Design and Fabrication of Automatically Guided Mobile Manipulator

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ABSTRACT

With the advancement of robotic technologies, the robotics research continuously seeks improvement in the automation. Robots have been beneficial in replacing humans not only in tasks they are efficient but also in those humans find undesirable because they are strenuous, boring, difficult, or hazardous. More efforts have been taken in the last several years for integration of multiple sensors into robot systems. Mostly the robots are used in the pick and place systems that lift, move and place objects in the desired location. Initially at early stages these are the fixed systems and later on they developed to mobile robots. Mobile manipulators are of such a kind. This paper deals with the design and fabrication of such a mobile manipulator integrated with a multi sensors that is automatically guided along the predefined path for accessing and manipulating remote objects. This robot system is developed to accomplish a given task remotely in our daily life based on simple communication between the robot and the commanding system. The specific task of the robot is to help humans to get the objects from the rack that is at a remote location. The mutual communication is achieved by the wireless communication module.

Keywords: Mobile manipulator, pick and place, automatic guided.

1. INTRODUCTION

A robot is a machine which performs a complex series of actions automatically, especially which are being programmable by a computer. At present the robots can be classified based on their use as general purpose autonomous robots and dedicated robots. General purpose autonomous robots typically navigate independently in known work spaces, by handling their own re-charging needs. A dedicated robot is a reprogrammable and an automatically controlled multipurpose manipulator operating in three or more axes which is built to carry out specific tasks.

Pick and place robots are the most popular material handling systems. These robots have the ability to perform tedious, repetitive tasks with ease, speed, allowing for faster cycle times and accuracy in comparison to humans. Aravind, 2009; developed a two degrees of freedom pick and place robot for material handling purpose. They perform repetitive actions without variation and accuracy by computer programming. Parameters such as direction, acceleration, velocity, and deceleration are specified by these routines. This pick and place robots most often used in industrial applications to move loads ranging from cardboard boxes to pallets and materials in and between production and storage environments around a manufacturing facility or a warehouse. With the improvement in technologies these robots have also been used in storage/retrieval systems which are known as storage machines.

Initially at early stages these are the fixed systems and later on they developed to mobile robots. Generally picking and placing at the floor level is easy using the fixed pick and place robot. But picking from a remote location at different heights especially from the rack type of systems is difficult. To accomplish such tasks mobile manipulators are being used.

The mobile manipulator is the combination of mobile platform and the robot manipulator. This mobile platform provides the extra DOF for traversing along the work floor and robotic mobility are two main advantages of the mobile manipulators. A five degrees of freedom mobile robotic manipulator was developed by Jinliang Guo, 2010; which avoids the obstacles and reaches the target with higher flexibility. Generally these robots be either manually operated, tele operated, or vision guided. An example for a tele operated mobile robot which assists in day to day life of humans with higher level of cooperation and effective communication was developed by Tomizawa, T. et al., 2002. The main components of the mobile manipulator are the mobile platform, robot manipulator, sensors for monitoring the environment and the controller which is the main component like brain for humans. Hvilshj M. et al., 2009; shared the ideas and working principles of developing an autonomous mobile robot, which assists in manufacturing and assembly lines. These can adapt to changes in the environment based on the sensors and the software plays a critical role in achieving the successful results. Konukseven I. and Kaftanoglu, B, 1997; developed a similar kind of multisensory controlled robotic system to make it more adaptable for various environmental conditions.

This paper deals with the design and fabrication of the manipulator which is of cylindrical type that is placed on a movable platform. This mobile manipulator will be moving as per the predefined path. A set of IR sensors are used to identify the path and to guide the vehicle to reach destination. Wireless communication, zigbee is used to send the commands to the robot about the source and destination.

2. METHODOLOGY

The mobile manipulator facilitates the humans in pursuing the objects from the remote locations. These manipulators can be tele-operated from the remote location using the wireless communication or remotely operated by the operator using the remote or they can be made autonomous based on the integration of multi sensors and controller in it. This controller guides the robot to navigate all around the work place. Based on the sensor information and the inbuilt program it accomplishes the given task automatically. In the case of autonomous robots the operator just needs to send the command wirelessly that is taken as the task by the mobile robot. The basic objective is shown in the Fig.1.

The operator sends the task to the mobile robot using wireless module. The information regarding the rack system number and the particular rack is stored in this command. The controller based on the received information drives the robot to reach the destination along the predefined path.

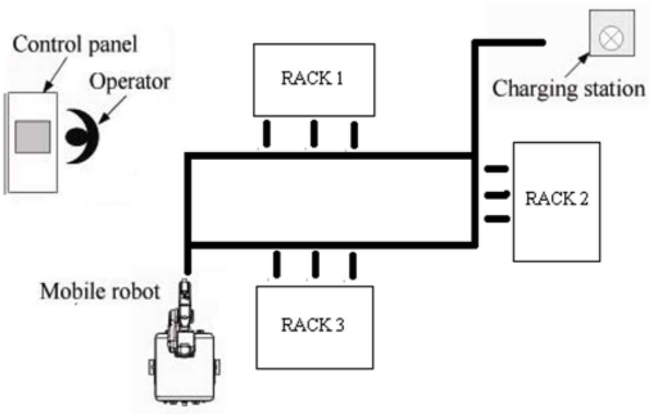

Figure.1.Concept of object browsing system using an automatic guided mobile manipulator

The IR sensors play a major role in this operation of guiding and detection of the rack. The charging station is used for automatic charging of the mobile robot that is autonomous.

Electronic design: The electronic control unit plays a major role in receiving the command from the operator and accomplishing the given task. Based on the command received through wireless module the controller actuates the mobile manipulator and control it to guide along the predefined path and reaches the destination where it is to perform the given task. The major components of the electronic control unit are wireless communication module, controller, sensors and motors for driving the mobile platform and the manipulator. The block diagram of the control unit is shown in the Fig.2.

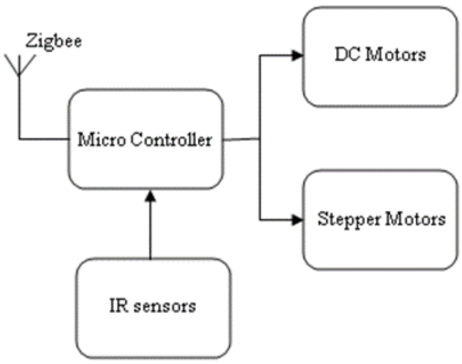

Figure.2.Electronic Control Unit

Wireless Communication: The wireless communication here is used to send the tasks to the robot from the remote location by the operator. The zigbee module is been used for this purpose that is connected to the UART port of the controller.

Micro Controller: The micro controller is used to receive the commands from the operator and guide the robot along the specified path to perform the given task. The P89V51RD2 micro controller is used in this project. This is an 80C51 microcontroller with 64 kB Flash and 1024 bytes of data RAM.

IR sensors: IR sensor combines an infrared emitter LED, phototransistor sensitive to infrared light into a single package. The LED and the detector are almost to be placed parallel to each other. It is a non-contact sensor. So, it is also called IR reflectance sensor. An array of IR sensors is used here for guiding the robot all along the guide path and to identify the particular column of the rack.

DC Motors: In this project Four DC Motors have been used to drive the mobile platform. These motors are driven by the controller with the help of L293d, a dual H-Bridge motor driver. A single driver can drive two DC motors at a time.

Stepper Motors: The stepper motors are used to drive the rotational, vertical and horizontal links of the cylindrical manipulator. Unlike DC motors, stepper motors divide the continuous rotation into sequence of steps. For this reason the stepper motors are chosen here to actuate various links for a required amount of angle and distance through a lead screw mechanism without any position feedback.

Relay: A device that takes a DC low power control signal from the controller and produces required high power directly to the loads from the energy source i.e. battery is known as Relay. In this project the relay is used to energize the coil that is wounded around the metallic piece which is attached at the end of gripper arm that makes the electromagnetic gripper.

Mechanical design: The mechanical design of the mobile manipulator is done using solid works 2009. The mobile manipulator is designed to maneuver in a linear/curved trajectory and is equipped with a gripper to grab object from the rack and release it at the destination. The gripper mechanism can change the height and move into/out of the rack by means of a lead screw and stepper motor arrangement. The vehicle is a four wheel drive system where the motors are coupled directly to the wheels. The conceptual model of the vehicle is shown in Fig.3.

The stepper motors are directly coupled to the lead screws using a coupler. The array of IR sensors board is fixed at the bottom of the chassis. The controller board and the battery set up are also placed at the bottom itself. The main components of the mobile robot as per the hardware are

- Mobile platform
- Manipulator
- Gripper

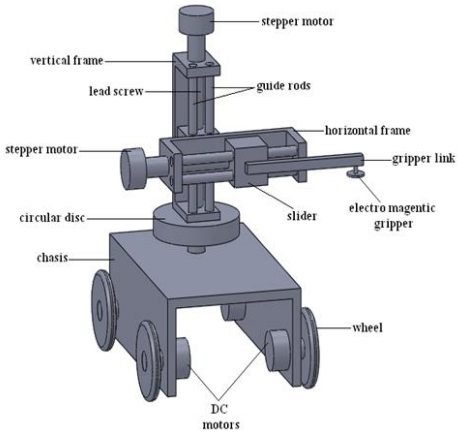

Figure.3.3D Model of the Vehicle

Mobile Platform*:* The chassis and four wheels with individual DC motors form the mobile platform that carries the manipulator over it. The chassis is of the dimension 250 x 300 mm and the thickness of the plate over the frame is 12mm. The wheels are of diameter 50mm each.

Manipulator: The manipulator used here is a cylindrical manipulator. It has a 3-DOF, one rotary motion and two linear motions. This manipulator consists of the rotational, vertical and horizontal links. The advantage of cylindrical configuration is that it can reach any point in a cylindrical volume of space. The vertical structure of this manipulator conserves the floor space and their horizontal reach is useful for far-reaching operations.

Rotational Link: A circular disc of diameter 70mm and thickness 12mm that carries the vertical and horizontal link arrangement forms the revolute or twisting joint of the cylindrical manipulator. The circular disc is coupled with stepper motor in order to provide the required angle of rotation both in clockwise and counter clockwise direction.

Vertical Link: The vertical frame with two guide rods, slider and a lead screw coupled with the stepper motor forms the vertical link. The slider of the vertical link carries the horizontal link and gripper arm arrangement. This produces the up and down movement of gripper. The dimensions of the vertical frame are 60 x 12 x 335 mm and the guide rods are of 10mm diameter and 360mm long. The lead screw is of 12mm diameter and 350mm long. This forms one of the linear joint of the cylindrical manipulator.

Horizontal Link: The horizontal link also consists of the same components as that of the vertical but differs in the dimensions. The slider in the horizontal link carries the gripper arm arrangement. The horizontal arm produces in/out movement thus enabling the gripper arm to move into the rack and out of the rack. The dimensions of the horizontal link are 235 x 12 x 60 mm. The guide rods are of 8mm diameter and 250mm long. The lead screw is of 10mm diameter and 250mm long. Both the linear and horizontal slider is having the same dimension of 60 x 45x 60 mm.

Gripper: Gripper is like a wrist of the human arm that is used to grab the objects. This plays the major role in handling the objects. To grab the metal objects, electromagnetic gripper is used here. Magnetic gripper is easier to control but requires a source of DC power and an appropriate control unit. A soft iron core material that is wounded with the current carrying conductor acts as electromagnetic gripper when the current is made to pass through that coil. This grabs the object when it is magnetized and release when the current flowing through it is stopped. Such an electromagnetic gripper is attached at the end of the gripper arm which is a hollow rectangular aluminium bar as shown. This arm is attached to the slider of the horizontal link so that it is able to move in/out of the rack. The dimensions of the gripper arm are 230 x 30 x 40 mm.

3. RESULTS

Calculations:

A. Force Calculation

Total mass over horizontal i.e. x-axis guide rods and lead screw = 1.5 kg

Force acting on the x-axis guide rods and lead screw

$F_x = m \times a$ (1)

$= 1.5 \times 9.8 = 14.7$ N

Total mass over Vertical i.e. y-axis guide rods and lead screw = 3.5 kg

Force acting on the y-axis guide rods and lead screw

$F_y = m \times a$ (2)

$= 3.5 \times 9.8 = 34.3$ N

B. Stepper motor Torque Calculation

Motor torque required to actuate the lead screw,

$T = F \times R \times \tan(\Phi + \alpha)$ (3)

Where,

F= Force

R = Mean radius of the lead screw

μ = friction coefficient= 0.2

Tan $\Phi = \mu = 0.2$

$\Phi = 11.30$

Torque required for x-axis motor = $F \times R \times \tan(\Phi + \alpha)$

$= 14.7 \times 5 \times 10^{-3} \times \tan(11.30 + 1.52)$

= 0.016 Nm

Torque required for y-axis motor

$= F \times R \times \tan(\Phi + \alpha) = 34.3 \times 6 \times 10^{-3} \times \tan(11.30 + 1.52)$

= 0.049 Nm

C. DC Motor Torque Calculation

Mass of the entire vehicle = 15kg

Weight of the vehicle = 15kg * 9.8 m/s^2= 147N

Radius of the wheel, r = 3cm

Net torque required for the drive system = Weight of the robot * radius of the wheel

$\tau = 147 * 3 * 10^{-2} = 4.41$ Nm (4)

Net torque required to drive the system is divided into four motors and the torque required for single motor= 1.10 Nm

4. CONCLUSION

The mobile manipulator has been fabricated and it is employed to carry out the pick and place operations from the rack. The algorithm was developed in such a way that it was very instrumental in guiding the manipulator along the pre-defined path. With the help of AI and vision sensor, the project can be made fully autonomous in the near future.

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