Two-Stage Static/Dynamic Environment Modeling Using Voxel Representation

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Presentation Overview:

- Introduction
- Proposed approach
- Experimental results
- Future works
Leading causes of death worldwide:

1. Ischemic heart disease
2. Stroke
3, 4 & 5. COPD, Lower respiratory infections and Lung cancer
6. HIV/AIDS
7. Diarrheal diseases
8. Road injury
9. Diabetes mellitus
Driver-, Vehicle-, and Environment-Related Critical Reasons

<table>
<thead>
<tr>
<th>Critical Reason Attributed to</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drivers</td>
<td>94%</td>
</tr>
<tr>
<td>Vehicles</td>
<td>2%</td>
</tr>
<tr>
<td>Environment</td>
<td>2%</td>
</tr>
<tr>
<td>Unknown Critical Reasons</td>
<td>2%</td>
</tr>
</tbody>
</table>

Shift the paradigm of the transportation system, in which the task of a driver changes from driving to supervising the vehicle.

Cars must get smarter and more capable
An intelligent vehicle's modules in terms of inputs and outputs

Here, our focus is on:

Environment representation and identifying static and dynamic part of sensor data.
Proposed perception system in terms of modules, inputs and outputs

**Sensors**
- Velodyne LIDAR
- INS (GPS/IMU)

**Low-Level Perception Module**
- Ground Modeling
- Voxelization
- Ground Piecewise Plane Modeling and Removing Ground Points
- Stage 1: Subtraction
- Stage 2: Histogram
- Modeling the Static/Dynamic Parts of the Environment

**To Higher-Level Perception/Planning/Control Modules**

**Sensor data:**
- Perception measurements
- Vehicle movement (localization) measurements

**Sensed information:**
- Piecewise plane model of ground
- Voxel model of static part of the environment
- Voxel model of dynamic part of the environment (motion grid)
Point Clouds Integration and Ground Estimation

Point Clouds Integration

Point cloud data → Point cloud of the frame n

Localization data → Transformed point cloud of the frame n - 1

... → Transformed point cloud of the frame n - m

Integrated point clouds

Piecewise ground estimation using stripes
Voxelization

Building voxel representation from point clouds

Point cloud → Ground parameters → Remove ground points → Voxelize → Voxel representation

A voxel grid discretizes the 3D space into small grid elements called voxel.

A voxel contains information about the space it’s representing.

Only non-empty voxels are indexed.
A piecewise plane fitting method for ground estimation and ground / on-ground objects separation

Notice the curvature of the ground that makes it impossible to model using only one surface.
Voxel-based Static/Dynamic Modeling of the Environment

First stage: provides a rough estimation of static/dynamic voxels by using a simple subtraction mechanism.

Second stage: further refines the results using a discriminative analysis on the 2D histograms computed from the output of the first stage.
Stage 1: Rough approximation of static / dynamic cells

Removing dynamic voxels

Static and dynamic voxels outputted from stage 1
Stage 2: Discriminative analysis of static / dynamic cells

The process of computing the binary mask of the dynamic voxels

1. Building 2D histogram of the static cells in the X-Y plane
2. Computing the log-likelihood ratio of histograms using equation (1)
3. Multiplying by the static part of the environment
4.得到dynamic part of the environment

2D histogram of the static cells
log-likelihood ratio of histograms
2D histogram of the dynamic cells
The log-likelihood ratio of 2D histograms of the approximated dynamic and static cells that are employed to determine the binary mask for the dynamic voxels.

\[ L_i = \log \frac{\max \{ h_d(i), \delta \}}{\max \{ h_s(i), \delta \}} \]
Static and dynamic voxels outputted from stage 2
Static/dynamic environment modeling using voxel representation
Computational analysis of the proposed method

Increasing the number of the integrated scans:
+ Stronger static/dynamic model
- Additional computational cost

Increasing the size of the voxels:
- Only non-empty voxels are indexed and processed
- In average nearly 1% non-empty voxels

Implemented in MATLAB

The proposed method works at 1.05fps
Future Works

- Improvement of the current work: make the system more robust, less dependent on thresholds assigned empirically, and to assess its performance in real-time applications.

- Classification of moving objects.

- Static objects should be taken into account. Object detection and classification from static parts of the environment.
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Thank you for your attention

Questions?