An RFID Based Activity of Daily Living for Elderly with Alzheimer's

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Abstract. With the proliferation of emerging technologies such as Internet of Things (IOT) and Radio Frequency identification (RFID), it is possible to collect massive amount of data for localization and tracking of people within commercial buildings & smart homes. In this paper we present the design, implementation and testing of an RFID system for monitoring the wandering about of an Elderly with Alzheimer's at home. The novelty of the algorithm presented lies in its simplicity to detect the motion of elderly from one room to another for monitoring activity of daily living (ADL) and sending alert in case of an onset of emergency without the need for using massive sensors. The system was tested successfully in the lab and achieved an efficiency of 88%.

Keywords: IOT · RFID · Indoor localization · RSSI · ADL

1 Introduction

Alzheimer's is one of the most common diseases among the elderly. One of its most notorious symptoms is unawareness of their location. Thus, they are usually kept under constant observation by a nurse to make sure they do not put them self into harm's way. Tracking people's movement in the home is an essential requirement in many occupant-oriented smart home applications such as elderly monitoring, activity recognition. Knowing the Elderly's room location is vital in inferring their activity of daily living (ADL)s. The aim of this project is to propose an RFID-based localization system to reduce the health and safety of patients with short-term memory loss. In the past few years, Radio frequency identification (RFID) technology related applications has become more demanded than ever. The reason is that the implementation of an RFID system has a relatively low cost compared with any other alternatives. One of the most Known RFID based applications is indoor localization which will be utilized by us. Any RFID system consists of two main components. A reader connected with an antenna and many tags with unique serial number for each. The reader is responsible of identifying any tag within a specific zone with the help of the antenna and depending on the type of the tags used. For example, passive tags will provide a limited detection range while the active tags, which has its own internal power source to keep to its RF communication circuit working on continuous manner, will provide much wider range compared with passive tags. By analyzing data obtained by the RFID system, we will

M. U. Ahmed et al. (Eds.): HealthyIoT 2017, LNICST 225, pp. 54–61, 2018.
https://doi.org/10.1007/978-3-319-76213-5_8

be able to achieve our localization system. Our basic approach is to identify the room location of each patient by monitoring the doorways between the rooms, and by utilizing RFID system to confirm the crossing process, we can determine the new room location [1–4]. In addition to that, Internet of things (IOT) has played a vital role recently particularly for healthcare. The internet of things can be described as connecting everyday objects like smart phones, internet TVs, sensors and actuators to the internet where the devices are intelligently linked together enabling new forms of communication between things and people. It is envisioned that billions of physical things or objects will be outfitted with different kind of sensors and actuators and connected to the internet via heterogeneous networks enabled by technologies such as embedded sensing, RFID and wireless sensor networks. The reliance of healthcare on IOT is increasing to improve access to care, increase the quality of care and most importantly reduce the cost of care [5, 6]. Section 2 constitutes overview of overall proposed system including RSSI scanning algorithms. Section 3 constitutes the experimental results. The novelty of the proposed system compared to existing localization & tracking systems for activity of daily living lies in the fact that it only tracks the direction of motion of the elderly from one room to another and detecting his/her inactivity without the need to employ massive sensors. For the sake of simplifying the design we assumed a home consisting of two rooms only.

2 Overview

Our indoor localization system has four main components:

1. Mat Pressure Sensor
2. Reader and Antennas
3. RFID Tags
4. Crossing Detection Algorithms

All of these components are integrated together to provide the desired system efficiency.

2.1 Layout

1. *Pressure Mat Sensors:* In order to reduce the error and enhance the system efficiency, an extra level of detection is implemented. By placing two pressure mat sensors on both sides on the doorway, we will be able to detect when someone is trying to enter or leave a specific room. In case there is an attempt to cross the door, the system will be informed and consequently the reader will be triggered to initiate the electromagnetic radiation to energize the tags and thus collecting the required data to determine the patient room location. To monitor doorway crossings, we create two RF sensing zones initiated by two separate antennas, one on each side of the doorway. See Figs. 2 and 3. By knowing which of the two sensing zones of the

doorway was crossed first, the direction of motion can be determined. To be detected by the RF doormats, the Elderly must wear passive RFID bracelets around the ankles. Ankles are always at a consistent orientation and distance from the floor when walking, thereby converting a 3D positioning problem to 2D presence/absence decision. Moreover, in order to prevent repetitive pulses generated from the pressure mat sensors when pressed, a timing circuit is connecting the sensors to the reader's general purpose input/output (GPIO). The timing circuit utilizes 555 Timer IC to produce a constant output DC voltage of 1–15 V for about 20 s, and it will remain constant even if the mat is pressed again during the 20 s (See Fig. 1).

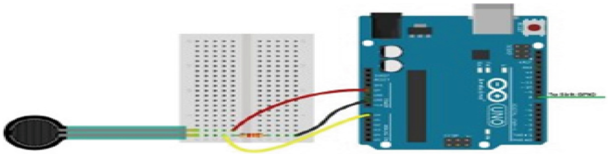

Fig. 1. Hardware layout

2. *Reader and Antennas:* An UHF (ultra-high frequency) frequency range is used for two Antennas with specific configurations controlled by a Sirit reader. The antennas are used to create two separated sensing zones, one of the zones should cover one side of the doorway, the other one will cover the other side, and both of them will overlap at the doorway (see Fig. 2). Both antennas work in the frequency range of 865–870 MHz. the coverage area of each zone are as shown above and has the following measures:
   - Width of the zone greater ranges from 0.5 to 0.7 m.
   - Length of the zone greater than width of doorway.

   Coverage area is controlled by changing the conducted power to antenna and thus, the power generated by the backscattering signal will vary resulting in different readings. See Fig. 2.
3. *RFID Tags:* The major requirements in the tags that are needed in our indoor localization system are to be user friendly, to have reasonable cost and efficiency. These requirements have led us to utilize passive RFID tag attached to an ankle bracelet. The tags used should be compatible with the UHF antennas mentioned above.

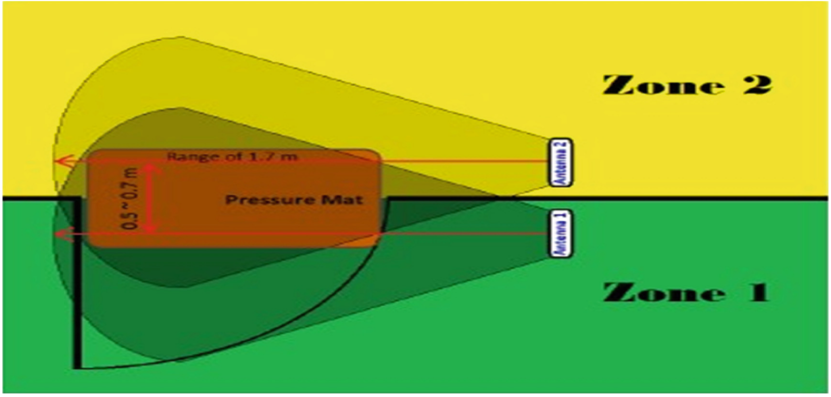

Fig. 2. Layout of the zone based RFID tracking of the elderly through doorway.

2.2 Algorithm

To detect precisely when an Elderly crosses a doorway, the anklet readings are processed by converting the anklet readings (RSSI) into clusters of possible doorway crossing events. A doorway crossing is detected if there are consecutive sets of readings from both of the detection zones of a doorway. The scan algorithm groups the raw RFID data from the sensing zones in each doorway into clusters based on their timestamp. See Fig. 4. There are three parts of the algorithm that composes the system; they are, in chronological order:

1. *Initiating the scan:* The event listener will listen for an event from the reader (when the elderly steps on the Matt situated in the doorway, and connected to Arduino microcontroller). Based on this, the program will retrieve the registered tags from Patient Database and will initialize two kind of array: the first array (i.e. TagAvg) will be used to register Received Signal Strength Indicator (RSSI) for each tag per antenna during the scan period.
2. *Determining the location of the tag (patient):* A thread will wait for scan from the reader (the reader will generate scan_complete_event when it's finished scanning). Then, the program will calculate the average RSSI reading per tag based on the values from first array (i.e. TagAvg). If the obtained average of RSSI for the tag is not equal to zero, it will be added to the second array (i.e. taglog). Initially, a DBscane filter on MatLab was used, but its results proved to be inefficient because the filter extremely smoothed the differences between subsequent RSSI readings of both antennas, which made the timestamps of the strongest readings of both antennas almost the same, thus it couldn't determine which antenna read its max RSSI first. Thus, it was replaced with a simple max filter on java that proved to be much more efficient, this most likely due the setup being efficient and producing already smooth and distinct reading. See Fig. 6 for Java code for reading RSSI.

3. *Filtering the tag reads:* The program will wait for the reader to report tag readings. If the reader reads a tag, the program will take the tag readings and compare it with the registered tags. If the tag is registered in the system, the program will add the antenna number and RSSI value to the first array (i.e. tagAvg). Otherwise, ignore the tag. See Fig. 5.

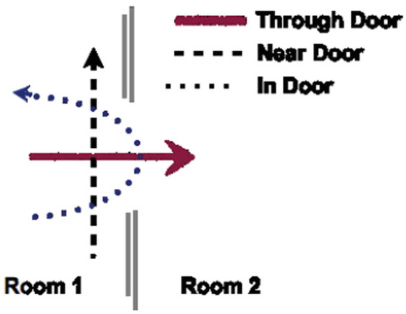

Fig. 3. RF sensing zones on both sides of doorway to determine direction of motion of elderly

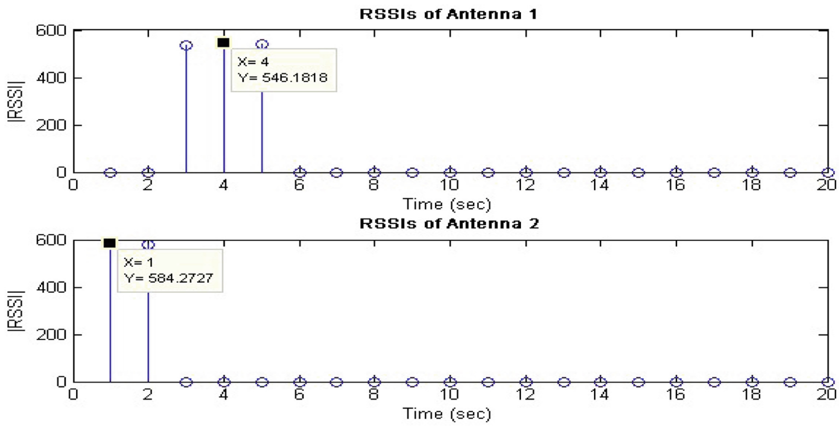

Fig. 4. Temporally sequenced raw data stream of RSSI data reads in 20 s frame from both sides of the doorway

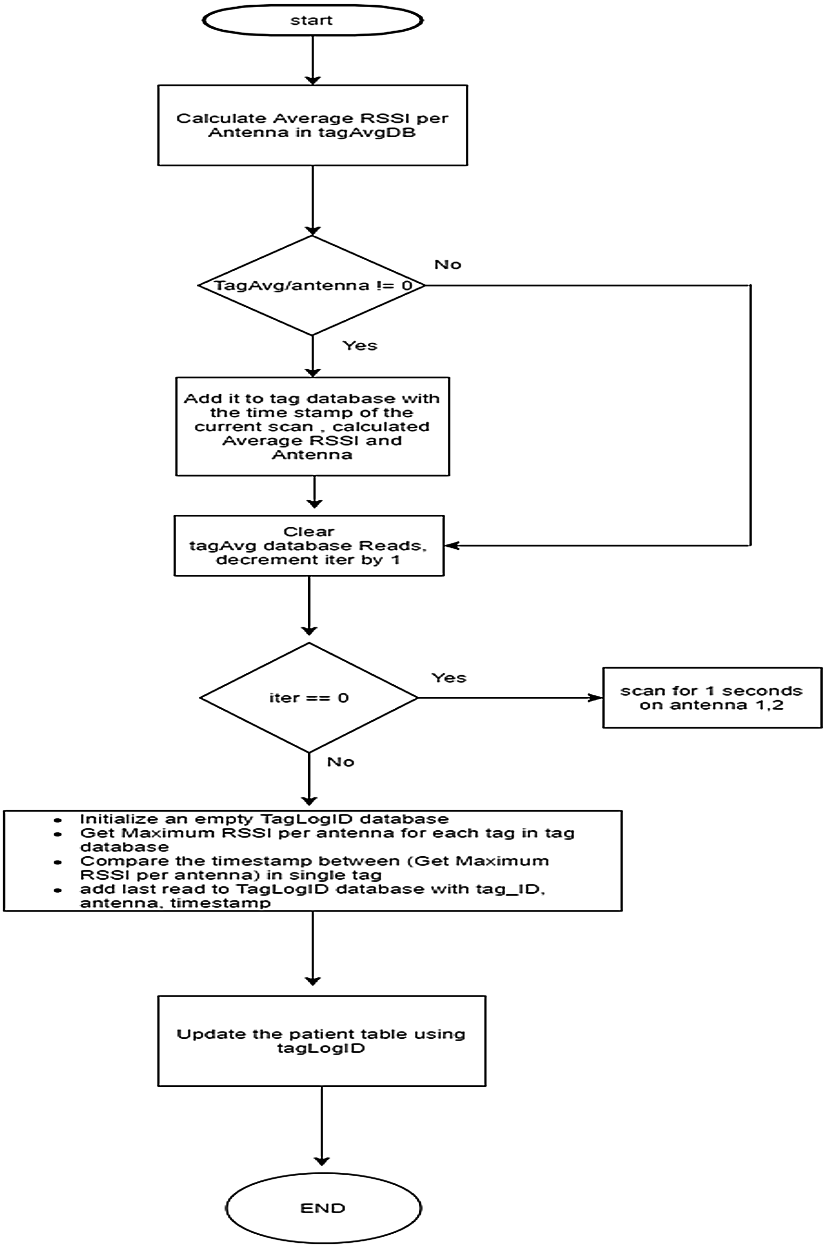

Fig. 5. RFID tag Scan & RSSI filtering Algorithm.

```
import java.time.Instant;
/*************
*→TagLog will contain the time stamp and RSSI reading

public class TagLog {
    /** time stamp **/
    private Instant time;
    /** RSSI reading **/
    private double RSSI;

     **Construct TagLog with RSSI and time stamp
   *→@param RSSI RSSI value
   *→@param time the time stamp of the reading
     */
  public   TagLog(double   RSSI,   Instant
      time){ this.RSSI = RSSI;
        this.time = time;
   *→@param RSSI RSSI value
   *→@param time the time stamp of the reading
     */
    public TagLog(String RSSI, String time){
        new TagLog(Integer.parseInt(RSSI),Instant.parse(time));
   *→return the RSSI value of the tag
   *→@return RSSI value of tagLog
     */
    public double getRSSI(){
        return RSSI;
    }
   *→return the time stamp of the taglog
*  →
   *→@return the time stamp
    public Instant getTime(){
        return time;
    }

    public String toString(){
      return("RSSI = " +RSSI+", time = "+ time);
    }
```

Fig. 6. Tag log Java code for reading RSSI

3 Experimental Results

3.1 Methodology

Experimental testing was conducted by having different group members walk through a lab door in different walking patterns. Two antennas were placed on both sides of the lab door each at around 1.5 m from the nearer edge of the door, their conducted power was varied until their range extended just to the farther edge of the door, placing the farthest point of the range at around 2.5 m as the antennas were placed on the ground at a right angle and 1 m away from each other. The antennas were also separated by two layers of aluminum foil in order to avoid interference (see Fig. 2). As soon as the Sirit RFID reader was initiated, it would scan 40 times for the duration of 20 s (2 scans/s).

3.2 Results

The system was tested in the RFID lab of King Fahd University of Petroleum and Minerals, and achieved an overall efficiency of 88% after 68 trials; about 50% of the failed trials were due to body shadowing (the tag was too close to the skin or was on the farther side of the farther leg from the antennas), 37.5% was due to hesitant walking patterns (going back and forth between the two zones several times during the scanning period), and 12.5% was due to setup errors (an antenna displaced or conducted power not adjusted). The *Patient checker, part of the algorithm, is* responsible for checking a patient's residence duration in designated rooms and sending an email notification about any abnormalities of the patient's behavior. For example, (e.g. staying in the restroom for more than an hour).

4 Conclusions

Alzheimer's disease is not just a burden to the patients but also to their family and care givers, Alzheimer's patients need special care twenty-four hours a day. Thus, an indoor localization system comes to the advantage of Alzheimer's patients in ensuring their safety and to advantage of their care taker in convenience. This paper demonstrated that an RFID-based indoor localization system is highly appropriate for guaranteeing the safety of Alzheimer's patients without invading their privacy. Furthermore, the system showed promising results and could easily implement and replicated and doesn't require high level maintenance. Limitation due to body shadowing could be avoided in the future using custom made RFID tags.

Acknowledgment. The authors would like to thank King Fahd University for the support of this project.

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