Practice and Application of Ski Simulator

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Abstract: *With the joint promotion of the spread of skiing and intelligent development in sports, ski simulators have gradually moved from the field of theoretical research to practical application; they are excellent tools that can solve the problems of bad weather and limited space at outdoor ski resorts, and are now being used in various places, such as ski education, professional training and public leisure. Based on the current application status of ski simulators, this paper will systematically study practical solutions for hardware setup and software implementation of ski simulators, analyze all kinds of usage modes, actual effects and core advantages in different situations, find problems in the application process from existing case studies, and propose targeted optimisation plans. Give some practical advice and theoretical support for the large-scale use and technological upgrading of ski simulators in this paper to promote nationwide dissemination and high-quality development of ice and snow sports.*

Keywords: *Ski Simulator, Application, Motion Capture, Scene Adaptation, Ice and Snow Sports.*

Introduction

Skiing is a demanding yet very enjoyable winter sport that has gradually gained popularity among people in China in recent years. Outdoor ski training is affected by bad weather and high venue fees, and there are also safety risks; therefore, it cannot be organised frequently, and the quality of the training is not high. With the rapid development of virtual reality (VR) technology, artificial intelligence, sensors and so on, ski simulators have gone from the realm of theory to that of application. With the help of accurate motion capture, realistic scene simulation and scientific feedback guidance will be added to correct the deficiencies of outdoor skiing, and a good link will be established between theoretical ski teaching and practical training. Many kinds of ski simulators have been developed and used around the world and in China recently. For example, the Joyful World Double-Plank Ski Simulator System has been successfully introduced in schools, gyms and other places, and has been selected as a good creative design option for the "Technology Winter Olympics Smart Beijing" project; thus, it has many applications. Based on the current application cases and technological implementation experience of ski simulators, this paper will systematically analyze the present situation of their use in practice and application from the perspectives of hardware configuration, software implementation, multi-scenario application, practical problems and optimisation strategies, to offer support for further technological optimisation and scenario expansion.

1. Practical Configuration Scheme of the Ski Simulator

Based on the current application experience of ski simulators and the effect of the application, cost control and scene adaptation have been considered in the development of a standard hardware configuration and a software implementation plan. These Designs are not only theoretical but have also been used in practice to meet all kinds of demands, and they will continue to develop with new technologies in the future. The hardware is modular, the software is based on well-known algorithms, and therefore the equipment can operate stably and be used in many places to meet the basic requirements of these applications[1].

1.1 Hardware Practice Setup

The Goal of Hardware is to achieve "Accurate Acquisition, Stable Operation and Scene Adaptation". Based on the application feedback for the components, some have been omitted from the Design to reduce complexity and cost. It has been widely used in many places and is suitable for all kinds of physical education, exercise and leisure activities.

1.1.1 Inertial Measurement Unit

MPU9250 is a well-known commercial Inertial Measurement Unit that has been widely used, and it has a 3-axis accelerometer, a 3-axis gyroscope and a 3-axis magnetometer. It can obtain real-time data on the skier's angular velocity, acceleration, limb attitude angles, magnetic field information, etc., accurately determine the trajectory of motion during gliding, turning, braking and jumping, and avoid the error of a single inertial measurement. The first two are relatively fast and accurate, and they can also detect changes in motion every few milliseconds. Based on the above analysis, it can meet the motion-capture needs of skiers of all abilities, provide a foundation of data support for motion feedback and optimisation, and be applied in professional training and teaching[2].

1.1.2 Pressure Sensor Module

Several FSR402 film pressure sensors have been placed on the simulated sliding platform, and based on the results of debugging, their positions have been optimised. At any time, the module can obtain the distribution of pressure, size and shift at the centre of gravity of a skier's feet on the platform and do so accurately. Based on the pressure data, it can be known how a skier distributes force and regulates their centre of gravity; therefore, motion optimisation can be achieved quantitatively. At the same time, it will also move the actuator module to change the platform resistance, restore the force feedback of real ski slopes, help beginners control the centre of gravity more easily, and improve the realism and user experience of the sliding simulation. The above Design has been widely used in the actual product called Joyful World Double-Plank Ski Simulator System.

1.1.3 Environmental and Posture Auxiliary Sensors

In fact, the SHT30 temperature and humidity sensor and the TFmini Plus laser rangefinder have been used in the construction of the monitoring system in this paper. SHT30 temperature and humidity sensors will be used to collect real-time environmental temperature and humidity data in various places for the basis of low-temperature scene simulation and equipment adjustment in all kinds of environments, etc. TFmini Plus laser ranging sensors can be used to find out how far a skier is from the equipment to prevent injury due to excessive motion, improve the precision of scene interaction, and achieve the effect of "the scene moving with the user". Therefore, the continuity and immersion of the experience will be increased, the safety of the equipment will be guaranteed, and the demands of multi-user environments will be met.

1.1.4 Main Control

STM32F103VET6 will be used as the main control unit. Based on the above, and after some trials, it has been decided that this chip is suitable for the purpose of data collection and analysis, algorithm calculation, peripheral communication and decision-making in this system. It has a Cortex-M3 core and can run at up to 72MHz; therefore, all the tasks of the various sensors, data collection, posture analysis, etc., will be handled efficiently, and all parts of the system will work well together and run stably. It has 512KB of flash memory and 64KB of SRAM; the program code, data cache and other intermediate results will be stored here. It has many communication interfaces, such as SPI, I2C and UART, and can be connected with all kinds of sensors, drive modules, displays, communication modules, etc.; thus, it meets the demand for multi-device cooperation and reduces the difficulty of subsequent maintenance.

1.1.5 Actuator Drive Module

The two modules are a hydraulic drive unit and a motor drive unit, and they work together. Based on the actual debugging and tuning of the parameters, the position and force regulation of the simulated sliding platform have been corrected properly. A hydraulic drive unit is a small electric hydraulic push-rod with a hydraulic damper that can continuously vary the slope from 0 to 35 degrees and reproduce all kinds of terrain on ski slopes accurately, such as alpine, cross-country and flat slopes. The motor drive unit is a 28BYJ-48 stepper motor; PWM (pulse width modulation) signals are used to control the speed and direction of the motor, drive the transmission mechanism, change the sliding resistance of the simulation platform in real time according to the movement and speed of the skier, and thus reproduce friction feedback at the interface between the skis and the snow. The three modules are

the drive module, the pressure-sensing module and the posture-sensing module; together they can adjust the position and resistance of the platform according to the needs of skiers of different ages. Therefore, the module will be stable and meet the demands of long-term, continuous operation[3].

1.1.6 Power Supply, Communication and Display Modules

Power Supply Module is a 26650 Lithium-ion battery pack. Optimisation has been carried out on the combined method to construct a 12V battery pack with a total capacity of 5000mAh; it can operate for more than 8 hours on a single charge and meet the long-term operating needs of professional training and commercial use. A charging protection circuit and a voltage regulation circuit have been added to prevent overcharging, over-discharging and overcurrent; thus, a stable power supply will be provided in cold weather and the life of the battery will be extended.

1.2 Software Application Practice

The Hardware Practice Configuration is employed to construct the software system, and some well-known algorithms have been applied. Based on the development scenarios mentioned above, some stable and effective functional modules have been created for the integration of training science and virtual reality. All the functions of the software have been tested for operation and meet the application requirements in all situations; they will be extended and improved in the future.

1.2.1 Posture Analysis and Feedback Algorithm

As the foundation for the application of ski simulators, a large amount of real data has been collected to train and optimise this algorithm. It can collect all kinds of posture and pressure information from various sensors accurately, then perform motion recognition, deviation analysis and personalised feedback[4].

1.2.2 Scene Rendering and Terrain Simulation Algorithm

Unreal Engine 4 will be employed to build and display the scene. Based on the above work, the scene database and rendering parameters have been optimised to build a scene system that can support many kinds of terrain, such as alpine, cross-country and flat slopes, and all sorts of weather, including sunny, snowy and foggy. It can display 2K high-definition pictures, have light and shadow rendering technology, and make the scenes more realistic and better reproduce the appearance of outdoor ski slopes.

1.2.3 Personalized Training Plan Algorithm

According to the actual needs of all kinds of users, the algorithm will be modified. It can offer personalised training plans for all levels and all goals of skiers, from basic classes for new students to the improvement of intermediate and advanced skiers.

1.2.4 Motion Control and Human-Computer Interaction Module

After many rounds of debugging, the motion control module can now properly receive the decision-making commands from the main controller and regulate the operation of the actuator drive module; thus, posture adjustment, resistance control and safety protection for the simulation platform have been realised. An encoder is employed to obtain the actual speed and position of the motor and platform in real time, and then, with the help of a PID algorithm, the output signal of the motor is adjusted to improve the control accuracy, stability and reliability of the sliding simulation. Based on the actual operation, the response time of the platform posture adjustment is less than 0.5 seconds, and it can promptly react to changes in user position.

2. Practical Application Scenarios and Effects of the Ski Simulator

Based on the current application cases of ski simulators, they have been widely used in many places for physical education, professional training, fitness and entertainment, community activities, etc. Based on the various application demands in different areas, many different application models have been developed. Based on the above verification, these models can solve the basic problems of all the above situations, improve the efficiency and convenience for users, and promote the spread and development of ice and snow sports. Among them, the Joyful World Double-Plank Ski Simulator System has been successfully introduced in many places, such as schools, enterprises and institutions, gyms and homes, etc., and has achieved good practical results.

2.1 Application Scenarios in Physical Education Classes

Ski simulators have been used for a long time in physical education to help improve the skills of students participating in winter sports at schools, universities, special schools for ice and snow sports, professional ice and snow training institutions, etc. According to the teaching needs, the arrangement and functions of the equipment have been optimised to form a standard teaching application model, and good results have been achieved in practice.

2.2 Application in Professional Training and Competition Preparation Scenarios

Gradually, ski simulators have started to be employed in the training of professional ski teams and for competition preparation to help with professional training, and have become necessary equipment. Based on the actual needs of professional training, a simulator has been developed that can accurately reproduce all kinds of terrain and snowy weather conditions at the competition venue to help athletes systematically and precisely correct their movements and improve the efficiency of preparation. Professionals of the ski team can use the high-precision motion capture and scene simulation functions of the simulator to create many kinds of snow trail conditions in all sorts of competition venues and conduct off-season training. Record the training data and movement weaknesses of the athletes in a simulator, and based on this data, help coaches develop customised training plans to improve the movement and performance of the athletes in competition. At the same time, many kinds of snow conditions and unforeseen circumstances can be created to train the athletes' emergency response skills. Based on the above, simulations have been used to improve the stability of athletes' movement and enhance their performance in competition. In addition, the simulator can show the path and turn angle of the athlete as they pass the gate in real time to help the athlete correct their racing posture according to the requirements for competition preparation.

2.3 Application Cases of Fitness and Entertainment Activities

The main uses of the market-oriented ski simulator app are exercise and leisure, such as gyms, indoor ice and snow experience centers, other commercial leisure areas, etc. As people are looking for both enjoyment and exercise, various entertainment applications have been developed with the aim of improving the equipment experience and functions to become popular with the public[5].

2.4 Application in Promoting Community and Public Service Development

With continuous efforts to bring ice and snow sports closer to the people, ski simulators have gradually entered communities and are now popular ways for more people to experience such sports. According to the demands of the local community, we will reduce the difficulty and usage fees of the equipment to make it more affordable and low-risk for them, thereby spreading the culture of ice and snow sports.

3. Problems and Optimization Strategies in the Practical Application of Ski Simulators

3.1 Main Problems at the Application Stage

Although some good results have been achieved in the application of ski simulators so far and their application scenarios are constantly expanding, some problems still exist in the process of large-scale application that affect the quality and promotion speed of the application. The three main reasons are as follows.

First, the equipment cost is relatively high, so we will not be introducing it. At present, the hardware setup and software development costs of ski simulators are relatively high, and so are the prices of the equipment. Primary and secondary schools, communities and small fitness centres have limited procurement funds, so it will not be possible to carry out this project. At the same time, the operation and maintenance costs of the equipment are high, professional staff are needed for maintenance and debugging, so the application cost is further increased and its popularisation is limited.

Secondly, the technology is not very advanced. Some of the ski simulators that have been developed so far do not have realistic scene simulation and motion-capture accuracy. For example, the ground simulation of the complicated ski track is not very realistic, and there is also a lag in motion capture at

high speeds that affects the user experience. At the same time, the functional adaptability of some simulators is relatively weak and cannot meet all the different demands of people of different ages and with different skill levels; for example, there are no special functions for older people or children.

Third, the application mode is too simple. Most of the time, ski simulators are still only used for the basic experience and training, and there are no other many applications. For example, the integration of ice and snow sports events, science popularisation and parent-child activities is not close enough, and thus the full application value cannot be realised. At the same time, there is no sharing of application experience in different scenarios, and thus the full effect of using a simulator cannot be achieved.

3.2 Target Optimisation Strategies

Based on the problems that have occurred in actual operation and taking into account the current stage of technological development and application experience, the following optimisation strategies are proposed to promote the wide application and technological progress of ski simulators[6].

Lower the promotion threshold to reduce the cost of promotion first. To reduce the procurement cost of the main hardware, we can buy in bulk and use new technologies. At the same time, small and affordable simulator models need to be developed to meet the procurement requirements of primary and secondary schools, community organizations, etc. Improve the research and development of the software by using good algorithms and thus reduce development costs. An organised operation and maintenance system should be established, training for the operation and maintenance staff will be conducted, and thus the costs of maintenance will be reduced and the popularisation of simulators promoted.

Second, the technology needs to be more convenient for the people to use. Continue to improve the posture capture algorithm and the scene rendering algorithm to increase the accuracy of motion capture and the realism of scene simulation, reduce latency at high sliding speeds, and enhance the sliding experience of real ski trails. Given that different people have different needs at different times in their lives and various skill levels, many of the equipment's functions need to be optimised and special modes added; for example, there is a simple mode for children and a leisure mode for older people to meet all kinds of demands. At the same time, the equipment operation interface should also be convenient for people to use, and all groups need to be able to start using it quickly. With the help of the interactive functions in the Joyful World Double-Plank Ski Simulator System, we will improve both the game and the user experience of this equipment.

Third, add new application modes to increase the value of the application. Enhance the integration of ski simulators in all sorts of places and add new application modes. Simulator racing competitions can be organised together with other events for ice and snow sports. In addition to science popularisation, other activities to promote the spread of knowledge about ice and snow sports and simulator experiences can also be organised. In addition to parent-child activities, parent-child interactive modes can also be added for the application of simulators. At the same time, a mechanism for sharing application experience across different scenarios should be established, excellent practical cases need to be summarized, and the overall application effect of simulators should be improved to help achieve the goal of "engaging 300 million people in ice and snow sports".

4. Conclusion

Many problems in outdoor skiing have been addressed by the introduction of ski simulators, and now they are being used to promote the development of ice and snow sports, improve professional training, and provide public entertainment and exercise activities. Based on the implementation cases and technical experience so far, the hardware configuration and software functions have been gradually improved, various application scenarios and standardised application models have been formed, and good results have been achieved in areas such as physical education, professional training, fitness and entertainment, community services, etc. For example, the Joyful World Double-Plank Ski Simulator System has been successfully introduced in many places and serves as a model for other companies in this field.

At present, ski simulators still have the problems of high cost, lack of technical flexibility, and only one mode of use in actual life; therefore, their large-scale development and improvement in application quality have been limited. In the future, we will continue to advance technology and cost control, improve the adaptability of equipment and user experience, innovate application modes, promote deep

integration of simulators with all kinds of scenarios, and expand the application value. At the same time, the sharing of application experience in all kinds of situations should also be expanded to promote technological iteration and large-scale application of ski simulators, thereby contributing to the nationwide popularisation and high-quality development of ice and snow sports, and providing new ideas and references for the practical application of intelligent sports equipment.

Fund Projects

Supported by the General Project of the Key Research and Development Program of the Shaanxi Provincial Department of Science and Technology (2024SF-YBXM-680), the Youth Innovation Team Project of the Shaanxi Provincial Department of Education (22JP070), and the 2025 College Student Innovation and Entrepreneurship Project: Snow Leap Pro --- "Dynamic Analyzer of Intelligent Ski Wearable Devices".

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