Robot For Assistance

Master Project
ME-GY 996

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Presented To:
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Project Description

Building a robot with an assistance duty.

Goals:

- Build a cheap and independent robot.
- Assist seniors, children or people with disabilities.
- Make use of mobile technology.

How It Works?:

Object → Mapping → Manipulation → Mapping → Delivery
Available Solutions

Toyota Human Support Robot (HSR)
Project Description

Robot For Assistance

Mobile Application

Mobility

Manipulation
System Description

- 4 DOF manipulator
- Wifi module
- Ultrasonic sensor (Obstacle avoidance)
- Logic level shifter
- iRobot Create
- Raspberry Pi
- Arduino mega
- Buck converter (5V, 3A)
- Pi camera
- Ultrasonic sensor (Depth)
- Ball grabber
- Raspberry Pi
Communication Protocol

TCP sender → USART → USART → USART → USART → TCP receiver

<table>
<thead>
<tr>
<th>Command Type</th>
<th>Character</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>f</td>
<td>f</td>
<td>Forward</td>
</tr>
<tr>
<td>b</td>
<td>b</td>
<td>Backward</td>
</tr>
<tr>
<td>r</td>
<td>r</td>
<td>Right 45 Degrees</td>
</tr>
<tr>
<td>e</td>
<td>e</td>
<td>Right 90 Degrees</td>
</tr>
<tr>
<td>l</td>
<td>l</td>
<td>Left 45 Degrees</td>
</tr>
<tr>
<td>k</td>
<td>k</td>
<td>Left 90 Degrees</td>
</tr>
<tr>
<td>t</td>
<td>t</td>
<td>Rotate 180 Degrees</td>
</tr>
<tr>
<td>s</td>
<td>s</td>
<td>Stop</td>
</tr>
<tr>
<td>v(0-1)</td>
<td>v(0-1)</td>
<td>Accept Encoder Distance</td>
</tr>
<tr>
<td>o</td>
<td>o</td>
<td>Return Ultrasonic Distance</td>
</tr>
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</table>
Mobile Application (Assist Me)

- Design of a mobile application capable of communicating with the robot via server protocol.

- User friendly application:
  - User will select an object at a particular position.
  - User will visualize the process as the robot move towards the object.
Mobility

Cad Software

Map Design

Outcome

Mapping
Mobility
(Obstacle Avoidance)

Reinitializing Map
Manipulation

Depth Measurement

Image Processing

Inverse Kinematics
## Manipulation (Inverse Kinematics)

<table>
<thead>
<tr>
<th>Link</th>
<th>a</th>
<th>$\alpha$</th>
<th>d</th>
<th>$\theta$</th>
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<tr>
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<td>14.5</td>
<td>0</td>
<td>0</td>
<td>$\theta(1)$</td>
</tr>
<tr>
<td>2</td>
<td>18.5</td>
<td>0</td>
<td>0</td>
<td>$\theta(2)$</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>$\theta(3)$</td>
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\[
\begin{bmatrix}
\cos(q_1 + q_2 + q_3), \ -\sin(q_1 + q_2 + q_3), 0, 16\cos(q_1 + q_2 + q_3) + (37\cos(q_1 + q_2))/2 + (29\cos(q_1))/2 \\
\sin(q_1 + q_2 + q_3), \ \cos(q_1 + q_2 + q_3), 0, 18\sin(q_1 + q_2 + q_3) + (37\sin(q_1 + q_2))/2 + (29\sin(q_1))/2 \\
0, 0, 0, 1, 0 \\
0, 0, 0, 0, 1
\end{bmatrix}
\]

Reachable and Singular Workspace

\[0<\text{Angle1}<180\]
\[-180<\text{Angle2}<0\]
\[-180<\text{Angle3}<0\]

(31,40)
Enhancing Manipulation

- Enhancing manipulation by considering the full 4-DOF range of the manipulator.
- Implementing a Kinect in order to measure the depth of the object with respect to the manipulator.
- Obtaining a faster and more efficient mode of pick up.

Adding a Kinect
Enhancing Manipulation

DH-Parameters

<table>
<thead>
<tr>
<th>Link</th>
<th>(a)</th>
<th>(\alpha)</th>
<th>(d)</th>
<th>(\theta)</th>
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<tbody>
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<td>0</td>
<td>90</td>
<td>0</td>
<td>(\theta(1))</td>
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<td>(\theta(2))</td>
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<td>2</td>
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<tr>
<td>3</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>(\theta(4))</td>
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</table>

DH Table

Workspace Limits

- \(0<X(\text{cm})<30\)
- \(-28<Y(\text{cm})<28\)
- \(0<Z(\text{cm})<30\)

Workspace Modeling
Enhancing Manipulation
Coordinate Transformation

\[ M_H = (K_M)^{-1} \times K_B = [\begin{array}{cccc}
0 & 0 & 1 & z_{wrtk} - z_{mwrk} \\
-1 & 0 & 0 & x_{wrtk} - x_{bwrk} \\
0 & 1 & 0 & y_{wrtk} - y_{mwrk} \\
0 & 0 & 0 & 1
\end{array}] \]
Enhancing Manipulation
Obtaining Position of an Object

**Major Steps:**

1. Obtain rgb and depth frame from the Kinect.

2. Defining the HSV range representing the color of the object.

3. Applying OpenCV techniques such as: Blurred, hsv and mask(Erode and dilate).

4. Track the centroid of the ball and identify it’s pixel location in the rgb and depth image.

5. Apply the necessary equations:
   
   $$x = (i - w / 2) * (z + \text{minDistance}) \times \text{scaleFactor}$$
   $$y = (j - h / 2) * (z + \text{minDistance}) \times \text{scaleFactor}$$
   $$z = 100 / (-0.00307 \times \text{rawDisparity} + 3.33)$$

6. Coordinate transformation between different frames.
Enhancing Manipulation
Recording with a Kinect

RGB image
Grayscale depth
Filtering
RGB depth
Enhancing Mobility

- Improving mapping techniques
- Mapping in a real environment.
- Using ROS packages for mapping: "gmapping".
- Experimenting with LIDAR sensor and a Kinect.

Area to be mapped
Enhancing Mobility

LIDAR

- Experimenting with a LIDAR attached to a mockup robot.
- Hokuyo URG-04LX LIDAR used for mapping
- ROS parameters adjusted with respect to the location of the LIDAR.
Enhancing Mobility
Kinect

- Mapping using the Kinect onboard.
- Aiming to achieve accurate results with less noise.
Manual Control

- Making use of a standalone Kinect one in order to manually control the robot.
- Driving the robot using a virtual steering wheel.
- Actuating the manipulator and picking up objects using our right arm.
Manual Control

- **Virtual steering**: Keep track of the right and left hand position in order to solve for the angle of rotation and well as the speed depending on the depth.

- **Arm control**: Keep track of the right hand and limit the control of the manipulator within its workspace boundary.
Conclusion

- Provided a robotic solution in order to assist people and pick up objects for them.

- Hacked and transformed the iRobot create into an assistive robot.

- Enhanced manipulation using a Kinect.

- Enhanced the mapping techniques using ROS packages.

- Extended the work and overrode the robot manually using a standalone Kinect.
Thank You

Questions?