Explore the role of sensors and machine learning in the context of mechanics in improving the indoor positioning capabilities of educational-assisted robots

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ABSTRACT

This paper discusses the sensor technology to improve the indoor positioning ability of educational assisted robot. Under the background of mechanics, by integrating various sensors (such as inertial measurement units, optical sensors, etc.) and using particle filtering algorithm, more accurate indoor positioning is realized. The study adopts modular design, which divides the robot system into three subsystems: robot, action recording and wireless remote control, and ensures performance through independent development and testing. In the positioning system, combined with odometer, IMU and lidar data, the dynamic particle number particle filtering algorithm is used to achieve global accurate positioning. This study is of great significance for improving the application effect and personalized educational experience of educational-assisted robots.

Keywords: Education-assisted robot, indoor positioning, sensor technology, particle filtering, modular design

1. INTRODUCTION

With the advancements in sensing, computing, motor, and control technologies, robots have become increasingly miniaturized and powerful, seamlessly integrating into our daily lives. As a subset of service robots, educational robots have evolved since the 1960s, when Stanford Research Institute initiated research into mobile robot autonomy, focusing on reasoning, planning, and control.[1] These robots have progressed from simplistic teaching tools to intelligent interactive companions, enhancing early childhood education, special education, foreign language training, and programming education. Their personalized learning plans and interactive capabilities rely heavily on precise indoor localization. This study concentrates on sensor technology within a mechanical context, leveraging particle filter algorithms to enhance the localization accuracy of educational robots, ultimately enhancing educational effectiveness and personalized learning experiences.[1]

2. DESIGN THE OVERALL SCHEME

This study aims to explore the application of sensor technology within a mechanical context to enhance the indoor positioning capability of education-assisted robots. The experimental design encompasses the selection and configuration of multiple sensors to ensure adequate data support and high-precision positioning requirements. Firstly, an inertial measurement unit is chosen, integrating accelerometers, gyroscopes, and magnetometers, which collaborate to provide comprehensive information on the robot's motion in space.[2] Secondly, optical sensors such as laser scanners and cameras are employed to assist in positioning by capturing environmental features. The sensor configuration takes into account the robot's size, motion characteristics, and working environment, ensuring optimal performance without mutual interference.

2.1 Design technique

This study used a modular design method to divide the robot system into three independent subsystems: robot subsystem, action recording subsystem, and wireless remote control subsystem. Each subsystem was independently developed and tested to ensure adequate performance. For each subsystem, special hardware and software testing tools are designed for module testing. After the successful module test, the system integration test was conducted. Because the robot is not highly required for artificial intelligence operation, the control system uses the embedded processor to realize the action

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control, including the design of the embedded software and hardware. The action recording function is realized through the action recording software of the graphical interface on the upper computer computer. Through this design, the robotic system is effectively divided into three subsystems, and the respective system block diagram is shown in Figure 1.

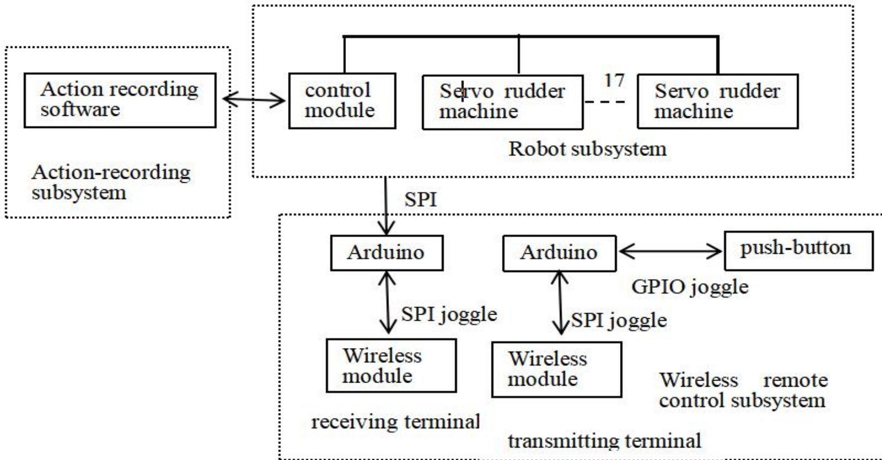

Figure 1. Robot system structure

2.2 Overall architecture of localization system

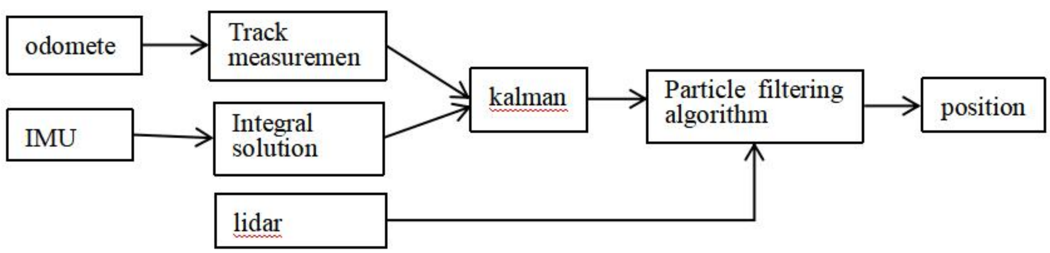

Figure 2. Dynamic particle number particle filter algorithm is set as a process

Indoor positioning technology mainly relies on a variety of sensors carried by the robot.[3] Kong X proposes, a positioning algorithm that combines binocular vision and IMU data, using extended Kalman filter and Sigma Point Kalman filter to improve the stability and accuracy of pose estimation. Z. Integrating odometer data with monocular visual inertial system data,[4] D. Dang et al. The data provided by these sensors is used in track inference and probabilistic localization methods, which are specifically divided into local localization information acquisition and global positioning. Milometer data by the track location information,[5] and IMU through the corresponding positioning information, then using an improved dynamic particle number particle filtering algorithm to local location information and the distance of laser radar information fusion processing, so as to realize the probability positioning, finally get accurate global positioning information.

2.3 Hardware system connection

In the indoor positioning system, the robot is equipped with the sensor that plays a key role. These sensors include the odometer, the inertial measurement unit (IMU), and the lidar, which together provide the necessary motion and location information for the robot. The data of the odometer is processed by using the probabilistic positioning method based on particle filtering, which includes the acquisition of local positioning information and the realization of global positioning. The odometer data is used to calculate location information, while the IMU data provides localization information through integration operations. This local localization information is then fused with distance data measured by lidar through an improved dynamic particle number particle filtering algorithm to achieve probabilistic localization and ultimately determine the global localization information. The IMU data is transmitted through the serial port. In order to facilitate the interaction with the microcomputer, the serial port to USB module is adopted to realize the connection with the USB interface. Both the lidar and UWB tag modules transmit data through the USB interface, so they are then directly connected to the USB interface of the microcomputer. When these steps are completed, the hardware connectivity and data communication of the experimental platform are established.

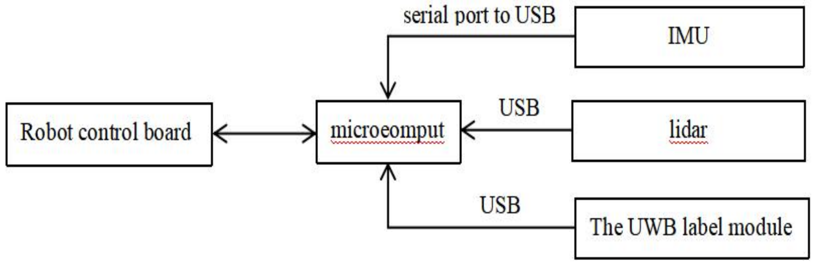

Figure 3. Hardware system connection diagram

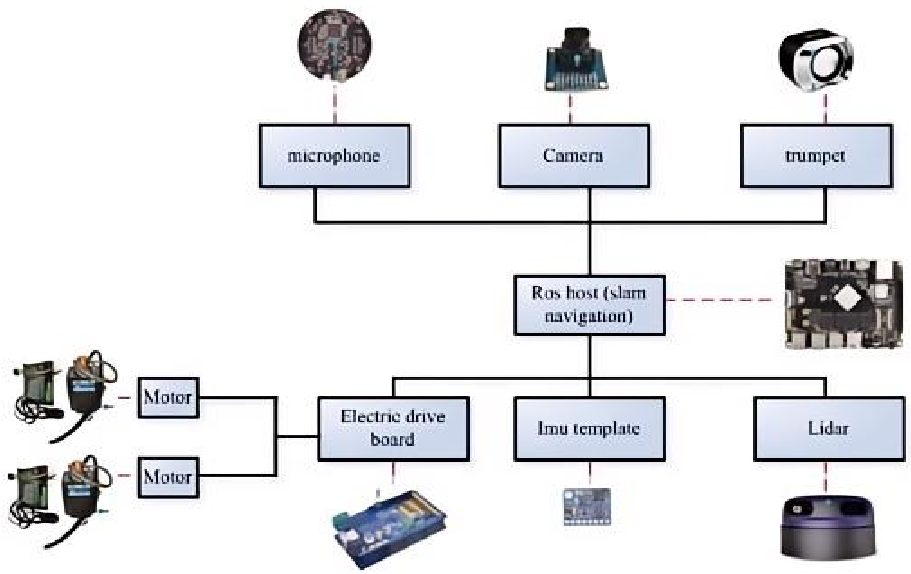

Figure 4. Hardware system connection diagram

As shown in Figure 4, We using the existing robot platform and two-dimensional laser technology, we construct the environment map by equipping the experimental robot platform with IMU modules, optical flow sensors, Bluetooth modules, controllers, and camera modules. The embedded R16 platform is incorporated to meet the positioning requirements for indoor mobile educational robots. Odometer data is obtained by directly reading the left and right encoder pulses.[6]

2.4. IMU localization data resolution

In this paper, we study the acceleration initiation deviation and static deviation of WT61C attitude sensor in the indoor binary positioning problem. Because the deviation of acceleration is different at each startup, the localization data calculated directly by integrating the accumulation will produce cumulative error. To reduce this error, a startup threshold (thresholdimu=0.05g) is set. When the acceleration along the x-axis or y-axis exceeds the starting threshold value, the acceleration value is included in the integral calculation; otherwise, it is excluded from the integral calculation.[7] In this way, the acceleration data is used during the process of movement of the mobile robot, while the acceleration bias is filtered out when the robot is stationary, thus reducing the cumulative error.

Table 1. Static deviation of WT61CThe number of measurements

	x-axis acceleration	**The y-axis acceleration**	**x-axis acceleration**	**The y-axis acceleration**
1	-0.013g	-0.011g	-0.003g	0.008g

2	-0.004g	0.001g	-0.002g	0.011g
	x-axis acceleration	**The y-axis acceleration**	**x-axis acceleration**	**The y-axis acceleration**
3	-0.004g	0.006g	-0.007g	0.007g
4	0.005g	0.012g	-0.003g	-0.001g
5	-0.018g	0.015g	-0.012g	0.011g
6	-0.010g	0.008g	-0.008g	0.010g
7	-0.009g	0.005g	-0.009g	0.006g
8	-0.008g	0.004g	-0.009g	0.006g

Several times of WT 61 C, the attitude sensor x axis and y axis acceleration start deviation and the standing deviation after each movement were measured, as shown in Table 1. As can be seen from the measurement data, the acceleration start deviation of IMU is different, and after a period of movement, the corresponding static deviation will also change, and the maximum absolute acceleration value of the start deviation and the static deviation after movement is 0.023g.

3. EXPERIMENTAL RESULTS AND ANALYSIS

After a series of experiments and tests, this study verifies the effectiveness of sensor technology in the context of mechanics in improving the indoor positioning ability of educational assisted robots. The experimental results show that the indoor positioning accuracy of the robot is significantly improved by integrating various sensors such as inertial measurement unit (IMU), lidar and odometer, and using dynamic particle number particle filtering algorithm for data processing. Specifically, IMU data provides the robot with continuous angular velocity and acceleration information,[8] while lidar assists in positioning by scanning the surrounding environment and capturing feature points, while the odometer estimates the movement distance and direction by recording the rotation of the wheel.

In experiments, we found that IMU data had high accuracy in short time, but produced cumulative error after long runs. Lidar data, while highly accurate, can be disturbed in complex environments.[9] Therefore, by dynamically adjusting the number of particles in the particle filter algorithm, and combining with a variety of sensor data for fusion processing, it can effectively reduce the error caused by a single sensor, and improve the overall positioning accuracy.

4. CONCLUSION

This study deeply explores the application of sensor technology in the context of mechanics in improving the indoor positioning ability of educational assisted robots. Through the integration of various sensors and the adoption of advanced data processing algorithms, the positioning accuracy of the robot is significantly improved. The experimental results show that the fusion application of sensor technology is an effective way to solve the problem of robot positioning in complex environment. Moreover, the successful construction of modular design methods and experimental platform provides strong support for subsequent studies. At present, as an emerging field, although there are many difficulties in the lack of course management platform, corresponding learning content and teachers.[10] Looking forward to the future, with the continuous progress of technology and the expansion of application scenarios, the indoor positioning ability of educational assisted robots will be further improved, bringing more innovation and change to the field of education.In the future, we can further explore the following directions:

(1) Deepening of Sensor Fusion Technology: Continuously optimize the fusion algorithms for sensor data, particularly focusing on positioning issues in complex and dynamic environments, to develop more intelligent and efficient fusion strategies.

(2) Construction of a Multi-modal Perception System: In addition to traditional sensors, incorporate multi-modal perception technologies such as vision, sound, and touch to build a more comprehensive environmental perception system, enhancing the robot's positioning performance and interaction capabilities in various scenarios.

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