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Developing a Telepresence Robot for Autism Diagnosis

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***Abstract* – The global COVID-19 pandemic posed significant challenges to the healthcare industry in maintaining continuous operations while adhering to strict physical distancing protocols. Critical functions such as delivering meals to patients, supplying medical instruments, monitoring vital signs, assisting those with impaired mobility, and ensuring accurate disease diagnoses became increasingly difficult. As the world adapts to a post-pandemic reality, robots are expected to play a more prominent role by becoming more self-reliant, adaptable, and collaborative. In response to these evolving needs, the Centre for Unmanned Technologies (CUTe) at International Islamic University Malaysia (IIUM), in collaboration with Prostrain Technologies, developed the innovative medical robot called "Medibot". Medibot, a telepresence robot, presents a promising tool for observing children's true behaviours and interactions—essential for diagnosing Autism Spectrum Disorder (ASD). Equipped with a high-resolution camera, Medibot facilitates seamless video conferencing between children and experts, enabling detailed behavioural analysis during diagnostic sessions. The presence of parents beside the child enhances comfort, while the robot's non-intrusive character encourages natural responses and interactions. Compared to traditional human-led assessments, Medibot's presence is less intimidating, potentially leading to more accurate diagnoses. Medibot's development is underpinned by a robust ROS-based software architecture, enabling autonomous navigation in complex hospital environments while avoiding static and dynamic obstacles with high operational consistency. Extensive testing has validated its mapping and navigation capabilities, ensuring smooth and predictable movements without human intervention, making the diagnostic process less intrusive and seamless. The incorporation of telepresence technology, primarily through a teleconferencing camera for live image streaming, represents a significant advancement in remote healthcare. With applications ranging from ASD diagnosis to broader medical monitoring, Medibot exemplifies the transformative potential of telepresence robotics in expanding access to specialized care and improving patient outcomes.**

Keywords*— Telepresence, Robot, Ros, Diagnosis, Autism.

I. INTRODUCTION

Healthcare personnel are finding robotics technologies to be a useful support tool, as noted in [1]. It is also mentioned that the healthcare industry is only now beginning to employ mobile robots because these machines must adhere to stricter regulations than those used in industrial environments. In hospitals, an autonomous mobile robot navigates through unpredictable and busy environments due to high activity levels. Meanwhile, mobile robots in industrial and storage spaces operate in a controlled and defined environment and travel along predetermined paths [2].

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In hospitals and clinics, autonomous mobile robots must be able to perceive the features of their dynamic setting, build a model of the environment, and find their location within it. Because of this behavior, a mobile robot may develop and optimize a navigation plan using a special planning algorithm. The robot must navigate the area unhindered and steer clear of objects inside its path. According to Rubio et al. [3], the basic features of mobile robots' autonomous navigation are locomotion, perception, cognition, and navigation.

In dynamic environments, mobile robots are usually outfitted with sensors that gather environmental information and create a spatial map of their surroundings. They can ascertain their precise or estimated location based on the map made to enable autonomous navigation. Simultaneous Localization and Mapping (SLAM) is the term for this procedure [4]. Several academic institutes and technological companies have utilized the open-source Robot Operating System (ROS) robotics middleware for robotics implementation to create a range of autonomous mobile robots. Robot Operating System (ROS) aims to enable the modularization of robotic applications and facilitate code reuse and portability across the robot development lifecycle. A distributed process framework called ROS offers function management, hardware abstraction, libraries, visualizers, and information flow between processes. A distributed process framework called ROS offers function package management, libraries, visualizers, hardware abstraction, and information flow between processes. It works with a variety of programming languages. These characteristics simplify testing, significantly reducing the time required to develop robotics applications and the expense of developing new robots [5, 6].

Table 1 provides numerous instances of cutting-edge mobile robots created with the open-source ROS framework.

TABLE 1. Application of ROS in mobile robots.

No.	Mobile Robot	Descriptions	Authors
1	PR2	Drink fetching and serving robot	Rosen Diankov et al. [7]
2	TurtleBot 3	Education and research platform	Lim et al. [8]
3	TIAGo	Domestic service robot	Vicente et al. [9]
4	Jackal	Indoor autonomous exploration robot	Noh et al. [10]
5	Wheel Mobile Robot	Low-cost navigation robot	Al Khatib et al. [11]

Autonomous mobile robots in healthcare are increasingly being utilized as telepresence robots, representing an advanced technological system that effectively empowers medical professionals and therapists to conduct remote interactions. Consequences of the COVID-19 pandemic, Murphy et al. [12] reported that robots' most common application was telepresence, allowing doctors and nurses to engage with patients from a far distance. This approach effectively addresses geographical barriers, ultimately enhancing the potential for improved access to specialized care.

From another perspective, numerous studies have brightened the potential benefits of employing robots in the diagnosis and treatments, particularly for those with ASD. Interactions with robots have shown promise in enhancing engagement skills, attention span, and emotional intelligence among ASD children. Furthermore, research, as cited in [13], suggests that robots can aid in improving the academic capabilities of ASD children. Notably, interactions between robots and ASD children have significantly demonstrated improved performance during clinical sessions [14]. The potential of these robots to enhance engagement between medical professionals and children with ASD holds the promise of more reliable and accurate diagnoses. Children with ASD stand to benefit significantly from the integration of telepresence robots, reducing the necessity for direct patient-doctor interactions while bolstering their self-confidence. ASD children often struggle with maintaining eye contact during social interactions [15], multiple behavioral challenges that clinicians confront during clinical sessions. Their enduring social communication and interaction deficits can lead to associated behavioral difficulties.

These robots offer a unique opportunity to observe autism traits in social contexts, potentially leading to more accurate diagnoses and better therapeutic outcomes. In diagnostic sessions, primary indicators and characteristics of autism traits are observed in social contexts. Therefore, our research seeks to harness the harmony between technology and medical professionals to achieve precise and robust diagnoses with undisrupted behavior.

In response to the concerns, the Center for Unmanned Technology (CUTe), in collaboration with ProStrain Technologies, has successfully developed a cutting-edge medical assistance robot called Medibot. Medibot is an advanced teleconferencing robot incorporating IoT capabilities, connecting seamlessly to the cloud and the internet. It is equipped with essential medical instruments, including a thermometer and blood pressure monitor, and added with a large screen and integrated camera for real-time conversation. The embedded Simultaneous Localization and Mapping (SLAM) and Robot Operating System (ROS) allow Medibot to construct spatial maps and optimize navigation plans, ensuring it can navigate dynamically changing environments without interruption. Ensuring that Medibot can move efficiently and autonomously from one location to the diagnostic session room is critical for creating a calm and controlled environment during ASD diagnosis. Children with Autism Spectrum Disorder (ASD) are often sensitive to changes in their surroundings and may experience anxiety or stress when faced with unfamiliar situations or disruptions. Meanwhile, the combination of telepresence capabilities aims to facilitate real-time remote diagnostics and therapy of children with ASD, improving their engagement and aiding more accurate diagnosis through improved social interaction analysis. Medibot utilizes real-time technologies as a telepresence robot that allows a diverse group of healthcare professionals, such as therapists, psychiatrists, and parents from various places, to convene simultaneously with the ASD child to assess diagnosis. The added value of a large screen can be used to evaluate the kids' behaviour while inducing them with the video stimuli projected on the screen.

II. SYSTEM DESIGN OF MEDIBOT

Medibot is engineered to fulfill the criteria of an autonomous mobile and telepresence robot. It weighs approximately 85kg due to its primary materials being steel and aluminium, and it includes two electronic wheelchair-grade tyres to meet hospital device usage standards. Its height measures around 165cm. A microcontroller board and a single-board computer (SBC) are fitted in the Medibot. The microcontroller board is mainly responsible for managing the actuation operations of the robot, while the SBC manages the telepresence IP camera, display, speaker, and laser scanner. It is responsible for reading input from the mode switch, control pendant, and emergency stop button and operating the left and suitable motors through motor drivers. Figure 1 shows the hardware architecture of Medibot while Figure 2 represents the development of the Medibot appearance, respectively.

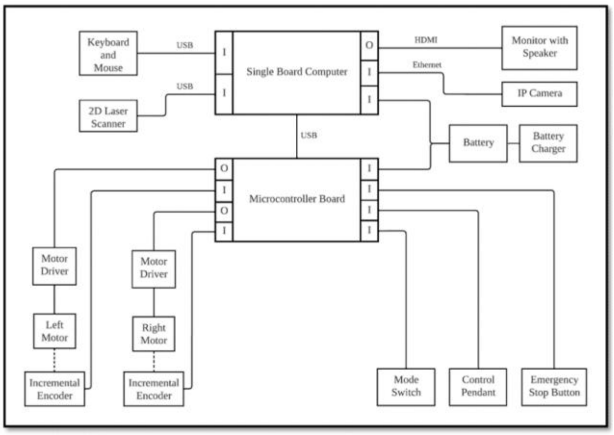

FIGURE 1. Hardware Architecture of Medibot.

FIGURE 2. Evolution of Medibot [16].

Medibot's architecture, with separate components for sensory data processing and actuation control, provides a research platform that explores efficient and modular robot design strategies with potential applications in healthcare and beyond. Researchers can leverage Medibot's hardware configuration to investigate novel approaches to telepresence, autonomous navigation, and human-robot collaboration, ultimately advancing the field of robotics and its potential in various domains.

From the software perspective, Medibot utilizes ROS as its backend system for managing low-level control interfaces, intricate sensing, and control algorithms. ROS offers a range of libraries and tools that prove valuable in developing robot applications. It consists of interconnected processes known as nodes, which engage in peer-to-peer communication within the network topology. During Medibot operation, specific nodes are responsible for distinct tasks, including lidar sensor control, motor control, localization, and path planning. ROS serves as a communication framework enabling these nodes to interact through two messaging mechanisms: topic and services. ROS topics operate on a publish/subscribe-based asynchronous message system. Publishers transmit topic messages to the system, while subscribers receive and process the published information. It is worth noting that multiple publishers and subscribers can be associated with the same topic. Figure 3 illustrates the ROS nodes within a Medibot system, each communicating with the others through topics.

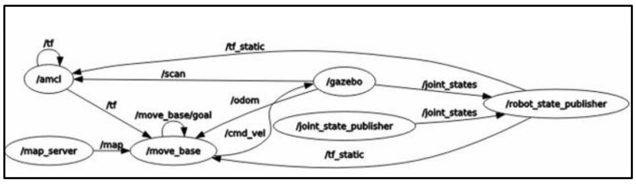

FIGURE 3. The rqt_graph of Medibot simulation during autonomous navigation.

A. *Autonomous Mobile Robot*

An autonomous mobile robot's guidance, navigation, and control algorithm is its fundamental component. Medibot uses a two-level planning architecture in ROS to assist with path planning. This architecture consists of a local path planner collaborating with a global path planner. To determine the best route to a given target point, the global path planner, which focuses on long-range planning, must have access to map data. In contrast, the local planner handles the robot's dynamics as it follows the created course and steers clear of unforeseen hazards. Therefore, in real-world applications, global and local path planning are typically incorporated into path planning systems and can be complementary solutions in enabling autonomous navigation.

The global planner implements the Dijkstra algorithm as it is the most widely used algorithm and the default algorithm used in the move_base package from the ROS navigation stack. Dijkstra's algorithm computes the shortest distance from the starting point to the goal point with the lowest cost. In the meantime, the local planner uses Time Elastic Bands (TEB), which entails updating the local path in response to dynamic barriers or possible deviations from the path and deforming the initial global plan by considering the robot's kinematic model. The low computational cost of this technology has led to its adoption in trajectory planning combined with obstacle detection and avoidance. The TEB local planner modifies the initial global plan by creating intermediate robot positions. It needs the safety distance between the obstacles, the robot's maximum speed and acceleration, and its geometric, kinematic, and dynamic limitations. The robot moves, and this configuration creates a series of rotational and velocity commands needed to reach the intermediate waypoints.

On the other hand, odometry plays a crucial role in state estimation during the navigation process, encompassing position, orientation, and linear and angular velocity, referred to as twist. It should effectively represent the transformation of the robot's base link frame into a static odometry frame. In the Medibot control system, there are two options for computing odometry: one is to derive it solely from the left and right wheel encoder readings obtained from the base controller, and the other is to utilize laser scan data for odometry estimation. One of these odometry calculations is then published to the GMapping SLAM node and the ROS navigation stack.

The relationships between the various coordinate frames employed in the robot's functioning must also be established. Four basic coordinate frames in this system are shown in Figure 4: base_link, lidar, Odom, and map. The frame is changed from the fixed Odom frame to the base_link frame via the odometry. Concurrently, the base_link frame to lidar frame frame transformation is handled by the robot's Universal Robot Description Format (URDF).

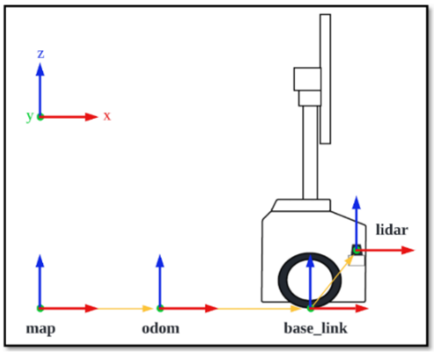

FIGURE 4. Basic frame transformation of the robot.

Medibot utilizes a Simultaneous Localization and Mapping (SLAM) technique during its operation. This technique involves continuously mapping an area while updating its location. To conduct a functionality test of Medibot, an environment map is created using the ROS GMapping package, which employs laser-based SLAM and incorporates data from the laser sensor and the robot's odometry to generate a 2-D occupancy grid map. When the SLAM node is initiated, the Rviz software is visually activated to represent the mapping process. Initially, the robot is remotely driven and carefully controlled as it navigates the environment. This process ensures that the map is generated incrementally and accurately, as depicted in Figure 5.

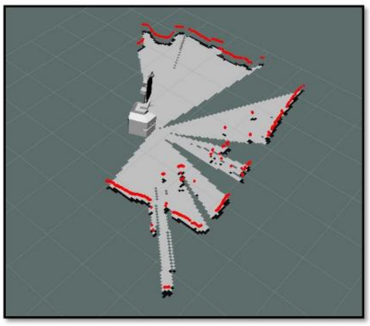

FIGURE 5. Running GMapping node in Rviz.

The SLAM node links changes in odometry values to the most recent and earlier scans of the surroundings after reading inputs from the laser scanner and odometry data. Consequently, as shown in Figure 6, the SLAM node progressively creates the updated map and posts the 2D occupancy grid data to the map subject.

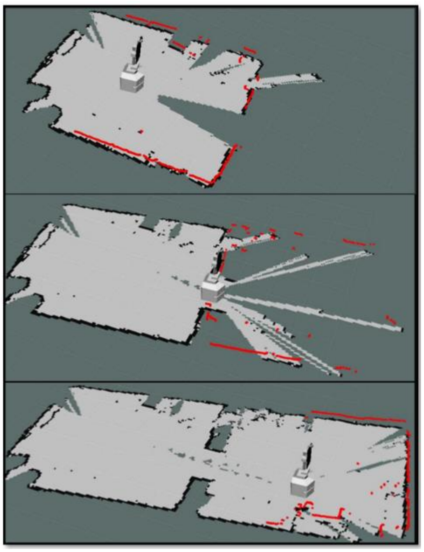

FIGURE 6. Updated Map Generated using GMapping.

Once the mapping process is considered complete, a 2D occupancy grid map is saved as a portable gray map image in .gm format with a .yaml file that contains the metadata. The map has a resolution of 0.05 meters. As depicted in Figure 7, the obstacles are presented in black pixels. Meanwhile, the pixels in light grey colour represent free space for the robot to move. The dark grey pixels represent the outer area not covered in the robot's motion.

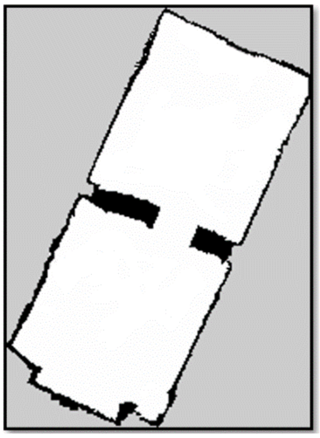

FIGURE 7. Pre-built map using ROS GMapping package.

The robot is localised in its surroundings by integrating the created map with real-time laser scanning and odometry data. Medibot's default localization algorithm in the ROS navigation stack was Adaptive Monte Carlo localization (AMCL). A particle filter is used in AMCL, a probabilistic localization method for two-dimensional robot movement, to estimate a robot's pose about a predefined map. Green markers in Rviz represent the convergence of AMCL particles, as seen in Figure 8. The dispersion of the particles explains the uncertainty in the robot's pose's localization. The particles gradually converge as the robot goes around the environment, showing how the robot's pose estimation has been corrected over time. Once the particles converge into the robot base frame, the robot is considered localized in the environment.

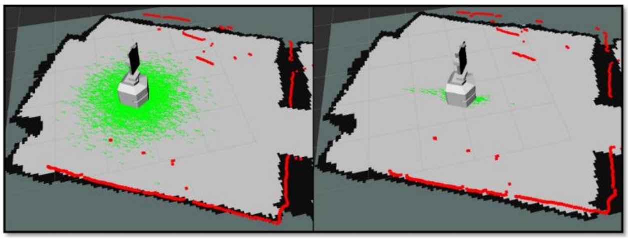

FIGURE 8. AMCL Particles Convergence in Rviz.

B. Telepresence Robot

The functioning of Medibot and its capacity for independent hospital and clinic environment navigation were covered in the preceding sections. Though little research currently focusing on teleoperation robots for ASD, several recent publications provide interesting information regarding telepresence robotics and their potential applications in healthcare and education. Therefore, research is being done on Medibot's potential as a telepresence robot to make a strong case for detecting ASD in young patients.

Autism's early detection is essential as it enables timely interventions and therapies that can significantly enhance a child's quality of life. However, the diagnostic process can be intricate and requires extensive observations and assessments. Here, telepresence robots serve as catalysts for this transformation. They empower medical professionals to observe and interact with children suspected of having autism in their natural environments, bypassing the potential biases of clinical settings. Experts can glean invaluable insights into a child's behaviour and development through these remote encounters, fostering more accurate and holistic diagnoses. One significant advantage of using robots in such interventions is their ability to attract and engage children effectively. Robots can be introduced to children with ASD as interactive toys, creating an engaging via stimuli and enjoyable play-like interaction. This approach allows children to feel entertained and in control while remaining manageable for therapists or medical professionals overseeing the interactions. A 2023 study [17] reviews the growing use of telepresence robots in supporting educational settings, particularly for students with disabilities, including ASD. These robots enable remote interaction, consultation, and behavioral support by offering an immersive presence miming in-person interactions. This is particularly useful for conducting consultations or therapeutic sessions that are less intrusive and more comfortable for children with ASD.

In the meantime, Alfuraydan et al. [18] have emphasized the noteworthy consistency in diagnostic outcomes for children with ASD between telepresence and traditional face-to-face methods. Both families and clinicians have expressed high levels of satisfaction with this approach. Telepresence robots have the potential to augment access to ASD diagnosis, particularly for cases that exhibit evident autistic characteristics rather than borderline traits. Notably, telepresence robots employed in the presence of patients' parents during diagnostic sessions contribute to a more natural and comfortable environment; meanwhile, a remote team of medical professionals can observe and provide valuable insights without necessitating physical presence, enhancing the efficiency and convenience of the diagnostic process. Researcher findings indicate that assembling a multidisciplinary team encompassing various fields, such as education and healthcare, can be challenging, as referenced in [19]. Diagnosing ASD often requires a collaborative approach involving a team of clinical psychology, psychiatry, and nursing professionals. Table 2 offers a comprehensive overview of telepresence robots for diagnosing children with autism spectrum disorder (ASD).

TABLE 2. A comparison between research in diagnosing children with ASD.

Source	**No. of Samples (Child)**	**Robot Type**	**Robot helpful**	**Measuring Techniques**	**Presence of Parents**	**Autonomous**
Daniel O. David et al. [20]	16	QTrobot	Yes	Gaze Orientation, pointing and vocal instruction	NO	Autonomous
Chung et al. [21]	30	Humanoid Robot	Yes	Social skill intervention, behavioral responses	NO	Semi-autonomous
Del Coco et al. [22]	8	Zeno humanoid robot	Yes	Numerical measures of gaze direction, head pose, and facial actions	-	NO

In a related context, video conferencing has proven to be an effective means of guiding families in properly executing assessment tasks with their children. This approach also suggests that achieving an accurate diagnosis of ASD in young children is attainable when evaluation procedures are conducted via video conferencing by trained clinicians. Research clinicians in [17] who observed and rated assessments conducted via video conference (VC) demonstrated an impressive level of accuracy (86%), specificity (88%), and sensitivity (83%) in diagnosing ASD, which is comparable to, if not better than, the results obtained from confirmatory interdisciplinary evaluation clinics.

Future research should prioritize the development of guided assessment capabilities that dynamically adapt to various interactive scenarios under the supervision of medical professionals. The introduction of Medibot, a telepresence robot, presents a promising tool for observing children's authentic behaviours and interactions, critical components in diagnosing ASD. A diagnostic session between the children and the medical team can be conducted in the presence of the parents beside the children. Medibot has a high-resolution camera that facilitates video conferencing between children and specialists, enabling detailed behavioural analysis. The advantage of non-intrusive monitoring is that it promotes natural responses and interactions. Medibot's presence is less intimidating for children than human evaluators, potentially leading to more accurate assessments.

Medibot's capability to download modules from the cloud enables interactive sessions where children engage in specific tasks or activities displayed on a monitor, aiding in assessing cognitive and social skills. Additionally, remote specialists can provide real-time feedback and analysis. In conclusion, Medibot emerges as a promising telepresence robot that facilitates and enhances the capabilities of specialized ASD teams. Zoder-Martell et al. [24] reported that children with ASD are neutral towards the telepresence robot in which they can interact regularly. This technology enables these teams to convene remotely, overcoming geographical barriers and ensuring accurate diagnoses while preserving children's natural behaviour in the absence of unfamiliar individuals.

Future studies should explore the longitudinal impact of Medibot-assisted interventions on the social development of children with ASD and the integration of advanced AI algorithms to further enhance the robot's diagnostic capabilities. Implementing Medibot could significantly advance personalized treatment plans, leveraging its ability to capture and analyze extensive behavioural data over time. Integrating machine learning algorithms could allow for predictive modelling and early intervention strategies tailored to individual needs. This approach aligns with the growing emphasis on precision medicine in ASD treatment, where interventions are customized based on detailed patient profiles. Consequently, Medibot has the potential to revolutionize ASD diagnosis and treatment, making it a necessary tool in both clinical and research settings.

Overall, this research underscores the critical role of innovative robotic technologies in advancing the field of ASD intervention and diagnosis. By fostering interdisciplinary collaboration and integrating cutting-edge AI capabilities, Medibot exemplifies the future of personalized, responsive, and effective care for individuals with ASD.

III. RESULTS AND DISCUSSION

This section presents a comprehensive analysis of the performance of autonomous navigation functionality, followed by an assessment of the effectiveness and efficiency of the embedded features for a telepresence robot.

A. Autonomous Navigation System

To assess the performance of Medibot's autonomous navigation, a series of controlled experiments were conducted, simulating various scenarios encountered in defined space environments. The robot's ability to navigate autonomously, avoid obstacles, and reach predefined destinations was meticulously examined. The research team also analyzed the adaptability of the robot's navigation system to dynamic and unpredictable hospital layouts.

The Medibot must always reset its position at the start by finding a home point (point A). This point is the first navigation goal in Rviz before any new navigation goal is sent to help the robot localize the environment faster. Then, the predefined waypoints method is implemented, denoted as A, B, C, and D, and the Medibot embarks on a sequential navigation journey, commencing at point A. This waypoint control script is iterated ten times for each test. Our study encompasses four distinct conditions of robot movements:

i. An obstacle-free environment,

ii. An environment featuring static obstacles, and

iii. An environment featuring dynamic obstacles along the waypoints and

iv. Actual hospital environment.

An Obstacle-free movement

Figure 9 visually presents the outcomes of the Medibot's movements through a green line, clearly indicating the robot's final position at Point D. Notably, the robot consistently navigates from Point A to Point D.

A box is placed halfway between points A and B and between points C and D. The robot's movement is illustrated by the green line in Figure 10. The robot successfully navigates around the obstacle and returns to its predefined waypoints, represented by the green lines.

An environment featuring dynamic obstacles

In Test 3, dynamic objects (marked in red) were positioned between points C and D. Remarkably, no collisions with these dynamic obstacles were observed. The robot demonstrated exceptional navigation skills as it successfully maneuvered around all dynamic obstacles, including those not initially part of the map.

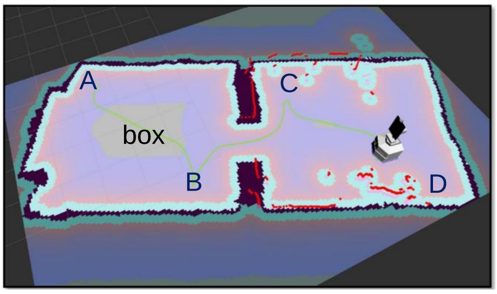

FIGURE 10. Test 2: Defined Waypoints from Point A to 3 different positions: points B, C, and D with a static obstacle between Points A and B and between Points C and D.

Figure 11 provides a visual representation of this achievement, showcasing the robot's ability to avoid static obstacles along the path from waypoint A to B and dynamically changing obstacles between Points C and D. During specific scenarios where an obstacle was approached too closely by the robot, a brief oscillation was displayed, and temporary challenges were encountered in determining a suitable path to reach the designated waypoint. Nevertheless, the robot exhibited resilience and adaptability as its trajectory was recalibrated over time, ultimately achieving its intended goal.

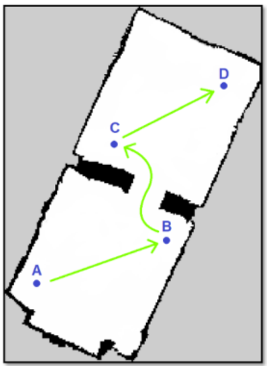

FIGURE 9. Test 1: Defined waypoints to 3 positions: points B, C, and D respectively.

An environment featuring static obstacles

It is worth highlighting that Test 2 exclusively involves immobile obstacles placed between predetermined waypoints. The findings in Table 3 show that the Medibot successfully evaded all static obstacles in the initial map.

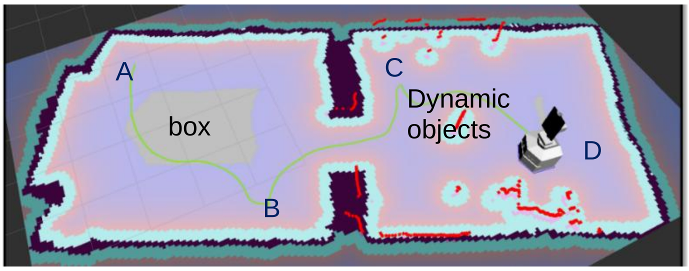

FIGURE. 11. Test 3: Defined Waypoints from Point A to 3 different positions, points B, C, and D, with a static obstacle between Points A and B and between Points C and D.

Table 4 shows that the robot's consistency in navigating through all waypoints and completing each trial is notable. Nevertheless, the average time required for completion in Test 3 is slightly greater than in Test 2. This outcome was anticipated due to dynamic obstacles in the test, which necessitated additional time for a new computation route for the robot to complete each trial safely.

In summary, in Tests 2 and 3 respectively, we observed that the robot consistently covered a similar cumulative distance while moving through various waypoints in each test. However, when comparing the two scenarios, it is noticed that the robot traveled farther on average in Test 3 than in Test 2. This outcome was expected because the robot had to navigate by avoiding unprecedented obstacles not discovered in the computation of predefined waypoints, requiring it to take slightly longer paths to complete each trial.

TABLE 3. Results for Test 2 of static obstacles' avoidance.

Trial No.	Collision With Static Object	Mission Completed From Pt. A To Pt. D	Time Taken To Complete (S)	Total Distance Traveled
1	No	Yes	48.93	12.16
2	No	Yes	52.69	11.98
3	No	Yes	51.19	12.23
4	No	Yes	49.93	12.28
5	No	Yes	51.82	12.36
6	No	Yes	50.27	12.09
7	No	Yes	47.72	11.92
8	No	Yes	50.50	12.02
9	No	Yes	50.64	12.02
10	No	Yes	46.40	11.88
Average			50.01	12.09

TABLE 4. Results for Test 3 of static and dynamic obstacles' avoidance.

Trial No.	Collision With Static Object	Collision With Dynamic Object	Mission Completed From P. A To Pt. D	Time Taken To Complete (S)	Total Distance Traveled
1	No	No	Yes	52.42	12.82
2	No	No	Yes	49.90	13.03
3	No	No	Yes	51.14	12.96
4	No	No	Yes	53.15	13.00
5	No	No	Yes	51.18	12.95
6	No	No	Yes	49.93	13.07
7	No	No	Yes	48.93	12.83
8	No	No	Yes	55.02	13.11
9	No	No	Yes	50.20	12.97
10	No	No	Yes	52.18	13.06
Average				51.41	12.98

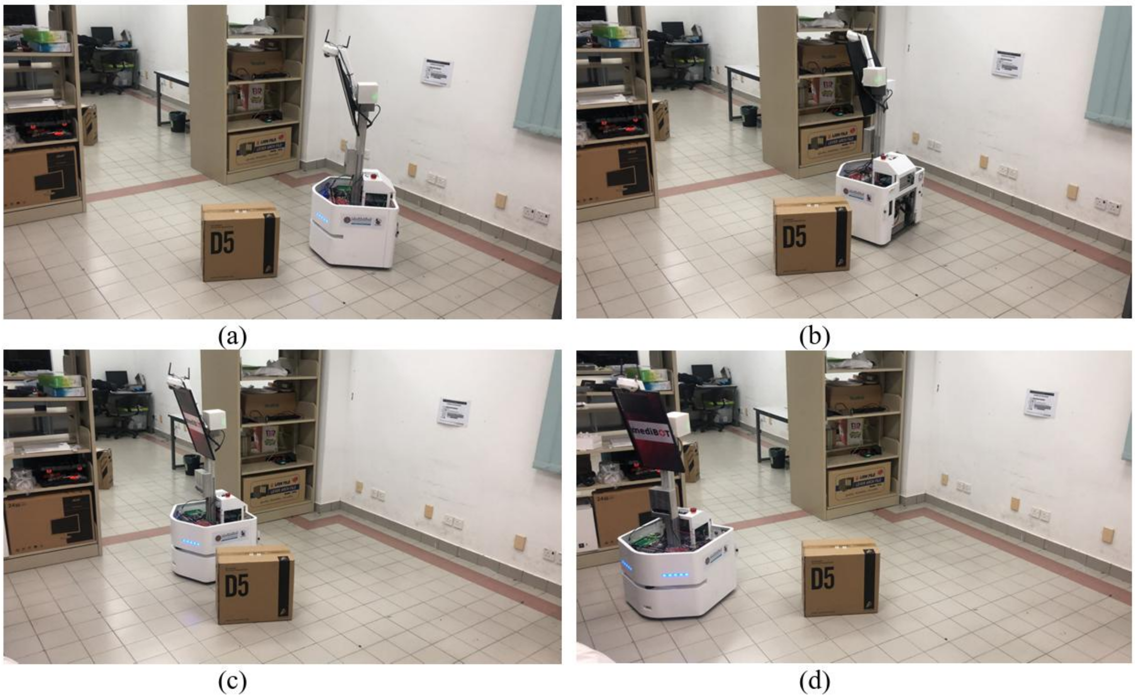

FIGURE. 12. Medibot avoiding a dynamic obstacle during autonomous navigation a) Robot has found an obstacle b) started moving to avoid collision c) followed a new computed route d) Robot kept moving at a safe distance.

Additionally, the experiment evaluated the performance of the path planner, ensuring that robots can navigate autonomously without colliding with static or dynamic obstacles. The implemented global and local planners avoided collisions in all tested scenarios, as depicted in Figure 12, where a robot safely avoids an obstacle and moves toward its goal position.

B. An actual test in a hospital environment

The actual test was also deployed at Sultan Haji Ahmad Shah Medical Centre, specifically at the pediatric ward. Some obstacles were placed about 3 meters away in front of the robot. The obstacles are listed in Table 5 and are detected if the robot stops before the collision. The results demonstrate that Medibot consistently operates without failure, maintaining repeatability performance even when facing static or dynamic obstacles.

The ambient noise level in a corridor was measured and recorded. The robot was then moved along a typical hospital corridor, passing about 1 meter in front of the person holding the sound level meter. The test was repeated twice; the results are recorded in Table 6 below.

The robot adds about two dBAs to the ambient noise level. The smooth functioning of video conferencing was also tested when it was placed beside a patient's bed with an accompanying nurse. In contrast, the other nurse/doctor was stationed at the control station room. The doctor at the control station then communicated with the patient on the bed with the help of the accompanying nurse. The test was then repeated with two other patients. The quality of the audio and video of the teleconference was noted. The doctor was able to communicate with the patient effectively. In response, the vital signs information captured by the accompanying nurse was relayed successfully to the doctor at the control station. The quality of the audio and video of the teleconference are summarized in Table 7.

TABLE 5. Results for Test 4 in the actual hospital environment.

Test No.	Obstacle	Obstacle Condition	Robot Response	Result
1	Human	Static	Stop	Obstacle Detected
2	Human	Dynamic (Moving)	Stop	Obstacle Detected
3	Bed (Leg)	Static	Stop	Obstacle Detected
4	Wall	Static	Stop	Obstacle Detected
5	Chair	Static	Stop	Obstacle Detected
6	Cleaning Trolley	Static	Stop	Obstacle Detected
7	Cleaning Trolley	Dynamic (Moving)	Stop	Obstacle Detected
8	Dust Bin	Static	Stop	Obstacle Detected
9	Food Trolley	Static	Stop	Obstacle Detected
10	Food Trolley	Dynamic (Moving)	Stop	Obstacle Detected

TABLE 6. Noise Level Test (dBA).

Test	Noise Level (Dba)
1	64
2	63.5
3	64
Ambient Noise	62

TABLE 7. Functionality Test of Components used in teleconferencing.

Component	Result
Audio	The audio quality is acceptable, as the nurse and doctor could successfully exchange patients' information. However, there were instances where a louder volume was necessary due to disturbance from other noise sources within the ward.
Video	The video was demonstrated to have minimal lag and almost real-time. The image quality of the live stream was good, and the image was sharp and not pixelated.

Audio and video functionalities are crucial in teleconferencing systems, particularly for engaging children in diagnosis sessions. These features enable the presentation of stimuli designed to enhance engagement and interactive participation. Professionals and therapists can observe and evaluate the children's responses in detail during the sessions. This remote observation is conducted discreetly, ensuring that the children remain unaware of the evaluators' presence, thereby maintaining natural behavioral responses. This method allows for comprehensive analysis and assessment by experts from various locations, facilitating effective and efficient teleconferences.

IV. CONCLUSION

In conclusion, Medibot represents a significant innovation in healthcare technology by reforming hospital operations and enhancing the diagnostic process for healthcare professionals and ASD patients. The telepresence capabilities enable remote and real-time consultations and behavioral assessment. Hence, it offers a non-intrusive evaluation tool tailored to the diverse ASD spectrum.

Medibot has the potential to expedite the diagnosis of ASD and improve outcomes of early intervention by integrating telemedicine solutions with traditional medical practices. Medibot's capabilities are a valuable screening tool for improving diagnostic accuracy and consistency across geographic locations.

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AUTHOR CONTRIBUTIONS

Nazreen Rusli: Methodology, Validation, Writing – Original Draft Preparation;

Zulkifli Zainal Abidin: Project Administration, Supervision;

Hazlina Md Yusof: Supervision, Writing – Review & Editing;

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CONFLICT OF INTERESTS

The authors reported no potential competing interest.

ETHICS STATEMENTS

Our research work follows The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org.

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