FIDUCIAL-BASED POSE ESTIMATION

ADEWOLE AYOADE
ALEX YEARSLEY
OVERVIEW

Objective
Motivation
Previous Work
Methods
  • Target Recognition
  • Target Identification
  • Pose Estimation
Testing
  • Results
Demonstration
Conclusion – Future Work
OBJECTIVE

Provide visual based pose estimation to supplement GPS and dead-reckoning localization for an autonomous mobile robot in an oil refinery.
MOTIVATION

• Robot will be used to inspect processes in a refinery roughly the size of Golden

• GPS has proven unreliable in industrial environments

• Dead reckoning navigation is unreliable when travelling large distances

• Supplement in identifying inspection locations as well
PREVIOUS WORK: FIDUCIALS

ARToolKit

- Target detection: Binarization of input image
- Decoding: correlation
- Fast but not robust to change in illumination
- Difficult to generate orthogonal templates

ARToolkitplus

- Digitally encoded payload

ARTag

- Detection mechanism based on image gradient
- Robust to lighting and partial occlusion
METHODS: TARGET RECOGNITION

Locate concentric circles using morphological operations

Code Outline

1. Convert image to grayscale
2. Threshold locally
3. Close the image with 5X5 disk
4. Perform blob analysis
5. Locate objects with the same centroids
METHODS: TARGET IDENTIFICATION

• Once the target has been located the target must be identified before it can be used to calculate pose

• Each target is equipped with a pattern of black and white stripes

• The pattern contains seven strips either black or white

• Algorithm loosely based on QR code
METHODS: TARGET IDENTIFICATION CONT.

1. Crop the “payload” out of the image
2. Locate the center of the payload
3. Move pixel by pixel to the across the image recording the number of pixels and their color
4. Identify changes from black to white (state changes)
5. Record the number of state changes and their corresponding pixel count
6. Normalize and compare with database
METHODS: POSE ESTIMATION

- A pose estimate is obtained using an iterative least squares approach to minimize the error $E$ between pose estimate $(x)$ and actual pose $(y)$ $E = |f(x) - y|^2$
- The location of the target and the six concentric circles in the target are known
- The robot's current pose is then projected into the image frame
- Compare the locations in the image frame
- Update the pose estimate
  - The update is performed using the Jacobian of the projection function
- Iterate until the convergence criteria is met
RESULTS: TESTING SUCCESS RATE

Target 1 Orientation 1 with occlusion

Target 2 Orientation 1 Payload

Target 2 Orientation 2

Target 2 Orientation 1 with occlusion

---

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Target 1 Success Finding Target</th>
<th>Target 1 Success Finding Payload</th>
<th>Target 2 Success Finding Target</th>
<th>Target 2 Success Finding Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100%</td>
<td>100%</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>2</td>
<td>100%</td>
<td>50%</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>1 (w/ Occlusion)</td>
<td>90%</td>
<td>90%</td>
<td>1 (w/ Occlusion)</td>
<td>0%</td>
</tr>
</tbody>
</table>
RESULTS: TESTING ACCURACY

- Camera orientation 1 – 0 deg to target plane
- Camera orientation 2 - 30 deg to target plane
- Maximum successful distance to target 13ft
- Maximum angle to target plane 45 deg

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Estimate X</th>
<th>Estimate Y</th>
<th>Estimate Z</th>
<th>Error X</th>
<th>Error Y</th>
<th>Error Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.36</td>
<td>0.06</td>
<td>3.37</td>
<td>3.74</td>
<td>0.06</td>
<td>3.37</td>
</tr>
<tr>
<td>2</td>
<td>-11.15</td>
<td>-9.78</td>
<td>91.81</td>
<td>4.85</td>
<td>0.28</td>
<td>2.81</td>
</tr>
<tr>
<td>Target 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-4.85</td>
<td>-9.40</td>
<td>81.97</td>
<td>0.34</td>
<td>0.10</td>
<td>1.97</td>
</tr>
<tr>
<td>2</td>
<td>-10.70</td>
<td>-9.99</td>
<td>93.28</td>
<td>5.30</td>
<td>0.49</td>
<td>4.28</td>
</tr>
</tbody>
</table>

*All units are in inches*
CONCLUSION-FUTURE WORK

• Visual based pose estimation can provide accurate real-time pose estimates
• Occlusions are problematic for target finding and identification

Future Work

• Improve robustness of code
  • Enable code to search for missing targets
  • Allow code to handle a variable number of concentric circles (4 being the min)
  • Adapt to make use of three cameras and compute uncertainty in visual pose estimate
  • Combine with Kalman filter localization algorithm used on the robot currently