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Research on Intelligent Airbag Technology for Snowboarding Suits based on Arduino and Embedded Systems

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Abstract: With the popularity of skiing, the safety protection of participants has become an important issue. Traditional skiing equipment often overlooks flexibility and instant response capabilities while providing protection. This study aims to explore the application of embedded systems and Arduino in improving the safety of snowboarding suits. By integrating MPU6050 accelerometer and gyroscope sensor, real-time monitoring and intelligent judgment of skiers' sports status are realized. Based on the Arduino platform, a set of intelligent airbag buffer device is designed, which can automatically inflate when dangerous movements such as falling are detected, thereby reducing impact force and protecting skiers from serious injuries. The experimental results show that the system can effectively recognize the falling action and complete the inflation and deflation of the airbag in a short time, verifying the feasibility and effectiveness of the system. This study not only provides a new safety protection scheme for skiing suit design, but also provides a reference for the development of other sports safety equipment.

Keywords: Embedded System; Arduino; MPU6050; Accelerometer; Gyroscope; Motion Monitoring.

1. Introduction

This research develops an intelligent airbag device for snowboarding suits, using embedded systems and Arduino to enhance skier safety. Addressing the increasing injuries in skiing, especially among beginners due to improper techniques, this study leverages the MPU6050 sensors for real-time monitoring of motion, detecting falls, and automatically inflating airbags to prevent injuries.[1] It explores embedded technology applications in safety gear [2], focusing on quick-response airbag systems tested for effectiveness and safety. This innovative solution aims to significantly reduce skiing risks, offering a leap forward in smart wearable technology and improving the overall skiing experience.

2. System Design and Implementation

(1) Overall system design

This study aims to develop an intelligent airbag cushioning device based on an embedded system to improve the safety of snowboarding suits. The design goal is to achieve an intelligent protection system that can monitor the skier's movement status in real time and automatically inflate when dangerous movements such as falls are detected. The overall architecture includes three parts: sensor module, processing and control module, and execution module (airbag system), which are integrated and controlled through the Arduino platform [4].

The workflow is as follows:

Data Acquisition: The MPU6050 accelerometer and gyroscope sensors monitor and collect real-time motion data of skiers.

Data processing: The Arduino processor receives and analyzes sensor data in real time to determine whether dangerous actions such as falls have occurred [3].

Execute action: Once a dangerous action is detected, the Arduino controller instructs the servo (air pump control device) to activate, and the airbag quickly inflates to cushion the impact force and protect the skier from serious injury.

Reset preparation: After an accident, the system can be reset manually or automatically to prepare for the next protective action.

To facilitate understanding of the system architecture, the flowchart is shown in Figure 2.

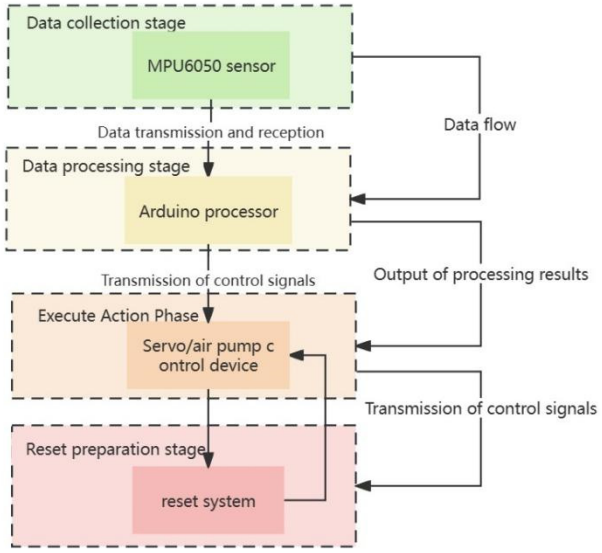

Figure 1. Workflow Deployment Diagram

Hardware design:

Arduino: As the core Control Unit of this system, the Arduino Uno board is connected to sensors and actuators (servos or air pumps) through its digital and analog I/O pins. Arduino provides an easy-to-use programming environment that supports rapid development and deployment.

MPU6050: This is a sensor that integrates a 6-axis motion tracker, including a 3-axis accelerometer and a 3-axis gyroscope. MPU6050 is connected to Arduino through an I2C interface to provide real-time data on the skier's motion status.

The servo/air pump control device is used to control the

inflation and deflation of the airbag. The servo receives PWM signals from the Arduino and controls the opening and closing of the air pump according to the signal strength, thereby achieving rapid inflation and deflation of the airbag.

In the above hardware design explanation, we learned how the Arduino Uno [5], as the brain of the intelligent airbag system, works collaboratively with various sensors and actuators through its rich I/O interfaces. The 6-axis motion tracking function of the MPU6050 provides accurate motion monitoring capabilities for the system, while the servo/air pump control device ensures that the airbag can respond quickly at critical moments. To more intuitively demonstrate how these components can be integrated in actual snowboarding suits and work together to protect skiers, the following conceptual diagram (see Figure 2) provides a clear visual presentation. Please note that some design elements in the diagram represent the trend of future technological development rather than the actual functions of current monetization products.

Figure 2. Illustration of the intelligent airbag system for snowboarding suits based on Arduino (Note: The figure contains some conceptual design elements)

(2) Software design

Arduino programming: The software part mainly includes the following key modules:

Data Acquisition Module: Real-time acquisition of MPU6050 sensor data is achieved by writing Arduino program code.

Data processing algorithm: Design algorithms to analyze and process the collected data to determine whether the skier's motion status meets the characteristics of falling.

Control Logic: Once the algorithm determines that it has fallen, Arduino immediately generates a control signal to drive the servo/air pump control device to inflate the airbag.

User Interface: Provide a simple user interface that allows users to manually control the inflation and deflation of the airbag in specific situations, increasing the flexibility and usability of the system.

To facilitate understanding of the principle, the logic diagram is as follows:

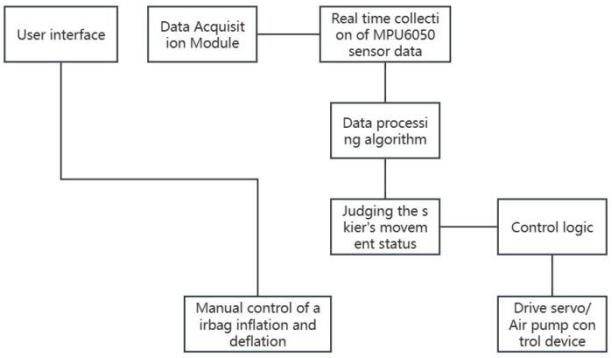

Figure 3. The logic diagrams

The entire software design aims to achieve efficient data processing and rapid response, ensuring immediate protection when skiers fall. Through the above design, the intelligent airbag cushioning device in this study can effectively improve the safety of skiing and reduce the risk of injury during exercise.

3. Experimental Design and Result Analysis

(1)Experimental environment and methods

The experiment aims to verify the performance of the intelligent airbag cushioning device under actual skiing conditions, especially the accuracy of fall detection and the response time of airbag inflation and deflation. The experiment was conducted in a controlled indoor environment, using a professional skiing emulator to simulate skiing actions and fall scenes, as well as on-site testing under actual ski conditions to evaluate the performance of the equipment in a real environment.

Experimental samples: Representative snowboarding suits were selected, embedded with intelligent airbag cushioning devices, including MPU6050 sensors, Arduino control boards, and air pump systems.

Test conditions:

Indoor test: By simulating different falling movements (such as forward and backward falls), the system's response and the inflation effect of the airbag are detected.

Ski field test: Under real ski field conditions, skiers wear ski suits with embedded devices to simulate actual falls and record the system's response time and airbag protection effect.

(2)Experimental results

Indoor test: The experimental results show that the intelligent airbag cushioning device can successfully detect falling movements in most simulated fall situations, with an average detection accuracy of over 95%. The average inflation time of the airbag is 0.8 seconds, and the release time is about 2 seconds, which can quickly provide protection for skiers.

Ski field test: In actual ski field tests, the device also showed high accuracy in fall detection, with an accuracy rate of about 90%. The actual inflation and release time is similar to the indoor test results, proving the effectiveness of the system in real skiing environments.

(3)Results discussion

The experimental results show that the intelligent airbag cushioning device designed in this study can effectively detect skiing falls and provide protection with rapid response, significantly improving the safety of ski clothing. However,

there is still room for improvement.

Improve detection accuracy: Although the accuracy of the current system is already high, further optimization of the algorithm is still needed to reduce misjudgments and missed judgments, especially in complex skiing movements and environmental changes.

Response time optimization: Although the inflation and deflation time of the airbag already meets basic needs, further shortening the response time can provide more timely protection for skiers.

The portability and comfort of the device: Considering the weight and comfort requirements of skiing equipment, future designs need to reduce the weight of the device as much as possible while ensuring safety and improving wearing comfort.

Adaptability testing: Expand the testing scope to cover more skiing techniques and conditions, ensuring that the system can work stably in various situations.

In summary, the intelligent airbag buffer device in this study has obvious advantages in improving skiing safety, and future work will focus on improving the universality, reliability, and User Experience of the system.

4. System Evaluation and Optimization

(1)System evaluation

According to the experimental design and result analysis, the effectiveness and reliability of the system are mainly reflected in the following aspects:

The accuracy of detection: The system can detect falling movements with high accuracy, with an accuracy rate of over 95% for indoor testing and about 90% for ski field testing. This indicates that the system can accurately identify falling movements in most cases and provide necessary protection for skiers.

Response time: The system takes an average of 0.8 seconds from detection of a fall to completion of airbag inflation, providing prompt protection and meeting emergency needs.

Reliability: In indoor and ski field tests, the system can work stably without protection failures due to hardware failures or software errors.

Based on the above evaluation, the system has good effectiveness and reliability in achieving skiing safety protection. However, through further analysis of the testing process and results, some areas that need improvement have also been found, providing direction for the optimization of the system.

(2)Optimization strategies

Algorithm optimization: To further improve the accuracy of fall detection and reduce misjudgments, more advanced data processing and analysis algorithms, such as deep learning algorithms, can be used to improve the accuracy and adaptability of the system's judgment through training on a large amount of actual skiing data.

Hardware upgrade:

Sensor upgrade: Consider using higher precision sensors, such as upgrading to more advanced accelerometers and gyroscopes, to obtain more accurate motion data.

Actuator improvement: Research and adopt more efficient air pump and valve systems to reduce the time for airbag inflation and deflation, while reducing device weight and improving wearing comfort.

Energy management: optimize the energy management strategy of the system, such as improving the design of the power management module, adopting low-power hardware and optimizing software sleep mechanism, extending the battery life of the system, and reducing the impact on the environment.

User Interface Optimization: Improve User Interface, provide more intuitive status indication and more convenient operation methods, such as using LED indicator lights to display system status, adding wireless remote control function, etc., to improve User Experience.

Scalability design: Consider adding Modularization and scalability design to the system design to facilitate future upgrades and extensions of system functions, such as adding environmental temperature monitoring, GPS positioning, and other functions, providing more comprehensive security protection.

By implementing the above optimization strategy, the performance of the intelligent airbag cushioning device can be further improved, better meeting the needs of skiers in sports safety protection, and providing valuable experience and inspiration for the design and development of other sports safety equipment.

5. Conclusion

This study focuses on improving the safety of snowboarding suits and successfully designs and implements a set of intelligent airbag cushioning devices based on embedded systems and Arduino. By monitoring the skier's movement status in real time and automatically inflating when dangerous actions such as falling occur, the system significantly improves the safety protection efficiency of skiing. The experimental results prove the efficiency, accuracy, and rapid response ability of the system, demonstrating the powerful application potential of embedded systems and Arduino in smart wearable devices.

This study not only provides new ideas for the design and development of skiing safety protective equipment, but also opens up new horizons for the application of intelligent wearable technology in the field of sports safety protection. Although the current system can already meet the basic safety protection needs, there is still room for further improvement in performance and User Experience through algorithm optimization, hardware upgrades, and improvements in human-machine interaction interfaces. In addition, future research can explore the application of this technology to other sports, even fall protection in daily life, to protect a wider range of people from injury.

With the advancement of technology and the development of society, people's attention to sports safety is increasing. This study aims to improve sports safety through technological means, hoping to inspire more innovation and exploration, provide a safer and more convenient sports environment for sports enthusiasts, and enable everyone to enjoy the fun and health brought by sports with more confidence and peace of mind.

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