2015 International Conference on Computational Science and Computational Intelligence

Smart Home System for Patients with Mild Cognitive Impairment

Shane Robert Maynard[1], Himanshu Thapliyal[1,3], and Allison Caban-Holt[2]
[1]*Department of Electrical and Computer Engineering*
University of Kentucky, Lexington, KY
[2]*Sanders-Brown Center on Aging*
University of Kentucky, Lexington, KY
[3]*Corresponding Author: hthapliyal@uky.edu*

***Abstract*—Estimates suggest that up to 20% of adults over age 70 years may have Mild Cognitive Impairment (MCI; cognitive changes without dementia) [1]. Such individuals may be able to function more effectively in their environment with some supportive services. Embedded automated systems could help provide additional protection from accidental injury and support for executing daily activities for individuals with MCI. In this paper, illustration of a home monitoring embedded system to increase safety and functionality to those with cognitive disabilities is provided. A proof-of-concept implementation of an automated garage door monitoring system that can monitor the open/closed status of the garage door, but also monitor other environmental variables has been developed in this investigation. The obtained sensor data is then used to execute particular macros, per situation, and react accordingly in order to circumvent injury and improve daily functioning of patients with mild cognitive impairment.**

***Keywords*— Active circuits; Integrated circuits; Microcontrollers; Sensor systems**

I. INTRODUCTION

Mild Cognitive Impairment (MCI) is characterized as cognitive impairment that does not meet criteria for dementia [1]. Typically, individuals with MCI have a recognizable deficit in at least one cognitive domain, but no dementia or impairment in Activities of Daily Living (ADL). Such individuals may display mild cognitive deficits that may be amenable to remediation via Smart Assistive Living (SAL) platforms. Some common symptoms of MCI include memory decline, difficulty tracking medications, forgetting appointments, getting lost in familiar locations, difficulty following conversations, and increased risk of falls [2, 3]. Many of these issues could be viable targets for SAL. MCI is associated with an increased risk of developing dementia at a rate of 10-15% per year [4]. Over time, as some individuals with MCI experience progression of cognitive decline, SAL can be adapted to provide increasing levels of support as needed, being customized to individual patient needs. Such support may allow some elders to remain independently living in their homes for longer than they would be able to without such assistance.

Remaining at home saves an average of $75,000 per person per year in the U. S. [5]. Delaying nursing home placement for even a few years could represent a significant financial savings for families of patients with cognitive decline, as well as the U.S. Healthcare system overall.

In the existing literature, researchers have explored the Smart Assistive Living (SAL) platform to enable older adults with dementia to remain at home, delaying nursing home placement. The platform is based on wireless sensor network and broadband network connectivity [6-7]. The various factors that should be considered when designing Smart homes for elders to remain living independently are discussed in [8]. The drawback of the existing Smart home systems is that they are financially costly and so are not affordable for many caregivers [9]. Further, recent advances in microcontroller technology have made complex and efficient computing, cheaply and readably available to the market. These low-power and reliable systems make perfect candidates in developing intelligent home monitoring and service solutions. Different systems should control different functions of the home, while always communicating with each other and the outside world. Such systems can give peace of mind to not only its residents, but also physicians or family who is unable to provide close monitoring of the patient. In this paper, we have illustrated that it is possible to implement home monitoring embedded system to increase safety and convenience to those with cognitive disabilities. We have developed a proof-of-concept implementation of an automated garage door monitoring system, which can monitor the open/closed status of the garage door, but also monitor other environmental variables. The obtained sensor data is then used to execute particular macros, per situation, and react accordingly in order to circumvent injury or save life of the patients with mild cognitive impairment.

The paper is organized as follows: Section 2 presents the concept of embedded home monitoring in greater detail and one idea of its integration with daily life; Section 3 presents the design of a garage monitoring system and the software that drives it; Section 4 summarizes the conclusions.

978-1-4673-9795-7/15 $31.00 © 2015 IEEE
DOI 10.1109/CSCI.2015.159

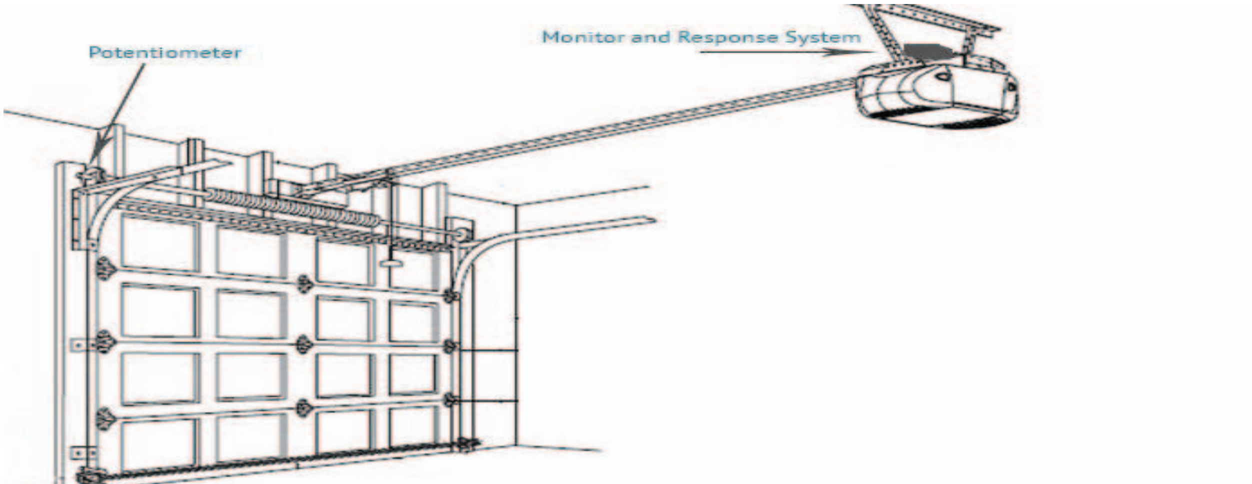

Figure 1: Top level hardware installation

II. EMBEDDED HOME MONITORING

Like general networking, there is no common implementation or topology of home monitoring systems, which works in every situation. However, taking a look at the big picture gives an idea about the general task such a system should accomplish which above all else is safety. Each room of the home should implement a system that can monitor different activity aspects of the room and react accordingly to the situation. The priority is the do what is necessary to prevent an accident from occurring, but in case of an emergency, react quickly to get external help (from the outside world). Secondly, the systems need to communicate with each other and provide a common interface for provisioning and data collecting. Each system would need to be customized to tailor to the patient's' needs, home architecture and other extra-environmental variables. Lastly, the system would cater to the comfort of the patient who may find simple household tasks now complicated. By nature, these systems need to be highly reliable and fault tolerant. Usually, when customization is a key factor, this tends to include higher cost and complexity for implementation. However, a system that is modular can be much less costly and can be easily managed. Malfunctioning units can be quickly replaced and would not necessarily require the assistance of a trained technical professional.

Communications with the outside world can be handled via many methods. One may rely on a home's Internet connection for this interface, however this solution however may not provide the reliability needed. Possible points of failure include ISP outages, or in home equipment failures such as routers or modems. Wireless networks provide convenience, but wired networks provide greater reliability. Though possible, standard SOHO (small office home office) networking should not be the only interface. Adding a secondary cellular connection to each module would slightly increase cost but can provide a valuable failover connection in the event of the primary's failure

The controllers themselves may need to share data between each other. Using an open standard like IEEE 802.11a, one can create a secure wireless network in which peers can quickly communicate with each other. Lastly, each module should share a common, human friendly interface, for provisioning, data collection and presentation. A general web interface, with a SaaS (Software as a Service) mentality, can make it easy for those who need to check on the status of their loved ones.

III. PROPOSED SYSTEM OVERVIEW

The goal is to construction a foundation for the proposed system. Initially, a single module, a garage door monitoring system, was developed as a proof of concept. A backend software system was developed to ease the addition of new modules going forward. The following sections give a high level overview of the implementation.

A. Definition and Implementation

The definition of the proposed system is as follows: The garage monitoring and response system will monitor the position of the garage door on a percentage opens basis, it shall also monitor CO_2 "Carbon Dioxide" levels in the room. The response, should be programmable, however by default the door position, and CO_2 level sensor data will be available via a mobile phone application, web service, or API call. Through its various interfaces, the garage door can be remotely opened and closed.

Several programmable macros should exist to react to sensor data. For example, suppose the garage door has been opened for an extended amount of time. The patient or consented user (caregiver) can get a notification that the door is left open and

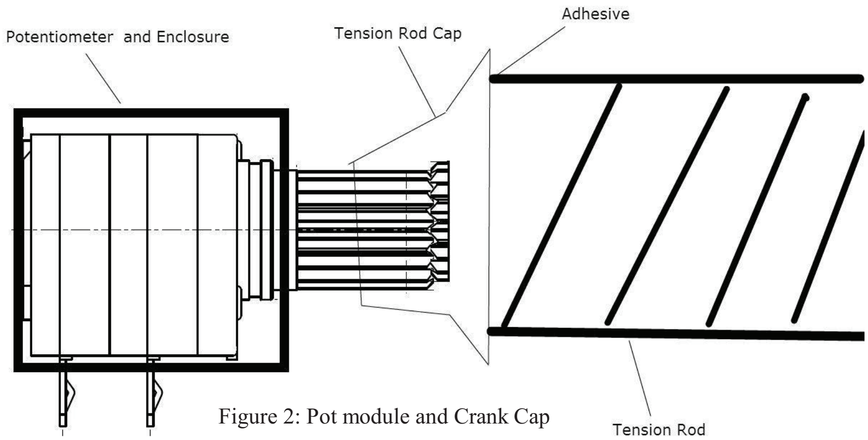

Figure 2: Pot module and Crank Cap

that the system will be closing it automatically in 'X' number of minutes. Perhaps the time is 11 P.M and the garage is open, the system will close the door automatically. Also suppose a vehicle has been started and the garage door is closed, once CO_2 levels reach a defined threshold the garage door will open automatically and contact emergency personnel. In general, common interfaces should exist to allow users the ability to define their own macros and responses.

This product will come with the following components.

- 1 – Embedded Module (Microcontroller)
- 1 – Potentiometer Module (Pot)
- 1 – Crank cap with adhesive housing
- 1 – 5v AC adapter
- 1 – 6 meter connection cable
- Various Potentiometer mounting brackets

B. Hardware Installation

Figure 1 provides a top-level overview of how the system hardware would be installed in the garage. Specifically, it depicts where the microcontroller and potentiometer would reside.

- The microcontroller would be securely mounted above the garage door motor keeping clear of any moving parts on the motor.
- The AC adapter should plug into the receptacle which powers the motor.
- Using a potentiometer mounting bracket, secure the pot module to the wall near rotating tension rod. The crank shaft of the Pot should face the flat rotating side of the tension rod.
- Use the adhesive backing of the Crank Cap to attach it to the outer surface of the rotating tension rod. Both the Pot module and the Crank cap should couple together. When the tension rod moves with the garage door, the cap should spin adjusting the Pot module accordingly. Figure 2 demonstrates it proper connection.
- Connect the Microcontroller and the Pot module together using the supplied connection cable. Take care to route the cable such that it will not interfere with any moving parts.

The system is powered by standard 120VAC, via a 5VDC inverter. Outputs from the system are connected to the garage motor activation pins. A potentiometer is connected to the tension rod at the far end. The potentiometer is used to measure the doors open/closed status by the variances in resistance as the tension rod rotates.

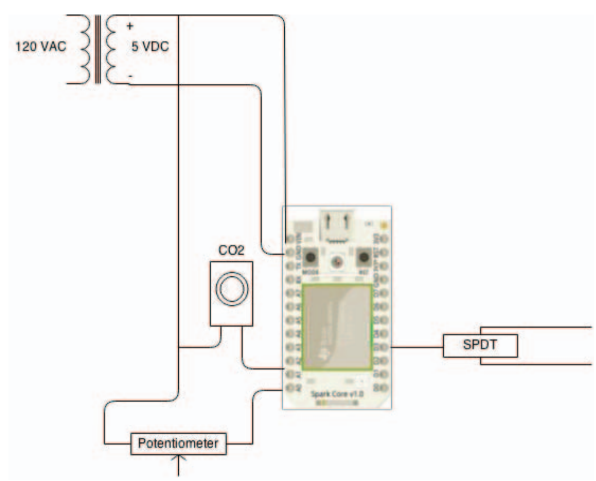

Figure 3: A High level schematic of the circuitry.

C. Circuit Implementation

For quick prototyping, a Spark Core [10], embedded microcontroller was used. The small unit supplied the necessary analog input/ digital outputs to meet specifications while also offering an onboard TI 3200C 802.11b/g wireless chip for network communication. In the future, this microcontroller can be replaced with a number of other suitable controllers for permanent installation.

Figure 3 is the schematic of the hardware. Two sensors are attached to the Cores respective analog inputs, a MQ5 CO_2 sensor and standard Potentiometer. A 3.3V relay is attached to a digital out pin and will serve as the mechanism for toggling the garage door. When voltage is applied to the relay, it will bridge the contacts on the garage door switch pins. When the relay is not powered, the contacts remain an open circuit. A quick, one second voltage, is enough to engage the garage door to open or close.

D. Software Implementation

The system connects to the Internet via the 802.11g wireless interface. It communicates with a central server hosted offsite through a standard, client initiated socket connection. It is the system's responsibility to send keep-alive messages to maintain a persistent connection to the server. All sensor data, and door controls are sent directly to and from the server across the Internet. The microcontroller uses the Spark API to receive and broadcast messages. The server side software, uses a python script to constantly poll the module for sensor status updates using API calls to the Spark framework. That data is then placed into a database for the respective user.

The server hosts a SQL database. The database contains users, module identification and status fields. When a new user is created, a username and password field are set and a unique ID is assigned to that user. A user can register their module, by providing the Spark ID. The Spark ID, according to the Spark API, is a unique ID to that microcontroller and is used for communication within Sparks API. This Spark ID is saved to a table and is associated with the users unique ID. There exists other tables which log the current and past sensor/instruction data, all of which is associated by the Spark ID. With this setup, one can have multiple users with multiple modules in the same database which can be easily and securely distinguishable.

A strict RESTful API has been developed to ease communications between the device, server and other interfaces including Web applications, mobile devices or dedicated controllers. This allows quick development of interfacing applications. Simple HTTP calls to the python script can perform various functions to the database, and send calls to the Spark API which controls the remote modules. A user must only provide their username, password, Spark ID and instruction in the GET/POST request. This allows the system to successfully identify who they are, understand which module they are speaking of and what function to perform. Figure 4 demonstrates how the route in which a module would receive API calls from the Python script.

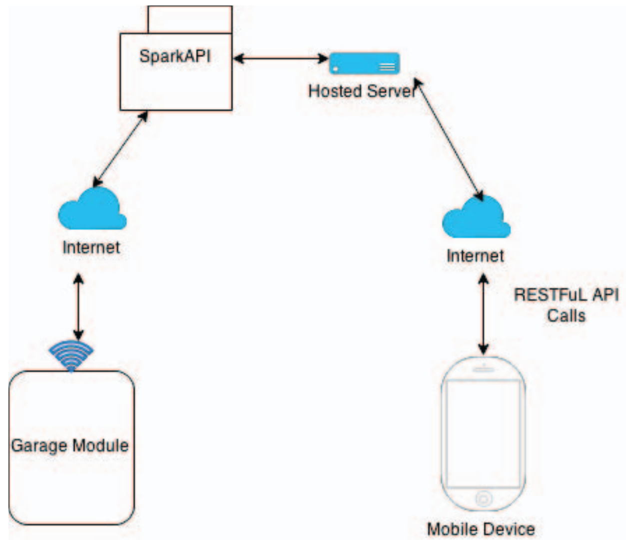

Figure 4: Simple Cloud Implementation

A python script, the logic, runs persistently on the server to review sensor data and log device behavior to dynamically create and suggest macros that may be useful to the user. The logic also handles scheduling of macro execution. The server also has the ability to make PSTN calls and send text messages as need. Information is always passed through a secure, encrypted SSL connection.

Text messages are sent using the Twilio [11] service API, whereas phone calls can be placed over standard SIP connections. Asterisk [12], is used as a software PBX to initiate SIP calls to the PSTN (Public Switched Telephone Network). This requires the service of an ITSP (Internet Telephony Service Provider). In this case, Vitelity [13] is used.

Notably, is the ability to quickly define other systems, which can perform different functions, based on its application and have it interface with other systems in the home through the API. This will allow for complete coverage of the home, to work in a sophisticated and automated way. This entire package is ran under the mindset of Software as a Service, where the integrity of the server will be handled by a corporate entity, relieving the user of this responsibility.

IV. CURRENT STATUS AND SUMMARY

Currently, a hardware prototype of the module has been constructed and its module software implemented. A server backend python script has been written and can communicate with the SQL server and Spark API to perform its primary functions and does so in a RESTFuL way. An authentication system is yet to be implemented along with its graphical interfaces including web and mobile apps. However, having the API working will make these tasks trivial. The software has been written in such a way, that adding new modules, such as lighting, HVAC or other personal safety/convenience devices easier to implement.

The intent of this paper was to show that it is possible to implement home monitoring software to increase safety and convenience to those with cognitive disabilities. It has been shown, via the example of the garage door opener that such a system can be realized and is in early development. The true power of the system becomes evident with additional modules working and communicating together, providing true umbrella coverage to the home, and giving peace of mind to the patient's loved ones.

REFERENCES

[1] E.M. McDade, R.C. Petersen, S.T. DeKosky, A.F. Eichler, “Mild cognitive impairment: Epidemiology, pathology, and clinical assessment”, 2014. http://www.uptodate.com/contents/mild-cognitive-impairment-epidemiology-pathology-and-cllinical-assessment

[2] Family Caregiver Alliance. https://caregiver.org/mild-cognitive-impairment-mci

[3] K. Delbaere, N.A. Kochan, J.C. Close, J.C. Menant, D.L. Sturnieks, H. Brodaty, P.S. Sachdev, S.R. Lord. “Mild cognitive impairment as a predictor of falls in community-dwelling older people”. American Journal of Geriatric Psychiatry, 20(10), pp. 845-53, 2012.

[4] J. Bischkopf, A. Busse, M.C. Angermeyer, “Mild cognitive impairment- a review of prevalence, incidence and outcome according to current approaches”. Acta Psychiatrica Scandinavica, 106, pp. 403-14, 2002.

[5] U.S. Department of Health and Human Services website: LongTermCare.gov

[6] Q. Zhang, M. Karunanithi, R. Rana, and J. Liu, “Determination of activities of daily living of independent living older people using environmentally placed sensors,” in *Proc. IEEE EMBS, 35th Annu. Int. Conf. Osaka, Japan,* 3–7 July, 2013, pp. 7044–7047.

[7] Q. Zhang, Y. Su, and P. Yu. "Assisting an Elderly with Early Dementia Using Wireless Sensors Data in Smarter Safer Home." In *Service Science and Knowledge Innovation*, Springer Berlin Heidelberg, 2014, pp. 398-404.

[8] Q. Ni, A.B. García Hernando,; I.P de la Cruz, “The Elderly’s Independent Living in Smart Homes: A Characterization of Activities and Sensing Infrastructure Survey to Facilitate Services Development”, *Sensors*, *15*, pp.11312-11362, 2015.

[9] J. O’Keeffe, J. Maier, and M. P. Freiman. "Assistive technology for people with dementia and their caregivers at home: what might help." *Final report prepared for Administration on Aging (Massachusetts)*,2010, pp. 1-30.

[10] Spark. (2015). Microcontrollers. http://spark.io

[11] Twilio. (2015). SMS Gateway Service. https://www.twilio.com/

[12] Digium. (2015). Asterisk Open Source PBX. http://www.digium.com/en/

[13] Vitelity. (2015). ITSP. http://www.vitelity.com/