Design of BearPi-Based Waste Bin With the Functions of Speech-Controlled Classification and Locating

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Yuxiang Xiong, Jie Shen* and Tianhong Zhou

Department of Information Engineering,Wuhan Business University, Wuhan Hubei Province, China.
Email : 20150623@whu.edu.cn

Abstract. To solve the current problems of waste classification and littering, this kind of BearPi-based waste bin with the functions of speech-controlled classification and locating is invented using the technologies of speech recognition and GPS. The device, with BearPi as its core element, uses solar panels and lithium batteries as power supply, IIC and serial interfaces for the respective control of PCA9685 steering gear driving board, an M5310_A communication module, ATGM332D locating module and SX-ASR-B speech recognition module, and finally, a GPIO and timer for the operation of the HC-SR04 module and an E18-D80NK photoelectric sensor. The devices could classify the waste through speech recognition or leave it for the users. Furthermore, it could detect the remaining capacity and location of the waste bins through the modules and update the cloud data for the users' convenience in finding and using.

1. Introduction

The 21st-century witnessed a continuous improvement in people's life quality, and unfortunately, a growth of waste (at a speed of about 8% per year) [1]. In most cases, the waste is disposed directly in landfill or incineration[2] due to the large quantity, although both ways will bring serious harm to the environment. Some debris will be disposed separately upon centralized classification, which requires excellent labor investment. At present, the government is trying to introduce classification into the stage of waste dropping. The policy has been proven effective in the waste classification pilot project in Shanghai while bringing some side effect-people to be reluctant to throw the rubbish.

The BearPi-based waste bin with the functions of speech-controlled classification and locating in this paper is designed to encourage the citizens to classify the waste and reduce uncivilized littering. The device uses solar energy and lithium batteries and thus applies to a lack of stable power supply. It could also classify the waste thanks to the speech recognition function to automatically open the corresponding waste bin lid, easing the users' trouble, simplifying the classification, and making it attractive. That is not all; the device uses various modules to update its location for the users to find nearby devices and discard their waste timely to prevent uncivilized littering.

2. Overall Design of the Device

The waste bin is explicitly designed to simplify the waste classification and improve the efficiency of waste disposal. It has to be functional in these three aspects: The first aspect is the classification of waste, including both the speech-controlled and the manual classification; the second is the report of device information to the server for updating; the last but the most important, is the solar power supply that could make the device movable. Figure 1 shows the overall design of the device.

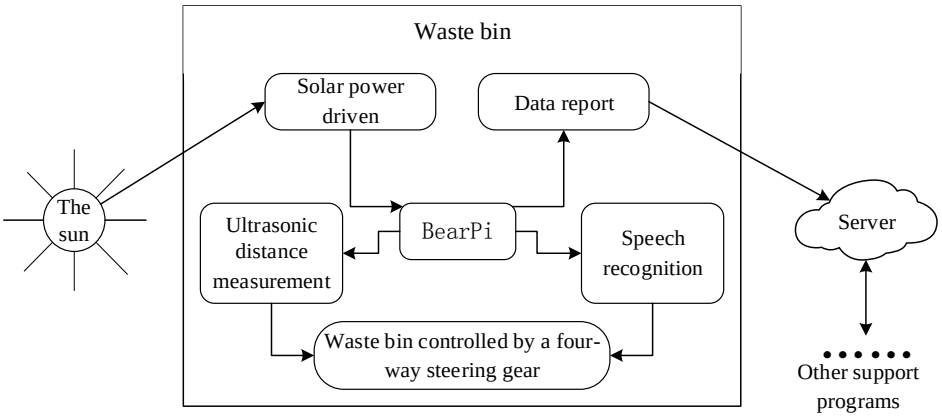

Figure 1. Overall design.

The speech-controlled classification is designed to be realized through speech recognition module and ultrasonic distance measurement module (for determining the waste bin to be opened) as well as the steering gear driving board (for controlling the waste bin by manipulating the corresponding steering gear); the data is reported using active infrared intrusion detecting module (for detecting the remaining capacity of the waste bin), GPS module (for locating the current position), GPRS module and MQTT client[3] (for data report); the circuit of the device converts the solar power into electric energy, stores it in the lithium battery and power both the 3.3V and 5V working power supply.

3. Hardware Design

Figure 2 is the diagram of the hardware connection in the device. As the figure shows: The needed hardware mainly includes the master control chip for device-controlling, modules with speech and locating related functions, such as speech recognition module, GPRS module, and GPS module, steering gear components for waste bin controlling as well as a circuit for charging and power supply.

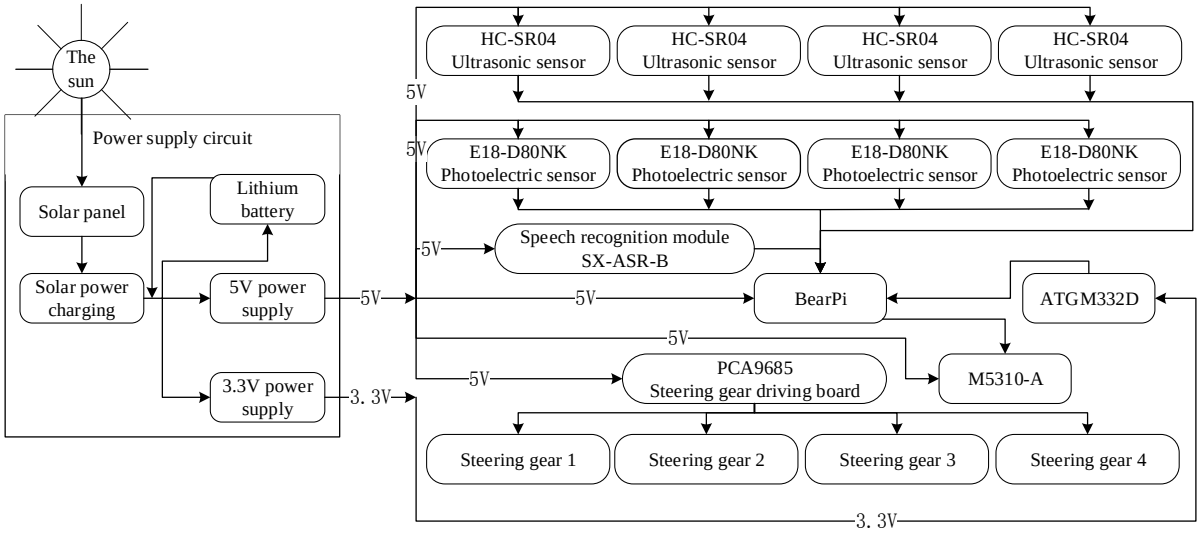

Figure 2. Schematic diagram of hardware connection.

3.1. Master Control Chip

Considering the limitations in outdoor usage and power supply, the waste bin needs a chip with low power consumption and many communication interfaces to connect with other modules. We selected BearpPi (see Figure 3) from numerous demo boards and chips.

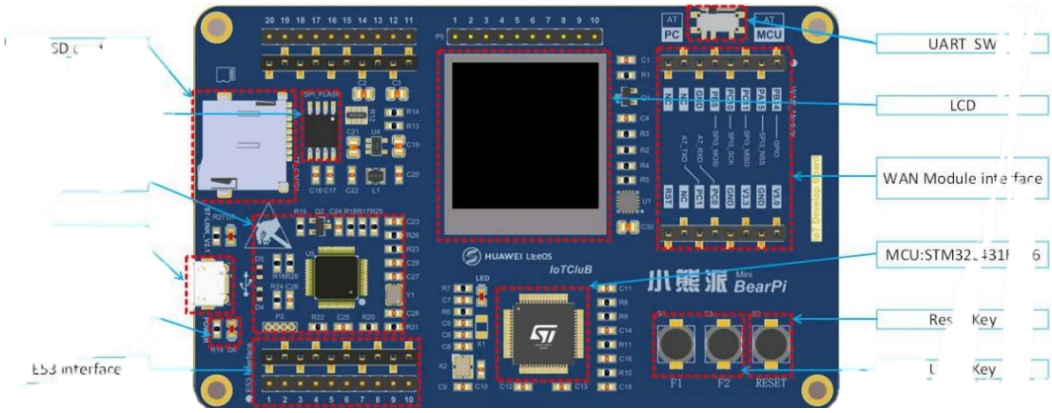

Figure 3. BearpPi.

The figure shows that the master control chip of BearpPi uses the STM32L4 ultra-energy-efficient controller of the ST company and could perfectly meet the device's relevant requirements. Also, for BearpPi, the pins of USART, ULPUART, I2C, SPI, and other STM32L431 chip interfaces are drawn out with the device's pin header to be connected to peripheral modules. BearpPi also has an ST-Link, USB and other interfaces for the convenience of program debugging.

3.2. Selection of Modules

Modules used to fall into four major categories: speech recognition modules, waste bin controlling modules, data detection modules, and data reporting modules. See Table 1 for their information.

Table 1. Selection of modules.

Function	Name of the modules	Model	Communication interface
Speech recognition	Speech recognition module	SX-ASR-B	Serial interface
Waste bin control	Steering gear driving board	PCA9685	I2C
	Ultrasonic sensor	HC-SR04	/
	steering gear	SG90	/
Data detection	Photoelectric sensor	E18-D80NK	/
	GPS module	ATGM332D	Serial interface
Data report	GPRS module	M5310-A of OneNET	Serial interface

The speech recognition module SX-ASR-B of the device uses a high-performance 16-bit nDSP processor that enables a recognition capacity of up to 100 entries by a non-individual-specific speech recognition algorithm. Read corresponding entries and groups into the module and finish connection through the serial interface of BearPi; the speech recognition module will then produce the results.

As for the waste bin control, steering gear driving board PCA9685 and steering gear SG90 are used[4] with the former connected to BearPi through the I2C interface and controlling different steering gears to open or close the waste bins. To allow the users to manually conduct the classification, an ultrasonic sensor HC-SR04 can detect any person approaching the waste bins and open the corresponding one.

The data detection function is realized based on a photoelectric sensor E18-D80NK[5] and GPS locating module ATGM332D. E18-D80NK could detect obstructions within certain distances by reflecting and receiving infrared rays and then determining if the waste bin is full. ATGM332D[6], a high-performance and energy-efficient locating module using both GPS and BDS as its information sources, has a serial communication interface that could connect to external devices and use AT instruction to obtain latitude and longitude information of the current position.

The device uses M5310-A of OneNET of China Mobile as the GPRS module for data reporting. It is

an industrial-grade multi-band NB-IOT wireless module with multiple built-in data transmission protocols (including LwM2M/MQTT /TCP/UDP/COAP) and extended AT commands. Serial interfaces and AT instructions could well facilitate the use of MQTT clients and data publishing.

3.3. Design of the Power Supply Design

The power supply, solar panel and lithium batteries are used to make the device more applicable in severe conditions. It uses the TPS61022 chip of TI to convert the power from lithium battery into a stable power supply of 5V3A, and uses the LM1117 3.3 chip to produce a regular power supply of 3.3V. While for charging, two options are available: Option 1 is to use the battery charger BQ25606 (produced by TI) with the function of power path management for independent and single 3A cell, and Option 2 is to use the CN3791 MMPT solar module with a charging current of 2A[7].

Option 1 uses BQ25606 for solar energy charging; we design a power supply module integrating the functions of charging, power supply and voltage regulation, as shown in Figure 4 (the schematic diagram of the circuit) and Figure 5 (picture of the actual product). The BQ25606 chip could realize a charging efficiency up to 92% when the current reaches 2A, support an input voltage ranging from 3.9V to 13.5V and has the function of power path management, yet it is not designed for solar charging, and therefore the actual performance might not be as imagined.

Option 2 uses a CN3791 MMPT solar charging module, as shown in Figure 6. The CN3791 charging module could track the maximum power point of solar panels, and the extensive practical tests it went through has proved its stable function and user-friendliness. The maximum charging current of 2A, however, is a shortcoming of the module.

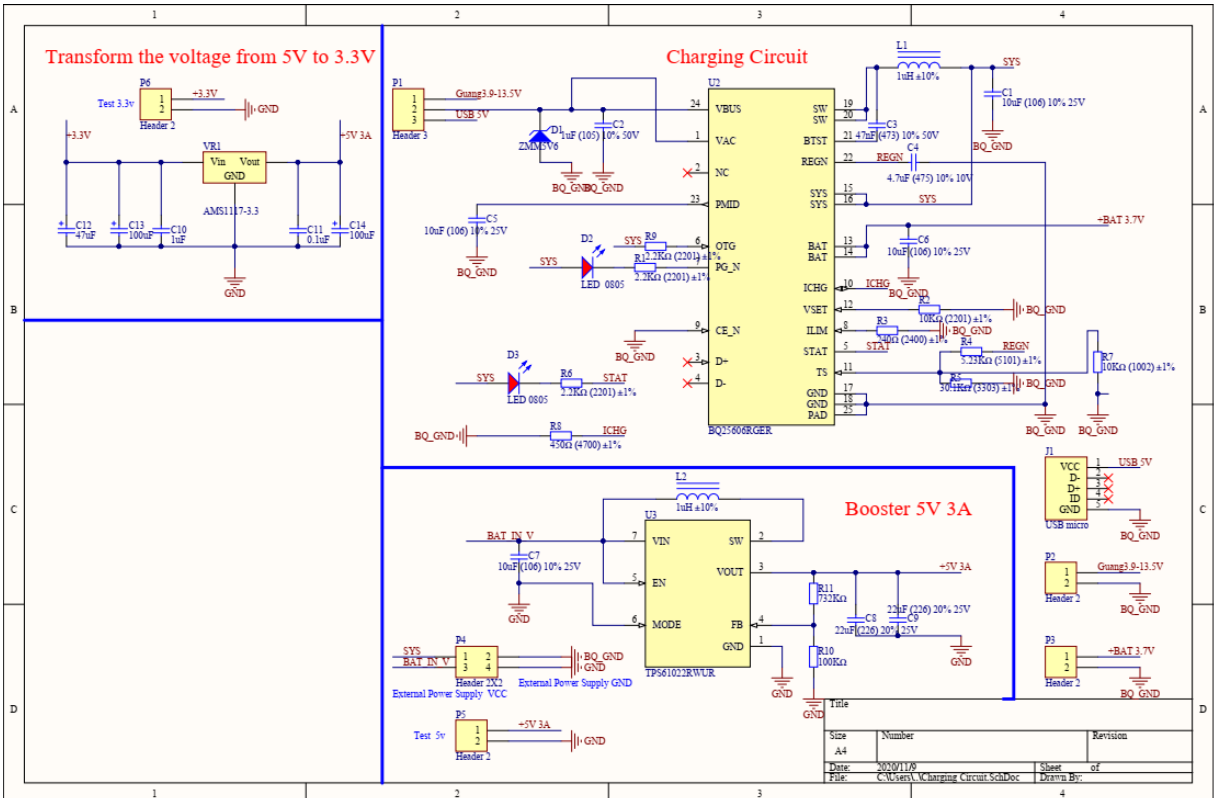

Figure 4. Schematic diagram.

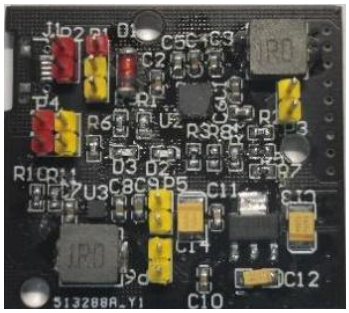

Figure 5. Picture of the actual product.

Figure 6. Solar charging module.

4. Programming

Functions, including waste classification, waste bin control, and data reporting, need to be realized through the device's design. Currently, a simple program logic may be able to enable some function, but the simultaneous operation of or flexible switching between multiple functions could not rely on such a mechanism. The function switching is readily solved by introducing the FreeRTOS operating system[8] into the STM32L432 chip program of BearPi and in the form of tasks. FreeRTOS will reasonably allocate the chip processing capacity to the device's four tasks, which are defined according to the functions like speech recognition, ultrasonic distance measurement, steering gear resetting, and data reporting.

The speech recognition task is aimed to manage the speech recognition module and use the determination of the module to control the waste bin or switch its mode; the ultrasonic distance measurement task manages four ultrasonic modules to measure the users' distance to the waste bin through the management of timer and GPIO and open the right bin; the steering gear resetting task manipulates only the steering gear driving board with the task itself counting the time for all the steering gears and ordering the driving board to close the bin at the end of the opening time threshold; the data reporting task manages the data detection mode and data reporting module, which collects the data from the former at regular intervals and register it with a GPRS module based on the MQTT protocol.

For these four tasks, the speech recognition task and steering gear resetting task are an essential part of the entire device for its operation.

4.1. Speech Recognition Task

As the designed flow chart in Figure 7, this task mainly opens or closes the waste bin by controlling the right steering gear's rotation angle based on the speech recognition module's result.

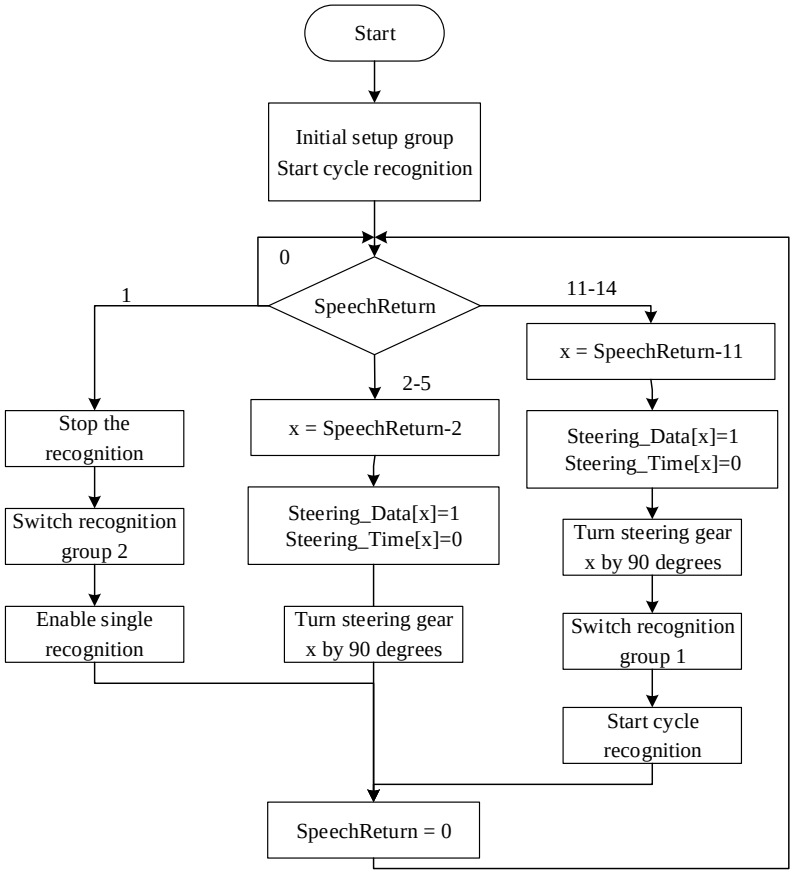

Figure 7. Flow chart of the speech recognition task.

The task requires first to initialize the speech recognition module with serial interfaces, set up the modules' speech recognition group, and enable the cycle recognition. The speech recognition module also uses serial interface communication for returning to recognition. The chip will automatically stop its current work to process any function input (interrupt processing). It recognizes the speech recognition module interface, and the program will set the SpeechReturn value according to the returned data. However, speech recognition tasks do not include interrupt processing; instead, such tasks only determine the changing value of SpeechReturn and enter the programming logic accordingly.

For such tasks, no action will be triggered and the detection and determination will continue when the value of SpeechReturn is 0; when the value is 1, recognition-stopping command will be sent to speech recognition module through serial interfaces, then set the speech recognition group to run 2 times of single recognition after the start, and the last, set the value of SpeechReturn to 0 to start new detection; when the value of SpeechReturn falls into 2-5, the numbering of the corresponding steering gear will be calculated with the symbol Steering_Data (symbol of the steer) set to 1, Steering_Time (time record) set to 0, the steering gear turned across 90 degrees by its driving board, and the last, the value of SpeechReturn set to 0 to start a new detection; when the value of SpeechReturn falls into 11-14, in addition to the the calculation of the numbering of the corresponding steering gear, the changing of Steering_Data and Steering_Time, and the controlled rotation of the steering gear, it also needs to set the recognition group of the module to 1, enable the cycle recognition, and then set the value of SpeechReturn to 0 to start a new detection.

4.2. Steering Gear Resetting Task

As the flow chart design is shown in Figure 8, this task mainly seeks to standardize all the waste bins' opening duration and avoid excessively long opening.

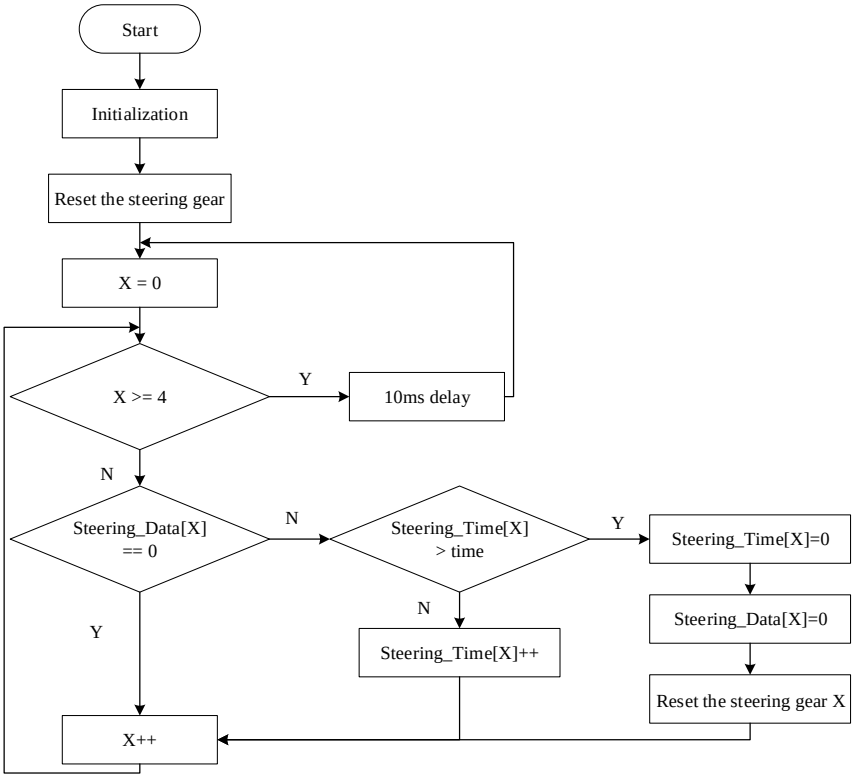

Figure 8. Flow chart of steering gear resetting.

At the beginning of this task, use I2C bus communication to initialize the steering gear driver, set the cycle of ITS PWM wave generation, and reset the four-way steering gear. Then use variable X to loop and traverse through the Steering_Data array, and when the corresponding data of the Steering_Data array is 0, loop through the next one after auto-increasing of X. When the value corresponding to the Steering_Data array is 1, it will start to determine the data corresponding to the Steering_Data array.

When the corresponding value of Steering_Data is greater than the preset threshold "time," the program will set both the corresponding values of Steering_Data and Steering_Time array to 0, and reset the related steering gear to close the waste bin. If Steering_Data's corresponding value does not exceed the preset threshold "time," the program will only increase the Steering_Time array's corresponding value by 1 and start a new traversal determination of the next steering gear upon the auto-increasing of x.

After a traversal cycle for the four steering gears (and when x has been increased to 4), the task will suspend 10ms, and then, a new cycle will start with the value of x set to 0. The task program leaves a 10ms interval between traversals, and the duration from opening to closing could thus be managed through the interval and the preset threshold "time."

5. Simulation Test

Follow the project design, use waste bin models to simulate the actual product, add steering gears to four bins and connect all the modules as the hardware design to get the stimulation device in Figures 9 and 10.

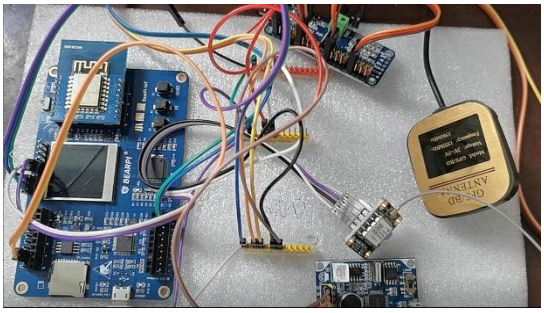

Figure 9. Picture of the actual product-1.

Figure 10. Picture of the actual product- 2.

Turn on the device switch to start the test. Say "medical mask" to the device, and the bin for hazardous waste will open within 1 second, as shown in Figure 11. It will close automatically after 30 seconds. Say "watermelon peel," the waste bin for kitchen waste will open, as shown in Figure 12. Nearby waste bins could also be found using the designed mobile phone APP.

Figure 11. Hazardous waste.

Figure 12. Kitchen waste.

6. Conclusion

In this document, we design a BearPi-based waste bin with the functions of speech-controlled classification and locating. It uses the ultra-energy-efficient chip STM32L431 in BearPi as the core controller and connects the required peripheral modules through various built-in communication interfaces of BearPi to enable speech recognition functions waste classification and GPS locating. Furthermore, the environmental limitation is broken with solar panels and lithium batteries used for power supply, and the network communication realized through the GPRS module could minimize the dependence of the device on the environment.

Use this design in real life, the speech recognition function could then help users in waste classification through, and the users could also find waste bins nearby with GPS. Speech recognition, seeming to complicate the activity of garbage throwing, actually makes the waste classification more attractive; on the other hand, the GPS locating technology could point the nearby bins to the users with the support of a mobile phone APP, saving the users' time in searching and prevent uncivilized littering. Based on the above, we believe that this design promises to solve current problems such as waste classification and uncivilized littering.

7. Acknowledgements

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8. References

[1] Wang Xiaohui, Fu Xiaoyan, Yangfan Yuanhang, Han Yujia. Analysis of Solutions Targeting the Root Cause of Waste Classification [J]. Chemical Enterprise Management,2020(26): 115-116.

[2] Wu Junmei. Main Environmental Problems and Improvement Countermeasures of Waste Incineration-based Power Generation Project [J]. Intelligent City,202,6(15): 96-97.
[3] Wang Hao. Design of Remote Control System Based on ESP32 Platform and MQTT Protocol [J]. Software Engineering,202,23(08): 38-41.
[4] Zhang Liang, Zhao Feiyue. Design of Four-legged Robot Control System Based on STM32-PCA9685 [J]. China Southern Agricultural Machinery,2020,51(14): 117-119.
[5] Lu Yiwen. Design and Implementation of Single-Chip Microcomputer Based Robot Cleaner[J]. Digital Technology and Application,2019,37(02): 7-8.
[6] Wu Qixin, Zheng Wenhao, Ye Zhipeng, Li Gang. Intelligent SMT32-based Guide Rod[J]. PRACTICAL ELECTRONICS,2020(13): 34-36.
[7] Hu Yiliang, Zhang Jie, Wang Xinghui. Self-powered Temperature and Humidity Monitoring System Based on Mqtt Protocol [J]. Microcontrollers & Embedded Systems,20,20(07): 69-71.
[8] Liu Haiyang, Li Yibo. FreeRTOS and Electromechanical Sensor-Based Human Body Assisting Mechanical Arm System [J]. Microcontrollers & Embedded Systems,2019,19(08): 65-67.