Nile Journal of Communication & Computer Science
Volume 7, June 2024
Journal Webpage: https://njccs.journals.ekb.eg

Development of an Advanced Medical Assistance Robot with Intelligent Guidance

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Abstract. As the COVID-19 pandemic has demonstrated, inadequate health care facilities exist to combat a pandemic. Furthermore, this has emphasised the critical urgency to swiftly establish healthcare facilities equipped to handle patients with infectious diseases, as well as to swiftly modify supply chains in order to produce the prescription medications and other supplies required for infection prevention and treatment of infected patients. The effectiveness of intelligent autonomous machines in aiding human endeavours to combat a pandemic has been demonstrated by the COVID-19 crisis. In many ways, artificial intelligence based on deep learning and neural networks can aid in the battle against COVID-19, especially in the control of autonomous medical robots. Using intelligent machines, health officials hope to prevent the spread of COVID-19 among medical and nursing personnel and patients. We present a sophisticated controller proposal for a hospital-based service robot. The purpose of this category of robot is to dispense medications and transport sustenance to individual patients. An autonomous line-following robot capable of detecting and following a line delineated on the floor while traversing patient rooms while maintaining direction control. Two controllers were utilised concurrently to achieve the desired results: one was a deep neural network controller designed to forecast the path of motion, and the other was a proportional-integral-derivative (PID) controller implemented to regulate speed and steering automatically.

Keywords. Simulation system, intelligent navigation, functional architecture, and environmental awareness.

1. Introduction

Daily growth is observed in the implementation of robotics, automation applications, and artificial intelligence in public healthcare [1–3]. By assisting medical personnel and physicians in performing complex tasks with precision and reducing their workload, robots enhance the effectiveness of healthcare services . To mitigate the transmission of Covid-19, a number of employment functions have been delegated to robotics, including food processing and cleaning duties in contaminated areas. Service robots, which are hospital-based iterations of mobile robots with limited degrees of freedom but a high payload capacity (Fig. 1). Surgical robotics, on the other hand, are dependable, adaptable, and precise systems with an error margin of millimetres at most [4-5].
Mobile robots are mechatronic devices that are operated by software and incorporate a variety of sensors—webcam, infrared, ultrasonic, GPS, and magnetic—in order to execute complex duties. DC motors and wheels are utilised to propel machines. Mobile robots are utilised not only in the healthcare sector but also in industrial, military, agricultural, and search and rescue operations to assist humans in completing difficult tasks. Numerous industrial logistics applications, including the transportation of hazardous and weighty materials, library inventory management systems, and the agricultural sector, are amenable to line-follower robots. Furthermore, these machines possess the ability to oversee patients within medical facilities and alert physicians to worrisome symptoms.

Figure 1: Line-follower service robots

A proliferation of scholars have directed their attention towards intelligent vehicle navigation as a result of the inherent limitations of conventional tracking methods imposed by the volatile environment in which a vehicle operates. Thus, neural networks and other intelligent control mechanisms are required. The issue of vehicle navigation is resolved through the application of their capacity to discern the non-linear correlation between input and sensor values. Autonomous robots must employ a blend of machine learning algorithms and computer vision techniques in order to attain "true consciousness". Numerous endeavours have been undertaken to enhance affordable autonomous vehicles through the implementation of diverse neural network architectures. An illustration of this is the proposition to implement convolutional neural networks (CNNs) in autonomous vehicles. A collision prediction system that integrates a CNN with a technique for halting a robot near the target point while evading a moving obstacle has been developed. CNNs for autonomous driving control systems to maintain vehicles within their designated lanes have also been proposed. For the purpose of mobile-robot motion planning, a PC equipped with an Intel Pentium 350 MHz processor was utilised to implement a multilayer perceptron network. The issue of mobile robot navigation was resolved in an additional investigation by employing a local neural network model [6].

Numerous motion control methods, including proportional-integral-derivative (PID) control, fuzzy control, neural network control, and combinations thereof, have been suggested for autonomous robotics. The majority of motion control applications employ PID control, and deep learning techniques have been integrated into PID control methods to improve performance and adaptability. The operation of sophisticated robotic systems that possess dynamic and reasonably precise motion frequently hinges on the implementation of these control algorithms. As an illustration, an imprecise PID controller was implemented.

This article conducted an assessment of the hospital's current outpatient department's guiding service. The primary issues and factors influencing patients' treatment at the outpatient clinic at this time have been examined and succinctly .

The preceding analysis demonstrates that the primary issues and contradictions in the outpatient department stem from the consultation process between physicians and patients. Medical guidance entails laborious labour, a high rate of repetition, and solid mechanics, but a low difficulty coefficient. Being patient-centered requires professional knowledge, patience, and a stable disposition. In contrast to human resources, intelligent medical guided robots possess the capability to promptly address individuals' requests for consultations [6-8]. Having the benefits of increased consistency, labour savings, and enhanced service speed and quality, it is crucial for enhancing the outpatient department's medical environment. During an epidemic, intelligent medical guide robots were utilised in hospital corridors in lieu of personnel. It can decrease the likelihood of cross-contamination and direct human contact, which is critical for averting the epidemic situation in the hospital's outpatient corridor.

2. How to Design Medical Guide Robot

2.1 Robot Designing

By analysing the robot's schematic, it is possible to ascertain the functional requirements for each component. The schematic representation of this intelligent guided robot is derived from the modelling of the preceding guided robot (Figure 2). Its refined appearance instills a sense of security and comfort among individuals and has the potential to alleviate the emotional tension that pervades the hospital corridor. Additionally, the mechanical arm bears the hospital's signature red "cross" emblem, which signifies that every patient will receive the utmost attention.

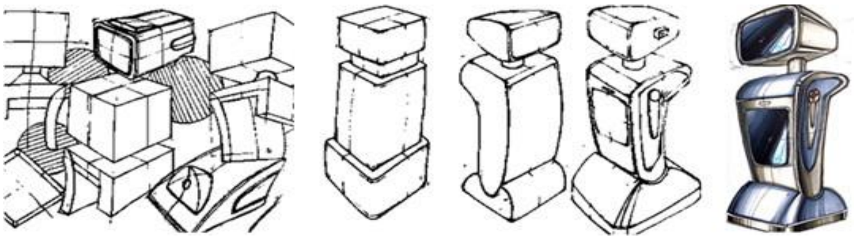

Figure 2. Design sketch.

2.2 Robot Model and Render

Subsequent to the conception illustration, the 3D model was constructed utilising 3D software. The dimensions of the model are approximately 0.5 m in width and 1.6 m in height. The rendered 3D model was imported into the Keyshot software, and the outcome is depicted in Figure 3.

Figure 3. The 3D model (on the left) and its rendition (on the right).

An exhaustive structural diagram of every component of the robot is illustrated in Figure 3. It is required to have a speaker instrument and a human-machine interface. The speaker device serves as the conduit for human-machine interaction, functioning primarily as the "mouth" and "ear" of the robot. It is capable of identifying various types of vocal data and transmitting it to the users [9]. The interactive interface presents real-time information regarding the environment during operation and in the dormant state. Located at the lower section of the robot are outlets for charging and radar scanning devices. As the "eyes" of the robot, the radar scanning device is primarily employed to detect and perceive current environmental data and assist the robot in autonomously avoiding obstacles and pedestrians. In the intermediate section of the fuselage, a navigation display screen and a robotic limb are installed. The limb is capable of unrestricted rotation, enabling it to indicate the way for the user. The robot system consistently enhances its service algorithm, as well as its comprehensiveness and quality, in response to patient feedback, with the aim of providing an improved medical service experience [10-12]. The ultimate visual representation is depicted in Figure 4 and 5.

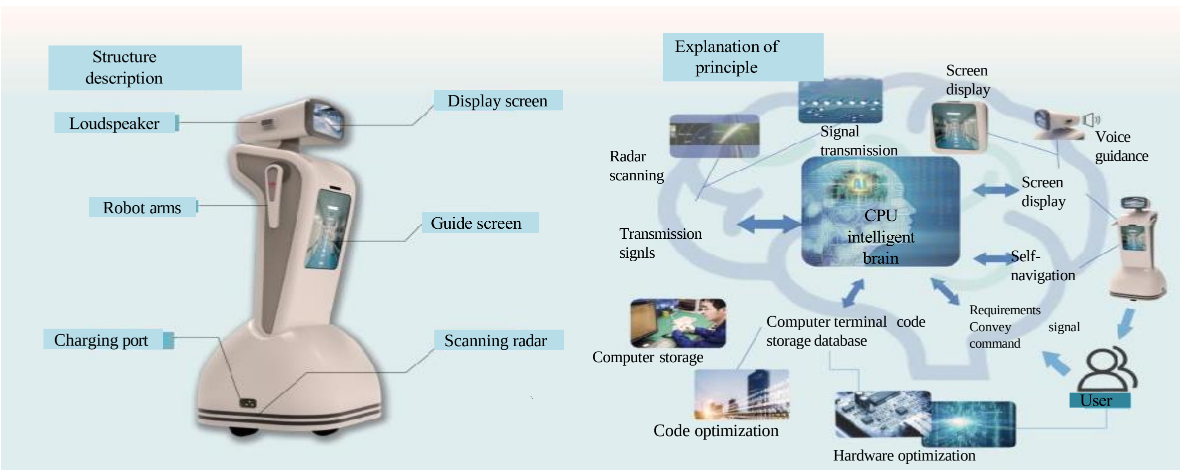

Figure 4. Structural illustration.

Figure 5. hospital scene layout

2.3 Autonomous Line-Follower Robot Architecture

The architecture and system block diagram of the line-following robot are delineated in this particular segment. Initially, an appropriate configuration was chosen to construct a line-following robot by connecting three infrared sensors to the motor driver integrated circuit (IC) via the Arduino Uno microcontroller board. The depicted configuration can be observed in the block diagram presented in Figure 6.

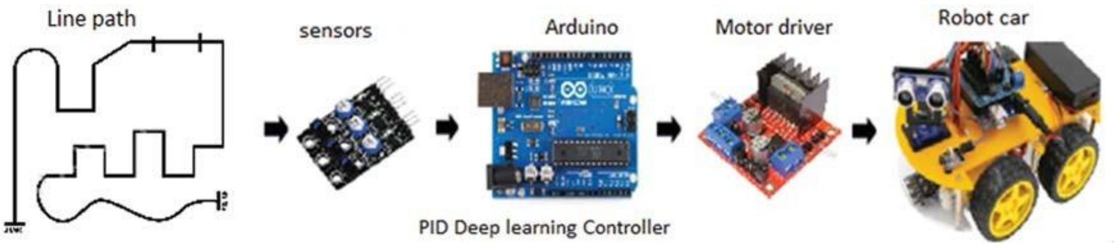

Figure 6: Block diagram of the medic line-follower robot

The line-follower robot was controlled by reading the infrared sensors and utilising the four DC motors; the speed of the left and right motors was established utilising a PID controller and the predicted error; the system was implemented on the Arduino Uno to ensure that the robot moved in the intended direction; and error prediction was accomplished by utilising the infrared sensors for line detection [13-15].

2.1 Mobile Robot Construction

The design of the proposed autonomous robot (Figure 7) is readily modifiable and adaptable to new research endeavours. The evaluation of the robot's physical aspect informed its design, which was determined by a variety of factors including mobility, material availability, and functionality.

Seven part categories were used in the construction of the robot:

(1) Four wheels.

(2) Four DC motors, or two.

(3) There are two foundational structures.

(4) An Arduino ATmega 32 board-based controller board.

(5) An L298N integrated circuit designed to drive a DC motor.

(6) A board for expansion.

(7) Module for line monitoring [16].

Figure 7: Medic line-follower robot prototype

2.2 Arduino Uno Microcontroller

The Arduino Uno, depicted in Figure 8, is a microcontroller circuit that is constructed around the ATmega328P. A USB connector, power port, ICSP header, reset button, sixteen analogue inputs that can be utilised as pulse width modulation (PWM) outputs, fourteen digital I/O pins, and a sixteen-MHz quartz crystal are included. The Arduino microcontroller board is capable of providing power to the DC actuator via a PWM signal [17].

Figure 8: Arduino Uno based on the ATmega328P

2.3 Tracking Sensor

The line-tracking sensor that was employed has the ability to distinguish between black and white lines (see Figure 9). A reliable output TTL signal is generated by the single line-tracking signal, allowing for more precise and stable line tracking. It is straightforward to accomplish multichannel operation by installing the line-tracking robot sensors that are required [18-20].

Figure 9: Tracking sensor

2.4 L298N Motor Driver

In order to run two DC motors, the L298N motor driver combines two full H-bridge circuits. Since most robots use a 5 to 35V DC voltage and a maximum current of 2A, this property makes it suitable for use in robotics. The L298N dual H-bridge module's pin designations are shown in Figure 10. Two pins, IN1 and IN2, regulate the board's orientation on the L298N. The L298N board's Enable pin, which was responsible for receiving the PWM signal, powered the motor [21-22].

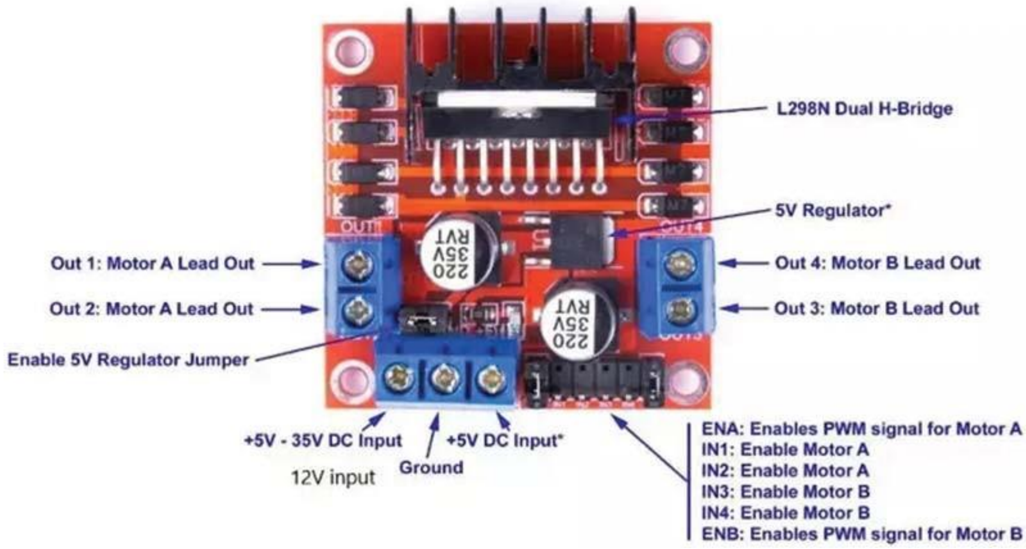

Figure 10: L298N IC motor driver

Figure 10 illustrates the wire connections that were utilised in the mobile robot's design and implementation. The embedded system, line-tracking sensors, DC motors, and the L298 IC circuit utilised to power the motors are depicted in this diagram.

3. General Technical Route

The hospital environment database was created utilising Webots and was subsequently retained in the robot's "brain." The paths between the target points in the hospital were systematically determined using the A* algorithm. Subsequently, the robot control system was provided with the coordinates of each path. Once the target position was communicated to the robot via the visual operation interface or voice, the robot issued corresponding instructions to the control system that indicated the intended shortest path. Following positioning with its own navigation and positioning module, the robot proceeded in accordance with the control program's predetermined path coordinates.

Ultrasonic distance sensors were employed to identify obstacles during the guidance process, enabling the formulation of distinct guidance decisions contingent upon the nature of the obstacle. In order to make the necessary adjustments, the trajectory will momentarily deviate from the intended course when an obstacle is detected. Upon determining that the distance between the surrounding obstacles and the designated safe distance has been exceeded, the robot will return autonomously to the initial trajectory guidance that was predetermined. Upon reaching the designated location, the automaton will stop momentarily to determine whether or not there are individuals in need in the vicinity. Upon utilisation, the robot will reestablish this location as its initial starting point, devise a revised trajectory towards the intended destination, and execute the guidance procedure. The robot will autonomously return to its initial position when not in use, allowing others who require it to utilise it. Simultaneously, the mechanical arm raises to remind pedestrians to proceed in a particular direction throughout the guidance process. In order to enhance the robot's service quality, the algorithm and associated hardware are consistently optimised in response to user feedback [23].

3.1. Driving System

Rapid steering is achieved by the robot through the regulation of the rotational velocity of four propelling wheels arranged in the left and right rows, as illustrated in Figure 11. The angle at which the robot must turn is precisely computed based on obstacle data of varying distances and angles detected by the robot's sensors. Subsequently, the corresponding motor velocities of the two rows of wheels are determined in order to regulate the robot's steering.

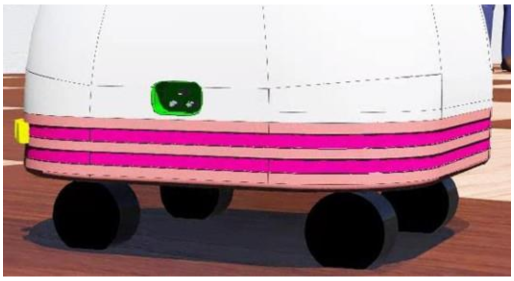

Figure 11. System of four-wheel motion

3.2. Environment Sensing Module

The setting is intricate, and there are a lot of people in the building. In order to identify different kinds of barriers, this study employs four ultrasonic range sensors. With its centimeter-level measurement accuracy, minimal blind region, and real-time obstacle distance accuracy, ultrasonic distance measurement is a powerful tool. For low-speed robot obstacle detection, an ultrasonic ranging sensor is a practical choice to consider. As shown in Figure 12, the four ultrasonic ranging sensors are positioned as follows: left corner, left centre, right middle, and right corner. Put the sensors ahead of the service robot's chassis.

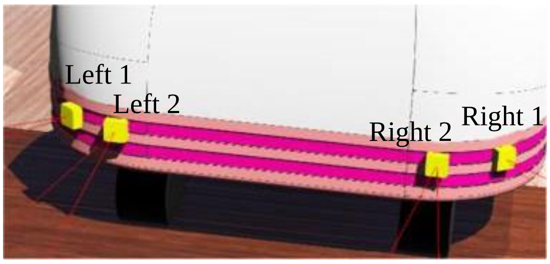

Figure 12. Sensor installation diagram.

The ultrasonic ranging sensor, when turned on, will start timing at the same time that it starts to produce ultrasonic waves in a specific direction. When they strike impediments, ultrasonic waves quickly bounce back from the atmosphere. The ultrasonic receiver immediately stops timing as soon as it receives the reflected wave, and using the time difference, it calculates the actual distance between the sending and receiving locations and the obstruction. Every conceivable combination of the four sensors' detection distances is covered by the decision system depicted in the picture.

more than the recommended minimum distance, which is reliable and safe. In order to make robot steering safer, the distance of objects identified determines the steering coefficient and the direction of the front and rear axles. All of the obstacles, regardless of height, are tested in the virtual environment.

It is possible that the chassis sensor will not detect the hospital seat if it does not have a seat in its lower part. There are four sensors on the robot's torso; two groups of sensors, one each on the top and bottom, make up the entire system. Generally speaking, if one sensor in a group detects an obstruction at a distance less than the safe distance, it's reasonable to assume that all of the sensors in the group have come to the same conclusion. The decision-making procedure is unaffected in this instance.

3.3. Navigation Module

The positioning module comprises an integrated inertial navigation system and GPS, which collectively furnish real-time position information for the robot. The robot's pose is determined by comparing the control platform with the high-precision map; path planning enables the execution of autonomous navigation.

The GPS device is affixed to the upper portion of the automaton in order to acquire up-to-date position data. The fundamental concept underlying algorithm and sensor control .

The information regarding the speed and acceleration of the robot is acquired through the integrated inertial navigation system (INS), which is situated atop the model. When GPS positioning is implemented, disturbances are simple to induce. Hospital corridors, high-rise structures, and trees that obstruct visibility are prone to multipath effect, which can significantly compromise the precision of positioning results or even cause them to be lost. Integrated inertial navigation typically comprises a reasoning calculation unit, accelerometer, gyroscope, magnetometer, and barometer inertial measurement unit. In situations where the GPS signal is feeble or non-existent, it not only provides a temporary solution to the problem encountered by differential GPS, but also uses the integral method to determine the closest three-dimensional high-precision location and can autonomously determine the speed and attitude of the robot.

The navigation and positioning module of the incorporated inertial navigation system is capable of independently acquiring both absolute and relative positions. The primary system utilised in the data processing of the positioning and navigation module is the integrated inertial navigation system. The state quantity is determined by averaging the attitude, position, and speed of the INS and GPS. At the end of each GPS epoch, the combined data is transmitted to the control platform for the purpose of generating decision instructions [24-28].

4. Proposed algorithm

The algorithm known as the A* search algorithm is employed to determine the shortest path. It is found in numerous applications, including artificial intelligence, due to its exceptional efficacy. The cost map can be generated by dividing the map space into grids of equal size and assigning a cost value to each grid based on the obstacle information presented on the map. The algorithm An "A*" is a combination of heuristic and formal methods. By calculating the distance between the current and final points via an evaluation function, it is possible to ascertain the direction in which the search should proceed. It will attempt alternative paths, examine neighbouring squares, and expand outward until it locates the target if this one fails.

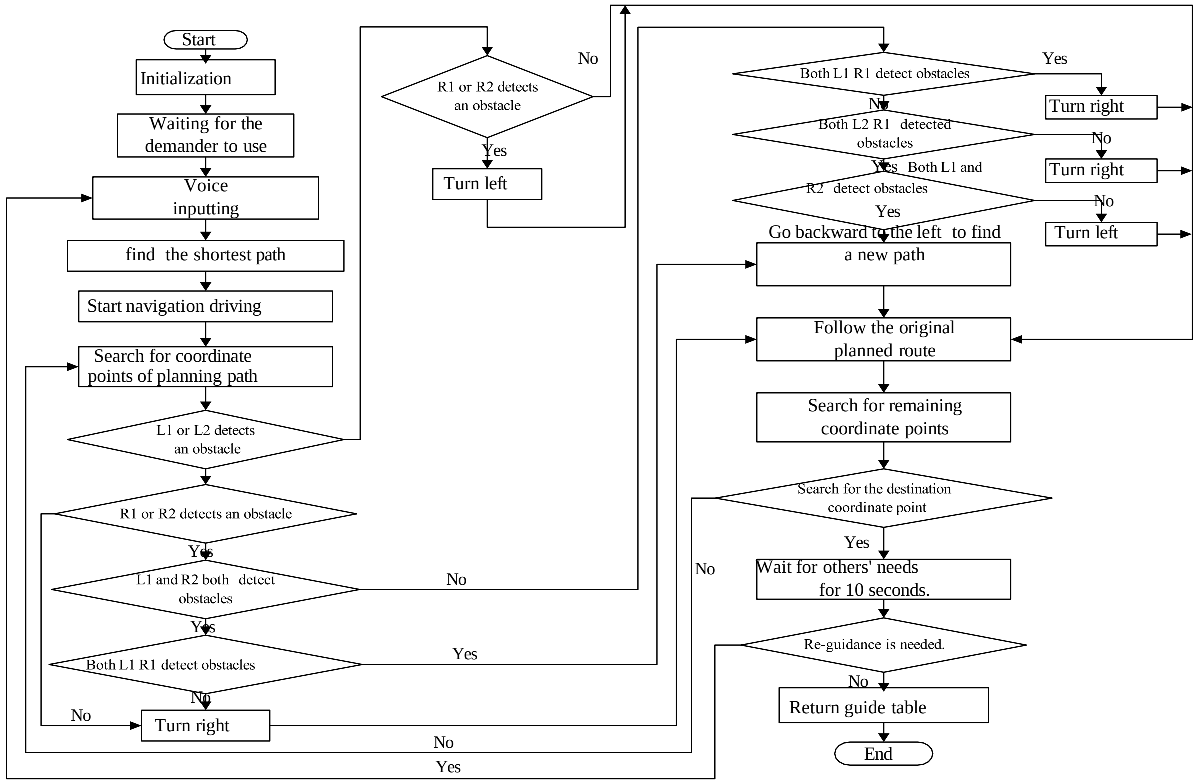

Figure 13. Controlling flow chart.

To determine the path between each target point in the simulation environment, the actual dimensions of the fixed obstacles in the hospital scene are entered into the grid map of the A* search algorithm. The path coordinates between the objective points are subsequently imported into the control system after being generated. By following this path coordinate, the automaton takes the shortest route, thereby conserving the time of the requesters as well as shown in figure 13.

5. Conclusion

In order to find the distance between each virtual destination, the A* search algorithm's grid map is pre-populated with the real-world measurements of the hospital scene's fixed obstructions. The configuration is updated to reflect the newly generated path coordinates between the target spots.The researchers in this work used Webots to model the autonomous navigation capabilities of a medical guide service robot they created. The robot was then tested in a hospital hallway. Patients would have access to smart, accurate guiding services if a hospital scene database were put into place. The robot can take patients to the right departments when given instructions via voice interaction; this feature makes it easier for medical staff to consult with patients. By using the A* search algorithm to find the shortest path between the goal locations, the guide method identifies each coordinate point that the robot must pass. The system uses ultrasonic ranging sensors at each coordinate point to detect information on nearby obstacles by utilising combined inertial navigation positioning technology and robotic GPS. When faced with barriers, autonomously avoid them. Instead of using the traditional tracking method—which involves positioning navigation equipment like tapes, colour bars, reflectors, and the like—this strategy ensures that the hospital grounds are clean and aesthetically pleasing.

Hospitals might save a tonne of money on labour services related to medical guiding if they used the medical guide robot instead of human medical staff. At the same time, it has the potential to improve the quality of medical services offered by present hospitals, make patient consultations more efficient, and give more patients the sense that they are receiving high-quality care. Medical services have become more intelligent thanks to advancements in intelligent technology, and the public's interest in medical health has grown as a result of improvements in people's quality of life. "Artificial intelligence + medical service" is a groundbreaking combination that proves the old way of thinking about healthcare is outdated. In the future, people will be able to get their medical problems solved by combining this idea with "internet plus" technology. It is feasible to effectively handle future medical issues that people may encounter by combining this with "internet plus" technologies.

mechanism for control. The requesters' time is also saved by the automaton taking the shortest route by following this path coordinate.

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