Accessible Section Detection for Visual Guidance

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Introduction

- Navigation and exploration
- Urban areas, indoor, outdoor
- Autonomy and mobility
- Obstacles and hazards

“Seeing Guide Cane” by ETH Zürich

Südostschweiz.ch
Related Work

- **Bumblebee**
  - Detects aerial obstacles, i.e., low hanging branches

- **Sonar sensors**
  - Replaces analog white cane
  - Breaks wheels to guide around obstacles

- **Bumblebee**
  - Focus on Pedestrian detection
  - Depth map template matching

Martinez et. al., 2008
Shoval et. al., 2003
Mitzel et. al., 2012
Approach Overview

- Many obstacles classes
- Stereo cameras for depth information
- Creation of disparity map
- Calculation of surface angles
- Accessible section
- Inside modular framework
In Euclidean space ($E = \{x_i, y_i, \delta_i\}$), points $p, q, r$ span a plane.

Rearrange and build orthonormal basis $B = \{p, q, r\}$ in projection plane.

$B$ is then equivalent to Gradient $\{\delta x, \delta y\}$.
Accessible Section Detection
Depth-Based Surface Angle Estimation

- Disparity $D$ of $(x_i, y_i)$ to calculate depth (baseline $b$, focal length $f_{focal}$) and resulting map $\Delta$:

$$D = \frac{f_{focal} \ast b}{x_{i_{left}} - x_{i_{right}}} \quad \Delta = \{(x_i, y_i, \delta_i)\}$$

- Convolution:

$$\nabla f = \frac{\delta f}{\delta x} \hat{x} + \frac{\delta f}{\delta y} \hat{y}$$

- Map $\Phi$ of gradient directions:

$$\phi = \arctan \frac{\nabla Y}{\nabla X} \quad \Phi = \{(x_i, y_i, \phi_i)\}$$
Accessible Section Detection
Block-Wise Selection Process

- Block-wise calculation
- Fixed kernel size(s)
- Process in vertical bands
- Start from lower image border for each band
- Collect (upwards) all blocks that fit criteria
Accessible Section Detection
Block-Wise Selection Process

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Accessible Section Detection

Example

Labeled accessible section and recognition classes: true positive (TP), false positive (FP), false negative (FN), true negative (TN)
Accessible Section Detection
BVS - Blind and Visually impaired Support system

- Modular design, small and easy to use
- Open source: https://github.com/nilsonholger/bvs (...-modules)
- Please feel free to use or contribute
- Work in Progress: Android client
Experimental Evaluation

Data Set

- Data set (20 videos) to evaluate system
- Challenges: intense ego motion, lighting variations
- Common urban scenes: walkways and side-walks, floors, static and moving obstacles
Experimental Evaluation Measures

- Precision-Recall
- Receiver Operating Characteristic
- $F_\beta$-Scores: combine precision and recall into a single value (weighting determined by $\beta$)

$$F_\beta = (1 + \beta^2) \cdot \frac{\text{precision} \cdot \text{recall}}{(\beta^2 \cdot \text{precision}) + \text{recall}}$$

- When evenly weighted, the F-Score becomes the balanced F-measure or $F_1$-score, we also use $F_{0.5}$ (precision > recall)
Experimental Evaluation

Overall Precision-Recall and ROC

OVERALL ACCURACY = 91.74 %

$F_{0.5} = 0.861$

$F_{1.0} = 0.828$
Accessible Section Detection for Visual Guidance

MAP4VIP@ICME2013

3FPS with labeled ground truth
Conclusion

- Efficient method to determine accessible section
- Derive section not blocked by obstacles

- Navigational aid using a mobile platform
- System that helps in everyday situations
- Investigate haptic or auditory output modalities
### Experimental Evaluation

#### Results Overview

<table>
<thead>
<tr>
<th>Name</th>
<th>$f_{ROC}$</th>
<th>$f_{PR}$</th>
<th>$F_{0.5}$</th>
<th>$F_1$</th>
<th>Acc.</th>
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<tbody>
<tr>
<td>Alley</td>
<td>0.928</td>
<td>0.882</td>
<td>0.937</td>
<td>0.916</td>
<td>0.901</td>
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<td>Alley L.</td>
<td>0.892</td>
<td>0.856</td>
<td>0.941</td>
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<td>0.862</td>
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<td>Bicycle</td>
<td>0.753</td>
<td>0.629</td>
<td>0.843</td>
<td>0.869</td>
<td>0.676</td>
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<td>Car</td>
<td>0.850</td>
<td>0.679</td>
<td>0.763</td>
<td>0.739</td>
<td>0.851</td>
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<td>Corridor</td>
<td>0.819</td>
<td>0.665</td>
<td>0.816</td>
<td>0.750</td>
<td>0.796</td>
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<tr>
<td>Fence</td>
<td>0.855</td>
<td>0.750</td>
<td>0.878</td>
<td>0.834</td>
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<tr>
<td>Flower-box</td>
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<td>0.607</td>
<td>0.838</td>
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<td>Hedge</td>
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<td>0.827</td>
<td>0.882</td>
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<td>0.814</td>
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<td>Ladder</td>
<td>0.836</td>
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<td>0.757</td>
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<td>Narrow</td>
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<td>0.924</td>
<td>0.922</td>
<td>0.928</td>
<td>0.929</td>
</tr>
<tr>
<td>Pan</td>
<td>0.759</td>
<td>0.548</td>
<td>0.843</td>
<td>0.861</td>
<td>0.650</td>
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<tr>
<td>Passage</td>
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<td>0.733</td>
<td>0.889</td>
<td>0.821</td>
<td>0.805</td>
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<tr>
<td>Railing</td>
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<td>0.626</td>
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<td>Ramp</td>
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<td>Sidewalk</td>
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<td>0.954</td>
<td>0.950</td>
<td>0.912</td>
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<td>Sign</td>
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<td>$\bar{x}$</td>
<td>0.852</td>
<td>0.753</td>
<td>0.861</td>
<td>0.828</td>
<td>0.784</td>
</tr>
</tbody>
</table>
Experimental Evaluation

Accuracy
Experimental Evaluation
$F_\beta$-Scores

$F_{0.5}$ Score
Precision > Recall

$F_1$ Score
Precision = Recall