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# Daily Life Activities Recognition Using RFID to Save Energy

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**Abstract**

Energy demand for household appliances in smart homes is nowadays becoming a serious challenge, due to economic and environmental reasons. Effective automated approaches must therefore take into account basic information about users, such as the prediction of their daily activities. User activity and behavior is considered as a key element and has long been used for control of various devices such as artificial light, heating, and air conditioning. Our approach aims at recognizing daily living activities of residents inside the home by simply relying on the analysis of environmental sensory data to minimize peak of energy consumption and thereby guaranteeing that maximum demands do not exceed a given threshold.

***Keywords:*** Activity Recognition; Sensor; Automation; RFID; Arduino; Energy Management; Intelligent Building

## 1. Introduction

Energy consumption in the home increases as more home appliances are installed. Energy demand of appliances in smart homes is nowadays becoming a severe challenge due to economic and environmental reasons, and effective automated approaches must take into account basic information about the residents such as their daily living activities. The activities of daily living have a considerable impact on the amount of energy consumed in all kinds of building [1]. Recognizing residents' daily living activities is an important subject, and has been addressed by many research groups using different types of physical devices and reasoning techniques [2, 3]. The recognition of activities of daily living implies the ability to recognize a resident's current activity based on information from various sources such as cameras and physiological and RFID sensors. Monitoring activities of daily living such as sleeping, cooking and eating can help to gather various context information such as long-term plans, regular routines for daily living [4] and personal preferences to guide the applications to be intelligent and behave adaptively toward the benefits of the residents.

Recognition of daily living activities bridges the gap between various context-aware applications and intelligent ambient sensors. Recognizing resident's daily living activities has aroused a great interest in the past decade. The first work done in human activity recognition (HAR) dates back to the late 90's [5]. Nowadays, much work is being done in activity recognition, most of it dependent on the use of wearable sensors which capture physical activity signals from the body, such as acceleration and angular velocity, or using different types of cameras installed inside the residence based on the events to be recognized. Using video cameras in daily living activities recognition is considered the most accurate approach, but at the same time it is obtrusive and intrusive to people's privacy. Nowadays, recent studies show the potential of using RFID radio information instead of video cameras for activity recognition. This approach has the advantages of being low cost and having high reliability.

In [6], the authors proposed a method to recognize a resident's daily living activities based on using accelerometers and RFID sensors. The accelerometers sensors are attached to resident's body to detect their motion and five other cases of body states. Meanwhile, RFID sensors are used to detect human–object interaction since these objects are attached with RFID tags. The RFID-tagged objects are detected by the glove that integrates the HF RFID reader of 13.56 MHz.

In [7], the authors proposed a simple sensory approach that uses RFID sensor network technology to recognize indoor daily living activities. The approach was based on using 3 UHF RFID readers and 25 WISPs (Wireless Identification and Sensing Platforms), which is a family of sensors that operate in the Ultra High Frequency (UHF) bands and read by UHF RFID readers. Each one of everyday objects are tagged with WISPs to detect when they are in use.

Based on the above, the mentioned studies have presented a set of approaches to recognize the resident's daily living activities, but have neglected to mention who carried out these activities. Without determining this, we will not arrive at a context-aware system able to manage the working of all household appliances depending on their regular usage by each one of the residents and their preferences.

In this paper, we developed a simpler approach that can represent activities over a range of timescales, from long-term (i.e., hours) to short-term (i.e., minutes) and relating each one of these activities to who was performing it. The system was based on using passive RFID tags. These tags are smaller and more cost-effective, and also there is no need to wear or attach it to the resident's body to recognize the activities in real-time.

This paper is organized as follows. Section 2 describes the design of our developed system; section 3 describes the implementation of the system and section 4 outlines the experimental framework used to evaluate the performance of our system. Finally, Section 5 presents our conclusions.

## 2. System design

The system is composed of five main parts: ACS712-20A current sensor; a DFRobot relay module RFID-RC522 reader module; an Arduino UNO, and an intelligent processor application. In the design, each one of the kitchen appliances will attach to a current sensor and relay module as shown in Figure 2.

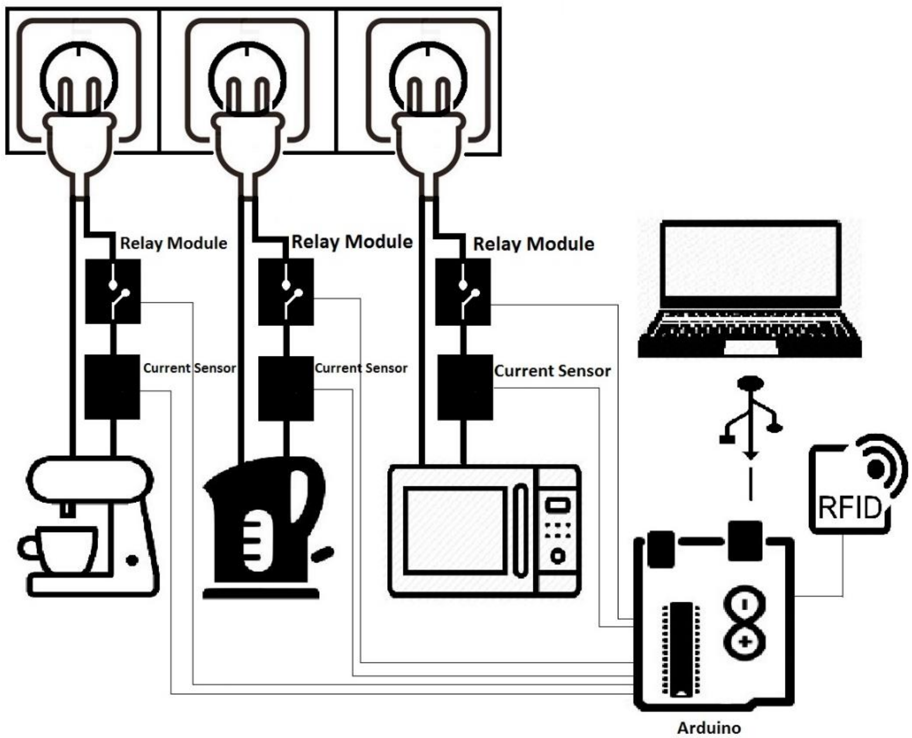



Fig. 1. System architecture

### *2.1. Hardware architecture*

- ACS712 current sensor provides economical and precise solutions for AC or DC sensing in industrial, commercial, and communications systems [8]. The main two functions of the sensor in the system are detecting the electrical current that flows through the wire, then measuring the consumption.

- DFRobot relay module is a standard relay module used with a controller board to interface external electrical circuits or modules [9]. In the system, the relay module will have the responsibility to switch the appliances either off or on.

- RFID-RC522 reader module is a highly integrated reader/writer IC for contactless communication at 13.56 MHz [10]. The purpose of using the RFID reader module is to identify the users of the system.

- Arduino UNO is a microcontroller board based on the ATmega328P [11]. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It is powered either with an AC-to-DC adapter or battery. The Arduino will be responsible for managing all the functions of the sensors, and also receives all the sensory data that come from the sensors, and then passes it to the laptop via USB port.

### *2.2. Software Architecture*

The intelligent processor application is composed of two parts as shown in Figure 2. The first part will be installed on Arduino, which will receive the raw data from sensors and convert it into useful information. The 'Rule Processing' part will be responsible for running the present rule, while the 'Rule Manager's' reponsibilty is to update the present rule. The 'Communicating Manager' will be resposible for relaying the information to and from the 'Second Part' which will be installed on the laptop. In this part, the 'Data Manager' will receive the information from the 'Communicating Manager', and then store it. The 'Learn' part - learning from the stored information, and then depending on what is "learnt"- builds the "New Rule" that will be sent back to the Arduino.

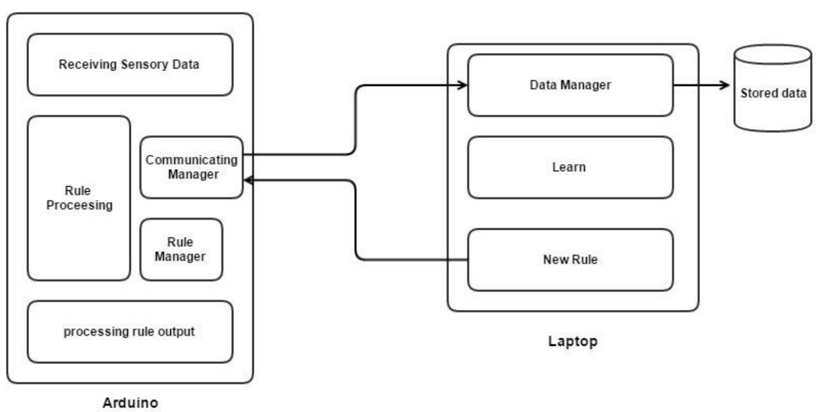



Fig. 2. Software Architecture

### 3. System Implementation

We propose a daily living activities recognition system based on analyzing the information that is obtained from the current sensors and RFID tags, and then generate dynamics rules that manage the work of kitchen appliances. The information obtained represents the resident's behavior patterns while performing their regular daily living activities inside the kitchen. These patterns specify the daily habits of kitchen appliance usage for each one of the residents. The analyzing process uses this information to extract the preferences for each resident. These preferences represent the rules, and according to them, the system will manage the work of the kitchen appliances. The rules will be dynamic, which means they will change if the residents change their daily living habits. Figure 3 describes the system implementation.

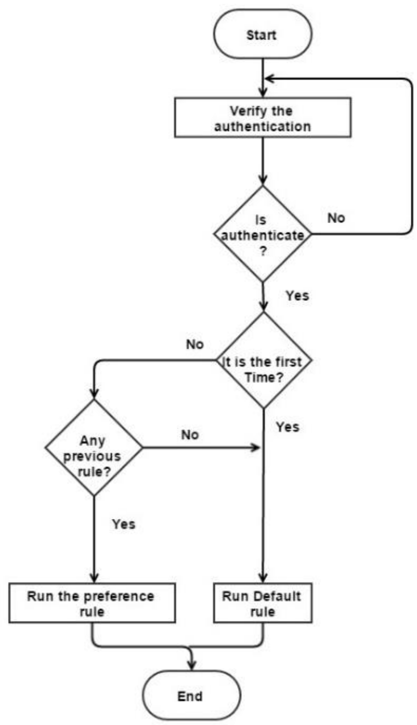



Fig. 3. System implementation

In the implementation, the system will set the initial state of all the relay modules to "open", which means, no electricity current will flow through the current sensors. Thus, an inability to use any of the kitchen appliances will ensure that the process of data acquisition is performed accurately. The switching process of the relay modules from "open" to "closed" will depend on authenticating the identity of the resident.

The RFID reader will verify the authentication of the RFID tag. To enable this, residents should first pass their RFID tag over the RFID reader when they want to use any of the kitchen appliances. Thus, each one of the residents will need to have an authenticated RFID tag by which to be identified by name. In an unauthenticated case, the system will let the relay modules continue in their previous state.

In an authenticated case, the system will firstly check if it is the first time that the resident has used the system or not. Then, if it is the first time, the system will run the default rule, which will change the state of all the relay modules to "closed". Subsequently, depending on the sensory data that comes from the current sensor, the system can determine which of the kitchen appliances are turned on and which are not. For the appliances that are not being operated, the system will change the state of their relay module again to "open". The resident's name and the information regarding operated appliances will then be related and stored together. When this activity is repeated by the same resident at the same time the system will have enough information about the resident and its related activities to build a specific rule for him that will be implemented automatically the next time.

In the case that the system has a specific rule for the resident, it has associated the name of the resident and error time with the activity. On that basis, the implemented rule will specify which relay modules should change their state, and also determine the duration of work for each one of them. If the resident wants to change the implemented rule, the resident should pass the RFID tag again over the RFID reader. In this case the system will rest and turn back to run the default rule. This modification will not be considered as an update to the rule until it's repeated.

**4. Demonstration Setting and Discussion**

The demo system setting is shown in Figure 2. In our laboratory experiment, two daily living activities that take place regularly in the kitchen were chosen to evaluate the system: making coffee using a coffee maker and heating water by using an electric kettle.

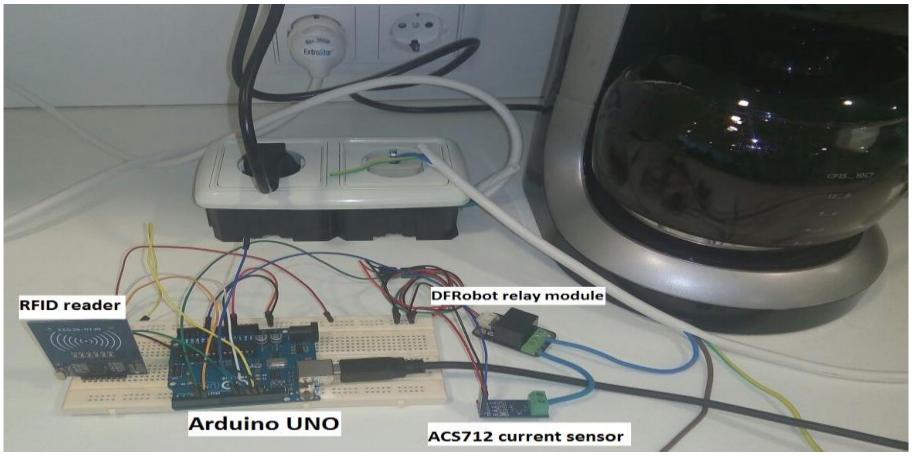
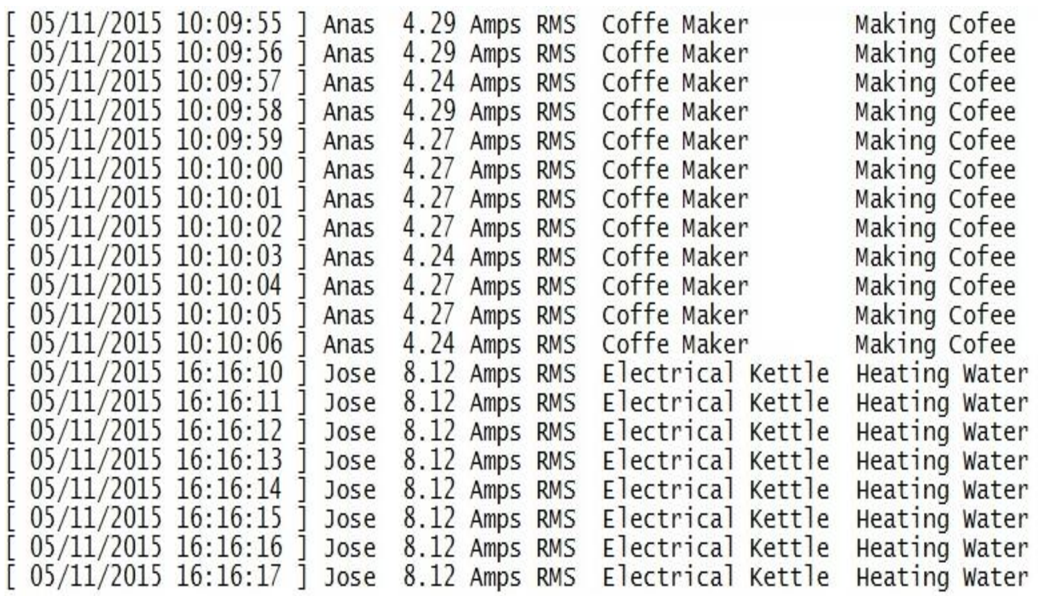



Fig. 2. Demonstration Setting up

All parts of the system were installed according to the previously mentioned system design, and both the coffee maker and electric kettle were attached to a relay module and current sensor. All the current sensors, relay modules, and the RFID reader was connected to the Arduino. The Arduino was connected to the laptop via USB port to send all sensory data to the intelligent processor application. Figure 3 presents a snapshot of the final result after we ran the experiment.



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[ 05/11/2015 10:09:55 ] Anas  4.29 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:09:56 ] Anas  4.29 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:09:57 ] Anas  4.24 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:09:58 ] Anas  4.29 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:09:59 ] Anas  4.27 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:10:00 ] Anas  4.27 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:10:01 ] Anas  4.27 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:10:02 ] Anas  4.27 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:10:03 ] Anas  4.24 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:10:04 ] Anas  4.27 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:10:05 ] Anas  4.27 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 10:10:06 ] Anas  4.24 Amps RMS  Coffe Maker        Making Cofee
[ 05/11/2015 16:16:10 ] Jose  8.12 Amps RMS  Electrical Kettle  Heating Water
[ 05/11/2015 16:16:11 ] Jose  8.12 Amps RMS  Electrical Kettle  Heating Water
[ 05/11/2015 16:16:12 ] Jose  8.12 Amps RMS  Electrical Kettle  Heating Water
[ 05/11/2015 16:16:13 ] Jose  8.12 Amps RMS  Electrical Kettle  Heating Water
[ 05/11/2015 16:16:14 ] Jose  8.12 Amps RMS  Electrical Kettle  Heating Water
[ 05/11/2015 16:16:15 ] Jose  8.12 Amps RMS  Electrical Kettle  Heating Water
[ 05/11/2015 16:16:16 ] Jose  8.12 Amps RMS  Electrical Kettle  Heating Water
[ 05/11/2015 16:16:17 ] Jose  8.12 Amps RMS  Electrical Kettle  Heating Water
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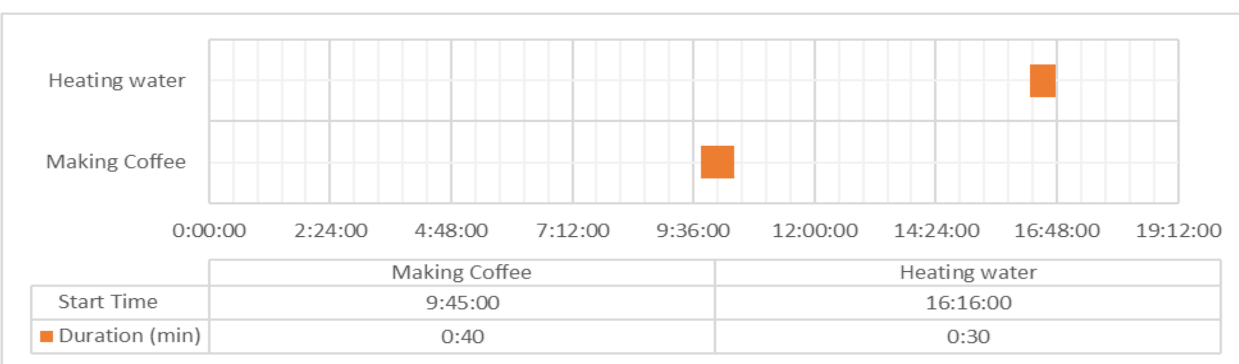
Fig. 3. Snapshot of final result

As is shown in Figure 3, the snapshot of the final result presents all the details related to the activity of making coffee and heating water as follows: the date, the start and end times of the activity, who performed the activity, the amount of consumption for each activity, the appliance used and finally the activity name. Figure 4 presents the time scheduling for the two activities; it shows the beginning and duration of each activity.




| | Making Coffee | Heating water |
|---|---|---|
| Start Time | 9:45:00 | 16:16:00 |
| Duration (min) | 0:40 | 0:30 |

Fig. 4. Scheduling activities time

Figure 5. Shows the amount of consumption for the coffee maker and electric kettle during their performing the activity.

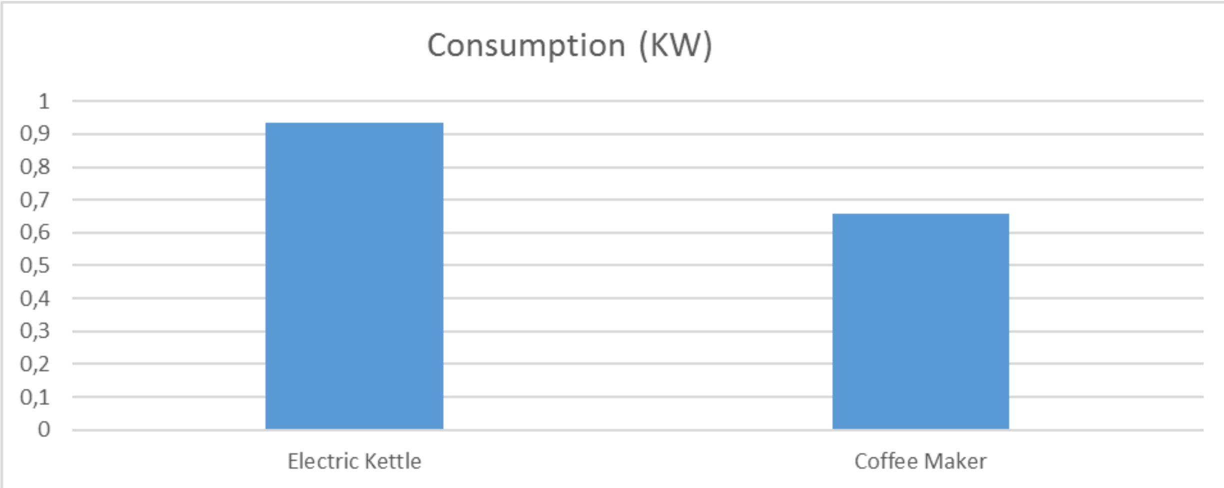



Fig. 5. The consumption in kilowatt

As is shown the above figures, the results highlight the efficiency of the system design. Before the adoption of the design in Figure 1, there had been two other proposed designs, the first one would have reduced the number of current sensors, by using one current sensor for all kitchen appliances, it would have been placed at the main electrical power line in the kitchen instead of attached to each one of the kitchen appliances. The deficiency in this design was in the difficulty to specify how much each one of the kitchen appliances consumed independently, since in using only one current sensor, it would only have provided the total amount of consumption for all kitchen appliances.

Therefore, to obtain the detailed consumption, separate calculations based on information previously unknown would need to have been carried out in order to arrive at the consumption rate for each one of the kitchen appliances

We found this design would have made the system not flexible enough to apply in deferent houses because each kitchen has different appliances than others, which would have made it necessary to calculate the consumption independently for each kitchen appliance before we installed the system.

The second one was dependent on attaching each one of the kitchen appliances with a current sensor, and using just one relay module at the main electrical power line in the kitchen. The relay module would have been responsible for switching the electrical power line either on or off, which would have entailed the ability to use either all of the kitchen appliances or none of them. The deficiency in this design was the inability of the system to schedule the various kitchen appliances for operation during different time intervals.

Comparing the design mentioned in Figure 1 with the other two possible system designs, we found this design to be more efficient than the others. The advantages of attaching each one of the kitchen appliances with a current sensor and relay module is that the current sensor gives the ability to know how much each one of the kitchen appliances will consume as shown in Figure 5, while the relay module gives the ability to schedule the various kitchen appliances shown in Figure 4 for operation during different time intervals.

The benefits of using RFID technology will contribute to creating a profile of activities for each resident, and these profiles will facilitate the formation of a general perception of resident preference profiles, which will help us later to build a context-aware system.

## 5. Conclusion

Daily living activities have a considerable impact on the amount of energy consumed in all kinds of building. This paper proposes a daily living activities recognition system to minimize peak of energy consumption, using 1) sensory technologies consisting of current sensors and a relay module, 2) RFID technology and 3) intelligent processor applications for data processing. In the present work, we develop a simpler approach that can represent activities over a range of timescales, from long-term (i.e., hours) to short-term (i.e., minutes) and relating each one of these activities with who was performing it. We described how the system parts would be installed and also the implementation process. Furthermore, to verify the effort, this paper also includes testing and simulation results that show the validity of the hardware design of the system. The hardware design makes the system fit to houses regardless of its size or number of appliances. On the other hand, the benefits of using RFID technology will guarantee the privacy, since using video cameras in daily living activities recognition is obtrusive and intrusive to people's privacy. Our future work will focus on how to make the system learn from the stored information, so that, depending on this "learning", the system will have the ability to generate dynamic rules that send back to Arduino in an easy way.

**6. References**

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