The Development of an Artificial Neural Networks Aided Image Localization Scheme for Indoor Navigation Applications with Floor Plans Built by Multi-platform Mobile Mapping Systems

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Contents

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• Methods
• Experiment
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• Future works
Motivations

• Taipei main station
Motivations

• Challenges

Accuracy

Applicability
• Real-time
• Convenient
• Easy to use

Integration!
Motivations

• Sensors, universal, applications

Range camera
WiFi & BLE
Camera
Accelerometer
Gyro
Magnetometer
Barometer
Photometer
GNSS

Product finding
Motivations

• Pedestrian dead reckoning

- Magnetometer
- Gyro
- Accelerometer

Accumulated error

Distance

Gyro rotation

Magnetic heading

Aiding positioning system!
Motivations

• Portable mobile mapping system

<table>
<thead>
<tr>
<th>iMAR iNAV-RQH</th>
<th>Gyro</th>
<th>Accelerometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>±400 deg/s</td>
<td>±20g</td>
</tr>
<tr>
<td>Drift</td>
<td>&lt; 0.002 deg/hr</td>
<td>&lt; 25 μg</td>
</tr>
<tr>
<td>Bias stability</td>
<td>&lt; 0.002 deg/hr</td>
<td>&lt; 10 μg</td>
</tr>
<tr>
<td>Scale factor error</td>
<td>&lt; 5 ppm</td>
<td>&lt; 100 ppm</td>
</tr>
<tr>
<td>Random walk</td>
<td>&lt; 0.0015 deg/√hr</td>
<td>&lt; 8 μg/√Hz</td>
</tr>
<tr>
<td>Misalignment</td>
<td>&lt; 25 μrad</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ladybug5</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shutter</td>
<td>0.2–2 sec</td>
<td></td>
</tr>
<tr>
<td>Focal length</td>
<td>4.4 mm</td>
<td></td>
</tr>
<tr>
<td>Angle of view</td>
<td>90% of full sphere</td>
<td></td>
</tr>
<tr>
<td>Pixel size</td>
<td>3.45 μm</td>
<td></td>
</tr>
<tr>
<td>Max resolution</td>
<td>2048*2448</td>
<td></td>
</tr>
</tbody>
</table>
Motivations

• UAV and LiDAR

<table>
<thead>
<tr>
<th>Scanning Laser Range Finder UST-20LX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection range</td>
</tr>
<tr>
<td>Accuracy</td>
</tr>
<tr>
<td>Repeated accuracy</td>
</tr>
<tr>
<td>Scan angle</td>
</tr>
<tr>
<td>Scan speed</td>
</tr>
<tr>
<td>Angular resolution</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td>Dimensions (W×D×H)</td>
</tr>
</tbody>
</table>
Methods

• Mobile mapping (for portable MMS)
Methods

- Simple marker recognition
  - Measure the marker location on the georeferenced image
Methods

• ANN aided image-based localization

• Multilayer feedforward neural network

Input layer:
One layer, eleven input neurons: pixel coordinates of four marker vertexes, the area of the recognized marker, the estimated distance from marker distortion, and sensor orientation - 11

Hidden layer:
One layer, eight hidden neurons, sigmoid activation function - 8

Output layer:
One layer, linear activation function, one output neuron: distance - 1
Methods

• ANN aided image-based localization
  • Simple position estimation

\[
\begin{align*}
\Delta y &= d \cos(\Delta \theta) \\
\Delta x &= d \sin(\Delta \theta)
\end{align*}
\]

(x + \Delta x, y + \Delta y)
Methods

**Pedestrian dead reckoning**

\[ x_k^{PKF} = [E_k \quad N_k \quad L_k \quad b_E, k \quad b_N, k \quad b_L, k] \]
\[ \Phi_k^{PKF} x_{k-1}^{PKF} + w_{k}^{HKF}, w_{k}^{HKF} \sim N(0, Q_{k}^{HKF}) \]

\[ z_k^{PKF} = [E_k^{aid} - E_k^{pdr}, N_k^{aid} - N_k^{pdr}] \]

\[ x_k^{HKF} = [\delta \psi_k \quad \delta b \psi, k] = \Phi_k^{HKF} x_{k-1}^{HKF} = \begin{bmatrix} 1 & \Delta t \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \delta \psi_{k-1} \\ \delta b \psi, k-1 \end{bmatrix} + w_{k}^{HKF}, w_{k}^{HKF} \sim N(0, Q_{k}^{HKF}) \]

\[ z_k^{HKF} = A_m - A_g \]
Methods

• Simultaneous localization and mapping
  • For UAV MMS
Methods

• Scheme

Joint Operation of MMSs
Camera-based portable MMS
LIDAR-based UAV MMS

ANN aided image-based localization
Map and georeferenced image
Heading sensor
Marker recognition
ANN distance estimation
Position

Integration system
PDR
Continuous, seamless and accurate navigation

First order control points
Portable MMS
Georeferenced images

Second order control points
UAV MMS
Floor plan

ANN aided image localization
Indoor navigation application
Methods

- Other image-based positioning methods for comparison
  - Simple distortion
  - Space resection
Experiment

- Training and testing images: 200, 32
- Experimental field: underground parking lot, 350 meters long, marker*12
- Smartphone: SONY Z3

Markers: 7, 11, 16, 22, 26, 31
Results and discussions

• Accuracy of georeferenced image

Accuracy analysis of georeferenced image

Check point ID

Error (m)

0 2 4 6 8 10 12 14 16 18

-1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6

Eastern error
Northern error
Height error
Results and discussions

• Accuracy of floor plan

<table>
<thead>
<tr>
<th></th>
<th>Mean error (m)</th>
<th>RMSE (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw floor plan</td>
<td>6.723</td>
<td>7.308</td>
</tr>
<tr>
<td>(after smoothing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected floor plan</td>
<td>0.999</td>
<td>1.210</td>
</tr>
<tr>
<td>(after rectification)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improvement (%)</td>
<td>85.141</td>
<td>83.443</td>
</tr>
</tbody>
</table>

Accuracy analysis of floor plan

Raw scanned result  
Smoothed scanned result
Results and discussions

• Image-based localization comparison
  • Simple marker distortion
  • Space resection
  • ANN aided image-based localization

Accuracy analysis of image-based localizations

Characteristic analysis of ANN model
Results and discussions

• Integrated to PDR

<table>
<thead>
<tr>
<th></th>
<th>User A</th>
<th></th>
<th>User B</th>
<th></th>
<th>User C</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RMSE (m)</td>
<td>LCE (%)</td>
<td>RMSE (m)</td>
<td>LCE (%)</td>
<td>RMSE (m)</td>
<td>LCE (%)</td>
</tr>
<tr>
<td>PDR</td>
<td>23.618</td>
<td>3.647</td>
<td>32.190</td>
<td>3.185</td>
<td>56.384</td>
<td>1.286</td>
</tr>
<tr>
<td>Proposed integrated system</td>
<td>3.322</td>
<td>0.425</td>
<td>3.158</td>
<td>0.211</td>
<td>5.019</td>
<td>0.433</td>
</tr>
<tr>
<td>Improvement (%)</td>
<td>85.934</td>
<td>88.347</td>
<td>90.190</td>
<td>93.375</td>
<td>91.099</td>
<td>66.330</td>
</tr>
</tbody>
</table>

Trajectory of user C

2018/2/27

Positioning, Orientation and Integrated Navigation Technologies Lab
Department of Geomatics, National Cheng Kung University
Conclusions

• This study proposes an indoor navigation system based on ANN aided image-based localization and PDR

• ANN is used to provide the estimated distance between camera and georeferenced marker, then combined to the orientation sensors to update PDR position

• The use of self-designed marker and simple recognition are in order to reduce the of image processing burden

• The results show the accurate long-term navigation with the positional error about 4 meters and the percentage of loop closure error about 0.3% after travelled 650 meters

• The smartphone and papers are the only required device and infrastructure
Conclusions

• The efficient joint operation of MMSs is proposed to collect the necessary information for proposed indoor navigation system: georeferenced image and floor plan

• Those productions make a well demonstration of navigation solution and has an ability of connecting the outdoor world
Future works

• Collecting more samples and identifying other impact factors for **model improvement**
• ANN for maker recognition (ex. CNN), because the accurate marker recognition is expected when the marker is blurred with longer camera distance
• Heading estimation are also considered
• Of course, the cloud server or another **powerful hardware** are needed
Thank You