Intelligent Trashcan Applications Relying on Internet of Things Technologies

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Abstract. Trashcans are the basic unit in the garbage-collecting procedure. This paper proposes an intelligent trashcan with flexible features, which is associated with a smart device application. The trashcan is able to detect RFID tags to decide whether to open its lid or not. The trashcan is also capable of moving around when it receives instructions from the remote application, and it has the ability to move according to a planned path. Different settings of the smart trashcan can be configured via the remote application. The proposed system has been implemented, and it is shown that the proposal is applicable.

1 Introduction

Waste management is an issue that concerns both developing and developed countries due to the fact that every individual produces solid waste every single day, which accumulates into a significant total amount of waste over a period of time. According to a recent article, 190 kilos of waste are produced every second across the world, which will be disastrous if not managed properly. The fundamental step of waste management is to gather the disposed-of garbage, and the common method involved is the trashcan. Various researchers have given impetus to the development of a clean city. The cleanliness of a city is highly relevant, as poor cleanliness causes foreigners to have a poor impression of a city, further leading to a negative impact on the nation's image.

The researchers of paper [1] proposed the use of a GSM (Global System for Mobile communication) module in Arduino Uno to report on the percentage of garbage in trashcans. Paper [2] proposed to use an IR module in Arduino Uno to detect the percentage of garbage in trashcans. The researchers of paper [3] suggested system architecture to find a time-optimal dynamic route for garbage trucks to support the 'Smart Clean City' project, which contributed to the time optimization of garbage collection. To enhance further the removal procedure of solid waste from trashcans, the authors of [4] proposed an e-monitoring garbage alert system based on IOT (Internet of Things) technology.

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The level of garbage in a dustbin is detected by an ultrasonic sensor, which is interfaced with Arduino Uno. By creating alerts when the garbage bin is full, the proposed system reduces the manual process involved in the garbage management of a public area. Further research [5] on solid waste monitoring has also been undertaken, and the proposed system is an integration of popular communication technology such as RFID, GPS (Global Positioning System) and GIS (Geographic Information System).

The method of estimating the garbage fill level is to interpret the image taken by a camera attached to the garbage collection truck. Indeed, the mentioned works contribute substantially to the waste management process. However, none of the mentioned works focuses on the ownership of a non-public trashcan. In Taiwan it is easily noticeable that some trashcans are secured with a substantial lock, such that unauthorized access to them is prohibited. Unauthorized use of a trashcan is troublesome to the owner, as it will be filled quickly and the garbage involved will mostly be unsegregated waste [6]. In this paper a smart, automated trashcan is proposed. The trashcan is fitted with intelligent features, such as automatic lid opening, movement ability and obstacle detection. The smart trashcan can be accessed by directing an RFID tag to the RFID reader attached to it. In this case the user does not need to unlock the trashcan manually during each garbage disposal session. The trashcan is also able to move according to a planned route formed by tapes. Aside from being an automated trashcan, it can also serve as a form of remote controlled appliance. A mobile device application is constructed to serve as the remote controller of the smart trashcan. The user can instruct the smart trashcan to open and close the lid, move around or simply switch to automatic mode. The rest of the paper will be divided into three main parts: the system architecture, the implementation result and the conclusion.

2 System Architecture

This section is divided into three main parts, which are the system structure, the smart trashcan and the remote control application for the trashcan. First we will examine the overall structure of the proposed system, which includes the smart trashcan, the smart device application and the database server. Next the smart trashcan will be explained. Finally we will consider the remote control application for the smart trashcan.

2.1 System Structure

Figure 1 illustrates the overall system of the smart trashcan communication mechanism. The proposed system is composed of the smart trashcan itself, a mobile device application and a server. The main feature of the smart trashcan is the ability to lift up the lid and give access to the tag owner when the attached RFID reader reads the tag. The communication between the smart trashcan and the user involves data transmission through a Bluetooth module. The data involved are the instructions given to the smart trashcan during the remote controlled session and the trashcan's utilization of the information that is accumulated when the RFID reader scans a tag. Since the smart trashcan itself is not able to connect to the Internet, the information will be sent to the server database through the mobile application. The data in the server database can be accessed on request through a computer.

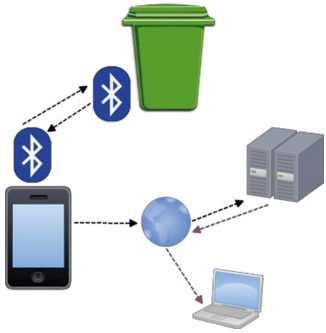

Fig. 1. System overview

2.2 Smart Trashcan

The smart trashcan is a trashcan integrated with the following: Arduino Mega 2560, a Bluetooth module, an RFID reader, a servomotor, a drive motor and wheels, a track sensor module, an L298N motor module and an ultrasonic sensor. Two main features are implemented: automatic lid opening after a tag is detected and movement according to a planned track. The smart trashcan will open its lid to give access whenever the RFID reader reads a tag. Figure 2 illustrates the lid-opening process to present a clearer concept. First of all the smart trashcan must be fitted with a power supply so that it can function properly.

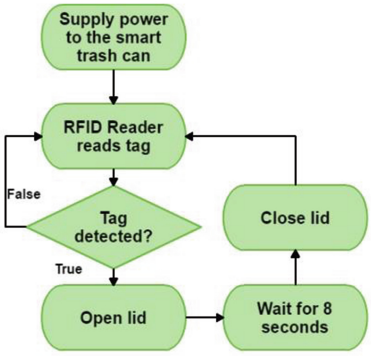

Fig. 2. Flow diagram of smart trashcan lid opening

The RFID reader mounted on the trashcan will start to detect tags. When a tag is detected, the smart trashcan will open its lid. The lid will stay open for eight seconds before it closes automatically. Then the smart trashcan will continue to read tags. In Sect. 1 it is mentioned that the smart trashcan can be controlled remotely by a smart device application. The remote control feature includes control of the lid.

When the lid is opened through the remote control application, it will not close automatically after eight seconds. Instead, the smart trashcan will wait for an order from the application. There are two ways in which the smart trashcan will move: first through remote control and second by following a planned track. The first method is performed by receiving instructions from the smart device application through a Bluetooth module. The smart trashcan is able to move forwards, move backwards, turn left and turn right. To avoid a collision, an ultrasound sensor is also installed in the smart trashcan. Whenever an obstacle is detected, the trashcan will turn right to avoid it. Next, we proceed to the second method, in which a path is planned for the smart trashcan and formed by black tapes. To enable the smart trashcan to move according to the track, a track sensor module is installed at the bottom of the trashcan. The track sensor module contains an IR infrared reflection sensor, which can be used for line following and edge detection. In a track sensor module, the infrared reflection sensor detects black lines and enables the object to move according to the lines.

2.3 Remote Controlling Application

The aim of the remote control application is to control the smart trashcan remotely. In our work the application is developed for an Android environment. The application has the ability to pair with the smart trashcan via a Bluetooth connection. Once they are paired, the application may control the lid, the motion and the interchange between the different modes of the smart trashcan. As mentioned in the previous sections, the opening and closing of the lid can be triggered by an RFID tag or by remote control. Through the remote control application, the user can decide which lid mode the smart trashcan will adopt.

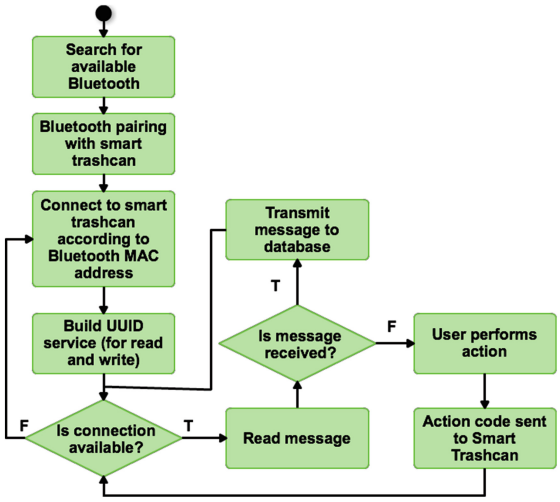

Fig. 3. Remote control application flow diagram

As the default setting, the smart trashcan remains static unless it is commanded to move around. Using the remote control application, the user may switch to the automatic routing mode in which the smart trashcan moves according to the black tapes.

The application also serves as the agent to transmit utilization data of the smart trashcan to the server database. Whenever the RFID reader reads a tag, the information is interpreted and stored in the Arduino module.

The information cannot be sent directly to the server, as the smart trashcan does not have the ability to connect to the Internet. Hence, when it is paired with a smart device that has the related application installed, the information will be passed to the application through a Bluetooth connection. Then the application will play its role by transmitting the received information to the server database if the smart device is connected to the Internet.

The flow diagram of the remote control application is shown in Fig. 3. Bluetooth plays an important role in enabling the communication between the smart trashcan and the application. Before the connection is established, the application will search for available Bluetooth devices. Then the smart trashcan is selected and a password is required to pair with the smart trashcan. The password is set to restrict unrelated people from accessing the smart trashcan. After successful Bluetooth pairing, the application and the smart trashcan are connected by the Bluetooth MAC address. A UUID service, which enables read and write communication, is built. If a connection is available, the application will start to read messages from the paired smart trashcan. If a message is received, for example RFID tag information, the message will be transmitted and stored in the server database. On the other hand, if the user performs any action, the action code will be sent to the smart trashcan. The smart trashcan will interpret the action code and adjust itself.

3 Implementation Results

A regular, plain indoor trashcan is selected as the basis of the smart trashcan. Figure 4 shows the implementation result of the smart trashcan. The trashcan is colourfully painted for a better visual effect. The components used are Arduino Mega 2560, an HC-06 Bluetooth module, an RFID RC522, a servomotor, a drive motor and wheels, a track sensor module, an L298N Dual H-Bridge Motor Controller, an ultrasonic sensor and a battery case, which are shown in Fig. 5. The components, except the servomotor, are installed at the bottom of the trashcan, and the implementation result is shown in Fig. 6. The smart trashcan is then attached to the base shown in Fig. 6. To move the lid, the servomotor is installed in the trashcan near the lid, as shown in Fig. 7, which illustrates the trashcan with an open lid. The installation functions to hold up the lid when required. Figure 8 illustrates the flow diagram of the smart trashcan. Once supplied with electricity, the pins of the component's input and output are initialized. The Bluetooth server service is also initialized and prepares to be connected. The Bluetooth server waits for a connection request from the remote control application. Once paired and password verified with the application, a connection will be established. The smart trashcan will read the instruction message from the application. At this point the user can control the smart trashcan by interacting with the interface provided by the remote control application. If any action is performed, an action code will be transmitted to the smart trashcan via the Bluetooth connection. If a message is received by the smart trashcan, it will interpret it and switch the trashcan mode according to the received action code. The remote control application will be discussed in the next paragraph.

Fig. 4. Smart trashcan

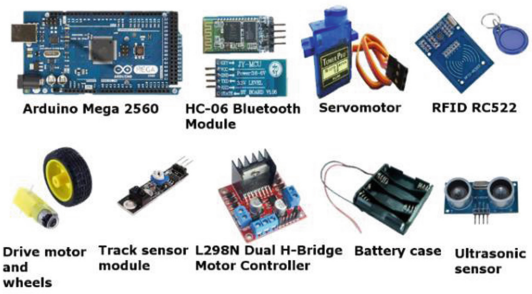

Fig. 5. Components of the smart trashcan

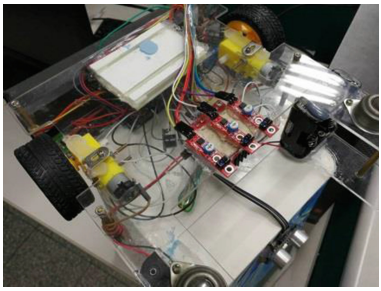

Fig. 6. Base of the smart trashcan

Fig. 7. Lid structure

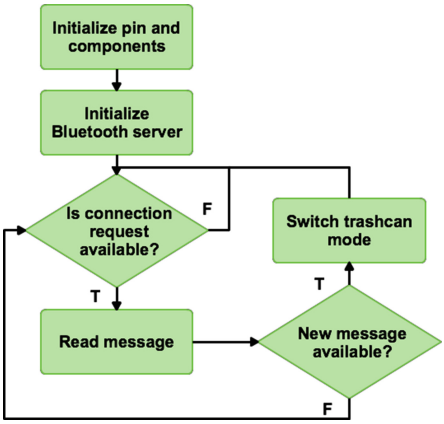

Fig. 8. Smart trashcan flow diagram

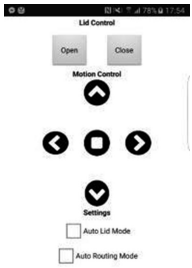

Fig. 9. Remote control application

Figure 9 presents the remote control application of the smart trashcan. The smart device application is developed for an Android environment using Android Studio 2.0. The application is able to pair with the smart trashcan Bluetooth module and control the smart trashcan remotely. The application features are divided into three sections on the screen. The top section is the lid control section, and two buttons are provided for the user to command the lid to open or close. Note that if the lid is opened using the button, it will not close automatically. Instead, the motor is programmed to wait for an instruction from the close button. The second section is the motion control section. The four buttons enable the smart trashcan to move forwards, turn right, move backwards and turn left. The button in the middle is the stop button. The stop button is available because the smart trashcan is programmed to move continuously once a direction button is pressed. Once a direction button is pressed, the trashcan will move in the desired direction until another direction button or the stop button is pressed. This purpose of this design is to avoid the user being obliged to press down the button continuously when the trashcan is required to move for a long distance. The bottom

section is for the settings. In this section two options are provided: the automatic lid mode and the automatic routing mode. The automatic lid mode grants permission for the smart trashcan to open its lid when an RFID tag is detected. This means that, if the corresponding checkbox is left unchecked, the smart trashcan is considered to be locked, and it will not respond to any approaching RFID tag. The automatic routing mode enables the smart trashcan to move according to the planned path. This feature is operated using the mounted track sensor module. The expected path is a route formed using black tapes, which form black lines. The path is built prior to the automatic routing mode being enabled.

Fig. 10. Automatic routing mode implementation results

Table 1. Relation between s1, s2 and s3 and trashcan movement

S1 (left)	S2 (middle)	S3 (right)	Movement
HIGH	HIGH	HIGH	Forward
LOW	LOW	LOW	Stop
LOW	HIGH	HIGH	Right
LOW	LOW	HIGH	Right
HIGH	HIGH	LOW	Left
HIGH	LOW	LOW	Left
LOW	HIGH	LOW	Forward
HIGH	LOW	HIGH	Backward

Figure 10 shows the implementation result of the trashcan's automatic routing mode. A black path is formed using black tapes, and the smart trashcan is placed at the starting location. The smart trashcan is then switched to the automatic routing mode. Figure 10(a)–(c) show the movement of the trashcan. It follows the route and is able to turn around at the turning points. This function is performed by the track sensor module. The track sensor module senses three values, which represent the colour of the ground. The three values are s1, s2 and s3, which indicate left, middle and right, respectively. They help the smart trashcan to identify the next movement. For a clear

depiction, the relation between the values of s1, s2 and s3 and the movement of the smart trashcan is shown in Table 1. A database is constructed on a lab server to receive data from the smart trashcan via the remote application. The database is a MySQL database, which is one of the built-in features of XAMPP, a free and open-source cross-platform web server solution stack package developed by Apache Friends. In our implementation the database is able to receive transmitted data successfully. The main utilization of the received data is to monitor the behaviour of each user.

4 Conclusion

In this paper a smart trashcan associated with a remotely controlled smart device application is proposed. The smart trashcan is integrated with an Arduino module, a Bluetooth module and RFID technology. The smart trashcan has the ability to control the opening and closing of its lid manually or based on an RFID tag, to follow a planned path and to move around. The remote application is able to pair with the smart trashcan via Bluetooth. The implementation results prove that the proposed ideas and features are applicable. In the future we will attempt to take further advantage of Internet of Things technology and implement more features, such as detecting the garbage fill level and creating alerts when the trashcan requires emptying.

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