STM JOURNALS

Journal of
Mechatronics and Automation

ISSN: 2455-1988
Volume 11, Issue 2, 2024
May–August
DOI (Journal): 10.37591/JoMA

https://journals.stmjournals.com/joma

Review JoMA

Autonomous Infection Control System

Jyothis JS[1], Lakshmi[2], Kannan S[3], Akash V[4,*], Justin Jose[5]

Abstract

Escalating problems arise mainly at hospitals due to transmission of microbes through air, which causes life threatening situations. Doctors, nurses and other members are more vulnerable to diseases from within the place. PPE kits and other disinfecting procedures require an in-human presence to do the work, which makes it more challenging and puts the person's life at risk. In current scenarios, human presence is required for sanitising and cleaning procedures, which makes them prone to infections. Thus a novel autonomous disinfection system is proposed to detect and disinfect the pathogens by inco-operating an autonomous robotic system for hospitals. The autonomous robotic system utilises a visual SLAM algorithm for navigation and mapping. It maps all user locations (beds of Patients). Initially the robot autonomously navigates to first location and Raspberry Pi Controller along with ultrasonic sensors ensures collision free movement. At the user location, Robotic arm with a camera is used to collect images of patients' beds. The presence of pathogens can be determined by analysing the grey scale images using image process technology. Then the microbes are disinfected by UV-C lights and sprayers stored in the body of the robot. The servo motors help to move the robotic arm in a user defined manner.with the servo motor. The imaging technology along with autonomous control of the robotic system enhances its ability to detect the infection threats with accuracy and ensure targeted and effective disinfection

Keywords: Robotic, path planning ,image processing , mobile robot ,decision making

INTRODUCTION

In hospitals, the transmission of microbes through the air poses significant threats, leading to life-threatening situations and heightened risks for medical staff. Current disinfection procedures, relying on manual intervention and personal protective equipment, expose individuals to infections. To address these challenges, we propose a novel Autonomous Disinfection System designed specifically for hospitals. This system integrates autonomous robotics with advanced sensing and disinfection technologies to detect and eradicate pathogens effectively. Equipped with a Raspberry Pi Controller and ultrasonic sensors, it ensures collision-free movement throughout the facility. At each location, a robotic arm equipped with a camera captures grayscale images of patient beds, facilitating pathogen detection through image processing technology. Subsequently, UV-C lights and sprayers, housed within the robot, target and disinfect identified microbes. The servo motors enable precise movement of the robotic arm, enhancing targeted disinfection capabilities. This integrated approach, combining imaging technology with autonomous control, enhances the system's accuracy in detecting infection threats and ensures effective disinfection. This introduction outlines the scope and objectives of our work, highlighting the innovative advances in autonomous

***Author for Correspondence**
Akash V
E-mail: akashkash2002@gmail.com

[1]Student, Electrical and Electronics Engineering, College of Engineering Perumon, Kollam, Kerala India
[2]Student Electrical and Electronics Engineering, College of Engineering Perumon, Kollam, Kerala India
[3]Student Electrical and Electronics Engineering, College of Engineering Perumon, Kollam, Kerala India
[4]Student, Electrical and Electronics Engineering, College of Engineering Perumon, Kollam, Kerala India
[5]Student, Electrical and Electronics Engineering, College of Engineering Perumon, Kollam, Kerala India

Received Date: May 20, 2024
Accepted Date: July 09, 2024
Published Date: July 30, 2024

Citation: Jyothis JS, Lakshmi, Kannan S, Akash V, Justin Jose. Autonomous Infection Control System. Journal of Mechatronics and Automation. 2024; 11(2): 12–18p.

disinfection technology tailored for healthcare settings. Through theoretical and experimental methods, we provide comprehensive insights into the research conducted, culminating in significant advancements in infection control within hospital environments. Our results and discussion section further elucidates the implications of our findings, emphasizing the transformative impact of our Autonomous Disinfection System compared to existing approaches [1].

PROBLEM DEFINITION

In the realm of disinfection practices, conventional manual methods often prove laborious, time-consuming, and potentially hazardous to human operators. The pressing challenge at hand lies in the design and development of a robotic solution adept at efficiently and safely disinfecting diverse indoor spaces, particularly critical environments like hospitals. Mitigating the spread of diseases and improving public health and safety standards are the primary objectives. Thus, the central problem statement revolves around the necessity for an autonomous disinfection robot equipped with the capability to navigate indoor environments autonomously and identify areas necessitating sanitation interventions. This paper aims to address this challenge by presenting the design, development, and validation of such a robotic system, elucidating its functionality, efficacy, and potential impact on enhancing disinfection protocols in healthcare settings and beyond.

Methodology

The methodology for developing an autonomous infection control system encompasses several intricate steps aimed at ensuring efficient pathogen detection and disinfection. Initially, the construction of the autonomous robotic system was undertaken, integrating vital components like DC motors for movement, ultrasonic sensors for navigation, and a camera for environmental perception. Furthermore, the inclusion of storage containers for disinfectants and a submersible pool-pump for effective spraying enhances the system's capability to eradicate microbial threats. Central to the system is the robotic arm, housing a camera and nozzle for real-time detection and targeted disinfection tasks, precisely controlled by a high-torque DC servo motor (Figure 1).

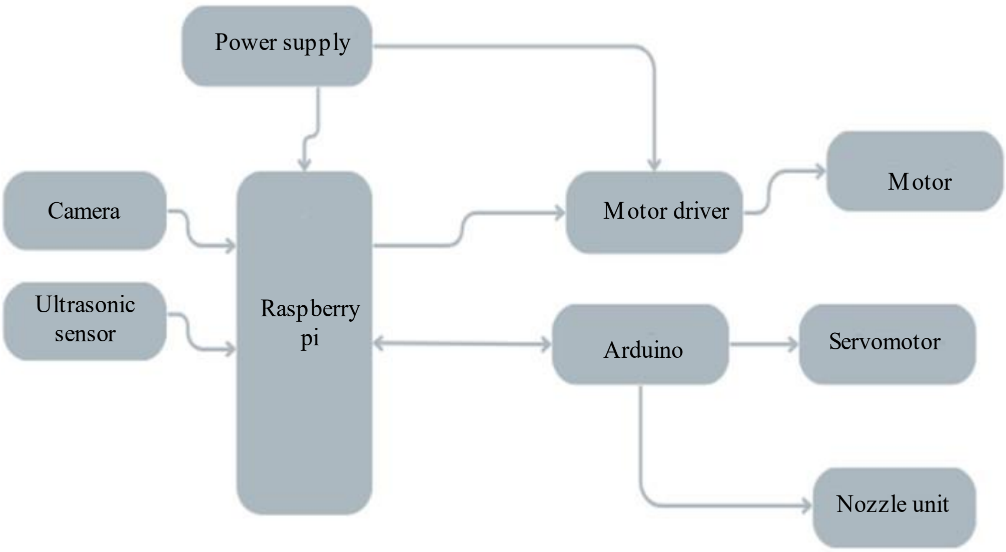

Figure 1. Block diagram.

Following the assembly of the robotic system, attention is directed towards image processing for bacterial detection. The robot is directed to predefined locations, where it captures grayscale images of the surroundings using the integrated camera. Through sophisticated image processing algorithms, microbial presence is identified and analyzed, facilitating accurate detection of contaminated areas. Upon confirmation of microbial presence, the robotic arm activates the spraying mechanism, effectively distributing disinfectants over the infected regions. This systematic approach, coupled with robust power management protocols and efficient communication mechanisms, ensures the autonomous infection control system's ability to autonomously detect and disinfect pathogens, thereby contributing to improved public health and safety standards in indoor environments, particularly within healthcare settings [2].

Block Diagram

The autonomous infection control system encompasses a sophisticated circuit design integrating essential components to fulfill its mission of pathogen detection and disinfection. At its core, the Raspberry Pi 4 serves as the system's central processing unit, orchestrating the operation of all interconnected elements. This miniature computer effectively coordinates the functionalities of sensors, motors, and communication interfaces, ensuring seamless interaction and precise control over the system's operations. Through real-time sensor data and feedback, collected primarily from ultrasonic sensors, the Raspberry Pi facilitates accurate mapping and localization within the environment, enabling the system to navigate with confidence while avoiding obstacles [3].

Circuit Diagram

The motorized components of the system, including DC motors regulated by the L298N motor driver, are pivotal for enabling physical movement. These motors power the wheels of the robotic system, responding to commands from the Raspberry Pi to traverse the environment autonomously. Coupled with ultrasonic sensors, they provide the necessary locomotion for the system to execute its designated tasks effectively. Meanwhile, the inclusion of a submersible water pump further extends the system's capabilities, enabling the spraying of disinfectant for sanitizing contaminated areas. Activated by signals from the Raspberry Pi, this component ensures thorough and targeted disinfection, contributing to enhanced hygiene protocols within healthcare settings and other relevant environments (Figure 2).

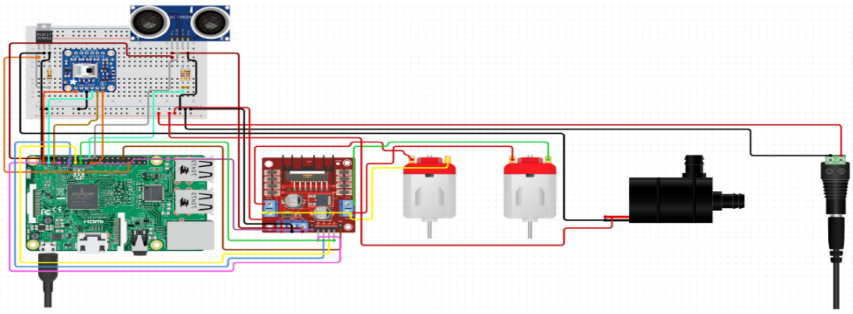

Figure 2. Circuit diagram.

The integration of a camera module adds a crucial visual element to the system, facilitating image capture and processing for various purposes. The camera is mounted on the robotic platform and records live views of the environment. The Raspberry Pi uses these images to plan paths, map the area, and identify microorganisms. This visual feedback enhances the system's perception capabilities, enabling it to make informed decisions and adapt to dynamic environmental conditions. Together, these components form a comprehensive circuit design, empowering the autonomous infection control system to detect pathogens and execute disinfection procedures autonomously, thereby promoting public health and safety standards effectively.

Components

Raspberry pi 4

The Raspberry Pi 4 stands as a cornerstone of modern computing, renowned for its compact size, versatility, and robust performance capabilities. The Broadcom BCM2711 quad-core processor, which can operate at up to 1.5GHz, and the Raspberry Pi 4's choices of 2GB, 4GB, or 8GB of RAM allow it to pack a lot of processing power into a tiny package. Its enhanced multimedia capabilities, including support for 4K video playback and dual-display output, make it an ideal choice for a wide range of applications, from educational projects to embedded systems and IoT devices. With a plethora of connectivity options, including Gigabit Ethernet, dual-band Wi-Fi, Bluetooth 5.0, USB 3.0 ports, and GPIO pins, the Raspberry Pi 4 provides ample opportunities for interfacing with external peripherals and sensors, facilitating seamless integration into various projects and applications. Moreover, its low cost and open-source nature have democratized access to computing technology, empowering enthusiasts, educators, and innovators worldwide to explore, experiment, and create innovative solutions across diverse domains (Figure 3).

Figure 3. Raspberry pi 4.

l298n driver

Robotics and other projects needing motor control frequently use the well-liked L298N integrated circuit (IC) as a motor driver. It is capable of controlling two DC motors bidirectionally, making it suitable for applications such as driving wheels or controlling robotic arms. The L298N module typically includes the L298N IC along with supporting components such as diodes, capacitors, and terminal blocks, simplifying its integration into projects [4].

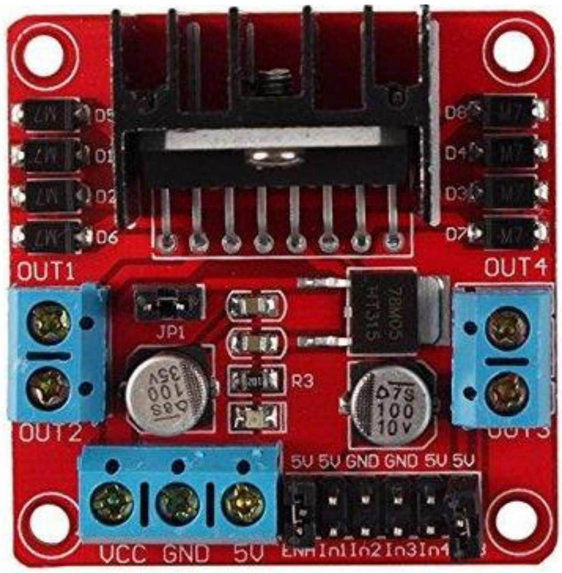

Figure 4. l298N Motor driver.

One of the key features of the L298N is its ability to handle high currents, making it suitable for driving motors with substantial power requirements. It operates on a wide range of input voltages and can control motors with voltages up to 46V and currents up to 2A per channel (Figure 4).

There are two H-bridges available in the L298N module, and each one can drive one motor. Each H-bridge consists of four transistors configured in such a way that the polarity of the motor's voltage can be reversed, allowing for bidirectional control. By applying appropriate logic signals to the input pins of the L298N, the direction and speed of the connected motors can be controlled.

Furthermore, the L298N module often includes protection diodes to suppress voltage spikes generated by the motor's inductive load, enhancing the reliability and longevity of the circuit. Its straightforward interface and robust performance make the L298N a popular choice for hobbyists, makers, and engineers seeking an efficient and reliable solution for motor control in their projects.

Ultrasonic sensor

The ultrasonic sensor is a versatile device widely utilized for distance measurement and object detection across various domains. Operating on the principle of emitting ultrasonic sound waves and measuring their reflections, these sensors provide accurate distance readings based on the time taken for sound waves to return to the sensor after hitting an object. Composing essential components like transducers, receivers, and control circuitry, ultrasonic sensors translate electrical signals into ultrasonic waves and back again, enabling precise distance calculations. These sensors offer a broad operating range, spanning from a few centimeters to several meters, catering to diverse application requirements. Short-range sensors are ideal for close-proximity tasks like obstacle avoidance in robotics, while long-range variants are suited for applications such as parking assistance systems in automotive contexts or industrial automation tasks (Figure 5).

Figure 5. Ultrasonic sensor.

Ultrasonic sensors are widely used in consumer electronics, automobile systems, artificial intelligence, and industrial automation. Their ability to provide accurate distance measurements, coupled with their ease of integration and cost-effectiveness, makes them indispensable components in various projects and applications. Whether employed in autonomous navigation systems for robots, proximity sensors in manufacturing environments, or parking assistance systems in vehicles, ultrasonic sensors play a crucial role in enhancing safety, efficiency, and automation across numerous sectors [5,6].

DC motor

A DC motor is a type of electrical motor that generates mechanical force by means of direct current (DC). The most popular kinds rely on magnetic forces generated by coil currents. The internal mechanism of almost all DC motor types, whether electromechanical or electronic, allows the motor to occasionally reverse the direction of its current in a specific section. The stator and armature of a basic DC motor contain a stationary set of magnets, and the magnetic field is concentrated by one or more windings of insulated wire encircling a soft iron core [7]. Large motors may have numerous parallel current channels, and the windings typically have multiple rounds around the core. The wire winding's ends are attached to a commutator. By using brushes to connect the revolving coils to the external power source, the commutator enables the sequential energization of each armature coil (Figure 6).

Figure 6. DC motor.

Battery

This is a 3s Li-ion Rechargeable Battery Pack with a nominal voltage of 12.6 volts. The 1200mAh capacity of this battery pack comes from three series-connected cells. The battery pack contains a built-in BMS to prevent short circuits, overcharging, and overdischarging. details The voltage used for charging is 12.6 V. 600 mA of charging current Pack nominal voltage: 11.1 volts Tested for 500 mA and 1 A of discharge current. 1.2mA is the maximum discharge current. Safety (With BMS Added) Protective Short Circuit 12.8 V for overvoltage and 9.2 V for undervoltage cutoffs in applications[8]: Modest UPS Battery for Asset Tracking, Vehicle Tracking, and GPS Tracking; Backup WiFi Modem or Router Battery PSP Industrial Machines 12V Remote CCTV Camera Lamps for emergencies RC vehicles and robots Audio Systems and Music Players Discover the potential of FYURI with our 12V 1200mAh Lithium Battery, an exemplar of dependability and efficiency[9]. This battery provides steady power for robots, toys, drones, GPS, CCTV, and industrial applications. It is BIS authorized and comes with a 6-month warranty (Figure 7).

Figure 7. Battery

CONCLUSIONS

To sum up, the suggested self-cleaning system presents a hopeful resolution to the growing issue of microbiological spread in medical facilities. By integrating advanced technologies such as image processing for pathogen detection and UV-C lights for disinfection, the system addresses the critical need for efficient sanitization while reducing the risk to human personnel.

The autonomous nature of the robotic system ensures targeted and effective disinfection without requiring constant human presence, thus minimizing the exposure of healthcare workers to potentially harmful pathogens. With its ability to map user locations, navigate autonomously, and utilize advanced imaging technology, the system represents a significant advancement in hospital hygiene management.

By implementing such innovative solutions, hospitals can enhance their infection control measures, ultimately leading to improved patient outcomes and a safer healthcare environment for all.

REFERENCES

1. Kittipong Yaovaja, Pongsakorn Bamrungthai, Prapapan Ketsarapong. Design of an Autonomous Tracked Mower Robot using Vision-Based Remote Control.IEEE Conference on IOT in Communication and Engineering; 2019; Eurasia. Taiwan
2. Yasunori ABE, Masaru SHIKANO,Toshio FUKUDA, Fumihito ARAI, Yoshio TANAKA.Vision Based Navigation System by Variable Template Matching for Autonomous Mobile Robot.Proceedings of the IEEE International Conference on Robotics & Automation ;1998 May; Leuven, Belgium
3. Balakrishnan Ramalingam ,Prabakaran Veerajagadheswar,Muhammad Ilyas ,Mohan Rajesh Elara ,Arunmozhi Manimuthu.Vision-Based Dirt Detection and Adaptive Tiling Scheme for Selective Area Coverage.Journal of Sensors;2018\
4. Giuseppe Oriolo ,Marilena Vendittelli, Giovanni Ulivi.On-Line Map Building and Navigation for Autonomous Mobile Robots.Proceedings of the IEEE International Conference on Robotics and Automation;1995. Nagoya, Japan
5. Iong Chio , Kaicheng Ruan , Zehao Wu, Kit Iong Wong, Lap Mou Tam, Qingsong Xu.Design and Autonomous Navigation of a New Indoor Disinfection Robot Based on Disinfection Modeling.IEEE Transaction on Automation Science and Engineering.2023 January; vol. 20.Issue 1. Page(s): 649 - 661
6. Md. Mushfiqur Rahman Saad, Md. Abdur Razzak.A Cost Effective UV Robot for Disinfecting Hospital and Factory Spaces for Covid-19 and Other Communicable Diseases.Prceedings of the IEEE World AI IoT Congress (AIIoT).2021
7. Abhishek Rai,Chinmay Chaturvedi,P K Maduri,Kushagra Singh.Autonomous Disinfection Robot.Proceedings of Second International Conference on Advances in Computing, Communication Control and Networking (ICACCCN);2020. India
8. Toshio FWKUDA, Yasunari YOKOYAMA, Yasunori ABE, Kouetsu TANAKA, Fumihito ARAI, Koii SHIMOJIMA, Shigenori ITO, Yoshio TANAKA.Navigation System Based on Ceiling Landmark Recognition for Autonomous Mobile Robot.Proceedings of IEEE International Conference on Robotics and Automation.1996 April; Minneapolis;Minnesota. USA
9. Aditya Mehta,Apeksha S,Pranav Banagar.Design, Analysis and Development of an Autonomous Modular Disinfectant Robot.Proceedings of IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT).2022. India

