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Customizable Smart Food Cabinet and Refrigerator

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ABSTRACT

This smart appliances project is intended to create home appliances which are able interconnect one another and share data to provide convenient and comfortable environment to users. For this project, we successfully developed a smart food cabinet with the abilities to perform several things such as giving information about the items stored within the smart food cabinet to its users via a mobile application. By using the information, the users contact the store to order the items needed. The food cabinet takes the data from the smart cabinet about the items and combine them to its own data to give information about recipes selection according to the availability of the items in both smart food cabinet and refrigerator. The system is built based on Arduino and Raspberry Pi, and the results shows that the recipes displayed in the LCD are according the availability of the items. The information can be accessed via Android based application in a smartphone.

Keywords: Data sharing, smart appliances, smart cabinet, smart home, smart refrigerator

INTRODUCTION

In 2016, the Computer Engineering Department of Bina Nusantara University and Research Interest Group of Photonics and Computer Systems were assigned to develop a smart home appliances project. Two or more of the appliances should be able to interconnect to one another for data sharing and give valuable information to users which finally can support the users to live healthier, more comfortable, and feel secure with his/her home environment, especially for disability or elderly (Skubic et al., 2009). Figure 1 shows the research roadmap for this research, and the first project has already been accomplished by developing a smart refrigerator which has the ability to inform

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its items stored therein, to order items needed via mobile application, and to display some recipes according to available items (Pratama et al., 2018). Therefore, we carry on the project by developing a smart food cabinet with similar abilities, but it can take data from the smart refrigerator to combine the data and to give better recipes selection to the users according to the availability of the items in both stored appliances.

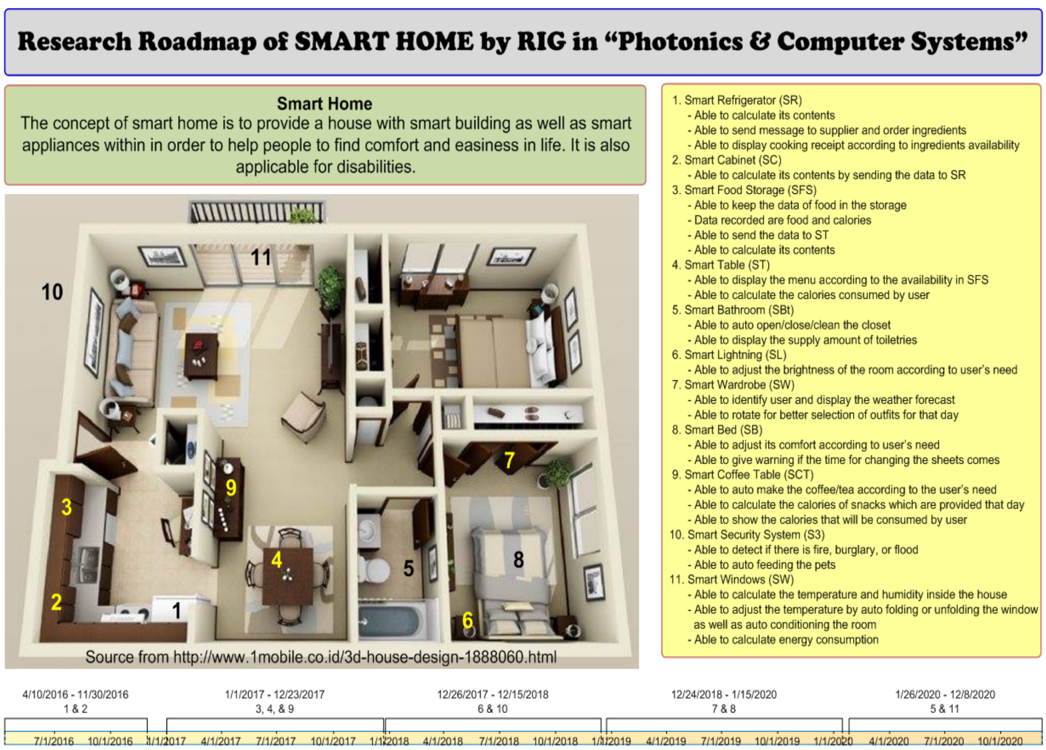


Figure 1. Research roadmap of "Smart Home"

The concept of smart cabinet we study, is basically for smart medicine cabinet (Wan, 1999; McLaughlin, 1973; Balasingam, 2011; Lanka, 2008; Jiang & Xu, 2014; Rejoyce et al., 2016; Calabretto et al., 2001) in which one of them was built with online system through the Internet (Wan, 2003), and some were equipped with antenna arrays which were used for real-time inventory monitoring (Boryssenko & Boryssenko, 2011). The other model of smart cabinet was for storing food in the kitchen by using camera for monitoring the inside of the cabinet (Logan, 2006). Besides the cabinet, a smart tray with a tag system was also developed in order to help user in arranging items inside the cabinet (Vaseloff, 2006; Handfield, 2006). The smart kitchen cabinet which had been developed, had its limitation in which the RFID connection inside the cabinet was not all stable and the accuracy of the load cell needed further improvement for better sensitivity (Amutha et al., 2012).

The smart food cabinet we develop in this paper is based on the previous experiment by Higgins et al. (2014 & 2017) but with several modifications. One of its modification is that it can take data of items stored within the smart refrigerator and combine the data, and display cooking recipes according to the items stored in both the smart food cabinet and the refrigerator. Moreover, the information about items' availability can be accessed via a smartphone by the user or the user and by having the information, the user can order the items from the stores through the mobile application. However, the information about calories and expired date have not been included in this design. In the next project, we plan to develop a smart table which is equipped with the information about calories which can be transferred to the smart table from the smart food cabinet.

The main purpose of this research is to build smart modules that can be customized according to user's needs and installed in the current refrigerator or then the users' food cabinet. Therefore, in the first design, the user determines the items stored both in the food cabinet and the refrigerator as needed. The smart modules can be customized easily and placed in the food cabinet and the refrigerator so that function of the refrigerator is better than the regular ones.

METHODS

Experimental Setup

The diagram block of the system is drawn in Figure 2. The system used load cell (Muller et al., 2010) as the weight sensor to determine the weight of each items. The items stored in the cabinet were sugar, potatoes, onions, salt, pepper, turmeric, cooking oil, and flour while the items stored in the refrigerator were eggs, carton milk, carrots, and tomatoes. The sensors used in the refrigerator were ultrasonic (Sigfusson et al., 2004) sensors, and switches which were placed in the compartment according to its items stored. Actually, the module could be customized according to the user's needs. The number of compartments or shelves installed or used as the saver could be added or reduced from the specific design and the purposes also could be changed according to users. The specification in this research is the minimum requirements.

In this paper, we focus more on the smart food cabinet since the smart refrigerator is discussed in different paper. As seen in Figure 2, the loadcell data is sent and processed in Arduino and the result is sent directly to Raspberry Pi to be combined with the data from the smart refrigerator. The combined data is processed into information about the availability and the weight measured for each item. The information can be seen via both Android based smart phone and LCD. The users can order the items from the stores by sending short messages (SMS) or WhatsApp (WA) application. Instead of information of the available items, the smart food cabinet shows the recipes according to the combined available items from both smart refrigerator can be accessed only from LCD temporarily.

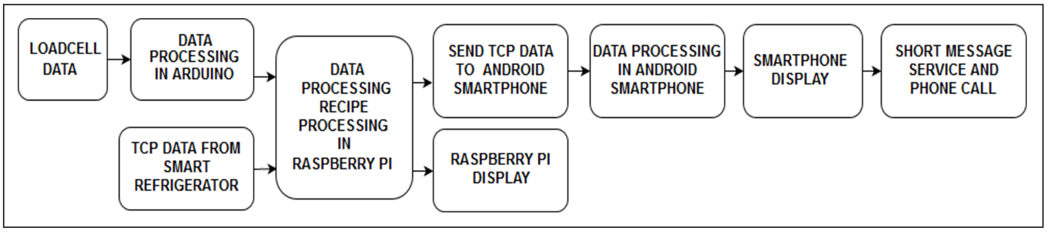


Figure 2. Diagram block of the system

The topology used in this experiment is not using public internet protocol (IP) as we can see in Figure 3. The interconnection is among a smart refrigerator, a smart food cabinet, and an Android based smartphone while the local interconnection is between a smart refrigerator and a smart food cabinet. Inside the Wi-Fi router, there is also a VPN interconnection to the internet server which functions as an alternate connection between the one with and without public IP. The smartphone receives and transmits the data from the server as an intermediate.

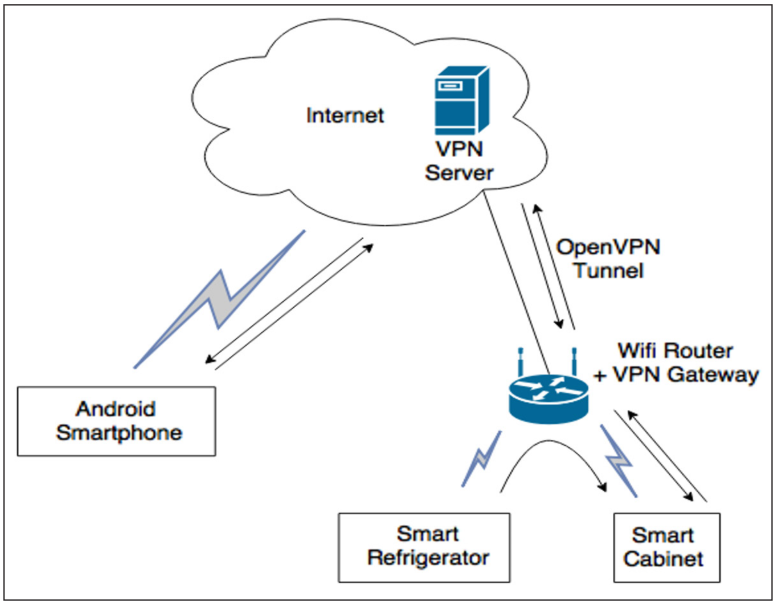


Figure 3. The topology that is used without public IP accessed

Figure 4 shows the flowchart of the whole system. In the beginning, the program initializes all necessary variables then it continues by running three threads; the transmission control protocol (TCP) thread, the serial communication, and the recipe database. The program finishes whenever an exit button is pressed.

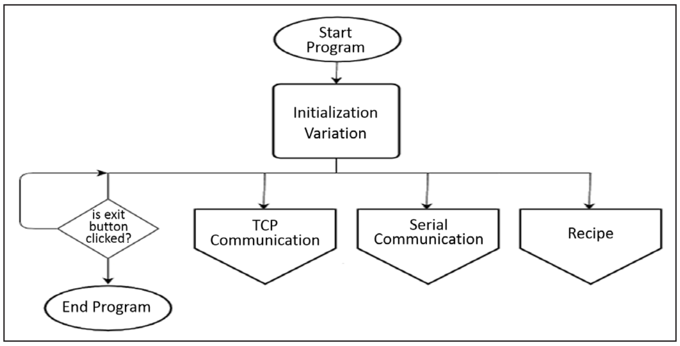


Figure 4. Main flowchart diagram

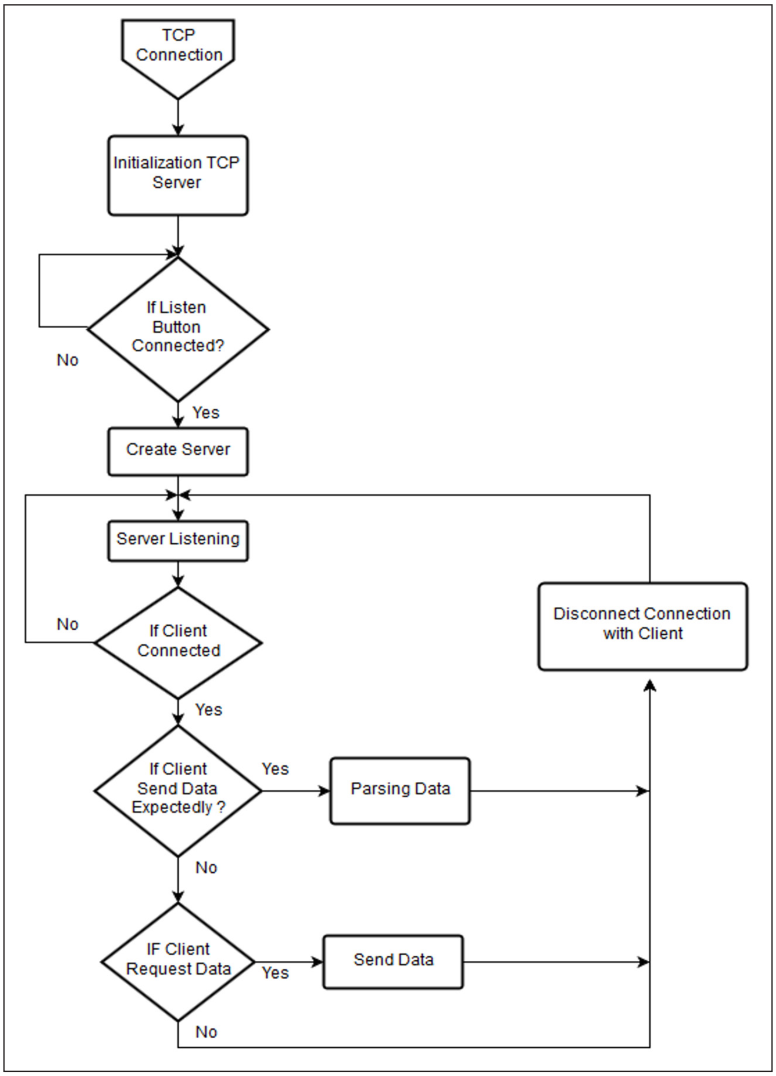


Figure 5. TCP communication flowchart

It can be seen in Figure 5 that TCP communication threat is initializing the listen push button and when it is pushed, it creates a server and waits until all clients send the data. If the data are on the right format, they are transferred to the variables otherwise they are removed. The information of the items' availability is sent to the clients whenever there is a request. This process is a looping process and it always checks the client from time to time.

In serial communication thread, shown in Figure 6, the first step is deleting all data in the internal serial port of Raspberry Pi then this action is followed by checking the refresh port button until it is pushed to refresh the serial port inside the combo box. The crucial

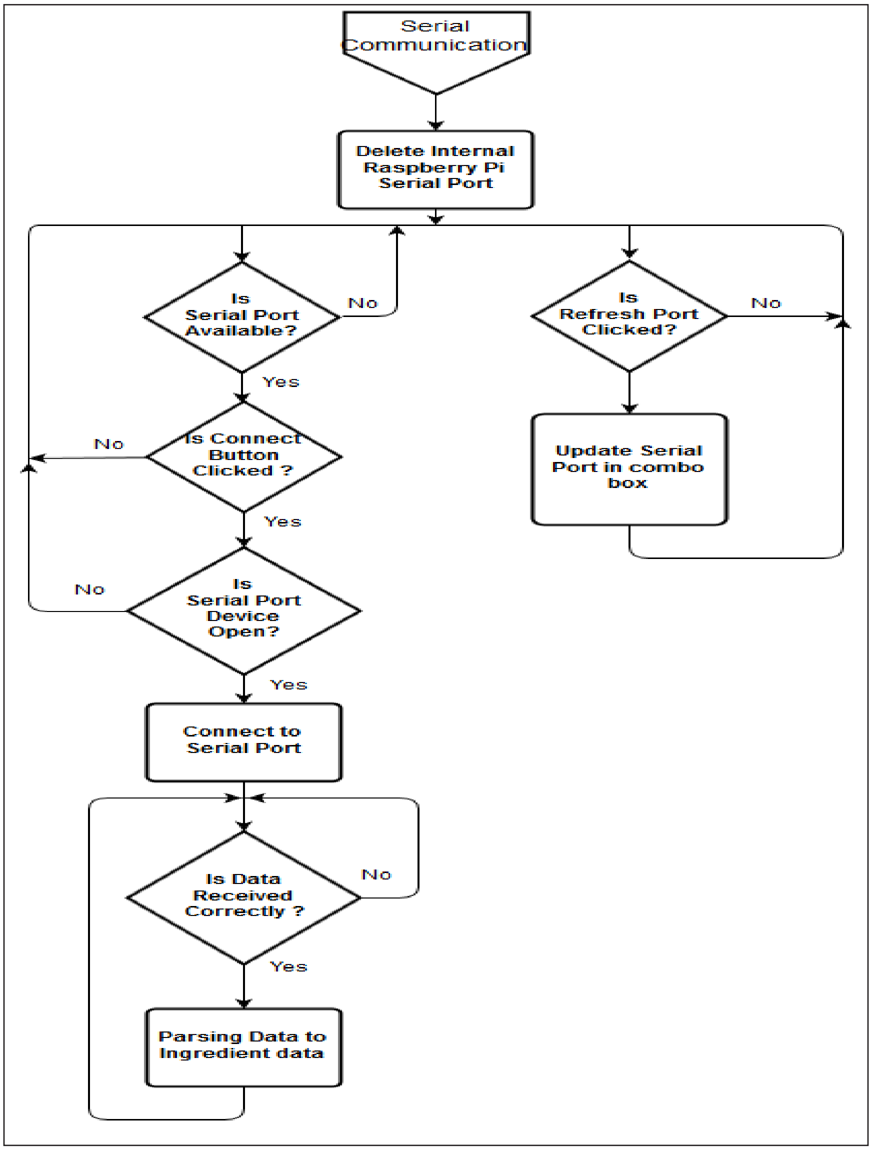


Figure 6. Serial communication flowchart

process is checking the format of the data which later on is compared with the acceptable format. These data are used for providing the correct recipes according to the availability of the items in both smart refrigerator and smart food cabinet.

The detailed flowchart of how recipes can be selected and displayed in the LCD according to the available items in both smart refrigerator and food cabinet can be seen in Figure 7. In this thread, the program initializes variables used in recipe database and separates them in the form of table which can be accessed via graphic user interface (GUI). The selection includes "save", "add", and "refresh". Each selection does the process according to its name where "save" for saving the recipe in the database, "add" for adding the recipe in the table and after 'add', it should be followed with "save" for saving it in the database. "Refresh" is for refreshing the display. The additional "edit" and "delete" selections are also used for editing and deleting the recipes.

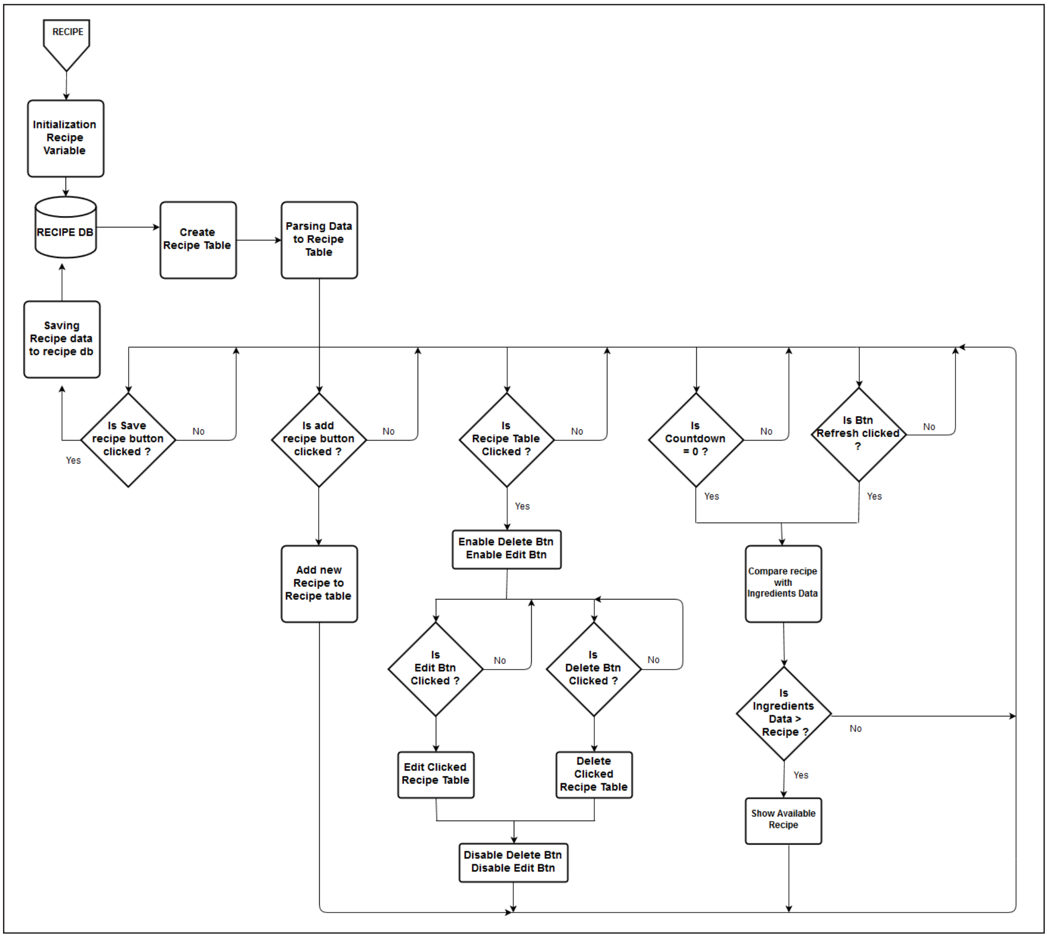


Figure 7. Flowchart of database of recipe

Figure 8 shows the flowchart of Android application for the smart food cabinet. This flowchart shows that initialization of the program is by refreshing all variables. Android sends the request to IP to detect both local network and the Internet. The data sent via IP is displayed in the smartphone and LCD as shown in e Figure 9. Users can see the items availability both in the smart refrigerator and food cabinet from the smartphone and can select the media for sending messages to the desired store for ordering the items. Users can use SMS, WA, or direct call via phone the store for ordering the items. While in LCD, users can see the recipe selection and items availability at the same time. However, the process of ordering items should be via a smartphone and should not be from the LCD. It can be seen in Figure 9, the first column shows the selected recipes according to the availability of the items. The recipe is seen in the second and third column while the last one shows the availability of the items.

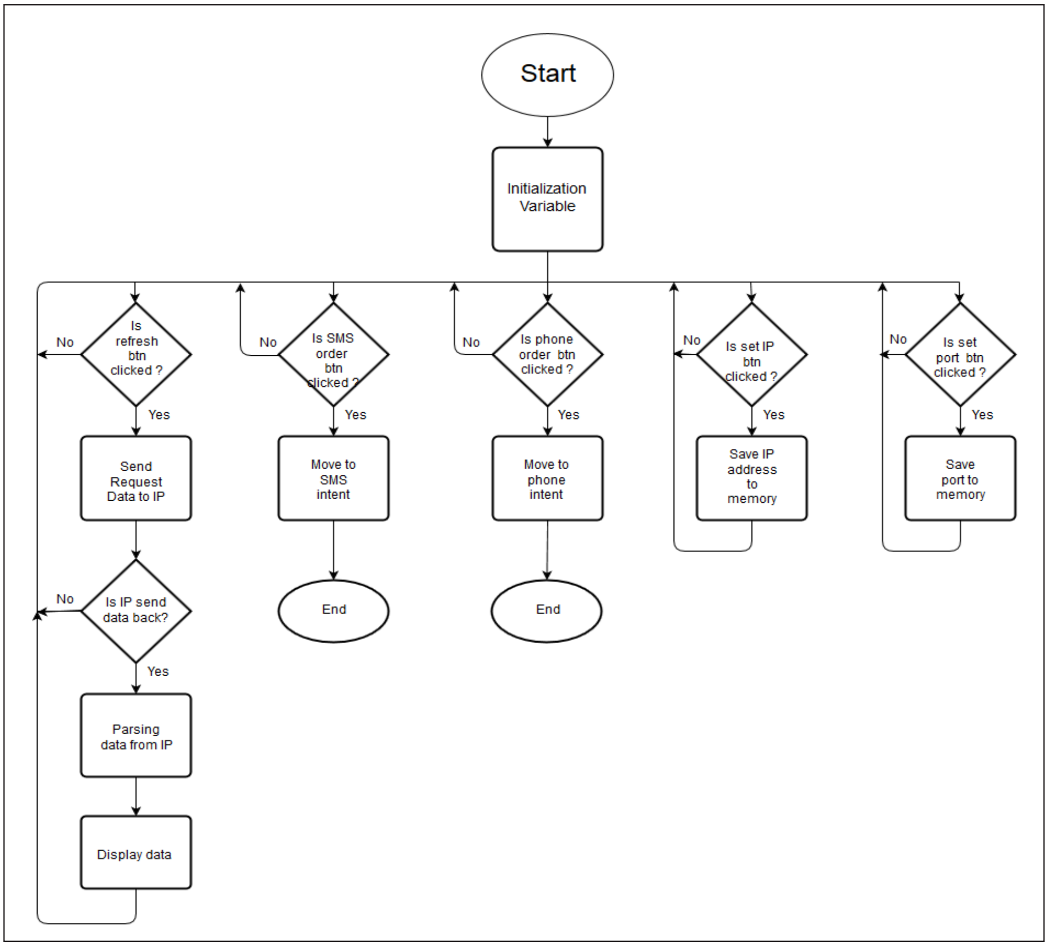


Figure 8. Flowchart of Android application in the smartphone

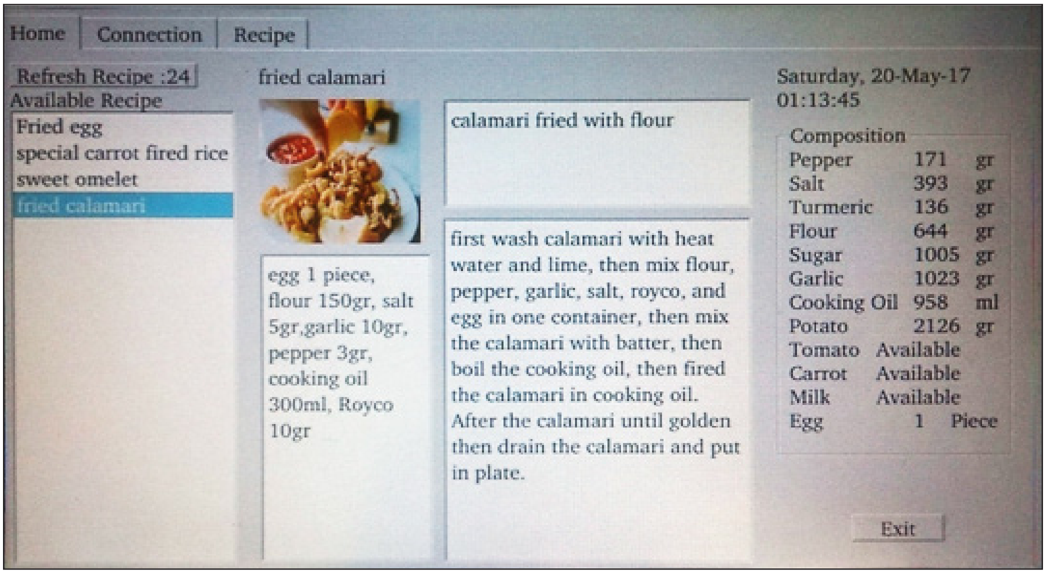
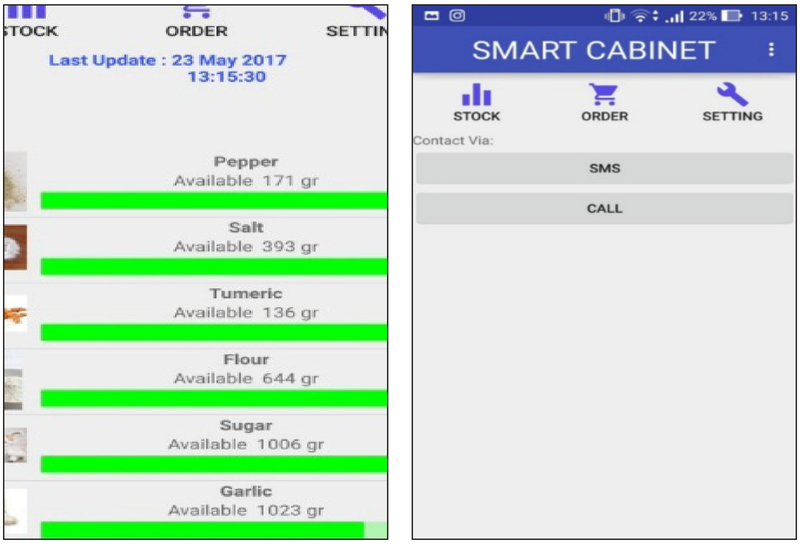


Figure 9. LCD displayed the recipe according to the availability items either in smart refrigerator or smart food cabinet

Figure 10 shows three different menus in the Android applications; (a) the availability of the items, and (b) the selection for order either with SMS or phone call even by WA. The whole system can be seen in Figure 11 and this system is registered for a simple patent.



(a) (b)

Figure 10. Android application displayed in the smartphone: (a) availability of items, and (b) selection for order

(a) (b)

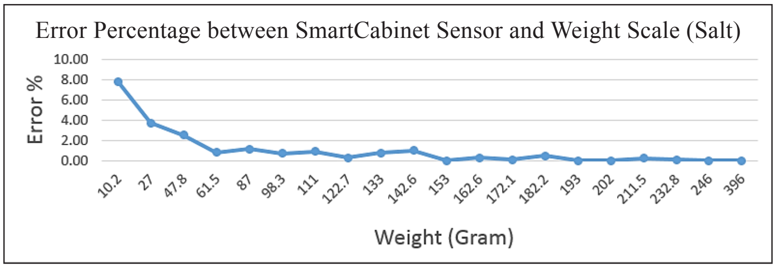
(c)

Figure 11. (a) The smart food cabinet and smart refrigerator, (b) smart food cabinet and its loadcell, and (c) smart food cabinet with its compartments on the loadcell

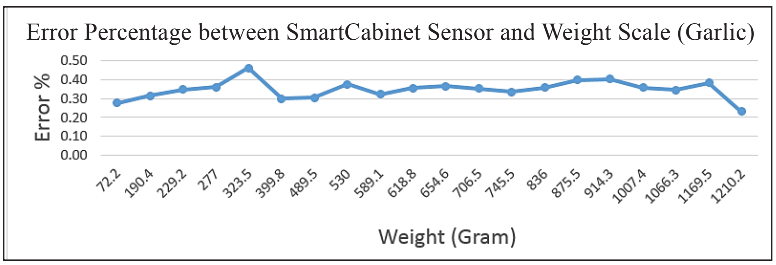
RESULTS AND DISCUSSION

After designing the system, we tested the accuracy of information given by loadcell and compared to the accuracy measured by using a calibrated digital weight (JCS-3A; resolution 0.1 gram; capacity 3 kg). The information was tested for its accuracy when it was displayed both in the LCD and the smartphone. The last one, we measured its accuracy of the recipes displayed according to the availability of the items.

On the first experiment when we compared the accuracy reading from the loadcell and from the digital weight, we found out there were several error readings which was not significant, as low as 7.84% to 0.28% as shown in Figure 12. The error depended on the sensitivity of the loadcell, especially when we used two kinds of loadcell. To measure salt, pepper, and turmeric, we used 1 kg loadcell since users normally did not keep a large number



(a)

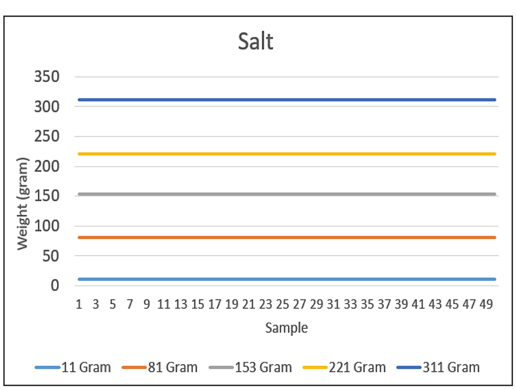


(b)

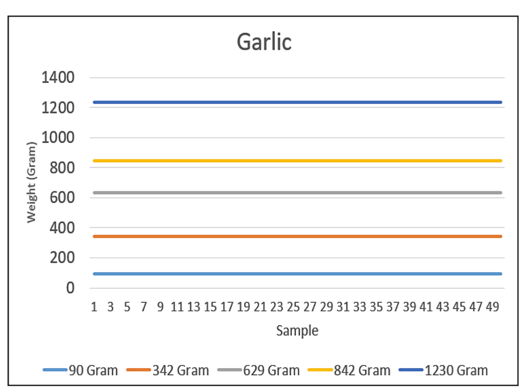
Figure 12. Error reading for: (a) loadcell with capacity of 1kg and (b) loadcell with capacity of 5 kg

of these ingredients. On the other hand, we used loadcell of 5 kg since users tended to save big sum of sugar, potatoes, onions, cooking oil, and flour. The sensitivity of readings was determined by the type of loadcell. Nevertheless, the consistency of measurement results is good as it is shown in Figure 13. In this paper, we only provide the measurement results of salt and garlic as representative data since the rest of measurement is almost similar.

From the measurement results, we sent the data directly to both a smartphone and an LCD and we measured the time respond of data transfer. Figure 14 shows the results of this measurement where the average response time is 237 ms or as similar as real time measurement.



(a)



(b)

Figure 13. Reproducibility testing of weight reading by loadcell for: (a) salt, and (b) garlic

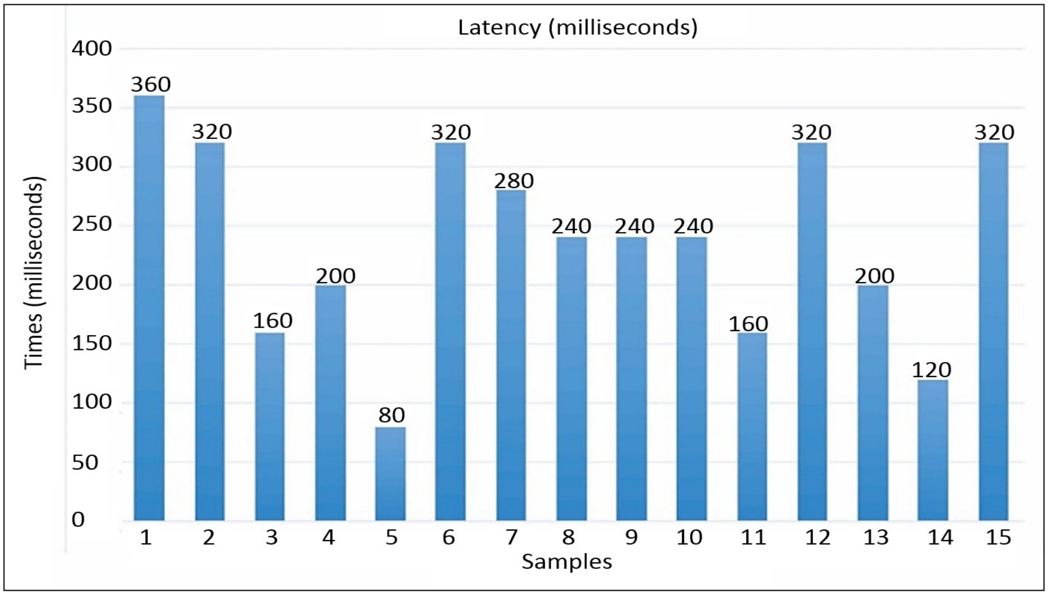


Figure 14. The latency of data transmission

Figure 15 shows some examples of recipe displayed according to the availability of the items. The items seen next to the LCD means that they are not in the sensor that is why they are read as 'not available' and the smartphone shows the availability of the items. In Figure 15(a) the recipes selection are garlic, prime ribs and oven-roasted asparagus where both of these recipes do not need eggs, milk, and cooking oil. Figure 15(b) shows the recipe selection of fried egg, omelet with milk, fried calamari, plain stir-fried kangkong leaves, curry tikka masala sauce, scones, potato soup, fluffy pancakes, garlic prime ribs, sweet potatoes casserole, mashed potatoes, oven-roasted asparagus, and French toast that did not need carrots as ingredients.

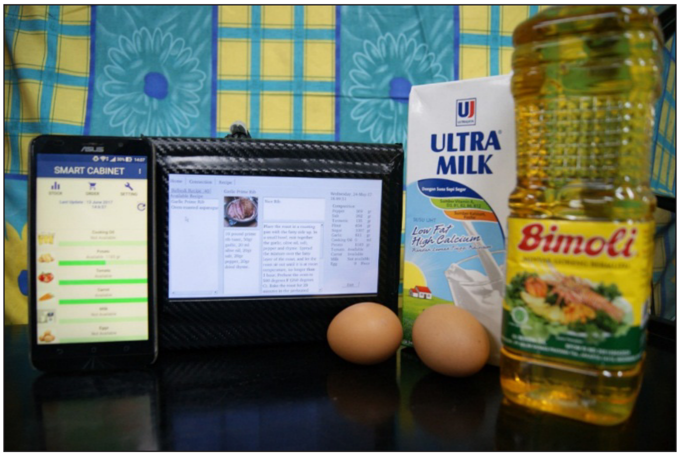


Figure 15(a). The recipe selection when eggs, milk, and cooking oil were not available

Figure 15(b). The recipe selection when and carrots were not available

As for the price comparison, the whole smart modules in both refrigerator and food cabinet consumed less than US$ 300 while in the commercial smart refrigerator ranged from US$ 3500 to US$ 5800 (NBCNEWS.com, 2013; Eadicicco, 2016; The Australian, 2018). The ability was almost similar but is not widely affordable for people in the development country like Indonesia.

CONCLUSION

Designing and building a smart food cabinet system that can receive data from smart refrigerator in this work has been successfully done. The data read from each sensor are successfully transmitted to the embedded system based on Arduino and Raspberry Pi in a real-time transmission. The information of the availability of items both in smart food cabinet and smart refrigerator can be accessed from either LCD or smartphone which also lead the selection of desired recipe according to the availability of items.

The smart module in this project can be customized by the user by using the current cabinet and refrigerator s/he has without any necessity to buy the new ones. In the future, the system will be combined with a smart table for calories information to make the users have additional benefit from this project. Moreover, the price of each smart modules are less than US$300 and it is a lot cheaper than the one available in the market.

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