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An Innovative Humanoid Assistant for Performing Simple & Repetitive Tasks

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***Abstract*—This paper focuses on technical innovation in Autonomous Guided Vehicles having a Semi-Humanoid Structure, that can be used as a helper in the office, restaurants, schools, colleges, etc. In the present era, human workforce is very expensive and hiring human workforce for same repetitive work is not economical viable. Hence, there should be technical innovation and develop a machine that can carry out these repetitive works, and human force can be used for other complex and dynamic works. This bot can deliver hard copy of document in the office, operating elevators, and other repetitive tasks. Technology used are ROS (Robot Operating System), Robotic Arm (Kinematics & dynamics), OpenCV, Machine Learning, path planning algorithms.**

***Index Terms*— ROS (Robot Operating System), SLAM (Simultaneous Localization & Mapping), Robotic Arm, Autonomous Navigation.**

I. INTRODUCTION

Semi – Humanoid Assistant is a semi-humanoid robot that can carry out various tasks and help the organization to increase productivity. This bot makes use of the concept of Autonomous Guided Vehicle, where the map of the room is with the bot, and it navigates as per the map with real-time obstacle detection and avoidance. The navigation system includes the concept of Self-Guided Vehicles and doesn't make use either Line Following or any other crude method for navigation. Autonomous Guidance is achieved by ROS (Robot Operating System). The driving mechanism includes stepper motors and omni wheels. The bot makes use of Omni-Directional Kinematics for the movement i.e., the bot need not change its orientation to move in any direction. The bot has two arms to perform various tasks viz., operating elevator buttons, carrying stuffs etc. The bot connects to Wi-Fi and operates within the Local Area Network. User can use a Graphical User Interface to operate the bot. The interface includes the option of selecting the bot, source, and destination for the bot. As soon as the bot receives the destination location, it calculates the optimal path from its current position to the actual destination and

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proceeds towards the destination. The bot also, has a local path planner, that allows bot to detect the real-time obstacles and avoid them by re-routing the path in real-time to reach the destination. If the bot is required to travel to multiple floors to reach the destination, then the bot first, computes path from its current position to the elevator on that floor, as the bot reaches the elevator, it enters the elevator as every other human and selects the floor to reach the destination. As the bot reaches the floor, map of that floor will be loaded and again, the optimal path is computed and reaches the destination. Elevator operation is carried out by the two arms built. After the completion of the task, the bot returns to its home location.

II. Literature Survey

There is a lot of development in Autonomous Guided Vehicles, Humanoid Bots, Robotic Arms, etc., for example, there is an Autonomous Guided Vehicle developed using ROS, the bot navigated itself inside the room successfully without any collisions. But it can move on a single floor and cannot be used on multiple floors [1] [7] [8]. There were also Line Following bots deployed with PID Algorithm. PID Algorithm helps the bot to move in the desired pattern and reach the destination [2]. There are also bots, deployed with ROS, omnidirectional kinematics, and SLAM Algorithms. These bots include Omni wheels to achieve omnidirectional kinematics and ROS loaded with Navigation Stack having SLAM algorithms that help in mapping, path planning, and navigation of the bot [3] [4]. There are also robotic arms, that are either operational with a joystick or mimicking human hand. There is research done on the robotic arm, that mimics human hand movement, i.e., human need to wear a glove with numerous sensors and those sensors senses hand motion and signals the robotic arm, the arm mimics these actions [5]. There is also a robotic arm, that unlike mimicking a human hand, it is controlled using a joystick. The joystick movements are signaled and transmitted to the algorithm and move the arm to the joystick motion [6].

Almost all the research conducted is either with the robot or with the robotic arm. There is also research conducted for the actual humanoid robots, but those robots are expensive and not suitable to be used in office campuses, or any other simpler tasks. The idea we proposed in this paper is to combine the research of robots and robotic arms, and build an economical robot, that can be used in the office and for other simpler tasks. The idea is to build a robot with Autonomous Navigation and the Robotic Arm, this robot uses an autonomous navigation technique to compute the optimal path from source to destination, and the robotic arm is used for pick and place operation, delivering stuff, operating elevators, etc. The arm can do various tasks which opens numerous applications of the robot.

III. Idea & Methodology

The idea is to develop a Semi-Humanoid Bot, that can travel in the office campus, deliver the hard copy of files, serve beverages, collect trash, provide information to visitors as KIOSK, etc. The plan is to first develop a system to map the room, since the bot should have complete knowledge about the floor like, where the wall is, where a particular cabin is located etc., basically a map of the floor. Then the map will be stored with the robot, and during navigation, that map will be used by it.

The bot uses SLAM (Simultaneous Localization And Mapping) for navigation from source to destination. After the task assigned is completed, the bot returns to its home location and remains there until the next call.

The bot will comprise of two functional 3 DOF arms that can be used for various purposes viz., operating elevators, carrying stuff, etc.

For precise movement and braking whenever necessary, open-loop bipolar stepper motors are used and omnidirectional wheels (100 mm in diameter) are used for moving around. For room mapping and navigation, LIDAR technology is used. Raspberry Pi 4b is used as the brain of the bot. The bot has a typical human-like structure except for the legs. The bot can carry a load of at least 5kg.

IV. Room Mapping System

A miniature version of the bot is used for mapping a room or a floor. The Room Mapping Bot (RMB) is comprised of normal wheels and simple DC Motors, with LIDAR, Raspberry Pi 4b, and other control electronics. Raspberry Pi runs ROS noetic (Robotic Operating System), which helps in the controlling of the bot and producing a reliable operation of the robot. ROS uses MQTT protocol for communication RMB uses ROS to run the mapping algorithms. RMB uses both Hector SLAM and G-Mapping for room mapping (as per convenience). RMB is radio-controlled with the help of HC12 Transceivers. RMB runs in every corner of the room and produces a 2D map of the area. The map is then fed to the actual bot for Navigation.

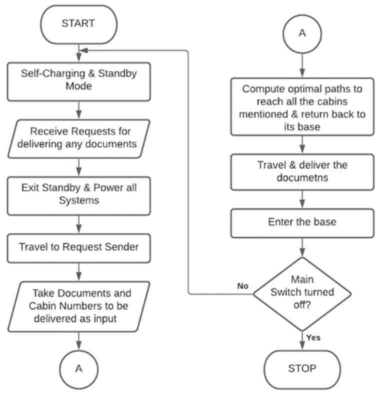


Fig 1. Flowchart of the working of the bot

Fig 2. LIDAR

Fig 3. Map of a real room mapped (1)

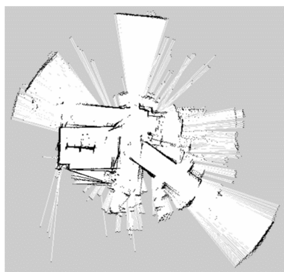


Fig 4. Map of the real area mapped (2)

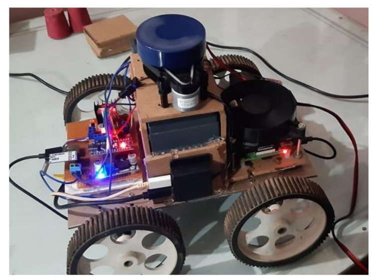


Fig 5. Room Mapping Robot

V. NAVIGATION SYSTEM

RMB develops a 2D Map of the area and feeds it to the actual bot, the main bot (Cooper: name of the main bot). Cooper also, uses Lidar, Raspberry Pi as the brain, and other control electronics to control other hardware like arms, motors, etc. Once the navigation stack is launched, several parameters are loaded like, cost-maps, URDF file of Cooper, the map of the area, etc. Once all the parameters are loaded, there are two maps namely Local Cost-Map, and a Global Cost-Map loaded, the Local Cost-Map is created by the on-board Lidar, for real-time obstacle detection and avoidance. The Global Cost-Map is loaded when the actual map of the area gets loaded, this helps the bot to learn the area that is available for the motion and the location of the permanent obstacles.
Once all the parameters are loaded, initially we should re-map the actual position of the bot in the map concerning the real world (only in prototype and will be solved in next versions). Later a position and orientation in the map can be specified and Cooper computes the shortest distance from its present location of the destination and heads towards the destination. The kinematics involved in the movement in Cooper is Omni-Directional Kinematics, using Omni Wheels.
When the navigation stack is loaded, and providing the destination, ROS will publish movement values corresponding to translational and rotational values to /cmd_vel topic. Arduino establishes serial communication with Raspberry Pi and connects to ROS with the help of the rosserial_arduino node. Arduino subscribes to /cmd_vel topic and retrieves the values published and moves the bot accordingly.
While the bot moves, ROS expects to know the exact location and speed of the bot at all the time, this is done by publishing odometry values by the Arduino.

VI. ROBOTIC ARM

Cooper has two functional 3 DOF arms, to operate elevators, carry stuff, etc. The arm is built using Servo Motors, and aluminum as the body of the arm. As of now, the arm is capable of operating elevator buttons. The arm movement is mainly dependent on the Forward and Inverse Kinematics Mathematical Model. The arm consists of three rotational joints and no translational joints. The Forward and Inverse Kinematics Models are devised for a 2 DOF arm since the third link in the arm is always intended to be parallel to the ground surface.

Fig 6. Omni Wheel

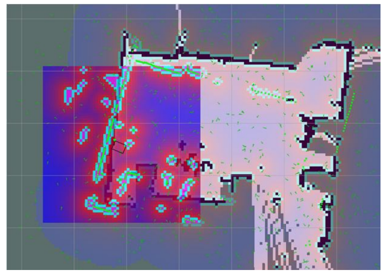


Fig 7. Map when Navigation Stack is Loaded

The arm is interfaced with ROS, ROS advertises a topic and publishes coordinates for the arm to reach. The arm is connected to Arduino, which reads the coordinates published by the ROS, computes Inverse Kinematics, and operates the arm. The reach of the arm is approximately 90% accurate.

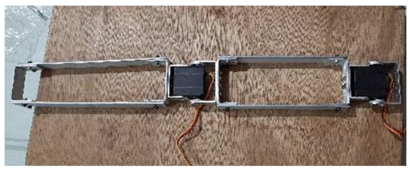
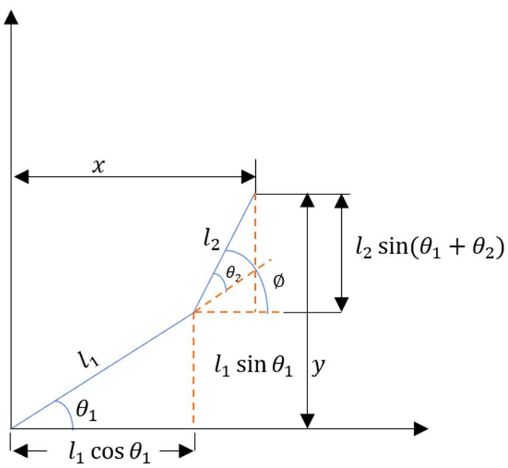


Fig 8. Robotic Arm

A. Forward Kinematics

Forward kinematics refers to the use of the kinematic equations of a robot to compute the position of the end-effector from specified values for the joint parameters. The kinematics equations of the robot are used in robotics, computer games, and animation.



Known terms are: θ_1, θ_2, l_1 & l_2

Terms to find are $x, y, \emptyset$

From fig, we can devise:

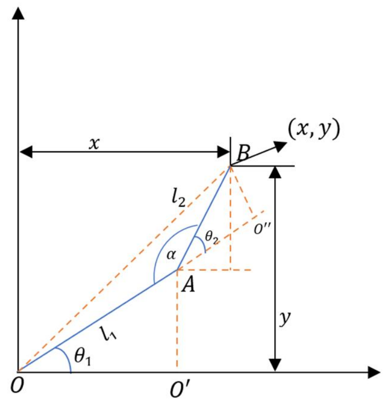
$$x = l_1 \cos \cos \theta_1 + l_2 \cos \cos (\theta_1 + \theta_2)$$
$$y = l_1 \sin \sin \theta_1 + l_2 \sin \sin (\theta_1 + \theta_2)$$
$$\emptyset = \theta_1 + \theta_2$$

The equations can be re-written as:

$$x = l_1 C_1 + l_2 C_{12}$$
$$y = l_1 S_1 + l_2 S_{12}$$

B. Inverse Kinematics

In computer animation and robotics, inverse kinematics is the mathematical process of calculating the variable joint parameters needed to place the end of a kinematic chain, such as a robot manipulator or animation character's skeleton, in each position and orientation relative to the start of the chain.



Known terms are $x, y, \emptyset$

Terms to find are: θ_1, θ_2

From figure and calculations, the following equations are devised:

$$\theta_2 = \left[\frac{x^2 + y^2 - (l_1^2 + l_2^2)}{2 l_1 l_2}\right]$$

$$\theta_1 = \frac{y}{x} - \frac{l_2 sinsin\, \theta_2}{l_1 + l_2 coscos\, \theta_2}$$

VII. RESULTS

Room Mapping Bot is used initially for mapping the room or the area and produce a 2D map of the area. In fig 2 and fig 3, the white area in the map means the area is explored and is available for movement, the grey area is the unexplored one, and black areas represent the area that concerning explored and is an obstacle. With the help of G – Mapping or HectorSLAM SLAM algorithms, ROS produces the map. By either using Remote Connection or an optical drive, the map can be transferred to the main bot (Cooper).

Cooper uses the map to navigate around the room or the area. Cooper also runs ROS that loads the navigation stack for the navigation. Destination and the orientation can be specified on the map once the navigation stack loads it. SLAM algorithms compute the optimal path from the current position to the destination and move the Cooper. Cooper also provides the details of its speed and location to the ROS for an efficient and realistic movement.
The navigation performed by this version of the bot is not accurate, since of the hardware limitations. We have made use of an open-loop stepper motor and Arduino. Open-loop stepper motors are unable to provide real-time feedback from the motor to the microcontroller. Hence, the feedback is hardcoded in the microcontroller as of now. It also would have helped, instead of Arduino microcontroller, a more powerful microcontroller was used. The Room Mapping System is also not accurate because of the same reason.
Semi-Humanoid Assistant adds to the present technology, promotes the ideology of Atmanirbhar Bharat. This bot can bring reforms in the economic development of the country, helps the companies to reform their financial status. This bot also reduces human stress and allows humans to extend their limits and improve their potentials, and companies can use their skills more efficiently and improve the status of the company.

TABLE I. ARM ACCURACY

Sl. No	Co-ordinates Provided (X, Y)	Coordinates Obtained (X, Y)	Accuracy
1	30,20	28,19	94.16%
2	5,10	6,9	95%
3	30, 2	31, 3	73.33%
4	15,15	13,15	93.33%
5	20, 20	20, 21	97.5%
Average Accuracy			**90.664%**

TABLE II. NAVIGATION LINEAR ACCURACY

Sl. No	Distance Asked to Cover (m)	Actual Distance Covered (m)	Accuracy
1	1	1.5	50%
2	1.5	2.5	33.33%
3	2	3	50%
4	2	1.5	75%
5	3	2	66.67%
Average Accuracy			**55%**

TABLE III. NAVIGATION ROTATIONAL ACCURACY

Sl. No	Provided Angle for Rotation	Actual Rotation	Accuracy
1	10^0	15^0	50%
2	45^0	60^0	66.67%
3	90^0	125^0	61.11%
4	120^0	150^0	75%
5	180^0	220^0	77.78%
Average Accuracy			**66.112%**

VIII. CONCLUSION

Semi-Humanoid Assistant adds to the present technology, promotes the ideology of Atmanirbhar Bharat. This bot can bring reforms in the economic development of the country, helps the companies to reform their financial status. This bot also reduces human stress and allows humans to extend their limits and improve their potentials, and companies can use their skills more efficiently and improve the status of the company.

FUTURE WORKS

In the future, next, newer, and improved versions of the same will be developed. The development is the upcoming versions includes, re-designing the entire body to achieve higher space and design efficiency. The electronics and other hardware will be upgraded to achieve higher accuracy with improved efficiency. Re-designing the wheelbase assembly, so that the Cooper can move on rough terrains easily without misbalancing. Develop a decent GUI that can be used to manipulate the bot.

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