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AUTONOMOUS SEARCH ROBOT FOR UNKNOWN AREA

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A R T I C L E I N F O

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A B S T R A C T

Now Egypt is among the world's most significant archaeological destinations, home to the intricate profound secrets of the ancient Pharaonic civilization. The Pharaonic tombs, adorned with symbols and frescoes, showcase the unique art of sculpture, painting, and architecture from those ancient times. These tombs are located across Egypt, from the famous pyramids to remote desert areas.

In today's rapidly advancing technological era, robotics is a transformative innovation, revolutionizing fields from industry to space exploration.

Inspired by this, it initiated a project to develop a robot capable of entering Pharaonic tombs and other narrow spaces inaccessible to humans, addressing the critical challenge of conducting precise surveys and capturing detailed imagery in such hard-to-reach locations.

This robot aims to offer innovative solutions for exploring unknown areas, which is particularly crucial for sectors like archaeological excavation and disaster management. The robot is designed to measure spaces accurately, create 2D maps of the areas it explores, and be equipped with a camera for visual inspection, ensuring precision and efficiency in its tasks.

Abbreviations

ASRUA	Autonomous search Robot for exploring Unknown Areas
IOS	International Organization for Standardization
LIDAR	Light Detection and Ranging
SLAM	Simultaneous Localization and Mapping
ROS	Robotic Operating System
TP	Trajectory Parameter
MRPT	Mobile Robot Programming Toolkit
RVIZ	ROS Visualization
NMPC	Nonlinear Model Predictive Control
DWA	Dynamic Window Approach
GPP	Global Path Planning
LPP	Local Path Planning
URDF	Unified Robot Description Format
YOLO	You Only Look Once
RGB-D	Red, Green, Blue – Depth
G-mapping	Grid- mapping
IMU	Inertial Measurement Unit

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1. Introduction

Egypt is considered one of the most important archaeological centers in the world, as its lands contain priceless historical treasures dating back to the ancient Pharaonic civilization. In recent decades, technology has revolutionized the field of archaeology, introducing new tools and methods that allow us to explore and understand these treasures in ways that were not possible before. Technologies have opened new horizons for studying archaeological sites and reaching places difficult or impossible to reach by traditional methods such as 3D imaging, ground-penetrating radar, and robots equipped with advanced sensors. So, nothing is impossible.

As Dr. Zahi Hawass 2021' company stated in his blog The Djedi Project was a notable exploration of the upper section of the Great Pyramid of Giza, conducted by international and Egyptian experts. The project was named after Djedi, according to a revered ancient Egyptian figure who advised the pharaoh on matters related to pyramid construction.

This paper proposes the practicality of designing and implementing an algorithm that allows an autonomous search robot to explore unknown areas in confined and narrow spaces. The robot must move independently and freely. The robot will assist in accurately mapping these regions and capturing clear images.

Incorporating advanced technology into archaeology improves efficiency and accuracy and contributes to preserving humanity's cultural heritage and transmitting it to future generations. As technology advances, it is only a matter of time before we discover more secrets of ancient Egyptian civilization, enhancing our understanding of human history and enriching global knowledge.

There are challenges when exploring specific Pharaonic tombs. These difficulties result in a lack of knowledge about aspects of civilization that remain inaccessible to humans for various reasons. Entering these tombs can pose health risks due to diseases that may have developed in sealed environments over millennia, or the tombs may be too small for humans to enter. This research focuses on creating an Autonomous Search Robot for Unknown Areas (ASRUA). The robot is small in size, autonomous, and equipped with a camera and rangefinder, which allows it to maneuver through tight spaces, move independently, and avoid obstacles. In addition, it uses a Light Detection and Ranging (LIDAR) device to create a two-dimensional map and provide detailed spatial information, aiding scientists in accurately mapping and analyzing these areas. Additionally, the robot's camera allows us to view inaccessible locations. Also in emergencies, it can be controlled manually.

This article is organized as follows: Section two: provides a literature survey of previous works on a self-searching robot for the unknown; Section three: Details the design of the algorithm of an ASRUA; Section four: Focuses on Evaluating the robot's performance and the testing for checking of them, along with an analysis of the study's results. Finally, Section five discusses the conclusion and outlines potential directions for future research [1].

2. Relative works

This section reviews the literature on various types of autonomous systems. Additionally, these surveys provide ideas and recommendations for designing and improving exploration algorithms, particularly those focused on ensuring compatibility with Egypt's cultural and societal context. Robotics has advanced significantly over time, and navigation is a critical aspect of robotics, requiring robots to have a map of their environment to move successfully. This issue is crucial to the behavior and movement of self-propelled robots. Mobile robotics has become one of the most dynamic fields of research. Today, it focuses on developing robots that can navigate autonomously across diverse environments, whether for indoor logistics or outdoor inspections.

Over the past decade, industrial robots have shifted from being exclusively used within production plants to finding applications in domestic settings, marking their entry into a new and advantageous field called service robotics. J. Eason, B. Noble, et al. 2021. According to the International Organization for Standardization (ISO 8373), the concept of a service robot can be defined as a robot that performs useful tasks for humans or equipment, excluding industrial automation applications. However, it is worth mentioning the fact that those robots tend to operate partially or completely autonomously, and the tendency is to reduce human intervention to the minimum. A simple task that any service robot must perform is to navigate, in most cases, through unstructured (unknown) environments; therefore, maps are not available, and the robot must build one on its own. The effectiveness and efficiency of navigation depend on having a map without large errors. However, this process is only one of the challenges any service robot must face to achieve decent autonomous navigation [2].

There are three main objectives for autonomous navigation of mobile robots, as indicated by research conducted by M. L. Ben Hamdan et al. in 2018: first, autonomous exploration of known or unknown environments; second, mapping; and third, location. Additionally, there are challenges when exploring specific Pharaonic tombs. These difficulties result in a lack of knowledge about aspects of civilization that remain inaccessible to humans for various reasons. Entering these tombs can pose health risks due to diseases that may have developed in sealed environments over millennia, or the tombs may be too small for human entry. This research focuses on creating ASRUA.

The ASURA robot is small in size, autonomous, and equipped with a camera and rangefinder, which allows it to maneuver through tight spaces, move independently, and avoid obstacles. In addition, it uses a LIDAR device to create a two-dimensional map and provide detailed spatial information, aiding scientists in accurately mapping and analyzing these areas. Additionally, the robot's camera allows us to view inaccessible locations. Also in an emergency, manual control may be required, emphasizing the critical role of separating environmental maps or models a fundamental task in mobile and service robotics. Service robots can implement two types of navigation first, navigation based on maps, and second, navigation requires a priori representation of the environment to plan trajectories that allow the robot to go from one point to another. However, it is not always possible to have a map. When the robot must carry out tasks in an unknown environment, it must perform an exploration of the place in which it is located to build a model or map of the environment.

In most situations, the robot is driven by a human operator, but in some systems the robot is capable of navigating autonomously while mapping. The latter case, it is called active SLAM. SLAM, which addresses the problem of building a map of the surrounding environment without any prior information and based on the data obtained from one or more sensors. This task is particularly complex, as the robot must simultaneously determine its position within a map that is still being generated. It means that the robot must simultaneously solve the problems of mapping and localization, both highly interrelated. This problem is known SLAM [3].

In this research, L. Ming et al in 2020, the integration of SLAM with the Robotic Operating System (ROS) middleware and the Mobile Robot Programming Toolkit (MRPT) was employed, which uses Trajectory Parameter Space (TP-Space) transformations for reactive navigation, while the ROS navigation stack serves as the standard for differential drive and holonomic wheeled robots. The study aimed to demonstrate the autonomous navigation capabilities of these methods. The research methodology included mapping using MRPT and comparing autonomous navigation techniques to evaluate their respective advantages and disadvantages for service robots, with a specific focus on the Summit platform and the Powerball robot manipulator. The advent of SLAM techniques motivated huge advances and opened new possibilities for robot development, but there are still considerable challenges in performance when adding environment dynamism or increasing dimensionality [4].

The researchers A. Zhen, H. Lina, L. et al in 2016, examined two SLAM algorithms available on the ROS, an open-source platform. They utilized additional applications, like RVIZ and Gazebo, to enable robots to adapt to their surroundings. The study [5] focused on factors influencing these algorithms, including movement speed, particle filter techniques employed, and mapping speed, all aimed at enhancing map accuracy. The algorithm's performance was evaluated by navigating using maps generated by these algorithms to various destinations within an unfamiliar indoor environment.

Robotics have advanced significantly over time, and navigation is a critical aspect of robotics, requiring robots to have a map of their environment to move successfully. The navigation of robots is central to the behavior and movement of self-propelled robots. Today, mobile robotics is one of the most active areas of research, with mobile robots capable of moving autonomously in various environments. The research focuses on the autonomous navigation of mobile robots [6]. This study by M. S. Jolio et al, 2013, presents the design and development of a Nonlinear Model Predictive Control (NMPC) controller for a four-wheeled Omni robot to solve the orbital tracking problem. The Omni wheel is a popular omnidirectional wheel used for mobile robotic applications that contains a series of free-moving rollers centrally mounted and perpendicular to the wheel. In addition to the ability to rotate around the axis, the Omni wheel can slide to help the robot move more flexibly. Conducted using the ROS platform, the navigation stack system was controlled to ensure smooth trajectory following and collision avoidance. The effectiveness and validity of the method are demonstrated through theoretical analysis and simulation results. In the study by N. WAS, H. Hawari et al. 2019, the kinematically constrained algorithm and the Dynamic Window Approach (DWA) algorithm are combined to achieve a mobile robot that can travel through globally optimal paths and avoid local dynamic obstacles. The algorithm improves the efficiency of the robot's movement by reducing the number of path bends, thus making it smoother and more consistent [7].

In the study by H. Suman et al in 2020, Path planning techniques for mobile robots are generally divided into two categories: global path planning and local path planning, where the local path closely aligns with the global path. Global Path Planning (GPP) is computationally more efficient and involves fewer turns. In contrast, Local Path Planning (LPP) better meets the robot’s motion requirements [8].

GPP involves the offline creation of a collision-free route for a mobile robot to travel from a starting point to a destination in a known environment, as explained in the research presented by C. Ching-Yu and J. Chia-Feng in 2018 [9].

However, since mobile robots often operate in partially unknown environments, global path planning alone is insufficient to handle unforeseen obstacles and real-time environmental changes [8]. As noted in a study by A. O. O. N. Johan in 2017, local path planning is therefore essential to help robots avoid collisions with dynamic objects [10].

The studies by M M. K. Rajesh et al in 2018, and F. Maksim et al too, in 2018 address challenges such as poor mapping accuracy, inefficient path planning, and high radar frequency demands encountered during mobile robot navigation in indoor environments. It introduces a four-wheel-drive adaptive robotic positioning and navigation system based on the ROS framework. Compared to Dijkstra's method, the algorithm enhances efficiency in path planning, where the study by M M. K. Rajesh et al, LPP, employs the DWA algorithm, which excels in obstacle avoidance and facilitates real-time path planning by integrating sensor data. The ROS framework was utilized to develop both the mathematical model of the four-wheel adaptive robotic skid steer and the Unified Robot Description Format (URDF) model of the mobile robot. The system has demonstrated success, achieving high precision in constructing environmental maps and accurately performing navigation tasks, where research by F. Maksim et al, the G mapping algorithm was utilized for map creation, and the A* algorithm and the DWA algorithm were implemented for path planning. Introducing a global information evaluation function addresses the issue of falling into local optima. However, challenges such as reliance on the odometer remain unresolved [11،12].

This research by Lluvia et al in 2021 offers a comprehensive study of techniques in algorithms that map areas without prior information and using data from one or more sensors. While many robots are manually operated, some systems can autonomously navigate during the mapping process, a method referred to as active simultaneous localization and mapping (active SLAM). This technique is based on actively computing pathways to explore the surroundings while creating a map with minimal error [13].

The paper by C. Cesar et al in 2016 suggested a practical application through an advanced navigation aid for the visually impaired, designed to steer them away from obstacles and guide them to their desired destination. This application consists of two algorithms, SLAM and YOLOv5, which are intelligent guidance-capable mechanisms installed on the bottom capable of controlling omnidirectional wheels. Positioned atop this mechanism are a 2D LiDAR and an RGB-D camera mounted on a smart cane, enabling the system to sense its surroundings and autonomously guide the user. Notably, the system's unique feature lies in its ability to gauge the distance between the smart cane and obstacles using a 2D LiDAR with a cartography algorithm, facilitating SLAM. The results of the tests reveal the laser SLAM's precision to be 1 meter with a deviation of ± 7 centimeters, enabling effective obstacle avoidance and navigation in both indoor and outdoor settings. In addition, the YOLOv5 algorithm, which allows for the swift and accurate identification of various objects, aids the visually impaired in navigating safely [14].

3. SYSTEM

The system of the ASURA as an autonomous robot depends on understanding its surrounding environment (localization) and navigating without crashing into either moving or stationary obstacles in its path (mapping) as it travels from one point to another. Many different algorithms can be used to implement SLAM, such as Hector SLAM or G Mapping, which are all provided by ROS. Here in this research, G Mapping, the most popular SLAM algorithm, was used. This research was accomplished with the help of SLAM, as SLAM, as mentioned before, enables a robot to create a map of an unknown environment while simultaneously determining its position within that environment. Use the G Mapping algorithm, which is used for mapping. G Mapping is a popular method of the SLAM algorithm used in the field of robotics.

G Mapping utilizes a grid-based representation to build the map. The algorithm works by integrating sensor data from laser range finders or depth sensors to estimate the robot's position and update the map concurrently. It employs a particle filter-based approach known as Fast SLAM, which efficiently handles the computational complexity of SLAM problems.

A map consists of a grid (matrix) of cells, with cell sizes ranging from 5 to 50 cm based on the resolution. Each cell can either be empty or occupied and has an occupancy probability between 0% and 100%. Unknown areas are marked distinctly. There are three possible states for a cell: space (free space), represented by white; unknown, represented by gray; and occupied (obstacle), represented by black. This is updated according to the data read from the LiDAR sensor by frequency 10HZ (updating by 10 data per second). The description of the model map is shown in Fig. 1

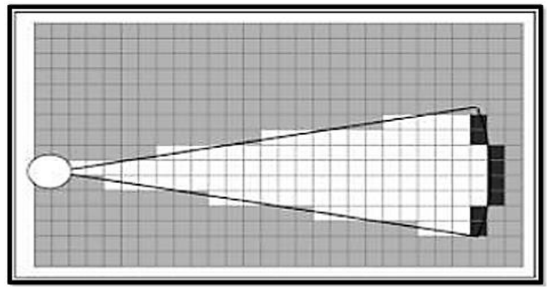


Fig.1. The model of grid map a (matrix) of cell.

A prototype robot was developed with sensors responsible for navigation. It comprises several parts: the upper body, made of aluminum alloy 1060, which supports a weight of approximately 0.4 kg; the lower body, also made of aluminum alloy 1060, supporting a weight of approximately 0.8 kg; and the middle body, which uses the same aluminum alloy to withstand a load from 0.4 kg (the weight of the LIDAR and camera) and a load 1 kg (the weight of the Raspberry Pi, battery, and four motors). Aluminum was chosen for its high strength-to-weight ratio, excellent strength, lightweight properties, and resistance to corrosion.

The motor, with a shaft and screws made of steel, is designed to withstand a load from 3 kg. Steel is known for its exceptional mechanical properties, including high strength, hardness, and resistance to wear, ensuring reliable operation under varying loads and environmental conditions. Finally, the robot uses four rubber wheels, which provide excellent traction on various surfaces, enhancing its ability to move smoothly and robot can bear comparison up to 3.025 Mpa . The rubber's inherent shock-absorbing properties help protect the robot's components from impact and vibrations. Fig. 2 illustrates a prototype robot.

Fig. 2. A prototype robot of an ASRUA

Implementation of the components of internal electronics and sensors responsible for navigation in Fig 3:

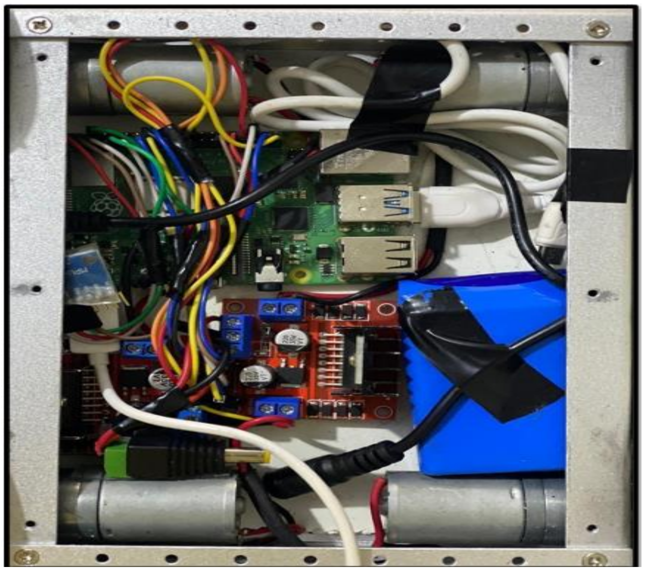


Fig.3. Connection the internal components

Raspberry Pi 4 Model B: This is a compact computer that can be connected to a monitor. It is the main brain and is used as a controller because it meets the design's specific needs. It is equipped with a powerful quad-core processor and sufficient memory, providing substantial computational power for running ROS nodes and processing sensor data.

LIDAR is a remote sensing technology that uses laser light to measure distances and create detailed three-dimensional maps or point clouds of the surrounding environment.

Raspberry Pi Camera Module V2: It carries an 8-megapixel Sony IMX219 image sensor, which has great performance in capturing high-resolution images and videos. We use this camera to monitor the actions the actions that the robot takes.

l298N driver: This L298N Motor Driver Module is a high-power motor driver module for driving DC and stepper motors. This module consists of an L298 motor driver IC and a 78M05 5V regulator. The L298N module can control up to 4 DC motors or 2 DC motors with directional and speed control.

DC Motor: The motor is designed to produce high torque at very low current consumption. It is a great replacement for the rusty or damaged DC geared speed reduction motor on the machine.

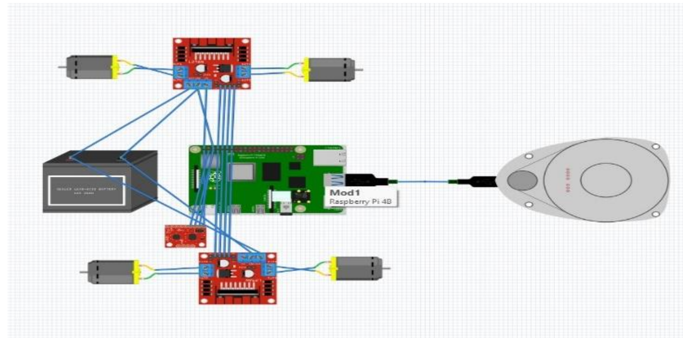


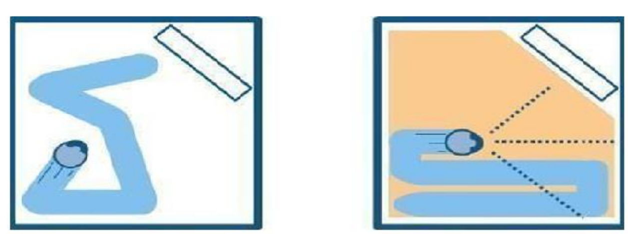
Fig. 4. The internal components of responsibility for navigation

Inertial Measurement Unit (IMU): IMUs are used to measure the robot's linear acceleration and angular velocity, allowing for accurate tracking of its motion. By integrating the acceleration and velocity measurements over time, the IMU can provide estimates of the robot's position and velocity, which are vital for odometer calculations. Odometer provides the robot with an understanding of its current position and how it is moving in its environment. Fig 4 represents the internal components of responsibility for navigation**.**

4. METHODOLOGY

Robots equipped with SLAM can calculate the necessary movement using data such as wheel revolutions and input from cameras and other imaging sensors, a process known as localization. Additionally, the robot uses its camera and other sensors to create a map of obstacles in its environment, ensuring it doesn't clean the same area multiple times; this process is referred to as mapping. Through G mapping which enables robots to create accurate maps of unknown environments.

The robot's movement is controlled either automatically via a LIDAR device or using a keyboard the movement.



a. Without SLAM: cleaning a room randomly   b. with SLAM: cleaning while understanding a room area

Fig. 5. Benefit of SLAM

How does SLAM work? Fig. 5 shows the benefits of SLAM work.

According to the flow chart in the following Fig. 6, the fundamental concept of SLAM involves combining sensor data over time to estimate the robot's path and simultaneously update the environmental map. The process includes:

Data Acquisition: The robot collects sensor data from various devices, such as laser range finders, cameras, or depth sensors.

Feature Extraction: This sensor data is processed to identify relevant features or landmarks in the environment, such as distinctive points, edges, or recognizable patterns.

Data Association: The identified features are matched to their corresponding locations on the map.

Estimation and Localization: The robot estimates its own position within the environment, usually employing probabilistic methods that maintain a probability distribution over possible positions.

Mapping: The map is represented in forms like occupancy grids, point clouds, or feature-based maps. It is continuously updated and expanded as the robot explores new areas and encounters additional landmarks.

Loop Closure: Detecting these loop closures allows the robot to recognize familiar locations and use this information to enhance the map's consistency and accuracy.

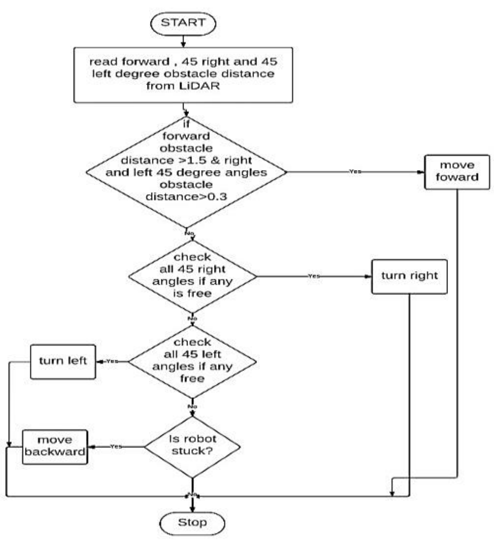


Fig. 6. The flowchart of the ASRUA

Optimization: often utilizes optimization techniques. These techniques work by minimizing errors and uncertainties in both the trajectory and the map representation. By continuously iterating through these steps, SLAM algorithms enable the robot to gradually construct a map of its environment while simultaneously estimating its position

G Mapping:

G Mapping uses a grid-based approach to create a map of the environment. The algorithm integrates sensor data, typically from laser range finders or depth sensors, to estimate the robot's position while simultaneously updating the map.

The process starts by initializing a set of particles, each representing a potential position of the robot. As the robot moves and collects sensor data, these particles are updated based on how likely the measurements are given the map and the estimated robot position.

Through iterative resampling and updating, G Mapping refines both the robot's position estimate and the map representation, as illustrated in Fig. 7.

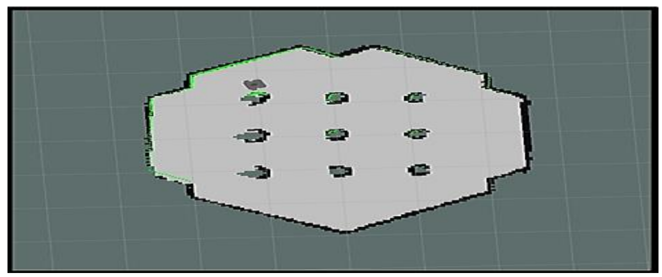


Fig.7. Example of G Mapping of SLAM

G Mapping enables robotic systems to autonomously plan, explore, and map their environment, supporting functions like navigation and obstacle avoidance. For instance, G Mapping can create a map of a location as the robot explores it, using data obtained from laser scan readings.

5. Simulation Procedure

The first step was to ensure illustrated in Fig 8, running resource that the system operates correctly and performs the desired tasks, such as map drawing using SLAM G Mapping. We used the teleop key package to test our robot's navigation.

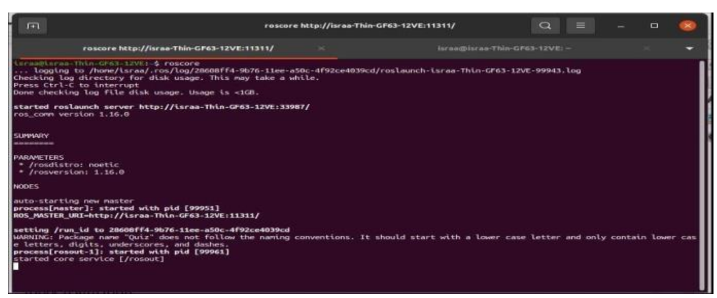


Fig. 8. Running rescore

Start ROS by typing the appropriate command, as illustrated in Fig. 9. Choose the TurtleBot3 Model: it was selected because it has the necessary components for our ASRUA, including navigation and obstacle avoidance Raspberry Pi camera and LIDAR.

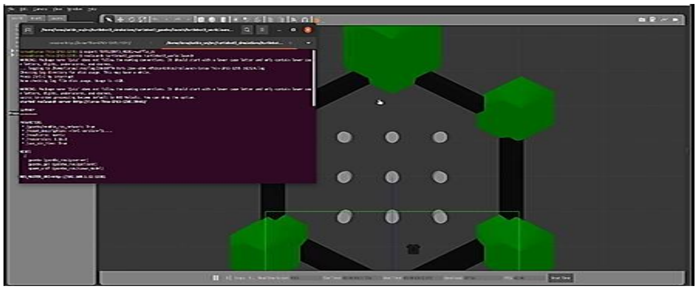


Fig. 9. ROS launch gazebo

Run Gazebo: We launched Gazebo, a 3D dynamic simulator, with one of its built-in maps (we chose a world map), as illustrated in Fig 10. Run SLAM G Mapping: This will create the map for our selected world.

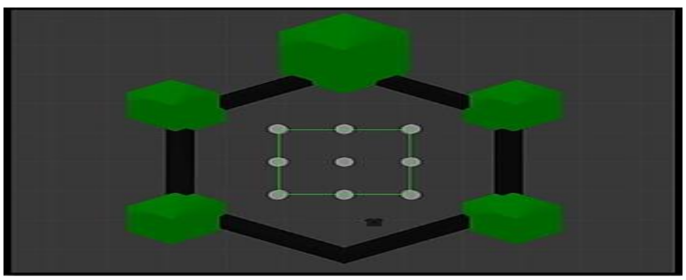


Fig. 10 World map

We need to ensure the map matches the one in Gazebo Fig. 11.

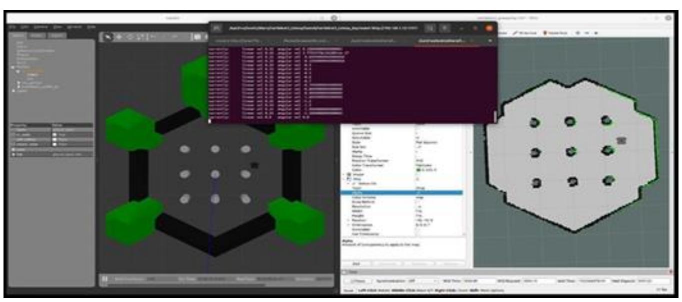


Fig.11. Start SLAM G Mapping

If not, we can use 2D pose estimation in RViz to correct it in Fig 12. The black points represent obstacles, gray areas are unknown, and white areas are free space.

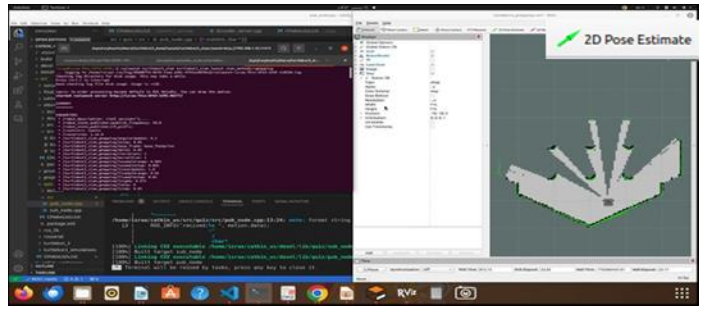


Fig.12. All the map is defined in G Mapping

Run Teleop key: This allows us to manually move the TurtleBot3 using the keyboard in fig 13.

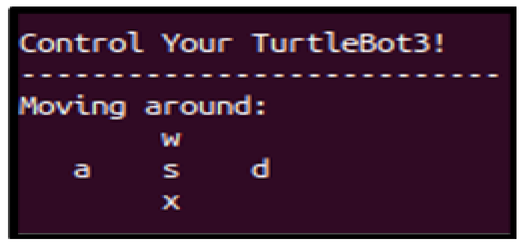


Fig. 13. Moving using TurtleBot3 key.

Save the Map: After scanning the entire map, we can save it for later use. Illustrate in fig 14.

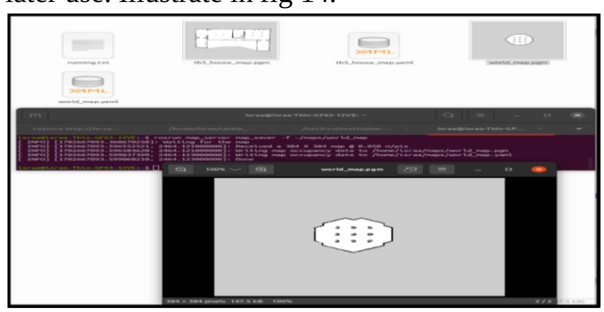


Fig. 14. Map saved.

Obstacle Avoidance: The algorithm is designed for obstacle avoidance using LIDAR laser scan data.

If an obstacle is detected nearby, the robot first checks 45 degrees to the right to see if it can turn right to bypass the obstacle and then proceed straight.

If the right side is blocked, it checks 45 degrees to the left. If turning left is possible, it will do so.

If the LIDAR readings remain constant, indicating a collision or potential collision, the robot stops, moves backward slightly, and reassesses the situation.

Problems facing ASUAR:

In this section, discuss the hardware and software challenges we encountered during the design and how we solved those problems and errors in implemented.

A. Hardware Problems and Solutions:

Limited Space: The small space inside the robot was insufficient for all components. It resolved this by efficiently arranging the components and placing the Raspberry Pi power supply on top of the robot.

The camera port had minor damage that caused an issue with reading the camera's topic. It resolved this problem by changing the camera cable.

Opening the robot for charging, it addressed this by creating a side opening on the robot for easy access to the charging cable.

Camera Mounting Issue: There was difficulty in hanging the camera module at the front of the robot. It was solved by creating a hole in the robot's body to mount the camera.

B. Software Problems and Solutions

Ubuntu Installation: it faced a major issue with repeatedly downloading Ubuntu for the Raspberry Pi, which was unresponsive post-installation. By consulting online resources, gathered information from various sources, and tried multiple times until successful, including installing the necessary drivers.

Defining GPIO Pins: There was an issue defining the GPIO pins on the Raspberry Pi controller. It is solved by downloading the GPIOD library.

Camera Recognition: After resolving the hardware issue, the Raspberry Pi did not recognize the camera's topic. Despite multiple attempts and online searches, it could not find a solution.

URDF in RViz: A significant problem arose when the project's URDF could not be properly defined in RViz. While the URDF was recognized during simulation, linking it with the hardware led to the project's wheel being undefined, preventing the connection of the hardware to RViz and the 2D map.

6. Results and Discussion

To assess the efficiency of ASRUA, it was evaluated on its ability to map surroundings, detect obstacles, and navigate to its destination in various environments. The evaluation considered multiple criteria: cost, manufacturability, usability flexibility, social and economic impact, health and safety, ease of use, and sustainability.

Cost: the evaluation: The financial cost of any project is essential to evaluating its feasibility. The total cost of the ASRUA amounted to $440, which is considered cheap compared to alternative solutions on the market while maintaining the accuracy of the results and the quality of the data.

Manufacturability: The evaluation of manufacturability in the ASRUA assesses the feasibility of being able to provide tools and components by importing them for these robots in the local market, through the design phase, techniques, assembly processes, and manufacturing.

Flexibility of use: It can be used for exploring unknown areas such as caves, buildings, temples, and pyramids.

Social and economic impact: ASRUA will provide the ability to excavate more archaeological sites, creating a boom in archaeology and bringing economic benefits to the country and institutions as this will stimulate tourism.

Health and Safety: ASRUA's health and safety assessment focuses on ensuring the safety of operators, especially when detecting obstacles in disaster and emergency areas, and maintaining health when detecting abandoned or closed areas due to the spread of diseases and viruses in closed environments.

Ease of Use: The ASRUA design prioritizes simplicity and ease of use, making it accessible for both experts and everyday users. It features user-friendly interfaces and straightforward operating instructions, which facilitate easy maintenance and repair, thereby extending its lifespan.

Sustainability: The ASRUA incorporates sustainability and environmental awareness into its design. Efforts were made to utilize efficient energy sources, like rechargeable batteries, to minimize dependence on non-renewable resources.

Compared to previous references [11]:

Previous studies have not utilized the features and software (ROS and Rviz) employed in our research within the tourism and antique sectors, making us pioneers in applying navigation robots in this field. Compared with the robot in the reference [11], it has a relative error of 2.76%.

Another advantage of our study is its cost-effectiveness. In Egypt, a robot imported from France was used solely for photographing the Great Pyramids at a significantly high cost. In contrast, our project can create 2D maps, calculate

areas, and capture photos and videos from various locations where our robot operates, all at a lower cost compared to other robots.
Lastly, compared to other navigation robots, our system achieves high accuracy using low-cost components the average map construction accuracy in the simulation scene is 0.216 m, and the average relative error is 2.6%.

- The error reached 1.4%, but the error in the reference has reached 1% compared to [11].
- The cost of this research has reached 580 dollars but the cost reached 1500 dollars for Waffle Pi.

Table 1 compared error and cost to other research

	True Value (m)	Measurement 1 (m)	Measurement 2 (m)	Measurement 3 (m)	Mean of Measurements (m)	Absolute Error (m)
Forward	20.00	20.38	20.03	20.26	20.23	−0.77
Right	.90	1.83	1.84	1.86	1.84	−0.056
Left	.52	0.49	0.496	0.50	0.495	−0.025
Back	.15	1.16	1.162	1.163	1.160	0.012

Table 2 G-Mapping mapping for the second environment; without obstacles [11]

1st trial	2nd trail	3rd trail
24.32	19.90	12.70
22.15	16.93	11.99
29.15	19.59	11.71
17.88	14.52	13.16
19.11	223.60	12.72

7. Conclusion

In conclusion, the primary goal of this paper is to rapidly and efficiently enhance the robot's capabilities through improved path efficiency. The proposed methodology is also adaptable to standard outdoor environments. **Following the approval of the Egyptian Antiquities Authority to utilize robots in archaeological excavation, efforts are underway to extract the necessary permits and security clearances to perform actual experiments at archaeological sites**, where the features that can be added:

The ASRUA robot functions effectively, but enhancements can optimize its performance in the future by integrating specific components and algorithms:
1) Using 3D LIDAR to make our robot draw 3D maps.
2) Using an Intel camera and machine vision to make us aware of all obstacles that it detects, whether they are antiquities or not.
3) Artificial intelligence applications can also help analyze ancient inscriptions and symbols, opening a new window for understanding Pharaonic texts and history.
Limitation:
Further exploration is needed to apply this method in outdoor settings, particularly in narrow passages or when integrating extensive road network data for long-distance planning.
Moreover, employing 3D laser scanning techniques enables the creation of precise digital models of antiquities, facilitating detailed study and preservation from natural and temporal decay.

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