Hindawi
International Transactions on Electrical Energy Systems
Volume 2023, Article ID 9871594, 1 page
https://doi.org/10.1155/2023/9871594

Retraction

Retracted: Precise Positioning of Redundant Robot Motion Energy-Saving Control Based on Sensing Technology

International Transactions on Electrical Energy Systems

Received 3 October 2023; Accepted 3 October 2023; Published 4 October 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] Y. Lu, "Precise Positioning of Redundant Robot Motion Energy-Saving Control Based on Sensing Technology," *International Transactions on Electrical Energy Systems*, vol. 2022, Article ID 6367598, 8 pages, 2022.

Hindawi
International Transactions on Electrical Energy Systems
Volume 2022, Article ID 6367598, 8 pages
https://doi.org/10.1155/2022/6367598

WILEY | Hindawi

Research Article

Precise Positioning of Redundant Robot Motion Energy-Saving Control Based on Sensing Technology

Yaping Lu

Department of Mechanical and Industrial Robotics, Applied Technology College of Soochow University, Suzhou 215325, Jiangsu, China

Correspondence should be addressed to Yaping Lu; 11231549@stu.wxic.edu.cn

Received 12 July 2022; Revised 29 July 2022; Accepted 3 August 2022; Published 25 August 2022

Academic Editor: Nagamalai Vasimalai

In order to provide intelligent drinking water service for human beings, an intelligent indoor positioning water delivery system is proposed. The system can realize the functions of automatic filling water and so on. Based on the UP Squared processor, the system extends the UWB positioning Zigbee wireless transmission gyroscope manipulator and other functional modules. Based on the UP Squared processor, the system extends the UWB positioning Zigbee wireless transmission gyroscope manipulator and other functional modules. MPU6050 module was used to sense the rotation angle, and PID algorithm was used to control the rotation of redundant robot. The position of water cup is sensed based on current magnetic effect and electromagnetic induction law. Ultrasonic module is used to detect the rising height of the outlet and the water level in the cup. Several parameters of the system, such as orientation, distance adjustment, and power consumption, and the whole process of water delivery are tested through experiments. The experimental results show that the designed robot has a measurement accuracy of 1 cm, a total of static power of 5.35 W, and a total of dynamic power of 13.6 W. *Conclusion*. The system has the characteristics of accurate positioning, fast and smooth steering, and low power consumption, which can meet the technical requirements of practical application in indoor intelligent positioning water delivery.

1. Introduction

With the increasing popularity of indoor robot applications, the demand for high-precision and low-cost positioning system is increasing. UWB is a carrierless communication technology that transmits data through very narrow pulses (nanosecond or picosecond magnitude or less), enabling high temporal resolution when receiving or sending data. In general, high-precision positioning can be achieved through distance difference calculation, but, in practical applications, positioning errors and even errors often occur due to clock error, non-line-of-sight multipath, and other reasons [1]. Because of its own limitations, a single sensor is often unable to meet the changing environmental requirements and generally needs to be combined with other sensors for positioning.

However, as UWB applications have just begun to be commercialized in recent years, applications based on UWB positioning are mainly concentrated in low power applications, which cannot meet the positioning requirements of indoor robots [2, 3]. The positioning requirements of indoor robots mainly include high-precision positioning data, relatively high positioning update frequency, low delay, a certain amount of positioning tag base station capacity, and ease of use and deployment. However, there is no mature UWB positioning system that can be applied in the field of indoor robot positioning.

In the process of acquiring UWB original location information, traditional methods based on bidirectional ranging, arrival angle, arrival time, difference arrival time, and so on cannot well meet the application scenarios of indoor robots. In view of the application of indoor robots, it is necessary to develop a set of requirements for high-precision networking communication and other functions. UWB technology can be used for communication, which can achieve other positioning functions such as visual laser radar inertial navigation that cannot be achieved.

Due to the existence of non-line-of-sight multipath and other factors, a single UWB positioning system under the interference of these conditions often needs to do a lot of optimization work before it can be applied in practical applications. It is of great significance to analyze the causes of these environmental interference factors to reduce the side effects brought by them. At the same time, a single sensor is often unable to meet the changeable environmental requirements due to its own limitations, and generally needs to be combined with other sensors for positioning. Through some algorithms, such as extended Kalman filter to combine UWB and AHRS navigation, it is of great significance to reduce the impact of interference on the environment, which is more conducive to the promotion of indoor robot positioning applications.

2. Literature Review

Bae et al. discussed IMU-based nonlinear vision detection and distance measurement combined with the EKF algorithm to reduce NLOS errors in the UWB environment [4]. Therefore, Li et al. and Zhang et al. developed the interior design space, a system based on a combination of INS and UWB. First, a standard error model has been developed for the combined navigation system INS and UWB, which includes the equivalent of INS and UWB. Based on the error model of the two subsystems, the concept of heavy melting was prepared and the integrated navigation system was adjusted to the static state. The error system is stable within 20 cm [5,6]. To connect the 6th track, build assembly stations at the UWB base station. In the work of Zhang and Yan, the sun melts UWB and IMU data within EKF to improve the positioning accuracy of mobile robots in a nonlinear environment [7]. Therefore, Li, Z. proposed a pedestrian navigation algorithm combining UWB and INS. On the one hand, the location calculation was combined with the UWB-based state particulate filter algorithm, and, on the other hand, the INS-based zero-velocity correction algorithm was used to solve the data navigation. Within the error equation of the INERTIAL navigation system, a combination of the navigation data of the two systems is implemented. In an easy-to-walk environment, the average accuracy of UWB and INS is 53.8% higher than that of UWB alone and 40% higher than that of INS alone. Based on the stable walking distance of the household, the average location accuracy of UWB and INS is 39.7% higher than that of UWB alone and 37.5% higher than that of INS alone [8]. This unit integrates IMU and UWB and has an extended Kalman filter (EKF) and an odorless Kalman filter (UKF) to improve integration robustness and accuracy. In order to facilitate the transmission of the central station, the relationship between the geometric distribution of the base station and the actual attenuation is considered. The simulation results suggest that the preliminary data provided by the IMU may affect the error analysis of the UWB [9].

This course can be used to learn and develop knowledge of Internet-based home plumbing, which performs water placement, control, automatic filling, and other functions, and can be used for smart drinking water services in offices, hospitals, households, and other places.

3. Research Method

3.1. Overall System Framework. This paper adopts four mechanical modules driven by DC motors, and the water pouring module adopts mechanical arm to deliver water. The control system includes UP Squared processor, motor drive module STM32F103x (MCU), Zigbee wireless module, UWB positioning module, manipulator module, power supply, and voltage regulator system. Mechanical system includes transportation and water pouring system through the close cooperation of mechanical system and control system to ensure the stability of movement and functional reliability. The following steps are performed:

(1) When the user needs the robot for service, he only needs to press the button switch and send the command to the UP Squared development board of the robot's general control center through wireless transmission of Zigbee module. The development board issues marching commands to start the robot and move forward. The auxiliary control of the robot is realized through the minimum module of MCU [10].

(2) The robot relies on the UWB positioning module to monitor the positioning information in real time, identify the target location, and calculate the required rotation angle and travel distance to reach the target. Through the L298N module driving motor operation to achieve the robot forward and backward position adjustment and other operating state controls and through the MPU6050 module sensing forward angle, the forward direction is constantly adjusted.

(3) When the robot reaches the target, it stops moving and uses the voltage of the magnetic coupling resonant coil to change with the space distance to achieve accurate positioning of the target water cup, so that the water outlet accurately aligns with the water cup and begins to discharge water. The water quantity of the cup is monitored in real time by ultrasonic rangefinder to ensure that the water in the cup will not overflow [11].

(4) After the mission, the robot can return to its original position and wait.

(5) When two or more targets send signals at the same time, the robot should respond respectively according to the time sequence of receiving signals to complete the water-pouring task.

The system scheme is shown in Figure 1.

3.2. UWB Module. The water delivery system must reach the position of the water cup quickly and accurately in order to realize the function of delivering water in a short time after receiving the water delivery request. Many common positioning methods do not meet the requirements.

Indoor environment is relatively complex, and infrared ranging positioning depth camera positioning and other

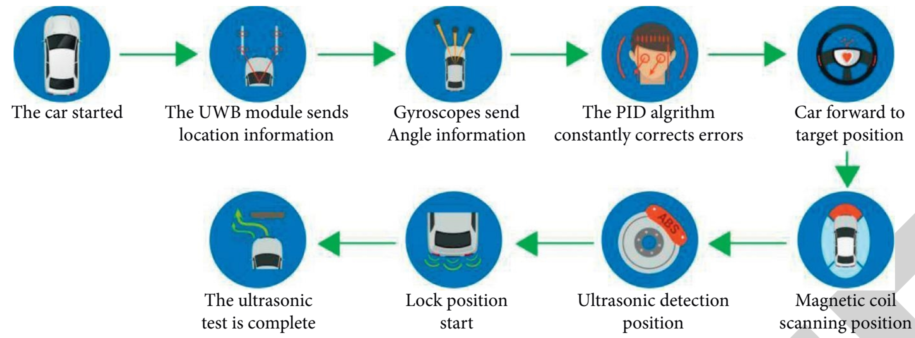

Figure 1: System work block diagram.

positioning methods do not have high accuracy. Moreover, the glass must be within the robot's visual range, but, in fact, due to the presence of factors such as shielding of indoor people's activities on the table, this condition is often not met.

(1) Indoor positioning has high accuracy requirements. The accuracy of GPS, WIFI, Bluetooth, and other positioning methods is mostly at meter level, which cannot meet the requirements of high-precision positioning.
(2) The signal transmission of Zigbee and other positioning modes is greatly affected by multipath effect and movement, and the accuracy depends greatly on hardware and environment.
(3) The slow response of ultrasonic positioning will increase the working delay of the system.

The UWB positioning adopts very narrow pulse data transmission, fast data transmission speed, positioning accuracy up to centimeter level, and strong anti-interference ability and has the advantages of low power consumption and high security. It can better meet the requirements of the system, so we use UWB module in the system for positioning.

The DWM1000 chip is an ultrawideband wireless transceiver chip, which has stronger anti-interference ability against multipath weakness and can also carry out reliable communication in high weakness environment. It is very easy to integrate into real-time location system (RTLS) and wireless sensor network (WSN).

In this paper, the communication method using double-sided bidirectional ranging algorithm only needs 5 times of communication to measure the distance between the label and the three base stations.

3.3. Perception Principle of Angle of Target Direction. The movement of water supply system, such as forward, left turn, arc, and retreat, can be divided into two orthogonal parts, namely, straight and turn [12]. In fact, it solves the problem of the angle and direction that the robot needs to rotate to reach the target position.

3.3.1. Angle Measurement. In Figure 2, point A is the position of the starting point, and three points S_0, S_1, and S_2 correspond to three positioning base stations. Through UWB module for ranging and positioning, the distance from the starting point to the third base station can be known. When the tag receives the signal from the target base station S_0, the main controller controls the robot to travel a short distance in the initial direction to obtain the real-time position information of A. V_1 is the vector of the robot's forward direction, and V_2 is vector from real-time position to target point direction. Move V_2 to point A′ for analysis, and then the angle that the robot needs to turn to the target point is the included angle θ of V_1 and V_2 [13]. The rotation angle of the robot can be calculated according to formula (1) under the condition that V_1 and V_2 are known:

$$\cos\,\theta = \left|\frac{\vec{v}_1 \cdot \vec{v}_2}{\left|\vec{v}_1\right| \cdot \left|\vec{v}_2\right|}\right|. \quad (1)$$

Figure out angle θ that the robot needs to turn.

3.3.2. Angle of Perception. After calculating the angle that the robot needs to turn, it also needs to tell the robot whether it should turn left or right. In the experiment, given vectors V_1 and V_2 with the same starting point, there are two cases:

(1) When $\theta_1 > \theta_2$:
   (a) When judgement condition is $\theta_1 - \theta_2 - \theta < 0.5^\circ$, we judge that $\theta_1 - \theta_2$ is the angle θ that the robot needs to turn, and the robot should turn right at this point.
   (b) When $\theta_1 - \theta_2 - \theta > 0.5^\circ$, we judge that $\theta_1 - \theta_2$ is not the angle θ that the robot needs to turn, and the robot should turn left at this point.
(2) When $\theta_2 > \theta_1$: it is contrary to the condition when $\theta_1 > \theta_2$. Because errors exist in label positioning, robot rotation control is not completely accurate; therefore, a single calculation may not allow the robot to accurately reach the target point [14]. Let the robot return to its rotation angle. When it is inconsistent with θ, the water supply system will constantly detect distance D between the real-time position $(x1, y1)$ of the robot and the target point $(x2, y2)$, as shown in the following formula:

$$D = \sqrt{(x2 - x1)^2 + (y1 - y2)^2}. \quad (2)$$

When the minimum distance between the robot and the target point is less than 10 cm, the robot is stopped; that is, it

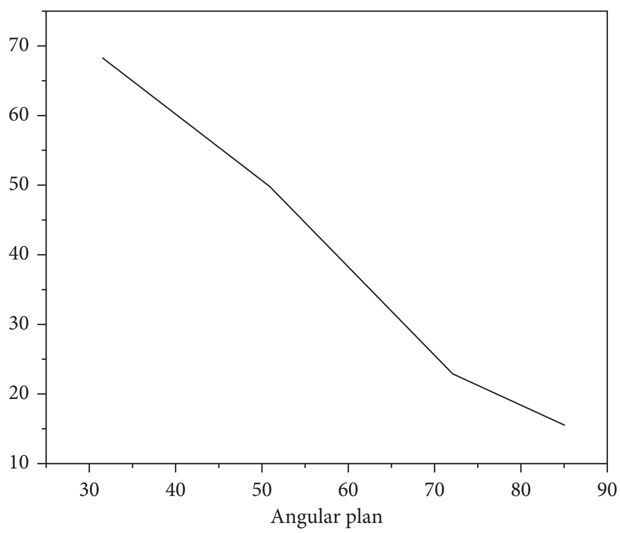

Figure 2: Angular plan.

is regarded as reaching the end point. If the minimum distance between the robot and the target point is greater than 10 cm, angle calculation and angle perception need to be conducted again after the robot stops. After obtaining a new angle, the robot moves forward until it reaches the destination [15]. Through this algorithm, the precision of robot addressing is greatly improved.

3.4. Direction Adjustment Algorithm. Through the calculation of the angle perception of the target direction, the direction that the robot needs to adjust is obtained. Next, the MPU6050 module is used to detect the angle of the robot rotation. The rotating speed of the robot is related to the energy output of the power supply. The situation when the power supply energy drops is different from that when the power is full, but the simple control strategy is prone to long rotation time or system shock. Therefore, we use PID control to improve the anti-interference ability of rotation process.

PID control is controlled according to Proportional Integral Differential of the deviation. In this system, the accumulation of errors is small, and there is no need to predict the arrival of the difference in advance to advance the response, so the scaling coefficient is mainly set [16]. By testing the system response under different proportions of parameters, the appropriate parameters are selected.

3.5. Precise Positioning of Outlet. After the water delivery system reaches the water cup accurately, it needs to accurately control the outlet valve to the top of the cup mouth. Considering the stability of the system, this paper adopts the magnetic coupling resonant radio transmission device for precise positioning. The main components of the magnetic coupling resonant radio transmission device include the following:

(1) Magnetic coupling resonance section: The resonant body is composed of resonant capacitor in series by the resonant coil, and the transmitting and receiving coils generate and receive magnetic field energy, respectively, which is the coupling medium of circuit and magnetic field. Transmitting coil adopts 1.3 mm enameled wire, cylindrical winding method $N = 3$ turns, diameter is 10 cm, and receiving coil and transmitting coil size winding method is completely consistent, to ensure that the natural frequency of receiving and transmitting coil is consistent [17]. Increasing the resonance frequency and mutual inductance between the two coils can effectively improve the transmission efficiency, but the increase of the resonance frequency and the increase of the coil diameter and the number of turns will bring about great coil loss resistance, affecting the transmission efficiency. Therefore, it is necessary to increase the coil diameter and reduce the number of turns. Under the condition that the inductance of the coil remains unchanged, this method can improve the transmission efficiency more effectively than increasing the coil turns and reducing the diameter. Finally, the resonant frequency is determined at 1.3 MHz.

(2) Magnetic field drive source: Including power supply and high frequency excitation circuit, the function of this part is to convert the DIRECT current of the DC power supply into the high frequency current in the coil, which is used to drive the magnetic coupling resonant part to generate resonant magnetic field and provide high-frequency energy to achieve radio transmission.

We designed an excitation coil placed below the water cup and fed it with pulse signals to stimulate the changing magnetic field in the surrounding space. An induction coil was placed near the water outlet of the robot, and the peak voltage in the coil was detected at the control end [18]. When the robot arrives at the specified position, the stepper motor can be first controlled to find the maximum angle of the emf peak value of the induction coil in a horizontal plane. It can be foreseen that this direction is the direction of the excitation coil. Then control the outlet vertical rise appropriate distance; control the stepper motor to move the water outlet to the direction of the excitation coil until the induction coil peak value reaches the maximum; at this time the water outlet will accurately reach the top of the water cup.

3.6. HC-SR04 Module Realizes Water Injection Control. In addition to accurately finding the position of the cup in the horizontal plane, it is also necessary to control the appropriate distance of the outlet rise in the vertical plane and complete the perception of the water level in the cup. The method of ultrasonic ranging is used in the experiment. The principle of ultrasonic ranging is to use the transmission speed of ultrasonic wave in the air as known, measure the time when the sound wave meets the obstacle after transmitting, and calculate the actual distance from the transmitting point to the obstacle according to the time difference between transmitting and receiving [19].

Ultrasonic ranging module HC-SR04 has the advantages of stable performance, accurate measurement distance, high-precision module, small blind area, and so on. It is widely used in the field of public security object ranging. The ranging steps are as follows:

(1) IO port is used to trigger ranging, and a high level signal of 10 is issued at the control port.
(2) The module automatically sends 8 40 kHz square waves and automatically detects whether there is a signal returned.
(3) If a signal is returned, a high level is output through the IO port. The duration of the high level is the time from the transmission to the return of the ultrasonic wave.
(4) When a signal returns, the timer is used to time the signal, and the value of the timer can be read when the receiver interface becomes low level. The distance can be calculated by obtaining the ranging time. Constant test can reach the value of the moving measurement.

The key to going up the right distance in the vertical plane is what does the feed system perceive as the right position. After analysis, it is found that when the height of the outlet has not exceeded the cup, there is a solid medium near the front of the outlet (cup). When the height exceeds the mouth of the cup, solid medium (wall) begins to appear in the far front of the outlet. Therefore, we can place an ultrasonic ranging module near the water outlet and stop rising after the distance exceeds the threshold value by setting a reasonable distance threshold value.

After the outlet reaches the specified position, control the relay. Start the water outlet. When the ultrasonic module detects that the water level in the cup reaches an appropriate position, a signal is uploaded to the controller to stop the water outlet and complete the corresponding work.

3.7. Zigbee Communication Module Data Interaction. After pressing the button of the pager, the intelligent indoor positioning water delivery system receives the water pouring request and starts to work. Because not all indoor environments are covered with WIFI signals, Bluetooth transmission is limited by distance and is vulnerable to interference, so Zigbee communication module with simple networking and long transmission distance is used for wireless data transmission. DL-20 wireless transmitting and receiving module is a wireless serial module based on Zigbee technology, which can connect two or more serial ports in wireless state to configure DL-20 module in point-to-point mode. Point-to-point mode has two data transfer ports: A end and B end. Data sent by the serial port A end is received by the serial port at the B end, and vice versa. In point-to-point mode, only two nodes on a channel can communicate with each other.

In the process of data transmission, transparent transmission mode is adopted. The user only needs to encapsulate the data according to the Zigbee protocol frame format and then send the data once. Finally, the data is received in sequence at the receiving end. In practical application, the baud rate is 9600, and two Zigbee communication modules are installed on the pager and robot, respectively.

4. Interpretation of Result

Intelligent indoor positioning water delivery system requires accurate positioning, strong adaptability to complex environment, and rapid and accurate angle adjustment and can better adapt to the change of induction coil in the moving experiment. The following parts are tested.

4.1. UWB Positioning Accuracy Test. In order to test the accuracy of UWB module in environments of different complexity levels, we conducted intensive reading tests in empty classrooms and classrooms with lots of shelters, such as desks and chairs. The specific methods are as follows:

(1) After the base station was arranged, 6 points were randomly selected indoors.
(2) Meter ruler was used to measure the distance between these points and base station 0, and the mean value was measured for three times, which was approximately regarded as the standard distance between point and base station 0.
(3) Place label 0 at each of the six points.
(4) At each point, the distance between the label and the base station is continuously measured 10 times.
(5) The error is represented by the mean of the difference between the measured data and the standard distance [20].

We found that the distance between the base station and the tag had no significant influence on the ranging accuracy, and the data error obtained by each measurement was within 10 cm. The error of ranging in complex environment is slightly higher than that in open environment, but it can still ensure high measurement accuracy. After taking the average value of the measurement for many times, the direction finding error is reduced to less than 1%, which can meet the requirements of the system for accuracy.

This is determined by the fact that UWB relies on very narrow pulses to transmit data. Theoretically, after passing through obstacles such as desks, narrow pulses will not produce significant attenuation. Therefore, even if there are many obstacles in the environment, the impact on the ranging accuracy is very small, which is consistent with our test results.

4.2. Direction Adjustment Algorithm Test. For reasonable PID parameter selection, while improving the rotation speed of the robot, the system should have good stability, that is, low shock degree, and strong adaptability when the power energy changes, that is, always have good reaction speed and high stability.

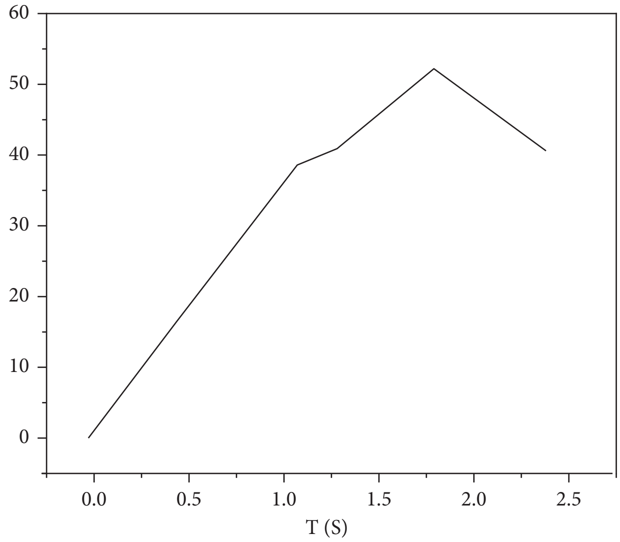

Figure 3: PID test data in the format of 1000-4.

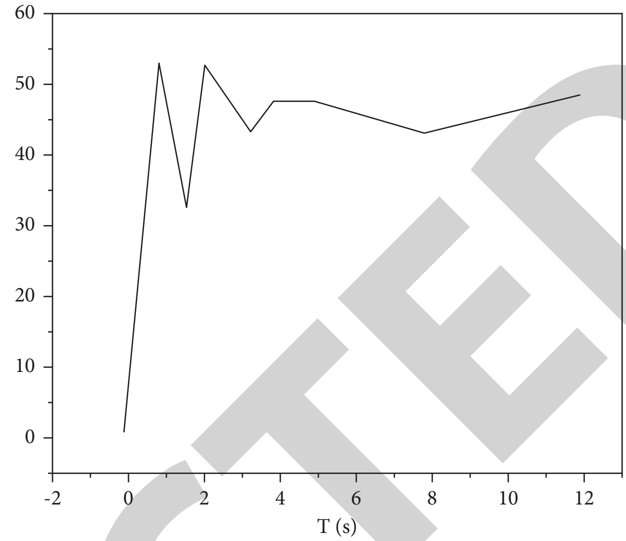

Figure 4: PID test data in the format of 1200-4.

Set the robot rotation target to 45, control the robot rotation, and upload the robot rotation angle to the control end in real time through the serial port. The angle changes obtained by different PID parameters were plotted into curves. After repeated tests, the curves obtained by selecting the best parameters are shown in Figures 3–5.

The first parameter of PID represents the overall speed of the system. The second parameter indicates the speed of response to instructions. After analysis, the overall speed of the first measurement is high, but the response time is long, the system vibration is serious, and the time to reach stability is long. The second group had less oscillation after the overall speed was going down. In the third group, after the overall speed is reduced, the oscillation is eliminated, so the parameters of the third group are more reasonable. PID parameters set after multiple attempts can make robots have quicker reaction while keeping the stable status. Moreover, it has strong adaptability under different power sources.

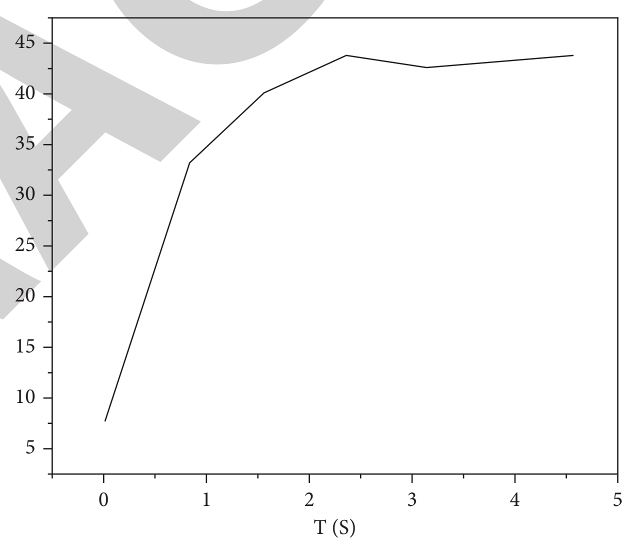

Figure 5: PID test data in the format of 1500-5.

4.3. Accurate Positioning Test of Outlet. In this paper, the extreme value of the induced electromotive force in the induction coil is used to determine the relative position of the water cup and the water outlet, which requires the obvious existence of the extreme value of the induced electromotive force and low detection delay.

Move the induction coil in horizontal plane and vertical plane respectively, and read the electromotive force in the induction coil, draw it into a curve, and observe the extreme value.

Because of the response delay, it is not easy to detect directly, so we detect the difference between the position of the electromotive force extreme value in the induction coil read by the system and the theoretical position, so as to describe the response delay of the system indirectly. The induction coil rotates at different angles in the horizontal plane, and the output voltage value obtained is shown in Figure 6. There is a voltage peak value at the position nearest to the transmitting coil, and its induction voltage value is the maximum.

HC-SR04 ultrasonic ranging module can provide 2~400 cm noncontact distance sensing function; the measurement accuracy can reach 3 mm. By analyzing the above measurement results, it can be concluded that the measurement accuracy of the ultrasonic ranging module used by the designed robot is 1 cm.

According to the power test of each module, the static power is mainly concentrated in the UP Squared processor, but the overall power is relatively low, with a total of 5.35 W, and the dynamic power is 13.6 W, about 2.5 times of the static power. It is found that the robot consumes very little power under static condition and can support data

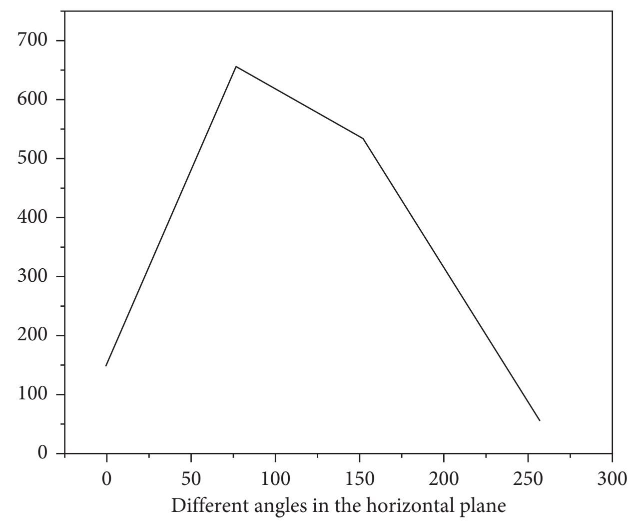

Figure 6: Induction electromotive force test data.

monitoring for a long time. It also has good endurance in cruise pouring mode.

5. Conclusion

The system designed in this paper uses Zigbee module to carry out data interaction between the pager and the robot; UWB module is used for precise positioning indoors. MPU6050 module is used to sense the rotation angle, and PID algorithm is used to control the rotation of the robot; the position of water cup is sensed based on current magnetic effect and electromagnetic induction law; ultrasonic module is used to detect the rising height of the outlet and the water level in the cup. It can well realize the two functions of water transport and water pouring, and the stability of the positioning accuracy movement and the reliability of the function have been well guaranteed; the function of intelligent indoor positioning water delivery is fully realized, to meet the technical requirements of practical application in indoor intelligent positioning water delivery.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

References

[1] S. Li, S. Guo, J. Chen, X. Yang, and H. Yang, "Multiple targets localization behind l-shaped corner via uwb radar," *IEEE Transactions on Vehicular Technology*, vol. 70, no. 99, p. 1, 2021.

[2] B. Biswas and A. Karmakar, "Electrical equivalent circuit modelling of various fractal inspired uwb antennas," *Frequenz*, vol. 75, no. 3-4, pp. 109–116, 2021.

[3] D. Kalra, M. Kumar, A. Shukla, L. Singh, and Z. A. Jaffery, "Design analysis of inductorless active loaded low power uwb lna using noise cancellation technique," *Frequenz*, vol. 74, no. 3-4, pp. 137–144, 2020.

[4] J. Bae, H. W. Kim, I. H. Kang, and J. Kim, "Dual-field plated β-Ga2O3 nano-FETs with an off-state breakdown voltage exceeding 400 V," *Journal of Materials Chemistry C*, vol. 8, no. 8, pp. 2687–2692, 2020.

[5] Q. Li, Y. Sun, and H. Fang, "Compact acs-fed uwb mimo antenna with dual band notches," *Applied Computational Electromagnetics Society*, vol. 36, no. 1, pp. 55–60, 2021.

[6] P. Zhang, X. Ren, and Z. Zhang, "An efficient self-motion scheme for redundant robot manipulators: a varying-gain neural self-motion approach," *Robotica*, vol. 39, no. 10, pp. 1897–1908, 2021.

[7] Z. Zhang and Z. Yan, "An adaptive fuzzy recurrent neural network for solving the nonrepetitive motion problem of redundant robot manipulators," *IEEE Transactions on Fuzzy Systems*, vol. 28, no. 4, pp. 684–691, 2020.

[8] Z. Li, F. Xu, D. Guo, P. Wang, and B. Yuan, "New p-type rmpc scheme for redundant robot manipulators in noisy environment," *Robotica*, vol. 38, no. 5, pp. 775–786, 2020.

[9] W. Luo, L. Shi, W. Xu, W. Chen, Y. YangYang, and Y. Ren, "High gain dielectric resonance antenna array for millimeter wave vehicular wireless communication," *Progress In Electromagnetics Research C*, vol. 108, pp. 63–78, 2021.

[10] J. Huang, C. X. Wang, H. Chang, J. Sun, and X. Gao, "Multi-frequency multi-scenario millimeter wave mimo channel measurements and modeling for b5g wireless communication systems," *IEEE Journal on Selected Areas in Communications*, vol. 38, no. 9, pp. 2010–2025, 2020.

[11] G. Zhu, D. Liu, Y. Du, C. You, J. ZhangZhang, and K. Huang, "Toward an intelligent edge: wireless communication meets machine learning," *IEEE Communications Magazine*, vol. 58, no. 1, pp. 19–25, 2020.

[12] J. B. Padhy and B. Patnaik, "Co-ofdm and dp-qpsk based dwdm optical wireless communication system," *Journal of Optical Communications*, vol. 42, no. 2, pp. 311–323, 2021.

[13] J. YiYi, Z. W. Liu, and W. Q. Zeng, "Isothermal extrusion speed curve design for porthole die of hollow aluminium profile based on pid algorithm and finite element simulations," *Transactions of Nonferrous Metals Society of China*, vol. 31, no. 7, pp. 1939–1950, 2021.

[14] J. Z. Shi, "A fractional order general type-2 fuzzy pid controller design algorithm," *IEEE Access*, vol. 8, pp. 52151–52172, 2020.

[15] R. Huang and X. Yang, "Analysis and research hotspots of ceramic materials in textile application," *Journal of Ceramic Processing Research*, vol. 23, no. 3, pp. 312–319, 2022.

[16] M. Fan and A. Sharma, "Design and implementation of construction cost prediction model based on svm and lssvm in industries 4.0," *International Journal of Intelligent Computing and Cybernetics*, vol. 14, no. 2, pp. 145–157, 2021.

[17] J. Jayakumar, B. NagarajNagaraj, S. ChackoChacko, and P. Ajay, "Conceptual implementation of artificial intelligent based E-mobility controller in smart city environment," *Wireless Communications and Mobile Computing*, vol. 2021, pp. 1–8, 2021.

[18] J. Chen, J. Liu, X. Liu, X. Xu, and F. Zhong, "Decomposition of toluene with a combined plasma photolysis (cpp) reactor: influence of uv irradiation and byproduct analysis," *Plasma*

Chemistry and Plasma Processing, vol. 41, no. 1, pp. 409–420, 2020.

[19] Z. Huang and S. Li, "Reactivation of learned reward association reduces retroactive interference from new reward learning," *Journal of Experimental Psychology: Learning, Memory, and Cognition*, vol. 48, no. 2, pp. 213–225, 2022.

[20] Q. Zhang, "Relay vibration protection simulation experimental platform based on signal reconstruction of MATLAB software," *Nonlinear Engineering*, vol. 10, no. 1, pp. 461–468, 2021.