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A Remote Navigation Methodology for a Four Wheel Rectangular Configured Holonomic Mobile Telemedicine Robot

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Abstract. This paper presents a navigation methodology for holonomic mobile robot that can be controller through the internet by a user in remote location. The wheels on this robot are placed in rectangular configuration which is different from normal configuration for this kind of drive system. This system is used in OTOROB which is a telemedicine mobile robot for orthopaedic surgeons that have remote presence capability to diagnose patients in remote area. Ultrasonic and infrared obstacle detection sensors are incorporated into the robot which can scan the robot's surrounding and feedback the data to remote user through internet. The placement of these sensors is crucial in order for it to provide accurate and reliable detection data. The navigation was tested rigorously to make sure it meets the high safety standards of hospitals. The experimental result shows that the robot was able to be navigated to a desired location without hitting any obstacles which was placed along its path.

Keywords: holonomic navigation, telemedicine, OTOROB, mobile robot, obstacle avoidance.

1. Introduction

Telemedicine is a promising solution for diagnosing patient in remote location without the doctor actually being there. It refers to the usage of medical information which is transferred over a communication medium from one location to another. OTOROB [1] is a mobile robot that is capable of providing telepresence diagnosing for orthopaedic surgeons in remote location. In order to undergo this task, OTOROB must have a flexible remote navigation system that will allow it to navigate through a hospital environment. Holonomic is relation between the robot's actual total degree of freedom and controllable degree of freedom.

L.Huang in [2] designed a four wheel omnidirectional mobile robot that has good driving ability and can move in directions that are difficult for a normal differential wheeled mobile robot. A similar design is used by R.Rojas [3] to provide the same Euclidean movement for a mobile robot used in RoboCup. Research by T.Qi in [4] improved the control system for a holonomic mobile system by using a fuzzy logic based PID controller. Mariappan in [5] also developed four wheel holonomic mobile robot which is incorporated with an optical tracking device (OTD) to navigate the robot autonomously. Robots in [2], [3], [4] amd 5 used a square base to mount the four motors.

Y.P. Hsu in [6] created a tour-guide robot with four wheel omni-directional drive that was incorporated with object or obstacle sensors. Ultrasonic and laser object detection sensors was used for this purpose. According to the research testing, the robot was able to detect obstacles and navigate to avoid them. K.H. Lin in [7] implemented ultrasonic sensor into a three wheel omnidirectional mobile robot to detect and avoid obstacles. The robot is able to communicate and display data on personal computer (PC) through ZigBee.

Holonomic mobile robot is well known for its agility and accuracy. In this paper, a four wheel rectangular shaped holonomic mobile robot will be presented. This robot can be navigated by a remote user through the internet. Due to its usage in hospitals, obstacle detections sensors are added to provide the user with vital robot surrounding data.

2. Remote Navigation

2.1. Architecture

The remote navigation system is designed to enable user to control the navigation of OTOROB over the internet. It is incorporated with an obstacle avoidance system by utilizing several object detection sensors. Figure 1 shows the block diagram of the system's architecture.

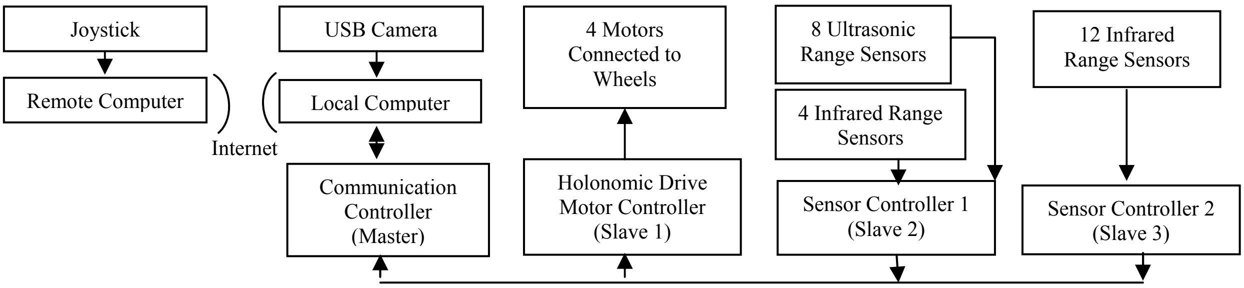


Fig. 1: Remote Navigation Architecture

Referring to Figure 1, remote computer hosts the graphical user interface (GUI) which acts as a command centre for user. It receives control signal from a USB Joystick which is then transmitted over the internet to robot's local computer. This GUI also displays data and video feed from the local computer. The user is able to monitor the robot's surrounding through video feed as well as from obstacle sensors. The GUI is created using Microsoft Visual Basics and utilizing its TCP protocol library for internet communication.

The Local computer hosts another GUI which processes all the controlling algorithms for the robot to operate. It acts as the brain of the robot by processing the signals coming in from sensors through communication controller and control inputs from remote computer. The GUI then sends appropriate signals to the motor controller to driver the mobile robot in any direction that the user desires.

Communication controller consists of a microcontroller which acts as an intermediate device to receive and send data to other controllers. It is developed using a PIC18F4550 microcontroller which has Universal Serial Bus (USB) and Serial Peripheral Interface (SPI) communication features. USB is used to connect the controller to local computer meanwhile SPI is for communicating with other controllers. The motor controller sends appropriate signals to drive the four wheel holonomic mobile robot motor.

Obstacle sensor controller 1 and 2 are basically microcontrollers that obtains raw signal from ultrasonic and infrared range sensors. It then converts the signal into distance in centimetres (cm) before sending out to local computer. Infrared sensors that were used consist of Sharp GP2Y0A21 which provides object sensing in narrow angle up to 80cm and Sharp GP2D120X which provide sensing up to 30cm. On the other hand, ultrasonic sensor used consists of Devantech SRF05 which provides sensing in wide angle to up to 3meters. Both sensors have their own advantages in this application.

2.2. Rectangular Configured Holonomic Driver

The holonomic drive system that is used for this robot has a different kind of wheel placement compared to normal holonomic mobile robot such as in [5]. Normally, the wheels are placed in a square configuration for this kind of holonomic mobile robot application but in this project, a rectangular configuration is used instead. Figure 2 shows the rectangular wheel configuration and wheel type used in this project.

Fig. 2: Rectangular Wheel Configuration and Wheel Type

The reason for this design is to accommodate OTOROB's stability requirement. Referring to Figure 3, OTOROB has an extending arm which holds a high performance camera. The arm is able to extend up to 80cm in front of the robot [8]. This requires the base of the robot to be stable when the arm is fully extended. At the same time, the robot is also required to move in tight spots which mean that its wideness should be smaller. Hence a rectangular shaped base with holonomic drive system is born. Moreover, the rectangular base configuration also provides overall stability when the robot is moving in forward direction which is the direction used most of the time.

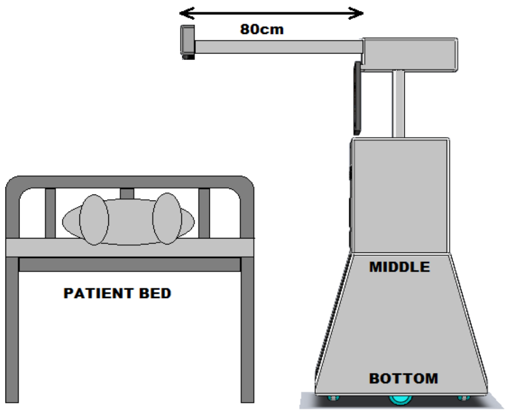


Fig. 3: OTOROB and its extending arm

The rectangular holonomic robot drive requires some modification to the navigation algorithm compared to a normal square system. In order for this holonomic drive system to function properly, speed of motor that is opposite to each other is coupled together.

$$V_1 = V_3 = V_x \quad (1)$$

$$V_2 = V_4 = V_y \quad (2)$$

where V_1, V_2, V_3 and V_4 represents the speed of motor 1, 2, 3 and 4 respectively. When the robot is moving in X or Y axis direction on horizontal plane, only motor in that particular axis should be turned on. For example, if the robot needs to move in X-axis, only motor 1 and 3 should operate at same speed. The same concept goes for Y-axis movement. A negative velocity means the robot is moving in the opposite direction. It is the same with normal square configured holonomic drive system.

For diagonal movement, there are two different methods to move the robot depending on its application. Referring to Figure 4(a), the robot can move either in 45° direction represented by C_1 which is similar to a normal square holonomic drive robot or in direction C_2 which is represented by the rectangular angle θ° where θ is

$$\theta = \arctan (L_y / L_x) \quad (3)$$

To move the robot in direction C_1, the velocity of V_x and V_y should be the same

$$V_{yc1} = V_{xc1} = V_x = V_y \quad (4)$$

Meanwhile to move the robot in C_2 direction, the velocity V_y and V_x can be represented by

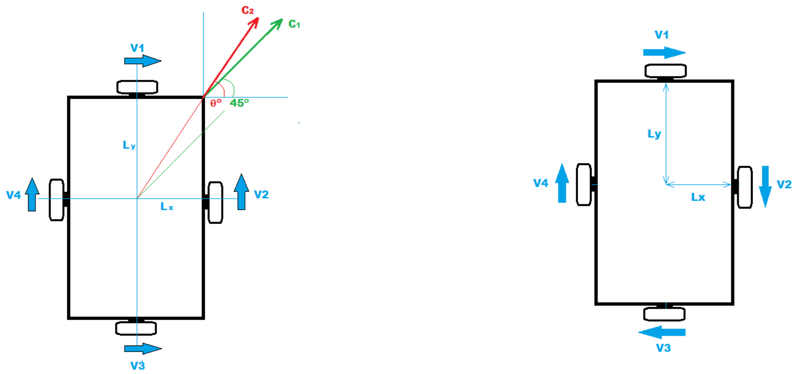
$$V_{yc2} = V_y \quad (5)$$

$$V_{xc2} = V_x \cos (90 - \theta) \quad (6)$$

Referring to Figure 5(b), due to the length L_x and L_y not being same, to rotate the robot on its middle point, the velocity of V_x and V_y must be

$$V_{Rotate\ X} = V_x \quad (7)$$

$$V_{Rotate\ Y} = (L_y V_x) / L_x \quad (8)$$



(a) (b)

Fig.4: Angles for diagonal and rotating movement

A negative velocity means that the motor rotates in opposite direction. After making the algorithm modification, the rectangular holonomic drive operates similarly to a normal square holonomic drive.

2.3. Obstacle Sensor Placement

Obstacle sensors consist of sensors that can detect objects or measure distance of the object. The placement of obstacle sensors on OTOROB's body is crucial for its navigation system. Two of the most common obstacle sensors used is infrared and ultrasonic range finder. Recent development in the electronics industry has made these sensors very accurate, reliable and affordable. Figure 5 shows the placement of different kind of obstacle sensor on the robots base and body. Referring to both figures, it is visible that the combination of all obstacle sensors detection beam covers crucial areas surrounding the robot.

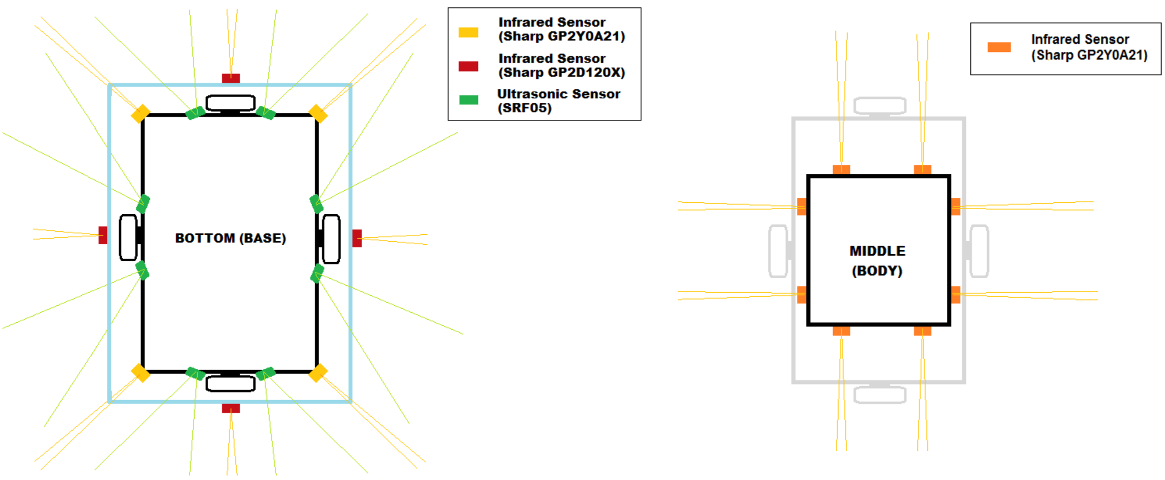


Fig. 5: Robot base and middle part sensor placement

The SRF05 ultrasonic has a wide detection angle such as shown in Figure 8. This is useful for detecting small or moving objects such as table's leg and also human's feet. It also works great in any lighting condition. The disadvantage of ultrasonic sensor is that it sometimes detects ghost sound reflection as an object or obstacle. On the other hand Sharp GP2Y0A21 and GP2D120X are useful to detect wall, big objects and doorways due to its small beam angle. Its disadvantage is that it may not detect dark objects and do not work properly in outdoors due to sunlight. As a result, both ultrasonic and infrared range finder sensors are used in this robot to obtain the qualities of both sensors.

2.4. Experimental Results

The remote navigation system for a rectangular configured holonomic telemedicine robot was tested in a room with obstacles. The user controlled the robot from another location with only the robot's camera and sensor feedback to navigate the robot. Figure 6 shows the robot being controlled through a path with several obstacles to reach point B. Different obstacle positioning was tested on the robot.

At first, only one object was placed in front of the robot. On the second test, the same obstacle is placed 45° in front of the robot. Finally, a few objects were placed along the way of the robot's path.

It can be seen that the robot was able to be navigated without hitting any obstacles on all tests. The user was able to make minor corrections to the robot's heading to avoid the obstacles and reach the destination. The robot also was able to be navigated through a doorway and corridor without any problem.

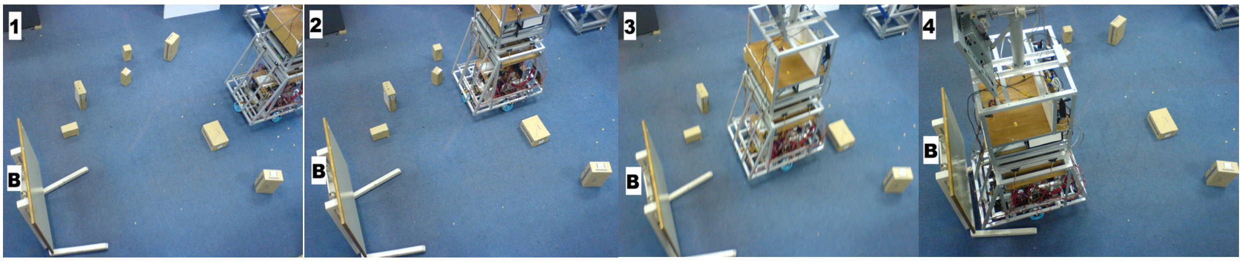


Fig. 6: Robot moving through obstacles

2.5. Conclusion

The work presented in this paper describes a remote navigation method for a four wheel configured holonomic mobile telemedicine robot. This navigation system will be used as a part of OTOROB which is a telemedicine robot for developing counties. The rectangular shaped holonomic drive proved to be very stable in this application. The obstacle sensor placement plays a vital role to ensure the robot does not hit any obstacles during navigation. The combination of ultrasonic and infrared range finder sensors produced a very accurate obstacle avoidance system. During the test, user was able to navigate the robot through a path without hitting any obstacles. This methodology is suitable to be used in OTOROB.

3. Acknowledgements

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