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Design of a Data Acquisition System Which Detects Signals Scavenged by Sensors Which Are Activated by Walking

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ABSTRACT: We designed a data acquisition system to scan data from four sensors on a pad [1], and to send the data wirelessly to the cloud [2]. We used microcontroller PIC18F4455 to read the signals from the four sensors on the pad, and process the data. We built our design in a printed circuit board. We did several experiments to make our system able to work accurately. We measured the noise value in the pad's sensors to find the threshold value, which helps us to distinguish between the noisy sensors and active sensors. We did another experiment to show its accuracy in counting steps. Also, we saved the data from the cloud in a text file. A major rationale for this effort is to help caregivers track people in critical locations including bathrooms, exit doors, and around hospital beds. Also, for security purposes the system can detect unauthorized entry through windows.

KEYWORDS: Energy scavenging; smart carpet; data acquisition system; wireless communication; sensors; personal detection

I. INTRODUCTION

New technology has served our life in several fields, one such technology is the smart carpet. Our laboratory has developed the smart carpet technology, which uses the signal scavenging idea to detect people moving on a floor [3]. Energy scavenging is the process of converting the energy that is available in our environment like wind, solar, and thermal to useful energy. The sensors of smart carpet are made from a conductive material (aluminum foil or copper) to detect energy noise of 60Hz (electromagnetic noise). This noise is increased when the sensor is touched [3]. This difference in noise value between touched and untouched helps to determine sensor activation in the smart carpet. The activated sensors generate signal value around 387 mV. On the other hand, the non- activated sensors produce signal value around 28 mV [4]. The use of this noise is to detect motion (stepping) on the sensors (useful energy). These sensors act like an antenna when touched. When the sensors are activated, the generated signal values are increased. Benefiting from this idea, we designed a data acquisition system to detect motion caused by stepping on a carpet pad. Basically, the system we designed has four data processing stages. The first stage is for choosing and amplifying one sensor's analog signal. The second stage is for digitizing the analog sensor. The third stage determines whether the sensor is active or not. The fourth stage is to send the data for the receiver. Figure 1 shows the system data processing stages.

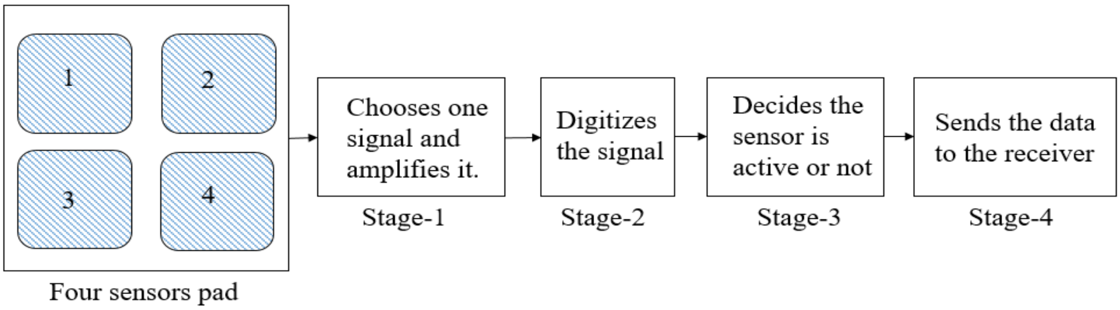

Figure 1. The system data processing stages

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In our data acquisition system, we set up a threshold to distinguish between the activated sensors and the non-activated sensors. The sensors that transmit signal values less than the threshold are considered as non-active. In contrast, the sensors are considered active when the signal values are greater than threshold. In our design, we used the Wi-Fi technology to send the data to the cloud from the data acquisition system by using the Spare Core [2]. The rest of the paper is organized as follows. Section II is a background study for our research. Section III describes the design layout. Section IV shows the pseudo code of the microcontroller. Section V explains the results of our board. Finally, section VI presents the conclusion and the important ideas for the future work.

II. BACKGROUND

Many projects have been done in our laboratory to design sensor floor carpets, designing data acquisition systems, and monitoring the measured data from the smart carpet [5, 6, 7]. In addition, research has been done to distinguish between falling patterns detected [8, 9].

The pad system has many valuable uses to protect elderly. It can be used in small tight spaces (bathrooms). Research showed that the most common location for fall injuries of people 65 years and older in U.S. homes was the bathroom (35.7%) as compared to other locations in the home [10]. These injuries most commonly occur at the transition point to and from the wet floor and bathmat[10]. With a system that senses motion (stepping) on the bathmat, this solution may save people's lives.

According to the Alzheimer's Association, the percentage of the geriatric population with deficits in cognition (i.e. dementia or Alzheimer's disease) who wander, reaches 60 percent [11]. So, detection of wandering seniors is another potentially useful application for this product. Wandering can result in extremely dangerous situations; the daily papers give accounts of a person leaving the home, and becoming lost or confused. For someone lost or confused outside of the home longer than 24 hours, up to half are found to result in injury or death [11]. With the carpet pads in place at the entrance/exit locations of the home, an alert can help caregivers track their movement from the home.

Of all offenders unlawfully entering homes, it has been found that 40% gain access through unlocked windows and doors when residents are not home [12]. Home security is another potential area of need that the carpet pad can address. Whereas the traditional home security systems track intruders with sensors when doors are opened or with security cameras, the carpet pads would be able to detect unauthorized movement by signaling when steps are taken after the system is activated. Sensor pads can be placed below windows inside the home or inside the doorways for the entrances to the home.

The data acquisition system that we designed reads the data from four sensors on a pad and sends the location of activated sensors to a computer and a wireless network chip (Spark Core) at the same time [2]. We believed that wireless communication to send the pad's data is better than using wired communication. The wired communication is useful for units close to each other, but inconvenient with long wires for distant communication inside a building, or for systems in different floors. We need wireless communication that it is easy to setup, less costly and it is easy to maintain. Wireless communication using a network WI-FI chip was a good solution. It is actually a board with multiple chips of an input voltage range of 3.6V - 6.0Vand small size[13].

III. METHODOLOGY

The data acquisition system consists of a multiplexer (CD4051BE), op-amplifier (TL082), analog to digital converter ADC (MCP3001), microcontroller (PIC18F4455), MAX232 (for voltage level matching), Spark Core (for the wireless communication), positive and negative voltage regulators (MC7805, MC7905), and output DC/DC converter (NMH0509SC).

The multiplexer selects one analog signal from four sensors in the pad carpet (figure 2). Next, the op-amplifier amplifies the signal ten times to make it easier for the microcontroller to distinguish and read the input signal. The ADC changes the amplified analog signal to a digital ten-bit word [14]. The microcontroller reads the input digital signal and converts it into an ASCII representation to make it readable by any computer. The microcontroller decides whether the sensor is active or not by comparing the signal's value with a threshold, which has the value of 1.46V. In addition, the microcontroller controls the multiplexer, op-amplifier and the ADC by sending enabling signals to turn them on. Furthermore, the microcontroller sends two address bits to the multiplexer to choose one of four sensor signals and a clock signal to the A/D for synchronizing. The output data signal of the microcontroller is shifted from five volts to

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eighteen volts by MAX232 to send to the serial port of the computer. The Spark Core receives the data directly from the microcontroller and publish it in the cloud.

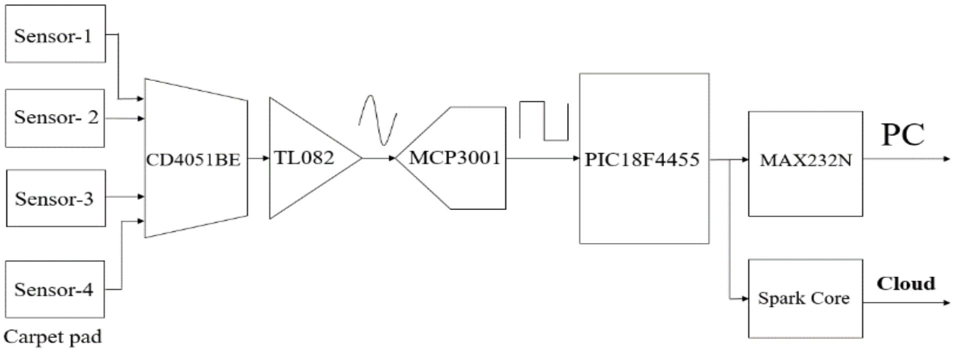

Figure 2. The data path of the design

In the Spark Core setting, we named the event "carpet1" for the published data, we named our Spark Core device "Jagmaji", and we set the data timestamp for Central Time (CT). In addition, we changed the data source to sensor data from the microcontroller, which was connected to the Spark Core through the serial interface. We matched the Spark Core setting to the microcontroller serial port setting (4800 bps for the baud rate) [2].

The DC/DC converter converts a single input of plus five volts to positive and negative nine volts [15]. The role of the regulators is to take the output (+9v and -9v) of DC/DC converter and change it to (+5v and -5v) to supply the other components of our system with power [16, 17].

The microcontroller needs to output data in a frame format. Since we labeled the pad as A, the output data frame configuration appears as SAXE. Where S stands for start of the frame, A stands for the name of the pad, X stands for the location of an activated sensor in the pad (position 1, 2, 4 and 8), and E stands for the end of the frame. The location X of the activated sensors is represented by one-digit hexadecimal, as shown in figure 3. Also, the system adds the sensors' location value when more than one sensor is activated.

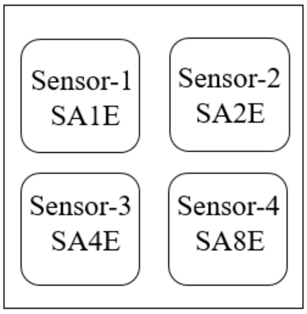

Figure 3. The output data frame for a pad

IV. PSEUDO CODE

The pseudo code for the microcontroller is explained in the steps below:
Step 1: Select one sensor from the four sensors by sending two address bits from PIC18F4455.
Step 2: Store the digital signal value from the ADC in a variable.
Step 3: Compare the digital signal value with the threshold.
    if (digital signal >Threshold)
  The output data=1.
    else
  The output data=0.
    end
Step 4: Collect the four sensors value in one-digital hexadecimal.
Step 5: Represent the data in an ASCII representation.

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Step 6: Compare the output data for the four sensors with zero.
Step 7: if (output data !=0)
Send the data through UART port with 4800 bps.
else
Stop sending the data.
end
Step 8: End.

V. RESULTS

The proto board or breadboard implementation is always limited by noise captured with all the lose wires and loops present in the board. It was important to create a printed circuit board to develop a more professional implementation. We implemented the design in printed circuit board (PCB) by using PCB Artist, a design layout software [18]. The board has dimensions of 3.27 inches by 3.65 inches, and appears in figure 4. We chose these dimensions for our board to allow it to fit inside an electrical box.

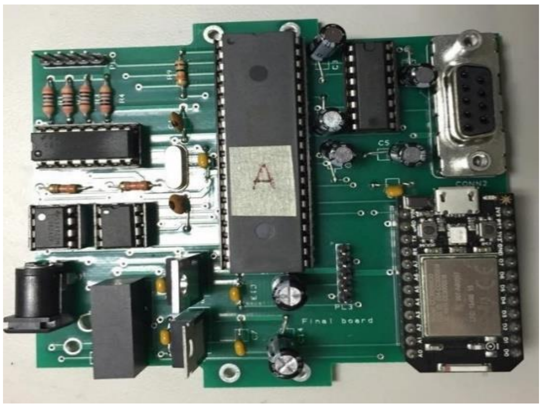

Figure 4. The printed circuit board picture

The threshold selection is very important in our project because it gives our design the accuracy to distinguish the active sensors from the noisy sensors. Recording data for one hour from one pad is sufficient to decide our threshold. Figure 5 shows the results of the experiment. The y-axis represents the amplitude of the sensors' signals without activation, and the x-axis represents the time. We notice that most of the signal value less than 300. In the range of (0-5V) that we used to reference our ADC of 10-bit resolution, 300 equals 1.46 V. We found it is desirable to use 1.46 V as a threshold. In figure 5, we notice there were some signals above 300 which we ignored because they occurred for only a short time and we want out system to be sensitive to stepping on the pad.

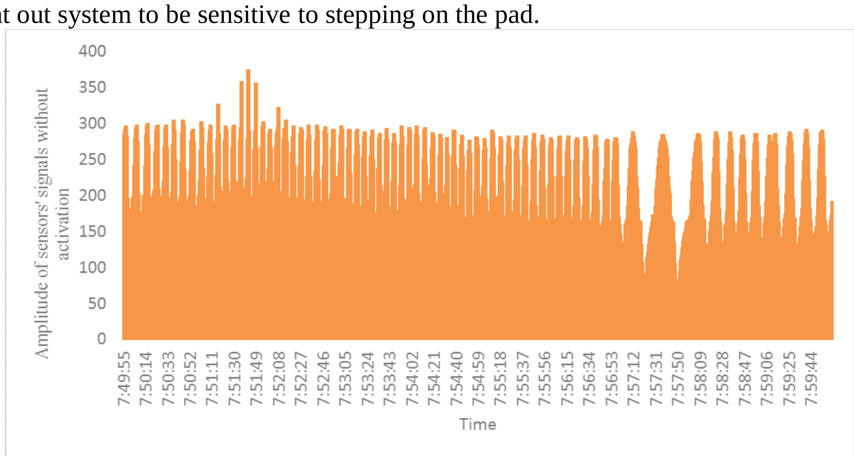

Figure 5. The histogram of the first experiment

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We did a second experiment to test the board and to show its accuracy in counting steps. We connected the board to a computer by a serial port to read the data from four sensors on a pad, using the Hyper Terminal software. The experiment was to tap each sensor 100 times and recording the output data in a file. The total taps were 400. We can see the result of this experiment on the histogram in figure 6. The y-axis represents the number of times the sensors were activated and the x-axis represents which sensor was activated during the experiment. The single sensor results are (1, 2, 4, and 8), notice the peaks at 1,2, 4 and 8 in figure 6. The other results (i.e. 3, 5, 6, C … etc.) indicate that more than one sensor was activated; likely due to the movement of the pad during the tapping. We see in the same figure, we obtained 133 data frames for sensor-1, 105 data frames for sensor-2, 137 data frames for sensor-3 and 99 data frames for sensor-4. The reason behind the data frames exceeding 100 is because the data scan time is much faster than human tapping speed, consequently each tap could result in multiple outputs.

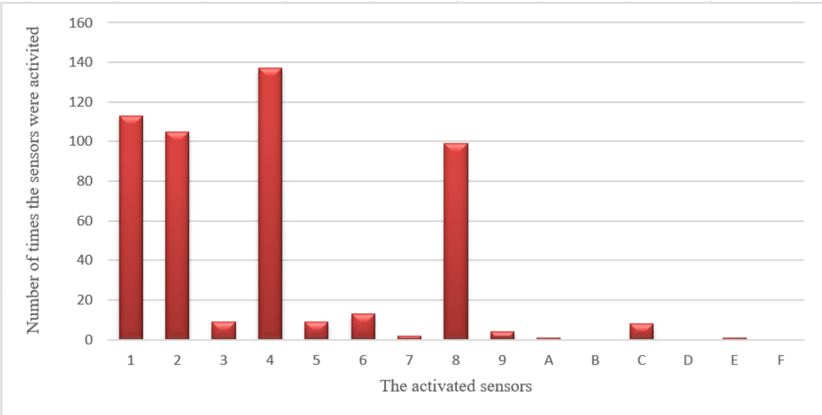

Figure 6. The histogram of second experiment

We did a third experiment to test the output data without any tapping. The result showed that the system is very clean when nobody steps on the carpet where we did not obtain any data from the data acquisition system. This accuracy helps us to achieve the purpose of building this system, which notifies the caregiver only when people walk on the pad.

Moreover, we connected the board to the computer by serial ports and recorded the output data by using the Hyper Terminal software. Then, we tested the output when someone stepped on the second sensor of the pad. Figure 7 displays the results on the Hyper Terminal screen. We noticed the correct data frame SA2E occurred six times in figure 7, which represents the second sensor in the pad, and SA4E is considered as noise.

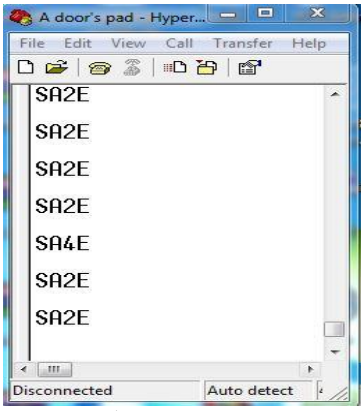

Figure 7. The result for activated second sensor in a pad

After that, we tested the capability of our system to send the data wirelessly using the Spark Core chip. We connected our board to a pad and collected the data on the cloud (Dashboard website). We stepped on the third sensor of the pad and we obtained the data (SA4E) in the Dashboard website as you can see in figure 8. Also, in the same figure, we

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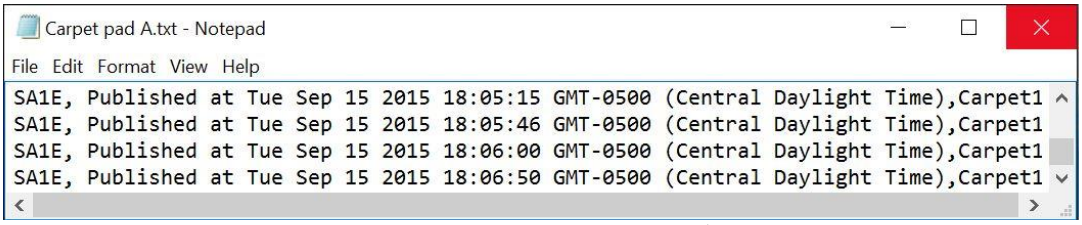
obtained "carpet1" as an event name, a timestamp of December 6th at 11:15:53, and Jagmagji for our Spark core device's name.

Figure 8.The cloud's Dashboard sensor's data from the Spark Core

Finally, for storing data and analyzing it, we saved the data that displayed in the Dashboard in a text file on a personal computer. We could save all the results shown in the Dashboard website in the text file, such as event name and data publish time as you can see in the figure 9. In Figure 9, we acquired the data SA1E which shows that the first sensor on carpet A was activated, and the timestamp was 18:05:15 and the date for the data Sep 15 2015.



Carpet pad A.txt - Notepad

File Edit Format View Help

SA1E, Published at Tue Sep 15 2015 18:05:15 GMT-0500 (Central Daylight Time),Carpet1
SA1E, Published at Tue Sep 15 2015 18:05:46 GMT-0500 (Central Daylight Time),Carpet1
SA1E, Published at Tue Sep 15 2015 18:06:00 GMT-0500 (Central Daylight Time),Carpet1
SA1E, Published at Tue Sep 15 2015 18:06:50 GMT-0500 (Central Daylight Time),Carpet1

Figure 9. The saved sensor data in a text file

VI. CONCLUSION AND FUTURE WORK

We implemented a data acquisition system to read sensor activation from a pad [1]. We send the data wirelessly from the data acquisition systems to the cloud [2], or we send it directly to the computer through the UART serial port. The data acquisition system sends the active sensor's data from the pad to the computer. We can use this system for several applications like security, detecting wandering people, detecting people in the bathroom, and reminding people that the stove is on. We did an experiment to test the noise in our system and to show its accuracy in counting steps. Also, an experiment was done to measure the threshold in the carpet pads to distinguish between the sensors' noise and the active sensors.

There are a number of useful changes we can make in the future. To reduce the power consumption of the microcontroller, we can use the sleeping mode feature by enabling the microcontroller only when there is stepping or motion on the pad. Additionally, the noise was a big deal in our boards, so reducing the noise will be good. This reduction will improve sensitivity of our pad system. Looking for other kinds of chips having less power consumption and size will of course be of benefit, such as the microcontroller and the DC-DC converter. Using the USB instead of MAX232 and the female adapter will reduce the size of the board, decrease the power consumption by eliminating one chip, and increase the data transmission speed to the computer. Finally, battery power is important, and charging is a central issue. We might consider harvesting additional power from the sensors' noise to power our boards and recharge a battery.

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BIOGRAPHY

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Harry Tyrer is a professor emeritus in the Electrical and Computer Engineering Department at the University of Missouri. Along with his years at MU, Tyrer's experience includes working at North Carolina Agricultural and Technical State University, Becton-Dickinson Research Center and the Cancer Research Center, as well as consultancies for McDonnell Douglas MSC and the Food and Drug Administration. His research areas are Biomedical instrumentation, Computer architecture and simulation, and Eldercare technology.