Research on the Application of Intelligent Information Processing in the Field of Sports Shoes

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Abstract: With the rapid advancement of modern science and technology, intelligent technology has developed rapidly and become a prevailing trend penetrating various industries. The traditional sports footwear industry is also undergoing innovative transformation by introducing advanced intelligent control systems. These smart systems are designed to realize core functions such as high-precision positioning, real-time fall detection, stable wireless signal transmission and intelligent data analysis feedback. With the joint cooperation of cloud service systems, mobile terminal equipment and built-in high-sensitivity sensors, the whole system can complete efficient information collection, transmission and data processing. This technological integration not only optimizes the overall performance of sports shoes, but also effectively guarantees users' exercise safety. Meanwhile, it can record movement data in real time, providing scientific and personalized reference for people's daily fitness training and daily health management.

Keywords: Sports Shoes; Intelligent Information Processing; Elderly Fall Detection; Sports Feedback

1. Introduction

With growing health awareness and rapid advancements in smart wearable technology, consumers' demands for sports health management have become increasingly sophisticated. While mainstream smart bands and watches currently available on the market offer basic functions such as step counting and heart rate monitoring, they still exhibit limitations in fitness scenario adaptability and deep integration of health data. Particularly for fitness enthusiasts and the elderly, existing products struggle to meet the following core needs: precise sports data tracking (e.g., gait analysis, real-time recording of calorie expenditure and exercise trajectories); proactive health management (dynamic monitoring of weight, body fat, and other obesity indicators); and safety assurance (instant alerts and positioning capabilities in case of accidental falls). Therefore, it is imperative to actively develop integrated smart control systems for sports footwear to address these needs.

2. An Overview of Sports Shoes and Intelligent Information Processing

2.1 Analysis of the Advantages, Disadvantages, and Market Demand for Sports Shoes

The core advantages of sports shoes lie in their functional adaptability and wearing comfort,

though they also have limitations in specific scenarios. The specific pros and cons are as follows:

Main Advantages: (1) Shock Absorption and Protection: The sole typically employs advanced materials such as EVA and air cushion technology, effectively absorbing impact forces from the ground during walking or exercise [1], thereby reducing injuries to joints like knees and ankles. (2) Breathability and Comfort: The upper primarily uses breathable materials like mesh fabric, enhancing air circulation to minimize foot ness and sweating. Paired with a soft insole, it fits snugly against the foot without feeling restrictive. (3) Grip and Anti-Slip: The sole pattern design is precisely engineered to increase friction across various surfaces, improving stability during movement and exercise. (4) Versatility for Multiple Scenarios: From daily commuting and casual shopping to running, fitness activities, and ball sports [2], these sneakers meet diverse needs with high practicality.

Main disadvantages: (1) Limited professionalism: General-purpose sneakers cannot replace specialized footwear. For instance, hiking requires the support of mountain shoes, while formal occasions demand the ceremonial qualities of leather shoes; sneakers prove unsuitable or functionally inadequate in these scenarios. (2) Rapid sole wear: To ensure traction, most sneakers feature soft soles that wear out quickly after prolonged use on rough surfaces or intense workouts, reducing durability and functionality. (3) Varying cleaning challenges: While mesh uppers are breathable, they tend to accumulate dirt and stains, and certain materials (such as suede) require specialized cleaning tools, resulting in higher maintenance costs compared to regular shoes.

As the most common type of footwear for daily use, sports shoes are extremely convenient for both athletic activities and everyday outings [3]. With the improvement of living standards, people have begun to prioritize body shape and health management, making running a popular means to achieve this goal. Consequently, the demand for sports shoes in the footwear market is exceptionally high. However, conventional sports shoe designs have reached saturation; only bold innovations and personalized customization in the sports shoe sector can help capture market share.

2.2 Intelligent Information Processing

Intelligent information processing is an innovative technology that integrates principles from information science, artificial intelligence theory, and data mining techniques. It simulates the human brain's information processing mechanisms through computer technology in complex information environments, enabling simultaneous automatic information collection, analysis, and deep processing while leveraging intelligent optimization capabilities [4]. The theoretical foundations of intelligent information processing include information theory, cognitive science, and machine learning, while its technical underpinnings involve big data processing and natural language processing technologies. These technologies optimize information utilization environments, addressing issues such as low efficiency and insufficient accuracy in practical information handling, with the key focus lying in high-level information decision-making and regulation. Compared to traditional information processing methods, intelligent information processing exhibits more pronounced intelligent characteristics: it supports various human intervention modes, self-adjusts to changes in information sources and data types, and dynamically optimizes processing workflows in real-time. It demonstrates strong adaptability, effective autonomous learning capabilities, independent information organization and integration, and collaborative processing of multi-source information. Upon detecting anomalies or processing deviations, it autonomously corrects errors efficiently and makes scientific information decisions based on multidimensional data. Unlike conventional systems, intelligent information processing combines quantitative data analysis with qualitative interpretation,

featuring advanced intelligent processing capabilities that fully meet the standards of complex information systems. Typically, the objects processed by intelligent information systems exhibit high complexity, heterogeneity, and uncertainty. Leveraging intelligent information processing technologies enables the execution of diverse complex information tasks, supported by robust technical capabilities that overcome the environmental and technical limitations of traditional information processing methods, thereby facilitating efficient deep information processing and value extraction. Currently, intelligent information processing is primarily applied in fields such as natural language understanding, image recognition, data visualization, and intelligent recommendation systems. The processing approaches are highly diverse, encompassing deep learning, fuzzy logic, and reinforcement learning techniques.

3. Innovative Design of Intelligent Information Processing in the Field of Sports Shoes

We utilize a cloud with powerful computing capabilities to process information and other functions. By embedding chips inside the shoes without compromising their normal wearability, combined with the built-in sensing system, we achieve multi-dimensional health management [5]. Specifically, a micro-pressure sensor array based on Micro-Electro-Mechanical Systems (MEMS) is implanted beneath the insole, capturing real-time foot pressure distribution across 2,048 sampling points. This data is integrated with the MPU6500 gyroscope to monitor three-dimensional motion posture, enabling the construction of a dynamic pressure-posture correlation model [6]. The system transmits data to the cloud via Bluetooth 5.0 and employs the TensorFlow Lite framework for gait feature extraction, accurately identifying six movement modes-including running and walking-and calculating body weight fluctuations based on pressure center trajectory deviations (with an error margin of ±5%), providing a basis for weight management for fitness enthusiasts. This system also enables continuous weight monitoring, meeting the weight management needs of some runners. In China, the aging population is accelerating, and the inability to promptly assist elderly individuals during falls remains a significant issue [7]. To address this, we have developed pressure thresholds and level sensors to detect potential falls, supplemented by existing positioning and WeChat mini-program feedback features to ensure elderly safety. Additionally, leveraging the product's existing capabilities, we analyze foot pressure distribution through pressure sensors and integrate medical data from the cloud to assess potential gait abnormalities. The cloud processes the collected data comprehensively using its computing power, presenting the results to users via icons or bar charts.

4. Intelligent Module Design

4.1 Low-power Processing Module

The entire control circuit is a low-power circuit powered by a 3V button battery, offering extended battery life and ease of replacement. The core processor is an IC controller integrated with a Bluetooth module and a built-in Hall sensor, capable of recording motion duration and distance to calculate speed. When the Hall counter sensor detects the magnetic field signal generated by the magnet, it triggers an interrupt on the core processor, awakening it from sleep mode. The processor then counts and records the current time while calculating the current speed. If no Hall sensor signal triggers an interrupt within two minutes, the processor records the last interrupt time as the end time of the journey. It subsequently calculates the maximum speed, average speed, total distance, start time, and end time for the entire journey, storing the data in memory (Figure 1).

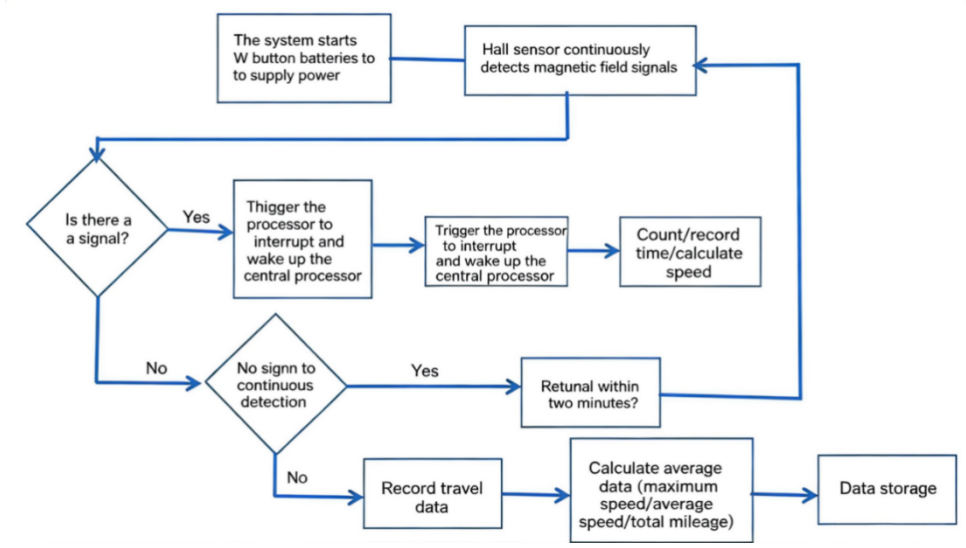

Figure 1: Low-power Processing Flowchart.

4.2 Data Interaction Module

The device stores the collected information on the smartphone. When the WeChat Mini Program connects to the controller via Bluetooth, it uploads all data to the Mini Program. The Mini Program then processes the data graphically and meticulously through the cloud, before sending it to the user via WeChat (Figure 2). Users can share their exercise data with friends or on their Moments.

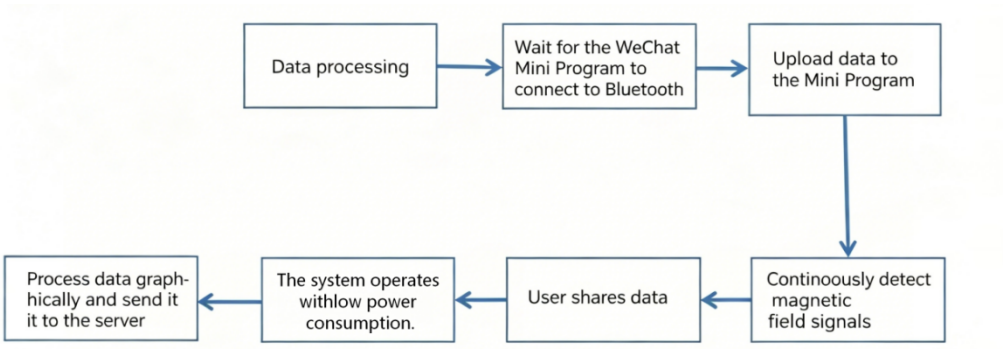

Figure 2: Data Interaction Flowchart.

4.3 Elderly Fall Detection Module

To address the needs of an aging society, the system innovatively integrates a triple-layer security protection mechanism [8]: First, a fall detection model based on pressure thresholds [9] is established, triggering an alert when the heel pressure drops by more than 30% and the horizontal acceleration exceeds 1.5g; second, a MEMS digital compass is integrated for real-time posture angle monitoring, with an tilt angle (>30° lasting 1.2 seconds) identified as a fall using a quaternionic algorithm (Figure 3); finally, the system connects with the BeiDou-3 positioning module and a WeChat mini-program to send emergency contact notifications within 5 seconds. Notably, the cloud-based medical database incorporates 100,000 cases of normal gait data. Through convolutional neural network analysis of the user's plantar pressure center movement trajectories, the system identifies eight types of gait abnormalities, including flatfoot and excessive internal rotation [10],

generating visualized assessment reports. The entire system is powered by CR2032 button batteries, achieving a three-month battery life via adaptive power management (operating current: 0.8 mA; sleep current: 0.02 mA). Its modular design complies with medical device standards, offering an innovative solution for smart elderly care and sports health applications.

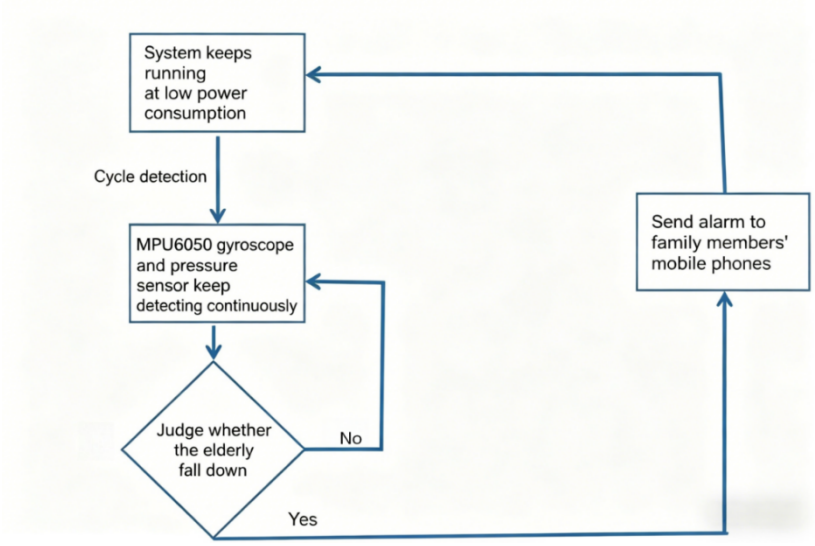

Figure 3: Flowchart of Elderly Fall Detection.

5. Overall Equipment Operation Process

When powered by a 3V button battery, the system initiates continuous detection via a Hall sensor. If a magnetic field signal is detected, the interrupt trigger activates the processor to count/take time and calculate speed. If no signal is detected, the system verifies whether no signal has been received for two minutes; if this condition is met, it records the end time, calculates travel data, saves the information to memory, and waits for Bluetooth connection with the WeChat Mini Program. Upon connection, the data is uploaded to the Mini Program for graphical processing and sent to the server, while motion data can also be shared with friends or on social media. The system also includes a fall detection module (using the MPU6500 gyroscope and pressure sensor): if an elderly user falls, an alarm is sent to family members via wireless notification on mobile devices (Figure 4). Throughout this process, the system operates in low-power mode until the next user interaction.

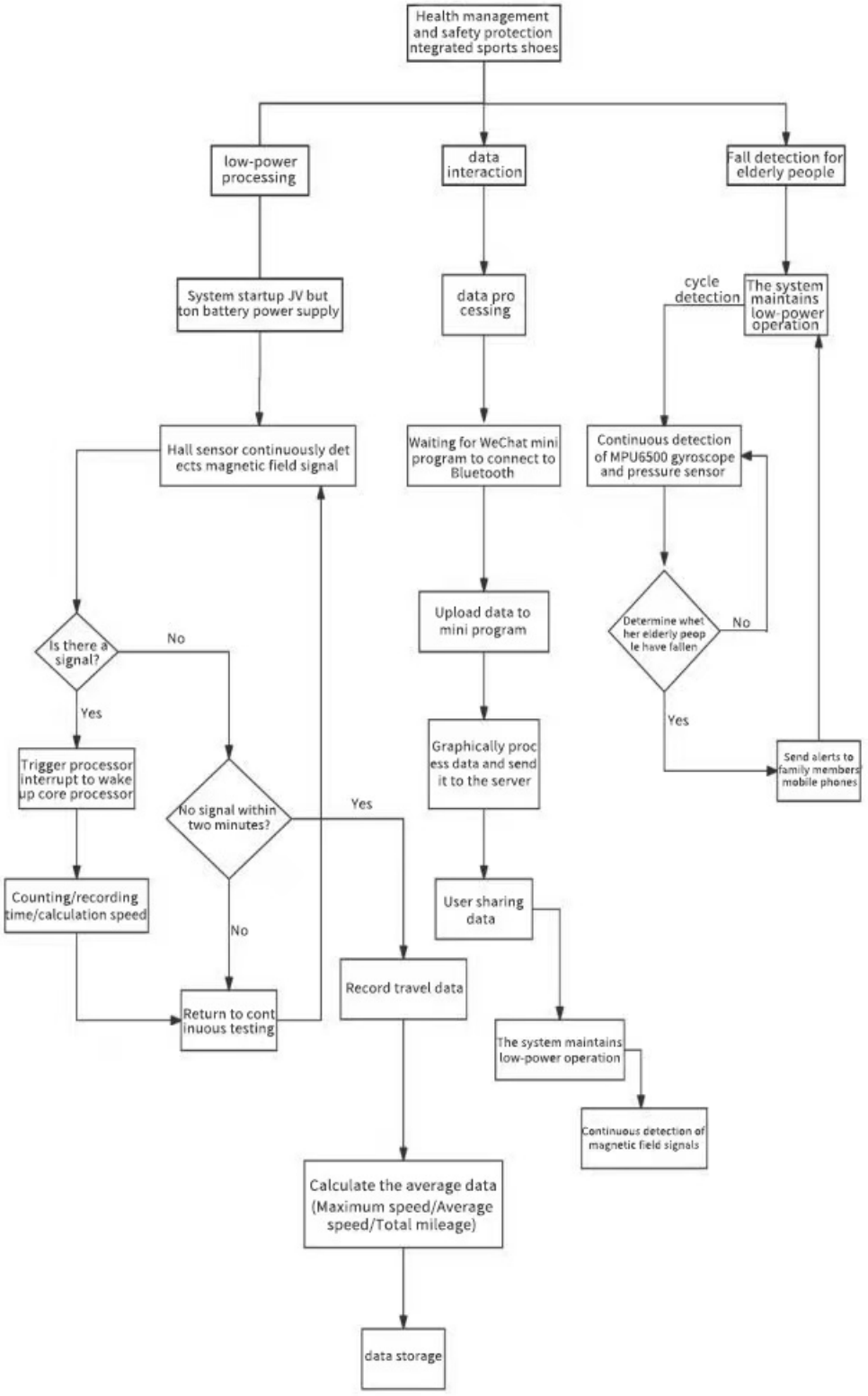

Figure 4: Overall Equipment Operation Flowchart.

6. Conclusion

This study investigates an intelligent sports shoe system based on smart information processing, which utilizes embedded sensors and cloud computing to achieve precise motion data tracking, fall

detection, and health management functions, effectively enhancing exercise quality and health safety for sports enthusiasts and elderly users. The system's integrated operational workflow combines data acquisition, processing, and feedback mechanisms, ensuring a closed-loop operation from motion monitoring to cloud analysis. The collaborative design of low-power processing modules, data interaction modules, and elderly fall detection modules not only demonstrates the system's advantages in energy efficiency, data accuracy, and real-time responsiveness but also significantly improves safety for older adults. This design addresses the functional limitations of traditional sports shoes through intelligent information processing technology while achieving dual objectives of personalized health management and social safety assurance. Future research will focus on optimizing sensor accuracy, expanding medical database integration, and reducing power consumption to further enhance the system's practicality and versatility in complex scenarios.

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