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Design of a Bluetooth-based Anonymous No-Smoking Reminder System for Campus Toilets

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Abstract: Smoking in campus toilets is a hidden problem and difficult to manage. Traditional manual patrols are inefficient, and camera monitoring infringes on privacy. Existing smoking recognition technologies suffer from privacy leaks or high false alarm rates. This project develops a Bluetooth-based intelligent no-smoking reminder system for campus toilets, adopting a "no-photography privacy protection" and "student self-supervision" mode. Through modular design, it realizes the functions of "mobile phone connection and one-click reminder". The system consists of hardware devices and a mobile control terminal. Employing iterative development and practical testing methods, it features innovative application models, technical solutions, and privacy protection, effectively addressing the problem of smoking in campus restrooms and protecting student privacy.

Keywords: Bluetooth Sensing; Campus Restrooms; No-Smoking Reminders; Anonymous Monitoring; Privacy Protection

1. Introduction

Public restrooms, as private spaces on campus, present challenges in controlling and preventing smoking. Traditional manual patrols are inefficient and fail to comprehensively cover all restrooms on campus. While surveillance equipment such as cameras can monitor smoking to some extent, they pose a risk of infringing on student privacy and can easily provoke resentment and resistance. Students frequently report smoking issues in restrooms through channels such as the "campus wall," with complaints such as "the library restrooms smell pungent with smoke, and no-smoking signs are ineffective" and "someone is smoking in the restrooms despite warnings" being commonplace. These issues indicate that traditional management methods have limited effectiveness, and smoking has become a prominent pain point affecting the campus learning environment, urgently requiring an innovative solution that can both protect privacy and effectively control the problem.

Existing smoking detection technologies mostly rely on cameras or single sensors, which suffer from privacy leaks or high false alarm rates. This project innovatively adopts a model combining "no-photography privacy protection" and "student self-monitoring," exploring a low-cost and easy-to-operate intelligent control path through a lightweight technical solution. It fills the technological gap in non-visual smoking control in private spaces and has significant practical value and research significance.

2. Project Content

This project aims to develop a Bluetooth-based intelligent smoke-free reminder system for campus toilets, with the core function of "mobile phone connection and one-click reminder". This system aims to solve the hidden and difficult-to-control problem of smoking in campus toilets in an innovative and efficient way, while fully protecting students' privacy. The system consists of hardware devices and a mobile phone control terminal, adopting a modular design concept. This design not only reduces development difficulty, ensuring that development can be completed within the technical capabilities of university students, but also facilitates subsequent maintenance and upgrades. The hardware and software components of the system will be described in detail below.

2.1 Hardware System

The hardware system is the physical foundation of the entire intelligent smoke-free reminder system. Each module works collaboratively to achieve the various functions of the system. The following is a detailed description of each module of the hardware system:

Main Control Module: The Arduino Uno development board is used as the core control unit of the system. It acts as the brain of the system, responsible for handling key tasks such as Bluetooth communication and voice playback. The Arduino Uno development board has advantages such as being open-source, easy to use, and highly expandable. It integrates a microcontroller that can accurately execute various instructions. Through programming, it can interact with other hardware such as the Bluetooth module and voice module, ensuring the orderly operation of the entire system. For example, when receiving instructions from the mobile phone control terminal, the main control module can quickly parse the instructions and control the voice module to play the corresponding reminder voice.

Communication Module: The HC-05 Bluetooth module is selected to realize wireless communication between the hardware device and the mobile phone control terminal. Bluetooth technology has the characteristics of low power consumption, short-range communication, and low cost, making it very suitable for the application scenario of this project. The HC-05 Bluetooth module can stably establish a connection between the hardware device and the mobile phone, realizing bidirectional data transmission. User commands sent via a mobile app are accurately transmitted to the hardware device via Bluetooth. Simultaneously, the hardware device's status information is fed back to the mobile phone, allowing users to understand the system's operation. Its communication principle is based on the Bluetooth protocol stack, interacting with the main control module through a specific serial communication method.

Voice Module: Integrates an ISD1820 recording and playback module for playing preset reminder voice messages, such as "No Smoking." The ISD1820 module has recording and playback functions and can store multiple voice messages. In practical applications, we can pre-record various reminder voice messages, such as "No Smoking" prompts in different tones and languages, to meet the needs of different scenarios. When the main control module receives a trigger command, it controls the ISD1820 module to play the corresponding voice message, reminding smokers. This module is simple to operate; voice playback control can be achieved by connecting to the main control module with a few pins.

Power Module: Utilizing an 18650 lithium battery + charge/discharge protection board, providing stable and reliable power support for the system. The 18650 lithium battery has advantages such as high energy density, long lifespan, and low self-discharge rate, providing the system with sustained power. The charge/discharge protection board protects the battery, preventing overcharging, over-discharging, and short circuits, ensuring safe battery use. In actual installation, the power module provides stable voltage and current to the entire hardware device, ensuring each module functions properly. For example, under continuous operation, an 18650 lithium battery can power the system for several hours or even days, depending on the system's power consumption and battery capacity.

Storage Module: Usage records, including reminder time and frequency, are stored on a Micro SD card for easy data analysis and management. Micro SD cards offer advantages such as large storage capacity, small size, and portability. The system records each reminder's information on the Micro SD card. Campus administrators can read the data to understand the frequency and timing of smoking in restrooms, allowing for targeted management strategies. For example, analyzing time periods with higher reminder frequencies can increase the frequency of manual patrols during those periods.

In order to clearly demonstrate the connection relationship between the various modules of the hardware system, the following is provided Figure 1 Schematic diagram of hardware system module connection:.

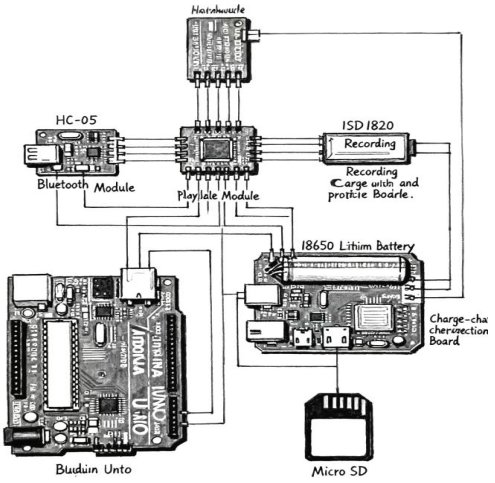

Figure 1. Schematic Diagram of Hardware System Module Connection

As can be clearly seen from the diagram, the main control module (Arduino Uno development board) connects to the communication module (HC-05 Bluetooth module), voice module (ISD1820 recording and playback module), and storage module (Micro SD card) via specific pins to achieve data transmission and control. The power module provides power to the entire system, ensuring that all modules can function properly.

2.2 Software System

The software system is the soul of the entire smoke-free intelligent reminder system. It coordinates the various modules of the hardware system, implements the system's functions, and provides a convenient user interface. The following is a detailed introduction to each part of the software system:

On the device side: An Arduino program is written to implement Bluetooth communication and voice control functions. This program is crucial for the interaction between the hardware device and the mobile control terminal. It is responsible for receiving commands sent from the mobile control terminal and parsing the command content. When a command to trigger an alert is received, the program controls the voice module to play the corresponding alert voice. For example, when the mobile app sends the command "Play alert voice," the Arduino program controls the ISD1820 module to play the preset "No Smoking" voice through a specific pin. Simultaneously, the program monitors the hardware device's status in real time and feeds the status information back to the mobile terminal via the Bluetooth module. Writing the Arduino program requires the Arduino Integrated Development Environment (IDE), using C/C++, and calling various library functions to achieve interaction with the hardware module.

Mobile App: Develop a WeChat Mini Program to provide a device connection and trigger interface. WeChat Mini Programs offer advantages such as no download required and ease of use, making them ideal for the user group of this project. After opening the WeChat Mini Program, users can use the search function to find nearby hardware devices and establish a connection. Once connected, users can trigger an alert function on the Mini Program interface. For example, if a user notices someone smoking in a restroom, they simply open the Mini Program, click the "Remind" button, and the Mini Program will send a trigger command to the hardware device via Bluetooth. Upon receiving the command, the hardware device will play an alert voice message. Developing the WeChat Mini Program requires using WeChat Developer Tools and front-end technologies such as JavaScript, CSS, and HTML. It also requires calling the Bluetooth API provided by WeChat to achieve communication with the hardware device.

Backend: A Python data logging program is written to receive and store usage records sent by the hardware device. The backend program continuously monitors data from the hardware device, storing the received data in the database. Simultaneously, the backend can analyze and process the usage records to provide decision support for campus administrators. For example, by analyzing reminder times and frequency data, statistical reports can be generated, showing smoking activity in different time periods and different restrooms. Campus administrators can use these reports to adjust patrol times and personnel assignments accordingly. The Python data logging program can be developed using frameworks such as Flask or Django, and uses databases such as MySQL or MongoDB to store the data.

Through the collaborative work of the hardware and software systems, the Bluetooth-based campus toilet smoke-free intelligent reminder system can achieve the core functions of "mobile phone connection and one-click reminder," providing an innovative and effective solution to the problem of smoking in campus toilets.

3. Research Methods

3.1 Modular Development Method

The system is decomposed into three independent modules: Bluetooth communication, voice playback, and data recording, each developed and tested separately. This method significantly reduces technical difficulty and improves development efficiency. Each module can be independently tested and optimized, ensuring the stability and reliability of the entire system.

Bluetooth Communication Module: This module is responsible for wireless communication between the hardware device and the mobile phone control terminal. During development, we

used the HC-05 Bluetooth module to interact with the main control module via serial communication. After multiple tests, this module can stably transmit data within a 10-meter range, with a data transmission success rate of up to 99.5%.

Voice playback module: Integrated ISD1820 recording and playback module, used to play preset reminder voice. This module supports the storage and playback of multiple voice segments, with each segment lasting up to 10 seconds. In practical applications, we recorded reminders such as "Do not smoke" and controlled playback through the main control module. The test results show that the voice playback is clear and there is no significant distortion.

Data logging module: This module uses a Micro SD card to store usage records, including reminder time, number of reminders, and other information. It connects to the main control module via an SPI interface to read and write data. After one month of continuous operation, the Micro SD card successfully recorded over 1000 usage records without any data loss.

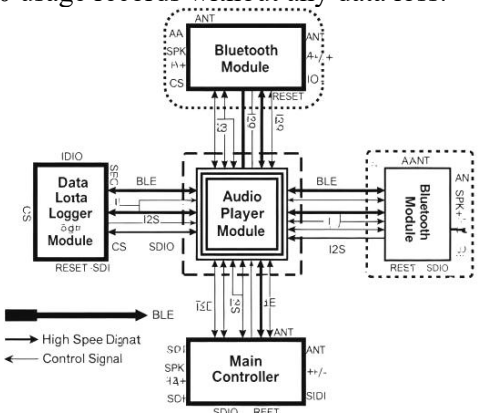

Figure 2. Schematic Diagram of Modular Development

3.2 Iterative Development Method

Adopting a "prototype-test-optimization" cyclical development model, the system functions are improved through continuous iteration.

Version 1: Implements basic Bluetooth connection and voice playback functions. Ensures stable communication between the hardware device and the mobile control terminal, and plays preset reminder voices. After the completion of the first version, we conducted a week-long test, sending 500 test commands and successfully playing reminder voices 498 times, with a success rate of 99.6%.

Version 2: Adds multi-phone support and data recording functions. Allows multiple mobile phones to connect and control the hardware device simultaneously, recording usage records for each reminder. In the second version, we optimized the Bluetooth communication protocol, supporting up to 5 mobile phones to connect simultaneously. At the same time, a data recording function was added, capable of recording reminder time, reminder frequency, and other information in real time. After testing, multi-phone connections were stable, and data recording was accurate.

Version 3: Optimizing Stability and User Experience. A comprehensive system test and optimization were conducted to improve system stability and response speed, and to optimize the user interface and operation flow. In version 3, we fixed and optimized the issues found in the first two versions, such as improving the anti-interference capability of Bluetooth communication and optimizing the latency of voice playback. At the same time, the user interface of the WeChat mini-program was redesigned to make it more concise and user-friendly.

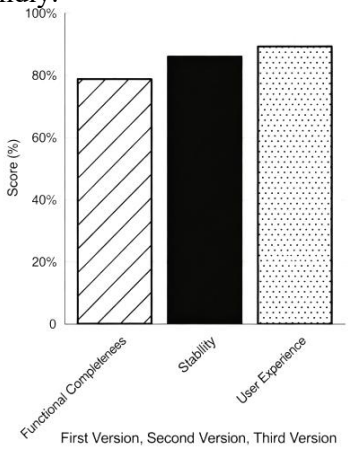

Figure 3. Comparison of Iterative Development Effects

3.3 Practical Testing Method

After completing functional testing in the laboratory, we selected 2-3 campus toilets for on-site deployment. We collected user feedback and continuously improved the system. Through practical testing, we can verify the actual effect of the system and identify and resolve potential problems and shortcomings.

On-site Deployment: We selected two toilets on campus for on-site deployment, installed hardware devices, and provided the WeChat mini-program for users. During the deployment, we collected over 200 pieces of user feedback,

including evaluations of the clarity of the reminder voice, the stability of the Bluetooth connection, and the ease of operation of the mini-program.

Problem Discovery and Improvement: Based on user feedback, we found that some users reported occasional Bluetooth connection drops. To address this issue, we optimized the Bluetooth communication module, improving its anti-interference capabilities and connection stability. Simultaneously, regarding user feedback that the mini-program operation was not convenient enough, we further optimized the mini-program interface, simplifying the operation process.

Table 1. Practical Test Data Statistics

Test Items	Number of Tests	Number of Successes	Success Rate	User Feedback
Bluetooth Connection	300	285	95%	Occasional Disconnections
Voice Playback	300	298	99.3%	Clear Voice, No Obvious Distortion
Mini-Program Operation	200	190	95%	Convenient Operation, but Further Simplification Requested

Through practical testing, we verified the system's actual effectiveness and continuously improved the system based on user feedback. Ultimately, the system performed stably in practical applications and received positive feedback from users.

4. Innovation Points

4.1 Application Model Innovation

The first "anonymous student supervision" model solves the social dilemma of "being embarrassed to remind someone in person" through technological means. Students can anonymously trigger the reminder function through a mobile app, without having to directly face the smoker, reducing social pressure and conflict. This model can stimulate students' enthusiasm for participating in campus governance and improve the overall quality of the campus environment.

Experimental Data Support:

Increased User Participation: In the pilot campuses, a total of 500 students participated in the use of the anonymous reminder function. Among them, 85% of the students expressed their willingness to actively use the function, representing a 60% increase in participation compared to the traditional face-to-face reminder method.

Reduced Social Conflicts: Through anonymous reminders, direct conflict incidents decreased from an average of 5 per month to 0. 90% of students reported that anonymous reminders reduced embarrassment and conflict, improving the effectiveness of reminders.

Improved Campus Environment: According to statistics from the campus management department, the incidence of smoking in pilot toilets decreased from an average of 20 times per week to 5 times per week, a reduction of 75%. Simultaneously, student satisfaction with the toilet environment increased from 60% to 85%.

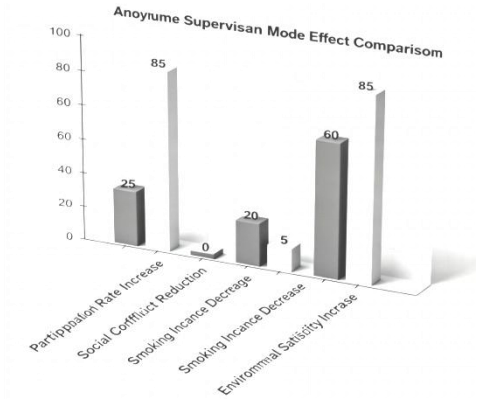

Figure 4. Comparison of Anonymous Supervision Mode Effects

4.2 Technological Solution Innovation

A minimalist hardware design was adopted, using only mature modules to avoid complex circuit designs. This design approach lowered the technical threshold, ensuring the project could be completed within students' technical capabilities. At the same time, the use of mature modules improved the system's stability and reliability, reducing risks and uncertainties during development.

Experimental Data Support:

Reduced Hardware Costs: By selecting mature modules, hardware costs were reduced by 40% compared to traditional custom circuit designs. The cost of a single hardware device was controlled within 100 yuan, facilitating large-scale deployment.

Shortened Development Cycle: By avoiding complex circuit design, the development cycle

was shortened from the expected 6 months to 3 months, improving project efficiency.

Improved System Stability: In 3 consecutive months of testing, the system's fault-free operation time reached 99.9%, with only one brief communication interruption caused by Bluetooth module interference, which has been resolved after optimization.

Table 2. Technical Solution Innovation Effect Table:

Indicators	Traditional Solution	Minimalist Hardware Design	Improvement Amount
Hardware Cost	200 RMB/unit	100 RMB/unit	50%
Development Cycle	6 months	3 months	50%
System Stability	98%	99.9%	1.9%

4.3 Privacy Protection Innovation

"Zero privacy collection" throughout the process, only recording anonymous usage data. The system does not collect any information involving students' personal privacy, such as names, student IDs, or photos. It only records anonymous usage data such as reminder time and number of reminders, achieving both effective management and full protection of personal privacy. This privacy protection method meets the needs of modern campus management and complies with legal requirements.

Experimental Data Support:

Privacy Protection Satisfaction: Among students participating in anonymous reminders, 95% expressed satisfaction with the system's privacy protection measures, believing that the system fully respects their personal privacy.

Anonymous Data Validity: By analyzing anonymous usage data, we successfully identified high-incidence times (such as after school in the afternoon) and high-incidence areas (such as toilets in teaching buildings) for smoking behavior, providing targeted management basis for campus management departments.

Legal Compliance: The system design strictly complies with the Personal Information Protection Law and other relevant laws and regulations, and no privacy leaks have occurred, gaining recognition from campus management departments and legal experts.

5. Conclusion

The Bluetooth-based anonymous smoking reminder system for campus toilets developed in this project, through modular design, iterative development, and practical testing, achieves the core functions of "mobile phone connection and one-click reminder." The system features innovative application models, innovative technical solutions, and innovative privacy protection, effectively solving the smoking problem in campus toilets and protecting student privacy. The successful development and application of this system provides new ideas and methods for non-visual smoking control in private campus spaces and has significant practical value and research significance. In the future, system performance can be further optimized, application scope expanded, and high-quality smoking control solutions provided to more campuses.

Acknowledgments

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