SUGISAKA MASANORI

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Research Article

An Intelligent Guide Hat Based on The Internet of Things

Suqing Duan, Yizhun Peng
College of Electronic Information and Automation, Tianjin University of Science and Technology, China

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ABSTRACT

The new guide cap utilizes an STM32 microcontroller as its control core, enabling a range of advanced features such as obstacle avoidance, intelligent recognition, voice interaction, and GPS positioning. The system incorporates the OpenMV4 Cam H7 Plus intelligent camera to provide continuous real-time monitoring and accurate feedback on important road information such as traffic lights and zebra crossings. Additionally, an ultrasonic sensor is employed to convert electrical signals into ultrasonic output, allowing for effective measurement of obstacle distances. to enhance safety, the system utilizes a Wi-Fi module and GPS positioning to transmit the user's location information in real time to nearby vehicles and pedestrians. This real-time communication ensures the maximum level of user safety.

1. Introduction

The new guide cap is powered by an STM32 microcontroller, serving as its control core and enabling a wide range of advanced functionalities. These include obstacle avoidance, intelligent recognition, voice interaction, and GPS positioning. To achieve these capabilities, the system incorporates the OpenMV4 Cam H7 Plus intelligent camera. This camera continuously monitors the surrounding environment in real-time, providing valuable feedback on important road information such as traffic lights and zebra crossings. For precise obstacle detection, the guide cap utilizes an ultrasonic sensor. This sensor converts electrical signals into ultrasonic output, allowing for accurate measurement of obstacle distances. Simultaneously, the system employs a Wi-Fi module and GPS positioning to transmit the user's location information in real time to nearby vehicles and pedestrians. This seamless communication ensures the highest level of user safety. The guide cap leverages the STM32 microcontroller as its control core, integrating features like obstacle avoidance, intelligent recognition, voice interaction, and GPS positioning. The OpenMV4 Cam H7 Plus intelligent camera continuously monitors the environment, while the ultrasonic sensor measures obstacle distances. Real-time transmission of location information through Wi-Fi and GPS enhances user safety significantly [1].

2. Intelligent Guide Cap Structure Design

2.1. *Overall system design*

The new guide cap incorporates an STM32 microcontroller as its control core, providing a comprehensive range of features such as distance and obstacle avoidance, intelligent recognition, voice interaction, and GPS positioning. Real-time monitoring of the system is achieved through the integration of the OpenMV4 Cam H7 Plus intelligent camera. This camera continuously captures and analyzes the surrounding environment, offering valuable feedback on critical road information, including traffic lights and crosswalks. To enhance obstacle detection accuracy, the guide cap is equipped

Corresponding author's E-mail: pengyizhun@tust.edu.cn URL: www.tust.edu.cn

with ultrasonic sensors. These sensors convert ultrasonic waves into electrical signals, which are then processed by transmitters to effectively measure the a Wi-Fi module and GPS positioning to transmit the user's location information in real time to nearby vehicles and pedestrians. This ensures the highest level of user safety. The design of the 3D model of the product is shown in Fig.1. The design of the physical picture of the product is shown in Fig.2.

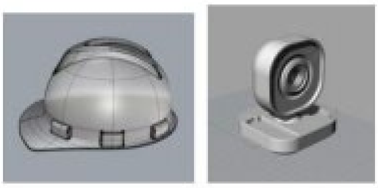

Fig.1 3D model of the product

Fig.2 Physical picture of the product

2.2. *Auxiliary sensors*

(1) OpenMV4 Cam H7 Plus

The product incorporates OpenMV-H7, a cost effective, scalable, and low-power machine vision module. OpenMV-H7 is built on a 32-bit ARM Cortex-M7 core and is powered by a MicroPython interpreter, making it easy to program machine vision algorithms directly on the embedded system [2]. OpenMV-H7 offers a range of communication interfaces, including synchronous/asynchronous transceiver, serial peripheral interface, and integrated circuit bus. These interfaces enable efficient processing and programming of complex algorithms, empowering OpenMV with impressive performance capabilities. It excels in tasks such as shape recognition, line recognition, color recognition, and more. The product leverages OpenMV-H7, a Python-driven machine vision module with a 32-bit ARM Cortex-M7 core. Its Micro Python interpreter simplifies embedded programming, while its communication interfaces facilitate the processing of sophisticated algorithms. OpenMV-H7 is well equipped for shape recognition, line recognition, color recognition, and various other tasks. The design of the OpenMV4 Cam H7 Plus picture is shown in Fig.3.

Fig.3 OpenMV4 Cam H7 Plus picture

(2) Ultrasonic Sensor

The ultrasonic distance measurement module utilizes the HC-SR04 ultrasonic distance sensor, known for its low power consumption, affordability, and ease of connectivity. The module's core consists of two ultrasonic transducers, one serving as a transmitter. Each pulse group emitted by the transmitter has a duration of approximately 0.5ms. The signal is then amplified through a transistor and passed through an impedance matching circuit, which couples a high voltage to the transmitting transducer.

As a result, the internal piezoelectric chip within the transducer begins to vibrate, emitting a pulse of ultrasonic waves at a frequency of 40kHz. When these ultrasonic waves encounter an obstacle, they are reflected back towards the sensor. The returning sound wave is processed by the TL074 chip, which filters, amplifies, and demodulates the signal. The STC11 chip is responsible for converting the ultrasonic waveform and level, and it detects the high-level signal for a certain duration known as the ECHO. Subsequently, the module enters a low power state, pausing its timing operations and reading the timer value that represents the round trip time of the sound wave. Using this time measurement, the module calculates the distance to the obstacle. The control program then processes the measured data [3], and if the distance is found to be less than 3 meters, the voice system immediately activates an alarm. The ultrasonic sensor's design can be seen in the accompanying diagram labeled as Fig.4.

Fig.4 Ultrasonic sensor

(3) Wi-Fi communication module

The module incorporates a 32-bit Tensilica processor, along with essential components such as a standard digital peripheral interface, antenna switch, RF balun, power amplifier, low-noise amplifier, filter, and power management module. This integration eliminates the need for numerous external peripheral circuits and greatly reduces the required PCB space.

One notable feature of the module is its support for low power consumption mode. In typical scenarios where a Wi-Fi connection is maintained, the module consumes only about 50mA of current. During periods of deep sleep, the power consumption is further reduced to as low as 10uA. The design of the Wi-Fi communication module is illustrated in Fig.5, showcasing the arrangement and connections of the components involved in enabling Wi-Fi communication.

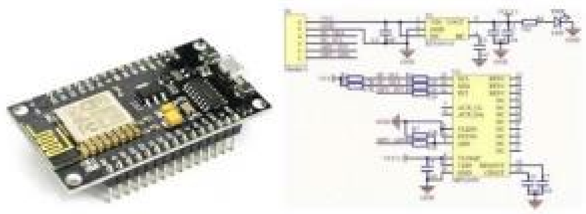

Fig.5 Wi-Fi communication module

(4) GPS Module

To power the GPS module, the STM32 microcontroller serves as the processor and receives data signals from the GPS signal receiving module. These signals are then transmitted to the serial interface of the STM32 microcontroller. The signal receiving module comprises several components, such as an inverter, signal channel, memory, central processor, and input/output interface. Communication between the GPS module and the STM32 microcontroller is established through the RXD1 and TXD1 pins of the UM220 module, which are connected to the STM32 microcontroller via a serial chip. Additionally, a reset circuit is integrated into the design, allowing for a low-level reset when the S11 button is pressed. This reset is triggered by a transition from a high to low BDRST potential. The peripheral circuit of the GPS module comprises GPS receiver devices and auxiliary circuits that support its functionality. For a visual representation of the GPS module design, please refer to Fig.6.

Fig.6 GPS module

(5) Voice interaction module

The voice interaction hardware consists of three main components: the AIUI speech recognition module, audio amplifier module, and speaker. At the heart of the voice module is the AIUI, which utilizes an intelligent hardware processor called R16, based on the Cortex-A7 architecture [4]. It employs K4B4G16 as the running memory, providing a memory size of 1GB. The storage space is facilitated by the NCEMASD9-08GEMMC flash memory [5].

For audio acquisition, the module utilizes the Cosmos CX20819-11Z ADC chip. This high-performance HD video ADC supports four-channel far-field voice capture. The AIUI and ADC chip are directly connected, enabling data interaction through a serial port. The serial communication parameters are set to a baud rate of 115200bps. The design of the voice interaction module can be observed in the provided diagram labeled as Fig.7.

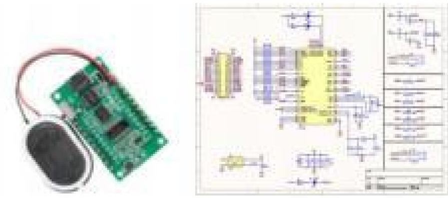

Fig.7 Voice interaction module

(6) Angle sensor module

The product incorporates the MPU6050, an integrated six-axis angle sensor from InvenSense. This sensor combines a three-axis MEMS gyroscope, a three-axis MEMS accelerometer, and an expandable digital motion processor (DMP) within a single package. The DMP enables the sensor to work in conjunction with a motion processing library to solve attitude-related calculations.

By utilizing the built-in DMP, the MPU6050 can output data from a nine-axis fusion algorithm through the IIC interface. This reduces the processing burden on the operating system, as the sensor handles the motion processing operations internally. The combination of the gyroscope, accelerometer, and DMP provides accurate and efficient attitude solving capabilities for the product. The diagram labeled as Fig.8 illustrates the design of the angle sensor module.

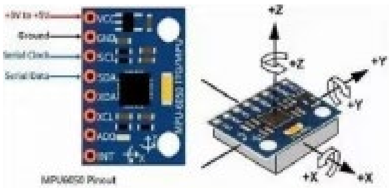

Fig.8 Angle sensor module

3. Intelligent Guide Cap Software And Algorithm

3.1. *Overall algorithm*

The product utilizes the STM32 microcontroller for C language programming, which is divided into two main parts: real-time control and real-time monitoring software. These software components enable various functions such as intelligent image recognition, ultrasonic distance measurement, and voice interaction.

In the main program, two interrupts are configured. The first is the network communication interrupt, which is responsible for receiving instructions and data from the monitoring computer. The second is a timer interrupt with a frequency of 1 kHz. When this interrupt occurs, the control interrupt subroutine is executed. This subroutine collects and processes data from each module, determines the current control mode and response type, and then applies the appropriate control algorithm to generate and send control signals. This efficient and accurate control mechanism allows the product to effectively perform its guiding function.

For instance, the OpenMV4 Cam H7 Plus distance measurement module is capable of performing precise and reliable distance measurements. It contributes to the overall functionality of the product by providing accurate distance data, which can be utilized in the control algorithm to ensure efficient and accurate guiding operations. The diagram labeled as Fig.9 presents the design of the overall algorithm communication picture.

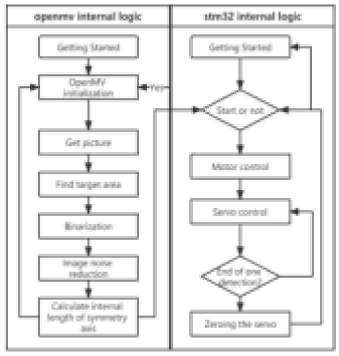

Fig.9 Overall algorithm communication picture

3.2. *Communication protocol development*

(1) The OpenMV platform utilizes Python as the programming language to drive machine vision modules. It is equipped with a MicroPython interpreter, which simplifies the programming of machine vision algorithms on embedded systems. The use of Python provides an accessible and user-friendly interface for developers to work with.

In addition to the programming capabilities, OpenMV offers various communication interfaces to facilitate the integration of complex algorithms. These interfaces include synchronous/asynchronous transceiver, serial peripheral interface (SPI), and integrated circuit bus (I2C). These interfaces enable seamless communication between the OpenMV platform and other devices or sensors, allowing for the processing and programming of advanced algorithms.

The OpenMV platform excels in a range of functions, including shape recognition, straight line recognition, and color recognition. It leverages its powerful hardware and software capabilities to efficiently perform these tasks. Developers can utilize the OpenMV platform to implement sophisticated machine vision applications with ease, thanks to its Python-driven approach and versatile communication interfaces. The diagram labeled as Fig.10 showcases the design of the OpenMV identification results.

Fig. 10 OpenMV identification results

(2) The ultrasonic module employs the DS18B20 digital temperature sensor to measure the ambient temperature. By referring to a pre-established speed of sound - temperature control table, the current speed of sound is determined based on the measured temperature.

Once the speed of sound is obtained, the module activates the counter for timing purposes. It utilizes the PWM (Pulse Width Modulation) module of the STC16F40K128 microcontroller to generate the ultrasonic echo. The generated echo is then transmitted into the receiving circuit, where it undergoes hardware processing such as shaping and amplification.

The microcontroller captures the trigger signal of the echo and records the moment of the falling edge. Through software filtering and a peak time detection algorithm, the peak moment corresponding to the arrival of the echo is identified. Finally, the distance to the obstacle is calculated based on the recorded time and the speed of sound. This process enables the ultrasonic module to measure distances accurately by leveraging temperature compensation and precise timing techniques. The design of the test results for the Ultrasonic module is depicted in Fig.11.

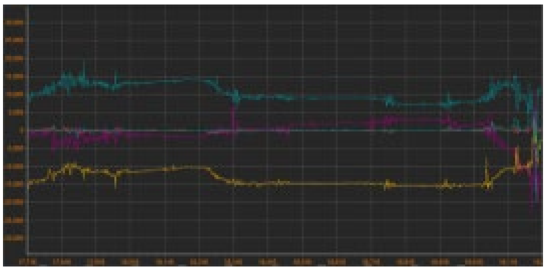

Fig. 11 Ultrasonic module test results

(3) The GPS module comprises four main components: data loading, data pre-processing, calculation and result return. The module interfaces with the GPS receiver to receive real-time feedback data. The received data undergoes processing and fusion techniques to enhance the positioning accuracy of the system.

By combining single-point real-time positioning and post-facto precision single-point positioning settlement solution, the system achieves improved positioning accuracy. This fusion approach leverages the advantages of both real-time and post-processing techniques to deliver more accurate results.

To enhance system security, the data transmission process incorporates RXM/RAW decoding technology. This technology ensures the safety and reliability of the program to the maximum extent possible, reducing the risk of data corruption or unauthorized access [6].

Furthermore, the ability to transmit location information accurately and in a timely manner to surrounding vehicles and pedestrians enhances safety. It reduces the potential security threats for individuals with visual impairments, providing them with valuable information about their surroundings and reducing the risk of unexpected situations. The design of the GPS module positioning results is displayed in Fig.12.

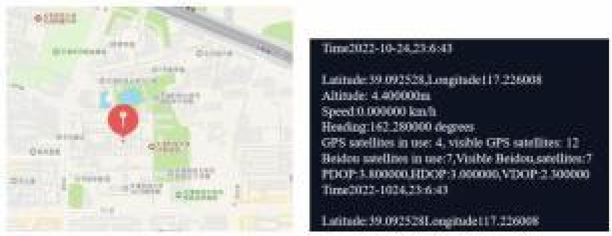

Fig. 12 GPS module positioning results

(4) The voice control component of the system is implemented in C language. During development, specific keywords are set for voice commands. The voice chip extracts the voice features and compares them with the predefined keywords. When a matching keyword is recognized, the corresponding data is sent from the voice chip to the main control board via the serial port.

Upon receiving the data in JSON format, the main control board analyzes it to extract the identification code associated with the recognized command. Based on the identification code, the board executes the corresponding operation or action associated with the recognized voice command.

This process allows for voice control of the system. By defining and recognizing specific keywords, the system can respond to voice commands by performing the desired actions. The use of JSON format for data transmission and analysis enables efficient communication and seamless integration between the voice recognition chip and the main control board. The design of the initialization and operation results of the Voice module communication code is depicted in Fig.13.

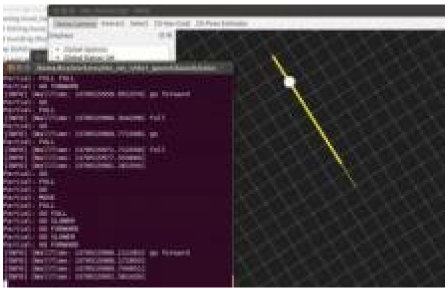

Fig. 13 Voice module communication code initialization and ope ration results

(5) The gyroscope module in this system utilizes the MPU6050, which combines a 3-axis MEMS gyroscope and a 3-axis MEMS accelerometer. Additionally, it features an expandable digital motion processor (DMP) that enables the integration of additional sensors [7].

The MPU6050 is capable of connecting to a third-party digital sensor, such as a magnetometer, through the I2C interface. By expanding its capabilities, it can output a 9-axis signal via either the I2C or SPI interface. The integration of the gyroscope, accelerometer, and DMP in the MPU6050 allows for accurate attitude resolution. It provides information about rotational movements and acceleration in three dimensions. Furthermore, the expandability feature enables the incorporation of other sensors to enhance the system's sensing capabilities. The design of the Gyroscope MPU6050 communication code running result s is shown in Fig.14.

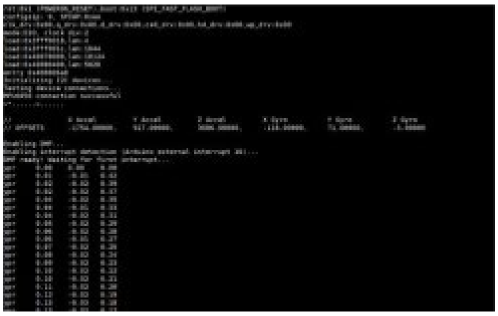

Fig. 14 Gyroscope MPU6050 communication code running results

(6) The WiFi module in the system utilizes the ESP8266 as the communication interface between the main processor and the guide cap. When the ESP8266 module starts up, it will print the name of the connected WiFi network and its own IP address. This information allows users to identify the network and obtain the IP address for further communication.

During operation, if the ESP8266 module is not connected to the server, it will continuously print a message indicating that it is not connected. This feedback helps in monitoring the status of the WiFi connection.

By leveraging the ESP8266 module, the system establishes a wireless connection and enables communication between the main processor and the guide cap. The module provides important network information and real-time status updates for effective monitoring and troubleshooting. The design of the WIFI module communication results is shown in Fig.15.

Fig. 15 WIFI module communication results

4. Conclusion

The intelligent guide cap is a comprehensive solution that integrates various sensors and external devices to address the needs and challenges faced by visually impaired individuals. Through a combination of microcontrollers, machine vision, Internet of Things (IoT), embedded systems, and voice control, this product provides practical functionality for visually impaired users.

One of the key features of this guide cap is its ability to analyze the surrounding environment using multiple sensors. By leveraging technologies such as machine vision, the system can accurately detect obstacles and promptly alert the user to avoid them. It also provides real-time information about the status of traffic lights at intersections, ensuring that visually impaired individuals can navigate safely. The guide cap further enhances safety by recognizing zebra crossings and providing guidance for blind individuals to cross the road in the correct direction. Voice prompts and other forms of communication enable easy interaction between the user and the system, providing essential information and instructions.

Through the widespread adoption of this product, more visually impaired individuals can gain increased independence in their daily lives. This, in turn, contributes to reducing societal misconceptions and prejudices towards blind individuals. Overall, the intelligent guide cap serves as a valuable tool for the development and inclusivity of society.

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Authors Introduction

Ms. Suqing Duan

She is currently pursuing her undergraduate degree at the College of Electronic Information and Automation, Tianjin University of Science and Technology. Her research field is embedded system.

Dr. Yizhun Peng

He is an Associate Professor in Tianjin University of Science &Technology. He recevived a doctor's degree in control theory and control engineering from the Institute of Automation, Chinese Academy of Science, in 2006.His research field is intelligent robot and intelligent control.