A FRAMEWORK FOR ROBOT LOCALIZATION USING SATELLITE IMAGES AND ROAD MAPS

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OUTLINE

• Robot Platform
• Problem Definition
• Framework Overview
• Framework Steps
• Results
ROBOT PLATFORM
• Developed at Rutgers DCS

• Capable of both indoor and outdoor operation

• Has substantial onboard processing capabilities

• Can process information from multiple sensors in real-time

• Can interact with humans

ROBOT PLATFORM
Features
ROBOT PLATFORM

Components

Face camera
microphone

GPS

Stereo Camera

Kinect

Computer

Speaker

Other Sensors
ROBOT PLATFORM

Kinect - Stereo
ROBOTIC PLATFORM
What have we accomplished so far?

• Indoor navigation
• Outdoor navigation
• Human interaction
• Outdoor localization without GPS
OUTDOOR ROBOT NAVIGATION USING SATELLITE IMAGES AND ROAD MAPS

Problem definition - Scenario
OUTDOOR ROBOT NAVIGATION USING SATELLITE IMAGES AND ROAD MAPS

Problem definition - Scenario

Satellite Map

Road Map

Stereo Images

Robot localization

No GPS!

Sidewalk

N31.3630, W24.4006
GPS Localization - Why no GPS?

GPS and Groundtruth

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FRAMEWORK

Overview
FRAMEWORK
Visual Odometry

Feature Matching

Transformation Estimation
- RANSAC based 6-DOF incremental transformation estimation between each frame
- Accurate in short run
- Can accumulate errors in long run!

Geiger et al., 2011
FRAMEWORK
Sidewalk Probability

Sidewalk Probability Function

Examples

Map
Road Map
Sidewalk Probability
FRAMEWORK
Stereo Disparity Estimation and Top View Reconstruction

Stereo Disparity Estimation

3D Point Cloud with Intensities

Hirschmüller, 2008

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FRAMEWORK
Map Matching

Preparation
- Make images same scale
- Find intensity edges for map region
- Find intensity edges for top view
- Take distance transform of top view edges

Matching
- Obtain chamfer matching score using image correlation
FRAMEWORK
Particle Filtering

Particles

- Each particle holds a sample of the PDF of robot states on the map
  \[ x_i = [X, Y, v, \theta] \]

Calculate Particle Weights Based on Observations

- Probability of a particle is the product of all observation probabilities for that particle

\[ W(p_i) \propto P(VO | x_i) \cdot P(SP | x_i) \cdot P(MM | x_i) \]
RESULTS
Localization Results

GPS and Groundtruth

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Localization Results

Visual Odometry

57 m
Localization Results

Visual Odometry & Sidewalk Probability
Localization Results

Visual Odometry & Sidewalk Probability & Map Matching
## Localization Results

<table>
<thead>
<tr>
<th>Localization Error</th>
<th>GPS</th>
<th>PF VO</th>
<th>PF VO, SP</th>
<th>PF VO, SP, MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dataset 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.52 m</td>
<td>15.22 m</td>
<td>2.00 m</td>
<td><strong>1.55 m</strong></td>
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<tr>
<td>Max</td>
<td>6.79 m</td>
<td>57.41 m</td>
<td>7.00 m</td>
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<td>Std. dev.</td>
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<td>Dataset 2</td>
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<td><strong>1.24 m</strong></td>
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<td>4.06 m</td>
<td>0.93 m</td>
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</tr>
</tbody>
</table>

570 m campus sidewalk dataset

500 m campus sidewalk dataset

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Results

Left Camera Image

Right Camera Image

Depth Disparity Image

Overall Map and Estimated Path

Estimated Position on Map

Current Top View Reconstruction from Stereo

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APPLICATIONS

• Safe and robust sidewalk navigation for robots
• Help visually impaired people navigate in crowded areas
• Help children walk safely in sidewalks
• Better interact with people and help them in their daily life tasks in real environments
Another Application: VEHICLE LOCALIZATION ON URBAN AND RURAL ROADS

GPS Accuracy localization

Point cloud generation

2 km rural path

Senlet & Elgammal, 2011 ICCV-CVVT
THANK YOU

TEDx Rutgers 2011

DCS Open House - 2011

Rutgers Day 2011

CBIM

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