible and the RFID reader is in a pouch under the palm; the rear view of the glove – the Gumstix, serial connection, and WiFi antenna are visible.

made up of a portable RFID reader[1], a full function miniature computer system[2], power, and connecting circuitry.

The RFID glove was assembled as follows[3]: We used a sports glove as a scaffold; A pouch was added on the palm to house the RFID reader. A wrist-strap was made with pouches for the batteries that power the glove and a strap for the Gumstix. A circuit board was sewed into the wrist strap; this houses a Voltage regulator, an LED for diagnostics, and a simple circuit that converts the output of the RFID reader into a form that can be consumed by a serial interface. The total cost of components for the RFID glove is approximately \$350 and individual tags cost in the region of \$1 each. Figure 1 shows some images of the RFID glove in action and some of its constituent parts.

In our system, passive RFID tags that are placed on various artifacts transmit their tag IDs when activated by the RFID reader in the glove. The RFID reader activates the tags, which return their IDs to the reader. The tag IDs are then sent to the Gumstix computer via a serial connection. The tag IDs are processed and sent to a remote database across a WiFi connection. In the database, tag IDs are associated with descriptions of the objects to which they are attached.

[1]From Parallax — http://www.parallax.com/

[2]From Gumstix, our computer consists of a connex400 XMBT motherboard, console-st expansion, and wifistix CF (EU) expansion — http://www.gumstix.com

[3]More details on the glove assembly are available on the project's wiki — https://secure.ucd.ie/twiki/bin/view/GumstixRFID/WebHome

In order to ensure privacy, tag reads are only recorded if the tag ID is already in the database. The database provides the framework on which our scenario applications are developed.

RFID was an attractive technology to use in our system because of its low cost and small size. The small size is particularly important because it allows us to easily attach tags onto objects in our kitchen model in an unobtrusive manner. Our RFID reader has a range of about 3 cm and so the user must be picking up the tagged object or hovering their hand over it in order for the tag to be read. However, RFID comes with many problems: tags cannot be read through the human body since it is mostly composed of water. For this reason, we placed the reader onto the palm of the glove rather than the back, even though this made it more difficult to grasp onto objects. We are currently considering alternative mountings for the reader.

3. APPLICATION SCENARIOS

We chose to implement applications to target two scenarios to assist sufferers of short-term memory loss in the home. The first attempts to assist them to complete routine (but complex) at-home tasks, the second tries to ensure that instructions for taking prescription medication are followed. Both applications use RFID and colocation to attempt to solve the problems at hand.

3.1 Recognising Routine Tasks

Our work is based on earlier work done by Intel in the development of an RFID glove. Their glove could accurately recognise the activities that were being undertaken at any time by examining their interactions with the artifacts in their environment. Our first scenario is an extension of this work. Our application will monitor ongoing routines and alert the user if there is a delay in their completion. This is particularly useful for helping users with short-term memory problems, since they often find it difficult to perform routine tasks if they have too many steps or if they are distracted. This scenario calls for the the development of software for remembering the position or context of tagged artifacts, and the development of a simple task detector that will remind the user when an incomplete task has been abandoned. The initial range of tasks will be a small set of simple routine tasks from the kitchen domain, which was used by Patterson *et al.* to good effect [9].

3.2 Reminding Users to Take Medication

Our second scenario is in some respects the inverse of the first. Rather than be concerned about the completion of tasks undertaken, we aim to recognise situations where tasks are not performed when expected. An example of this would be in routine medication of the potential user. This is a situation where the absence of an activity may have significant impacts on the health of the user, and where a reminder would be useful.

To complete this scenario, we must first recognise the actions associated with taking medicine. To this end, our experiments will involve placing the RFID tags on both the bottle and lid of the container holding the medicine, so that we can automatically capture the individual's interaction with the container. Once we have captured the raw data in the form of time stamped RFID tag detection, we will associate them with events or activities. We must then recognise the absence of those events at significant times. Most medical regimens calls for the ingestion of medicine at fixed times – every 4 hours, or 3 times a day – or at times related to other activities – before eating, for example. Using an activity model generated from the data, we will be able to build up an activity model and infer from it if and when the medicine has been taken by the individual.

4. EVALUATION FRAMEWORK

Our evaluation will take two forms. We will perform evaluations of both scenarios using volunteers to complete two tasks. The first will consist of performing a number of repetitive kitchen tasks in the presence of distractions, the second will involve remembering to perform a simple task (to simulate taking medicine) several times a day over the course of a number of days.

Data will be gathered from users in a number of forms: All interactions between the user and the tagged artifacts will be recorded and time stamped in a database; users will be asked to keep diaries of their behaviour over the trial period; and users will be debriefed with a short interview at the end of the trial period to qualitatively evaluate the system and to perform some quality control over the collected data.

We will perform quantitative evaluations by looking at the improvement in task completion with the reminding functionality turned on versus it being turned off. We will perform qualitative evaluations by issuing questionnaires with questions such as these:

- Did the reminding functionality remind you to complete your tasks appropriately?
- Did you find the glove useful?
- Did you find the glove overly restrictive?

5. RELATED WORK

At the current stage of our work, we are focused on the technical implementation details. This has allowed us to proceed with developing a working system. We are, however, aware that our proposal will be affected by related work in the field. This Section briefly surveys the relevant state of the art.

The earliest work on RFID gloves was done by Schmidt *et al*, who embedded an RFID reader into a work glove [14]. They suggested that tag reads could trigger applications, bookmark to information, and access individualized information. More recent work was done by Kuwamura et al., who developed a prototype system called "Ubiquitous Memories" [10]. Their prototype includes a wrist mounted RFID reader to record and index user experiences based on touch.

Intel Seattle has conducted similar research – they created an RFID glove and later, a more compact bracelet. One system they used to detect activities was learned models using different types of frameworks – Hidden Markov Models and Dynamic Bayes Nets [9]. Another system that they used was a mined model. By using searches on how-to web pages they were able to relate objects to activities and determine their usage probabilities [2]. They were able to determine which words were objects using WordNet. This was found to be slightly less accurate than using the learned models.

Our project is similar in focus to Intel's project and will likely develop one of the models that was developed by Intel for our event detection. However, our future work proposes something novel in that we wish to determine when an event has not taken place or when a user has not finished completing a task. This requires a model that can distinguish between when a task has ended and when a task has been interrupted. Ultimately, we would like a system that not only reminds people with short term memory loss to take their pills until they take them, but also alerts them if they get distracted midway through taking the pills.

Alternative sensing technology to mobile RFID cannot give the granularity of activity that is required for task identification in all cases. For instance, accelerometer data can tell us when the subject is moving, but not what they are moving towards. Stationary RFID readers can inform us when the subject is within their detection radius, but not what they are doing. GPS, Bluetooth and audio sensors can all determine location, but not activity. Environmental sensors could, potentially, notify the monitors of hazardous changes such as the presence of natural gas or carbon dioxide, but would not by themselves identify the cause of such changes.

One potential way to determine activity is to use visual sensors. Using appropriate image analysis, the subjects' activities could be identified, and the system could react appropriately. The issue that arises in this scenario is one of privacy. Elderly people may be averse to being monitored by video [16]. Visual monitoring may be seen as changing what was a private area – the home – into a more public one. The implications of this change are explored by Bohn *et al.* [4], expanding on the idea of personal borders [12] to identify some of the challenges in this area.

6. CONCLUSIONS

RFID has become popular in recent years for all manner of applications. This paper presents an implementation of an RFID-reading glove that is well suited to assisting sufferers of short-term memory loss to live independently in their homes. Two scenarios are presented: the first ensures that ongoing routine kitchen tasks are completed, e.g., if a kettle is boiled, and tea bags are opened, then a cup of tea should be made, even if the user is distracted. The second issues reminders to the user if medication is not taken according to their doctor's instructions. These scenarios are compelling because they fill a clear need and have low cost in terms of infrastructure or cognitive load. The information generated also has the benefit of being owned by the user — no information leaves their home without their permission.

Our research is a work-in-progress; we have completed our hardware implementation, we have outlined the scenarios we intend to tackle, and we have proposed an evaluation framework to test the efficacy of our approach. The next stage of our work is to implement the necessary routine detection algorithms and perform evaluations of our application of the scenarios. This work is part of a larger project on aiding human memory that includes related applications, such as systems for aiding reminiscence activities by groups [3] and portable diary applications.

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