Baby-Follower: a Child-Care Robot System Based on OpenMV and IOT

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Abstract. Frequent accidents of children at home have caused disastrous injury and economic loss. However, the traditional child-care robots mainly focus on human-computer interaction and emphasize educational function, which cannot be used specifically to solve children's safety problems. A child-care robot system based on OpenMV and IOT is proposed in this paper. The system is a smart vehicle-type robot, which recognizes and locates the target with the AprilTag label attached to children's legs and hazard points by the machine vision module, follows the children's movement, monitors the surrounding environment through sensors, uploads data to OneNET cloud platform and provides audible alarms of the emergency to the guardians in real time. Furthermore, it also provides video real-time transmission function, manual control function and data viewing function through browser and App to protect children from danger and assist guardians to accompany children's growth.

1. Introduction
According to “the special research report on the safety of children's household appliances” released by the global children's safety network, an international non-profit organization, 61.2% of children's accidental injuries occur at home[1]. Using artificial intelligence, machine vision, voice interaction and video interaction to promote the development of intelligent accompanying products is an inevitable measure to meet the needs of society. A child-care robot system named Baby-Follower is designed with OpenMV machine vision module and OneNET cloud platform. Combined with charts, voice, video and other data expression forms, the system realizes children's movement following, environmental monitoring, video return, danger alarming and etc., which greatly reduces the occurrence of children's family accidental injuries and the burden of guardians. And it also meets the demand of developing intelligent service robot at home.

2. Functions of the system
The functions of child-care robot system based on OpenMV and IOT are shown in Figure 1:
Figure 1: The functions of child-care robot system based on OpenMV and IOT

- **Children tracking and safety warning function**: In the automatic control mode, the OpenMV machine vision module is used to recognize the AprilTag label pasted on the children's legs to realize the real-time tracking of children[2]. The system can also identify the hazard points and provide audible alarm in time by pasting AprilTag label. The alarm sound may be recorded by guardians themselves or provided by the system[3-6].

- **Environment temperature and humidity detection function**: The temperature and humidity of children's environment is monitored through DHT11 sensor of the robot.

- **Flame smoke detection and alarming function**: When the parameters exceed smoke sensor threshold value or the flame sensor receives low power level, the buzzer alarm will be triggered. Alarming E-mail will be continuously sent to the bound mailbox through the OneNET cloud platform, so as to facilitate rescue timely and prevent accidents.

- **GPS positioning function**: The current position coordinates of the children can be determined by GPS module of the system. Position data is transmitted to the cloud platform, and then Baidu map API can be called to clearly show the activity route of children.

- **Video real-time transmission function**: The children's activity picture is fed back to the mobile App through the WiFi camera module[7]. In the manual control mode, the guardian can also control the robot movement through the App. Meanwhile, the guardian can record the children's wonderful moments through the camera and video recording function of the APP.

- **Data viewing function through browser**: The surrounding environmental parameters of children are uploaded to cloud platform through ESP8266 WiFi module[8-9]. The data information can be displayed graphically on the browser. Users can remotely view real-time data through the browser by visiting the following address:
  https://open.iot.10086.cn/iotbox/appspage/appview?openid=f9eacab3611f05841a84f2fbf52d7f33

- **Data viewing function through App**: The data on the cloud platform can be synchronized to the mobile App for data viewing. Users only need to download the device cloud App and log in to the same user account to view the collected data information and data analysis.
3. Design of system hardware

The hardware of the system is a vehicle-type robot controlled by Arduino UNO[10], which is integrated with OpenMV machine vision module, ESP8266 WiFi module, voice module, video transmission module, GPS positioning module, power supply and a series of sensors modules for environmental monitoring. The schematic diagram of system hardware is shown as Figure 2:

(1) The OpenMV machine vision module collects the signal by recognizing the AprilTag label, converting the analog signal into electrical signal, and sending out characters through serial port. Arduino-1 board drives the motor to rotate according to different receiving characters, and sends out the voice prompt recorded by parents with jq8900-16p voice module when recognizing the hazard points AprilTag label.

(2) The video transmission module transmits the real-time picture to the mobile phone App. The user clicks the corresponding control button of App, then the signal is sent to Arduino-1 board through special APK protocol to drive the motor to rotate.

(3) A series of sensors module include DHT11 temperature and humidity sensor module, flame sensor module, MQ-2 smoke sensor module and GPS positioning module are used to monitor children's home environment.

(4) Arduino-2 board receives the information collected by the sensors and sends the collected information to the cloud through the ESP8266 WiFi module at a fixed frequency.

4. Design of system software

The software design of the system is realized by Arduino IDE and OpenMV IDE. It mainly completes the identification of AprilTag label, serial port communication between OpenMV and Arduino, initialization of serial port of main control chip and each sensor module, configuration of ESP8266 WiFi module, completing TCP connection with cloud platform, periodically driving sensor to collect environmental data according to built-in program, data packaging and uploading to cloud platform.

4.1. AprilTag recognition and target tracking

The AprilTag is identified by OpenMV machine vision module, which transmits the position data to follow the target. OpenMV is a micro, low-power microcontroller camera that allows easy use of machine vision to complete applications. Because the QR code can be only recognized by openmv3 and above, the system adopts OpenMV3 module with STM32H7 series processor of main frequency.
up to 400MHz and built-in DSP and FPU. The machine vision module is programmed with Micropython by OpenMV IDE. Micropython is optimized python language for microcontroller which doesn't need any compiling environment as its biggest advantage.

Compared with the traditional visual recognition system, AprilTag increases the recognition code of icons, which has better robustness. It can effectively deal with occlusion, warpage and lens deformation while quickly recognizing. Therefore, the system uses AprilTag as the tracking identification label which can be detected more reliably in a longer range.

The TAG36H11 family of 586 AprilTag labels except Label No. 1 is used for children tracking, which ensures the customization and diversity for users. The 8 * 8cm fabric label is chosen to minimize the possibility of interfering with the normal movement of children, and the size is also measured to ensure that the distance between the robot and children is approximately 50cm. In addition, label No. 1 which made into 6 * 6cm cartoon stickers are defined as hazard warning label attaching to sockets, table corners, window sills and other hazard points. When a child is 30 cm away from the sticker, the robot will send out an audible alarm, prompting parents to take appropriate measures to avoid danger timely.

AprilTag recognition mainly includes the following four steps:

1) **Edge detection.** Canny operator is used for edge detection: Firstly, Gaussian filter is used to smooth the image; Secondly, the gradient intensity and gradient direction matrix of the image are calculated by Sobel operator; The third step is non maximum suppression to eliminate most of the non-edge points and finally the edge is detected and outlined by double threshold filtering to improve the accuracy. Figure 3 shows the AprilTag picture, the picture after Gaussian filtering and the picture after double threshold filtering edge.

![Figure 3: Image of edge detection](image)

2) **Quadrilateral detection.** This step is to find the required quadrilateral pattern in the edge image. The non-linear edge is eliminated firstly, and the adjacent edge is searched at the linear edge. A quadrilateral is detected if a closed-loop is formed.

3) **Encoding and decoding.** There are three encoding methods, the length of black edge color block is 8, 7, 6, respectively. For decoding content, point array is generated in the detected quadrilateral to calculate the value of each color block, and then a simple classifier is constructed according to local binary patterns to classify the color blocks in the quadrilateral, encoding the positive case as 1 and the negative case as 0. After that, it is matched with the code in the known library to determine whether the decoded QR code is correct.

4) **Position determines serial communication.** Based on the above steps, the coordinates of the four top angles of the label are determined, and then the coordinates of the center point are calculated. Since the FOV abscissa of the OpenMV lens is 0-160°, it is divided into regions. According to the area where the center point is located, the corresponding communication data is returned and sent to the Arduino main control board to further control the steering gear movement.

The flow chart of mark recognition and target tracking software is shown as Figure 4:
4.2. implementation of cloud platform application

Cloud communication and data upload are developed and implemented Arduino IDE. The data collected by the sensors of the system are sent to the OneNET cloud service platform for users to view through ESP8266 WiFi module. The data upload process is shown as Figure 5:
The device access and communication flow of OneNET cloud platform is shown in the figure 6:

Figure 6: The access flow chart

All operation and configuration of ESP8266 WiFi module are configured by AT command. The main control board configures AT command for ESP8266 WiFi module, so as to realize uninterrupted automatic uploading of data and uninterrupted updating of data points of data flow.

In the design of this system, the direct data transmission between terminal equipment and OneNET needs to be connected through TCP protocol. But the data upload is packaged and uploaded through the constructed HTTP protocol. That is, packaged into HTTP request message. HTTP request message mainly consists of request line, request header and request body (optional). In order to construct an HTTP request message, data firstly attached to the message for testing, then a TCP connection with OneNET is established. Finally, it is sent to the cloud server through TCP, so as to complete the upload of a data point. The example of sending specific HTTP request message by using TCP debugging tool is shown as follows:

```java
String cmd("POST /devices/588085320/datapoints HTTP/1.1\r\n" + "Host: api.heclouds.com\r\n" + "api-key:7q1q4MsZdwF7nal5cMErlVQIicU=\r\n" + "Content-Length:" + String(cnt) + "\r\n" + "\r\n");
```

It shows that the message sent is correct, and the response result is: {errno":0,"error":"success"}, indicating that the data can be sent normally through serial port debugging. After the devices are powered on and the ESP8266 WiFi module is initialized, the data collected by sensors can be sent to the OneNET cloud platform through the ESP8266 WiFi module.

5. conclusion

An intelligent child-care robot system based on OpenMV and OneNET cloud platform is introduced in this paper. The hardware and software design of the system is described in detail. The significance of the design is to integrate machine vision and IOT technology, to realize children's movement tracking, home environment monitoring, alarms of danger in real time and data uploading to cloud platform. The system has great potential in the field of child safety accompany and has a broad application prospect.

Acknowledgments

Jing Fang acknowledge financial support from Quality Engineering Project of Colleges and Universities of Anhui Province under Grant no. 2019JYXM0058.

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