ForgetMeNot: Memory Aid Using RFID Object Detection and WiFi Communication

Zachary P. Bowman, *Computer Engineering*, *Johns Hopkins University*,
Anne Pigula, *Biomedical Engineering*, *Johns Hopkins University*

***Abstract*— ForgetMeNot is a memory aid designed to help users start the day with everything they will need. Its main functionality will be controlled by a sensor unit located near the front door of the home, and will utilize RFID tags to detect important objects. The device will also leverage wireless internet to provide quick communication and an intuitive interface in the form of a smartphone app. ForgetMeNot will be a user-friendly, home-integrated reminder system that will easily and effectively assist the user every day.**

***Index Terms*—Intelligent Sensors, Magnetic Contact Sensor, Microcontroller Board, Radiofrequency Identification, RFID tags, Sensor Systems, Smartphone Application, Wireless LAN**

I. Introduction

In London alone, more than 22,000 people needed assistance from the fire department over the last three years because they locked themselves inside or out of their homes [1]. Millions more around the world undoubtedly forgot their keys but had a locksmith, landlord, or roommate let them in. These days, it seems that forgetting one's keys, phone, or wallet is part of the human condition, a consequence of rushed preparations in the morning.

There are a few partial solutions to this problem on the market, but none completely address the problem of forgetting these objects and tasks. For example, some systems use keychain FOBs to track keys and other items. If the user can't find his keys, he can activate a tracker device and cause the keychain FOB to vibrate or sound an alarm. This system is only helpful if the user loses his keys, not if he forgets his keys. There is also an existing system called Doh! [2], which uses RFID tags attached to a phone, wallet, or other belongings to send an alert if the user tries to leave without them. However, this system has no solution for tasks or objects which change from day to day.

Our memory aid system, ForgetMeNot, will use RFID tags to detect important objects and tasks, ensuring that keys and wallets are never left behind. It will also utilize web-based communications and a smartphone app allow operators to add additional reminders, in the form of tags or text-based messages. When a person exits, the system will identify the person by their phone RFID tag, check to make sure they have every necessary object, and text them with any missing objects or other preset reminders. Users have the option of activating a short-term tag, for objects which may not be required regularly.

It will require the following components:

- A microprocessor or other controller
- A wireless detection/ tracking system with a reader and a number of small, unique tags
- A sensor to track door opening/closing
- A user interface to allow control of system settings
- A visual and/or audible device to alert user

II. Methods and Materials

A. RFID

The central function of this device is wireless object detection and tracking, which could be implemented in several ways. The ideal system offers small, unobtrusive tags that can be easily attached to objects, preferably without an attached power source. It detects multiple unique tags automatically and simultaneously within a range of 1-2 meters. It's important that this system be user-friendly, so tags must be detected without any special effort from the user.

Few potential object tracking technologies meet these requirements. For example, Near Field Communications (NFC) uses radio waves to communicate with a battery-powered tag, but can only communicate within a range of 4cm or less [3]. WiFi systems use wireless internet to communicate between powered devices like laptops and cellular phones, but tags would have to be quite bulky to accommodate the power and internet requirements [4]. Bluetooth communications use short-wavelength radio waves to sync devices like cell phones and wireless headsets, but the use of multiple Bluetooth device-connected objects can cause interference [5]. Infrared (IR) communications, such as those used by television remote controls, are low-cost and have an appropriate range, but require line of sight interaction [6]. Likewise, UPC barcodes must be scanned manually. None of these technologies would be appropriate for implementation in this system.

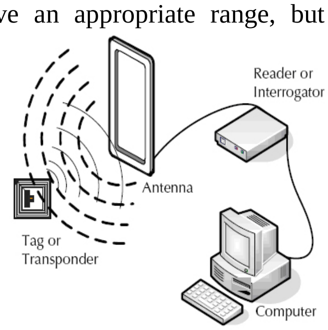

Figure 1: RFID readers send out an electromagnetic field which activates a small tag

Our chosen technology, radio frequency identification or RFID, uses radio frequency electromagnetic fields to communicate over distances

Johns Hopkins University, EN.520.448: Electronics Design Lab. Second research report draft submitted March 1, 2013.

The authors are currently undergraduates obtaining B.S. Degrees at The Johns Hopkins University, Baltimore, MD 21230 USA.
(e-mails: zbowman2@jhu.edu; anne.pigula@gmail.com).

of up to 30m. RFID tags can be active (battery-powered) or passive, and can be as small as a grain of rice. RFID is already commonly used for object tracking, particularly of inventory in warehouses and large stores [7, 8].

The specifications of RFID systems vary substantially with frequency. Low-Frequency (100 to 500 kHz) passive tags are small and inexpensive, but they have a short to medium read range (30cm) and can only read one tag at a time. High-frequency (850 to 950 MHz) and ultra-high-frequency (UHF, 2.4 to 5.8 GHz) passive tags have a long read range of around 1 m and 3-5m, respectively. They have higher read speed, minimal tag interference, and are more expensive. [9, 10]

TABLE 3: SYSTEM COMPONENTS

	Name	Description	Price
Microcontroller	Arduino Uno	Based on ATmega328, 14 digital I/O pins, 6 analog inputs, 5V operating voltage, 32KB Flash Memory	$25.00
WiFi Adaptor	CuHead WiFi-Shield for Arduino	802.11b WiFi certified, Low Power Usage, On-board PCB antenna, Compatible with Arduino Uno	$51.00
RFID Reader	ID-20	LF RFID Reader. 125kHz	$34.95
RFID Tags	EM4001 64-bit tag	Small, passive	$2.99
Power Source	Duracell MN908	Alkaline 12 V	$7.00
Buzzer	PA-100 Piezoelectric Beeper	Operates on 3-28 Vdc. 103 db sound pressure.	$3.75
LED	NTE30042 LED	5mm, Bright	$1.00
Door Sensor	SS451A Hall Effect Sensor	Omnipolar	~$4.00

Table 1: ForgetMeNot has a number of electronic components, incorporated into one design.

In order to meet budgetary constraints, we chose to develop a proof-of-technology model using a low-frequency system. The ID-20 reader is a 125kHz system which offers a read range of 20cm and is compatible with tags using the EM 4001 format. Because of its low frequency, objects will have to be scanned individually. Although this system did not have all of the characteristics that we had hoped for, it was sufficient for an early-stage model.

B. ARDUINO

An Arduino was used to coordinate and communicate with the various sensors and instruments in this system. Arduino is a low-cost, single-board microcontroller with an open-source computing platform. It can be powered by a 9V battery and has 5V and 3.3V voltage supplies. The Arduino used in this system, an Uno R3, has 14 digital pins and 6 analog pins to facilitate communication with multiple system components, as well as USB-to-serial communication. It has 32kb of memory distributed between flash memory (program space), SRAM (short-term storage), and EEPROM (long-term storage).

One of the benefits of using the Arduino microcontroller is the open-source language, including access to significant resources made available by fellow programmers. This community of hobbyists and programmers is invaluable, especially when incorporating multiple sensors from different manufacturers.

C. CUHEAD WIFI SHIELD

The ideal user interface is easy to access and interface with, allowing the user to change settings and set reminders as needed. A manual keyboard/screen would be bulky, time-consuming, and irritating. Another option was to utilize the user’s cell phone to send SMS messages to and from the system. Although this would open the system to more users, it would also limit the user’s control of the system to behaviors controlled by specifically listed text commands. Enabling smartphone control via WiFi allows users to easily send text reminders, activate one-time tags, and control the settings of the system. Although, this limits the system to smartphone users, it is the most cost-efficient, user-friendly, and appropriate user interface for the device.

The LinkSprite CuHead Wifi Shield for Arduino provides internet connectivity to networks following 802.11b protocol. It physically overlays the Arduino (Diecimila, Duemilanove, and Uno models), maintaining access to the communication pins and performing tasks like accessing webpages and hosting local servers. As with Arduino, the software is open-source and a large community of programmers provides support.

D. HALL EFFECT SENSOR AND MISC COMPONENTS

There are several additional project components which must interface with the Arduino, RFID reader, and WiFi Shield. First, a Hall Effect sensor paired with a magnet monitors the door. Hall Effect sensors adjust their output voltage when in the vicinity of a magnetic field, making them simple and effective proximity sensors to indicate when the door has been opened.

Additionally, the system includes an audio/visual alarm. A PA-100 buzzer and flashing LEDs attract user attention to indicate a forgotten object.

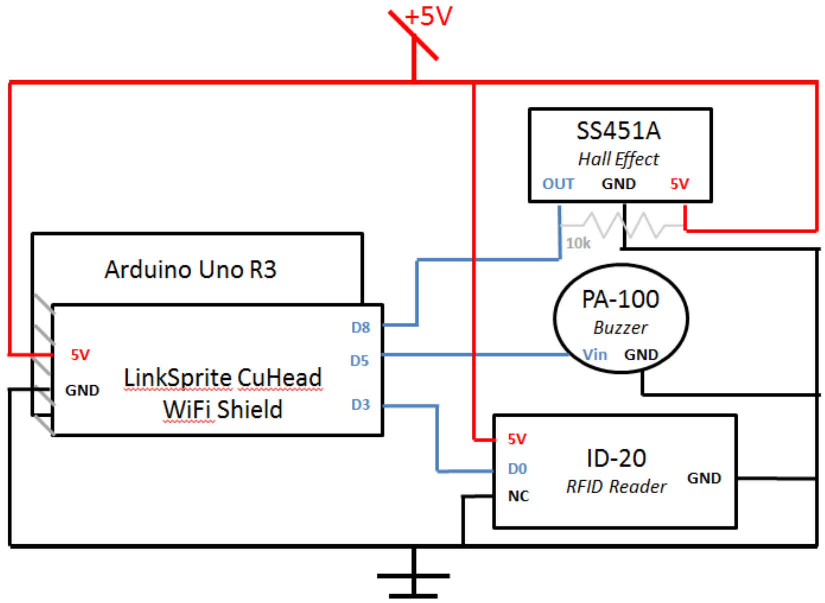

Figure 2: The elements of ForgetMeNot are wired together, as described above

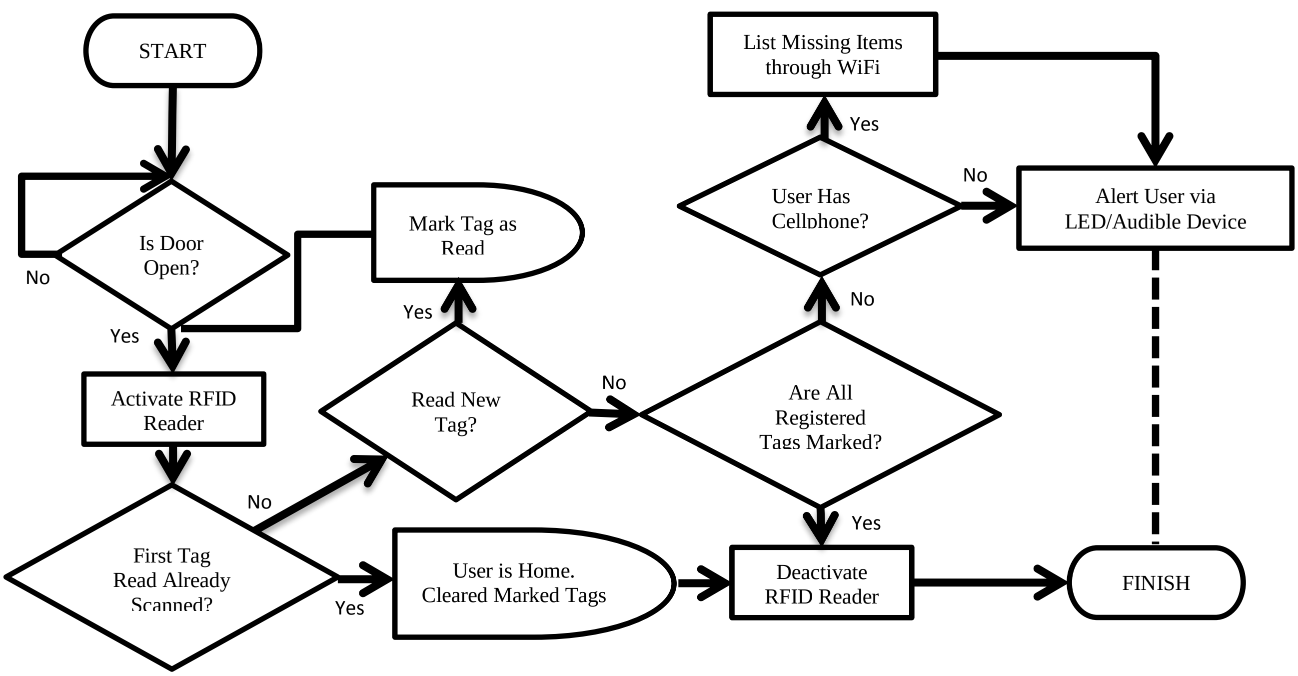

Figure 3: The RFID reader and Arduino track tagged objects to alert the user if any important belongings are missing.

III. RESULTS

A. RFID SENSING

The ID-20 RFID Reader was a moderately effective system for object detection. Although it had an advertised read range of 20cm, our tests showed much a smaller range, maxing out at 8.1cm. The tags were best read when held parallel to the reader, and when held perpendicular, they were read only when very close to the reader.

Because it uses a low frequency, presenting multiple tags to the ID-20 causes interference. In this case, the reader will see the first tag to enter its sensing field and won't scan another tag until the read tag has been removed from the field.

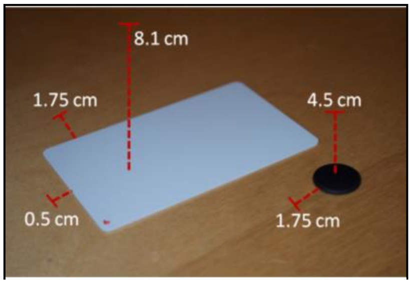

Figure 4: Both types of tags have the largest range when they are oriented parallel to the reader

B. ARDUINO

In many ways, the Arduino was the ideal microcontroller for this project. In particular, the vast open-source library and user-support were invaluable in developing the code.

The selection of an Arduino Uno presented a challenge, as the system did not have sufficient memory to support both the WiFi network and the RFID scanner, which required a total memory in the neighborhood of 40kb. We were able to compensate for this by storing many strings and variables in flash memory instead of SRAM. However, the Arduino Mega, with more than 128kb, may have been a more suitable choice for this system.

C. CUHEAD WIFI SHIELD

The CuHead WiFi Shield allowed for greater user interaction with the ForgetMeNot system. It hosted an HTML-based server on a local Internet, which a potential user could view and enter information into. On the opening page, the server displayed the current users and tags in the system, and offered a number of options for potential tasks. For example, a user could be added to or removed from the system, and tags could be added or assigned to a user.

When the user selected their desired task, the information was encoded into the URL and passed to the Arduino. For example, if the user selected the 'task' radio button labeled 'Add user' and named him 'John', the resulting URL would be

/?task=addUser&newUser=John

The Arduino would process the URL to determine its tasks, and could even change the server's appearance based on submitted information. If the user selected the task 'Assign tags', the presence of the substring '*assignTags*' in the URL would tell the Arduino to display different information, specifically an array of radio buttons to allow designation of tags to different users.

The downside of this method of information processing is that it is expensive in terms of memory and computer time. However, it was relatively simple to implement and with some creativity, allowed a great deal of information exchange.

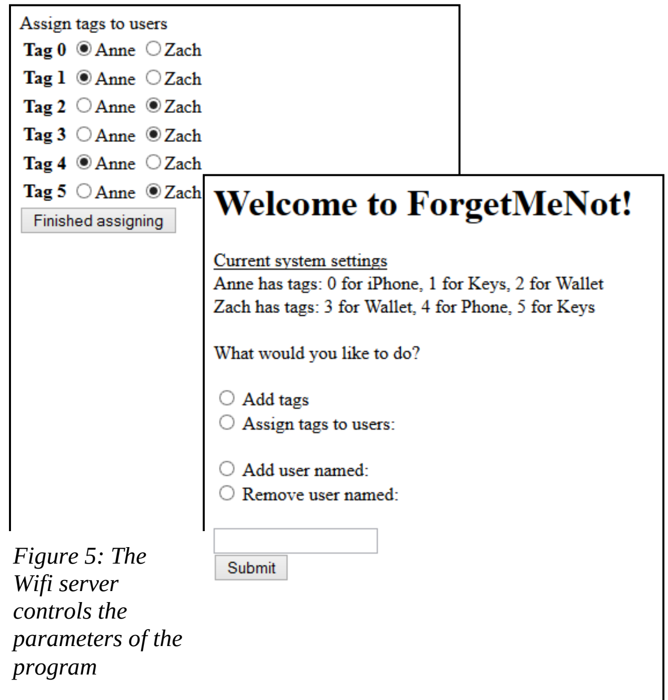

Figure 5: The Wifi server controls the parameters of the program

D. HALL EFFECT SENSOR

The Hall Effect Sensor was an elegant solution to the door monitor. When the magnet was held at a distance, the sensor passed a constant voltage of .18V, but when the magnet was brought near, the output voltage dropped to a negligible value, essentially zero. If the sensor was attached to the wall and the magnet to the door, the sensor would easily pick up a change in the door's position.

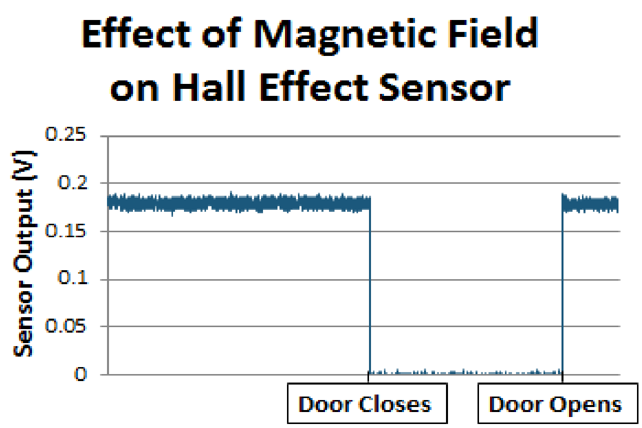

Figure 6: Moving a magnet affects the voltage output of a Hall Effect Sensor

IV. DISCUSSION

The ForgetMeNot system is able to track tags and interact with users via a web-based server. This prototype was very successful in that it showed that this technology could be used to do this. It functioned as expected.

In order for real-world use, there are a few significant changes that would have to be made to the design. First and foremost, it would be necessary to use an RFID reader utilizing a high-frequency wavelength such as 950MHz, so that multiple tags could be read simultaneously and with a range of 1-2m. This would allow users to simply walk through the field of the reader, and it would identify all tagged objects in their pockets and bags. Even cheap high-frequency systems cost from $300 upwards, so multiple-tag reading was unachievable for this project, but in a real implementation, it would be necessary to spend the money.

Secondly, the system would require more memory. Supporting a server requires a lot of space, which was a limiting factor in this project.

Finally, this idea would be better realized with a smartphone app as the communication interface. This app could send a text message or notification to alert users of forgotten items. If the phone was forgotten, it could call the phone to help the user find it. An app would also allow more flexibility of control to make ForgetMeNot even more user-friendly.

V. ACKNOWLEDGEMENTS

We'd like to give special thanks to Dr. Ralph Etienne-Cummings, Jamal Molin, and Xiaoyu Guo.

REFERENCES

[1] London Fire Brigade. "Firefighters Attending One 'Locksmith Job' Per Hour Title." [London]. 29 May 2012: http://www.london-fire.gov.uk

[2] Z. Honig, "Doh uses RFID and Arduino to help you remember your wallet, continues search for the 'Any Key'," EndGadget, 2011. [Online]. Available: http://www.engadget.com/2011/11/21/doh-uses-rfid-and-arduino-to-help-you-remember-your-wallet-cont/. [Accessed 20 2 2013].USA: Abbrev. of Publisher, year, ch. *x*, sec. *x*, pp. *xxx–xxx.*

[3] Nokia Corporation, "Introduction to NFC," Nokia Forum, 19 4 2011. [Online]. Available: http://www.adafruit.com/datasheets/Introduction_to_NFC_v1_0_en.pdf. [Accessed 20 2 2013].

[4] C. Yibo and R. Luo, "Design and Implementation of a WiFi-based Local Locating System," Portable Information Devices, 2007. PORTABLE07. IEEE International Conference on, pp. 1-5, 2007. J. H. Davis and J. R. Cogdell, "Calibration program for the 16-foot antenna," Elect. Eng. Res. Lab., Univ. Texas, Austin, Tech. Memo. NGL-006-69-3, Nov. 15, 1987.

[5] Bluetooth, "Bluetooth Technology 101," 2013. [Online]. Available: http://www.bluetooth.com/Pages/Fast-Facts.aspx. [Accessed 20 2 2013].

[6] M. Kaine-Krolak and M. Novak, "An Introduction to Infrared Technology:," University of Wisconsin, Madison, WI, 1995.

[7] K. Bonsor and W. Fenlon, "How RFID Works," [Online]. Available: http://electronics.howstuffworks.com/gadgets/high-tech-gadgets/rfid.htm. [Accessed 19 2 2013].W.-K. Chen, *Linear Networks and Systems.* Belmont, CA: Wadsworth, 1993, pp. 123–135.

[8] D. Dobkin, "The RF in RFID – The Tutorial," 12 2012. [Online]. Available: http://www.enigmatic-consulting.com/Communications_articles/RFID/RFID_frequencies.html. [Accessed 27 2 2013].

[9] C.M. Roberts, Radio frequency identification (RFID), Computers & Security, Volume 25, Issue 1, February 2006, Pages 18-26, ISSN 0167-4048, 10.1016/j.cose.2005.12.003. Available: http://www.sciencedirect.com/science/article/pii/S016740480500204X) [Accessed 28 2 2013].

[10] The RFID Network, "RFID Lessons from Real-World Implementation," [Online]. Available: http://rfid.net/best-practices/43-best-practices/160-rfid-lessons-from-real-world-implementations. [Accessed 27 2 2013].

Zachary P. Bowman is currently a student at Johns Hopkins University in Baltimore, MD. He will graduate in December of 2013 with a B.S. in computer engineering.

Anne Pigula is currently a student at Johns Hopkins University in Baltimore, MD. She will graduate in May of 2013 with a B.S. in biomedical engineering focusing in instrumentation, and a minor in mathematics.

Ms. Pigula was selected for a Provost's Undergraduate Research Award during the 2011-2012 academic year. Next year, she will pursue a Master's degree in Medical Robotics at Imperial College London.