Accessible Section Detection for Visual Guidance

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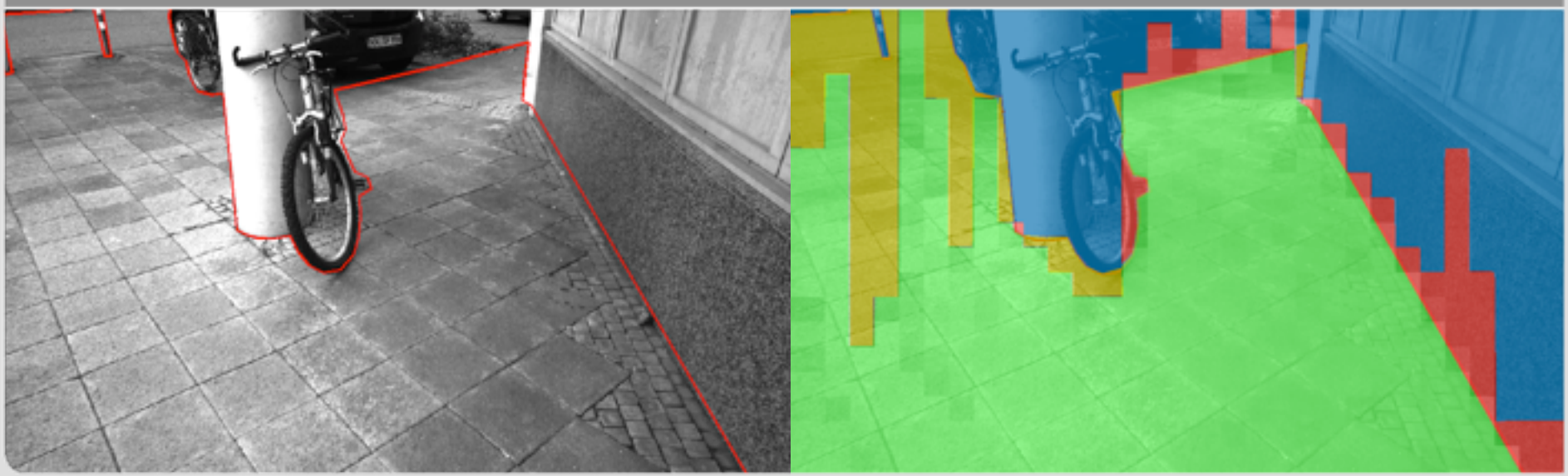


Introduction

Südostschweiz.ch

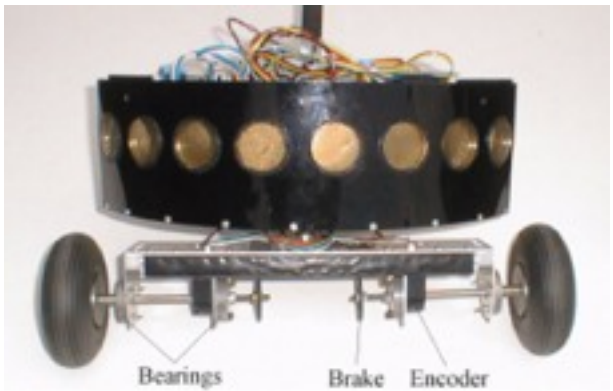
“Seeing Guide Cane” by ETH Zürich

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

Related Work

Martinez et. al., 2008

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



Shoval et. al., 2003

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

Mitzel et. al., 2012

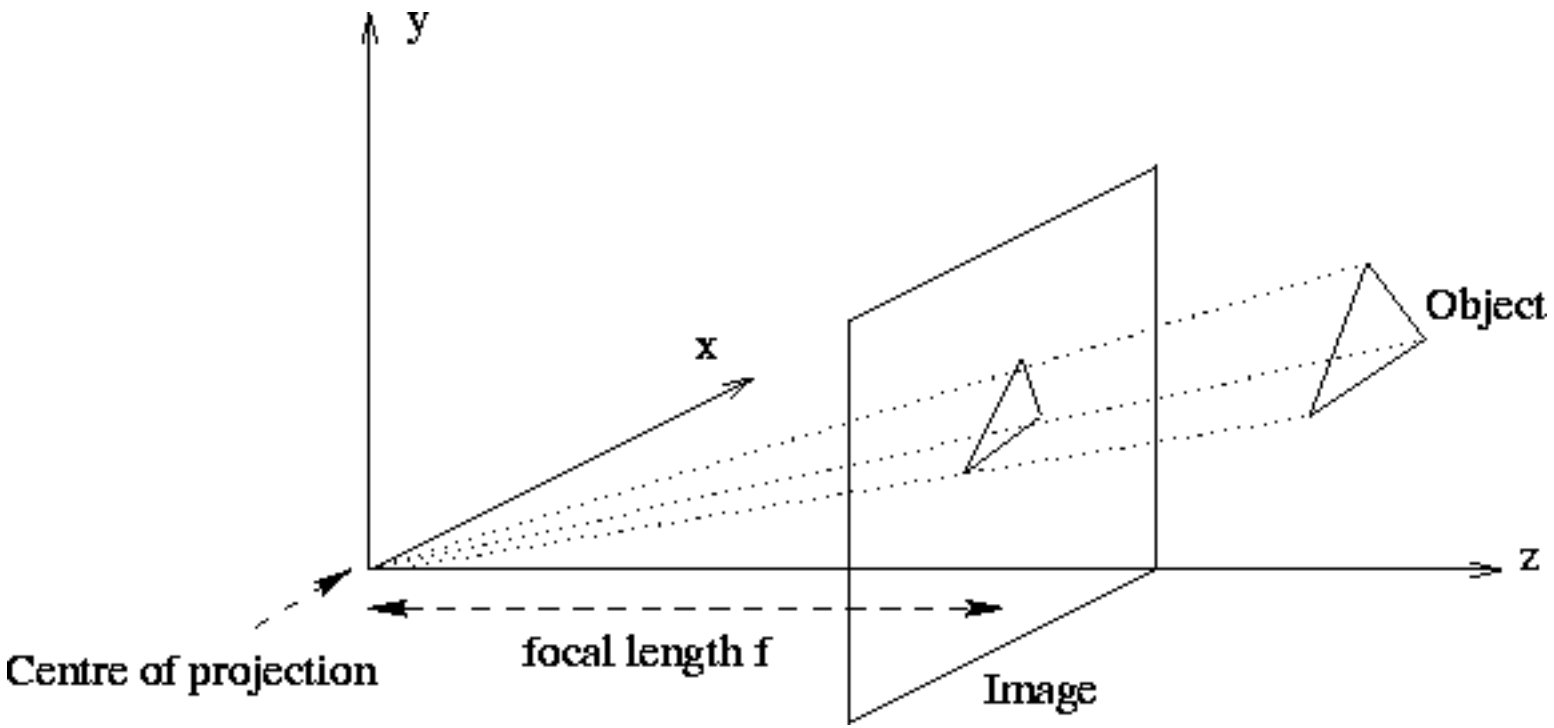
- Bumblebee
- Focus on Pedestrian detection
- Depth map template matching

Approach Overview

- Many obstacles classes
- Stereo cameras for depth information
- Creation of disparity map
- Calculation of surface angles
- Accessible section
- Inside modular framework

Accessible Section Detection
Orthonormal Projection

- 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 $\{\delta x, \delta y\}$



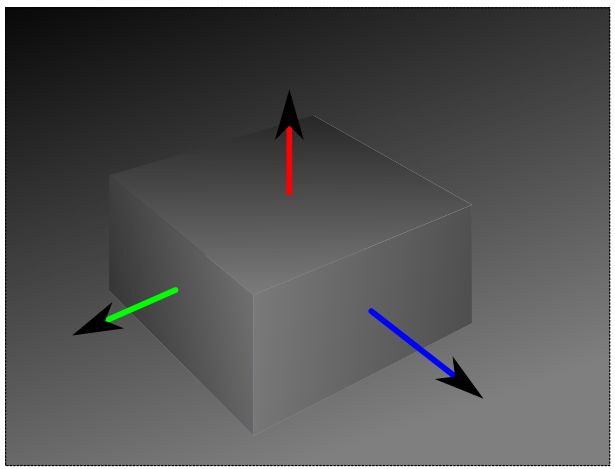
Accessible Section Detection
Depth-Based Surface Angle Estimation

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

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

- Convolution:

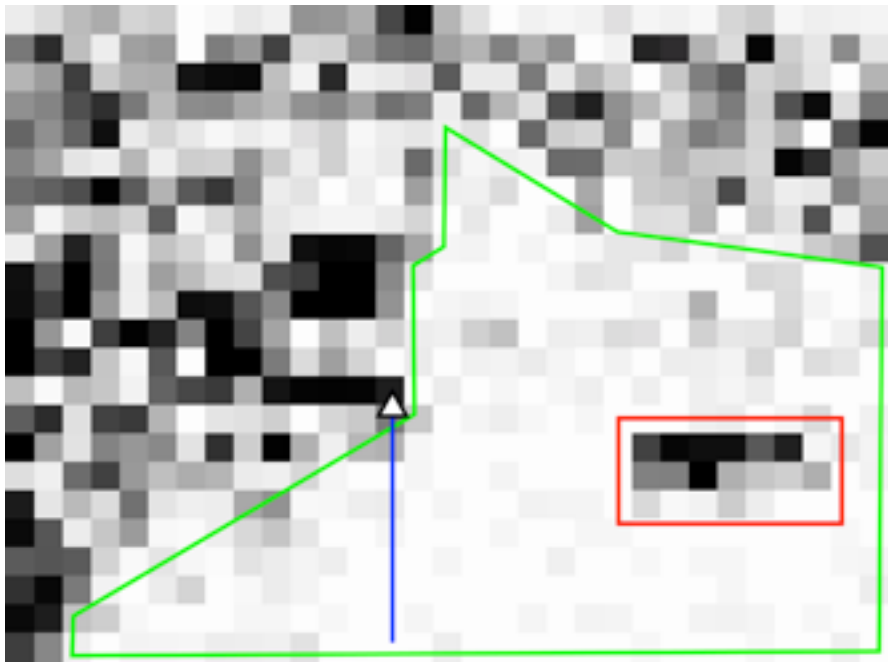
$$\nabla f = \frac{\delta f}{\delta x}\hat{x} + \frac{\delta f}{\delta y}\hat{y}$$



- Map Φ of gradient directions:

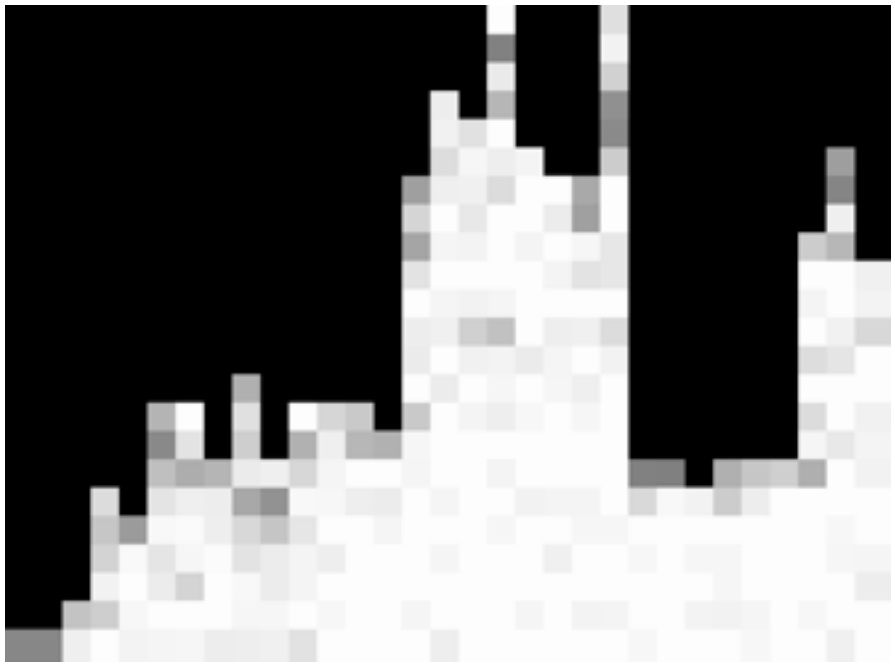
$$\phi = \arctan \frac{\nabla Y}{\nabla X} \qquad \Phi = \{(x_i, y_i, \phi_i)\}$$

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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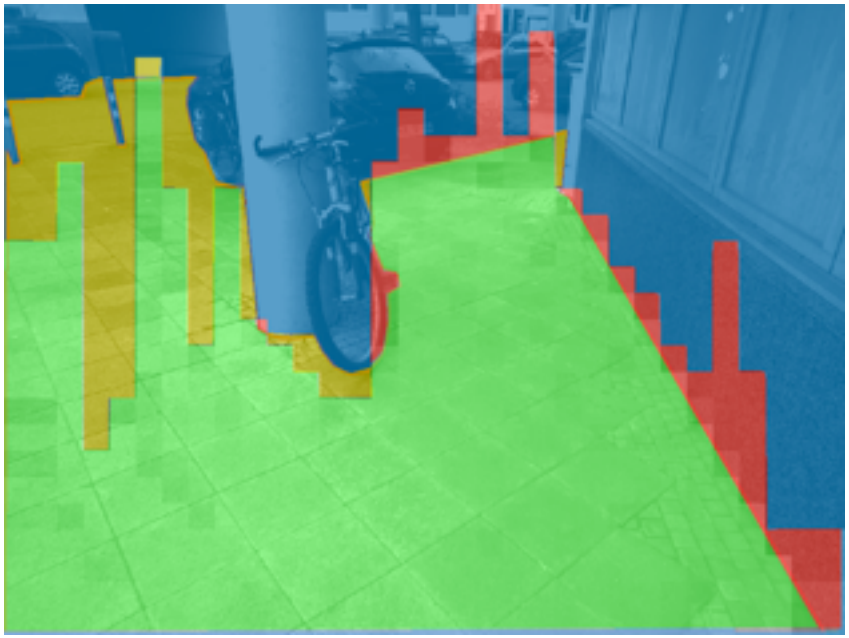
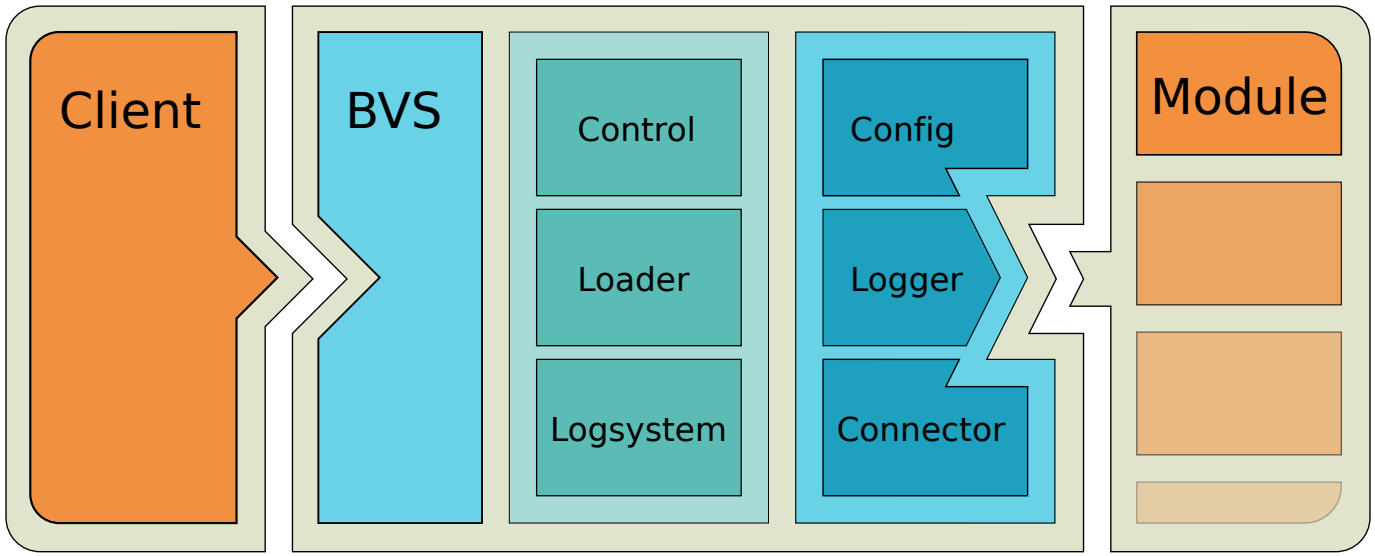
Accessible Section Detection Example



- 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

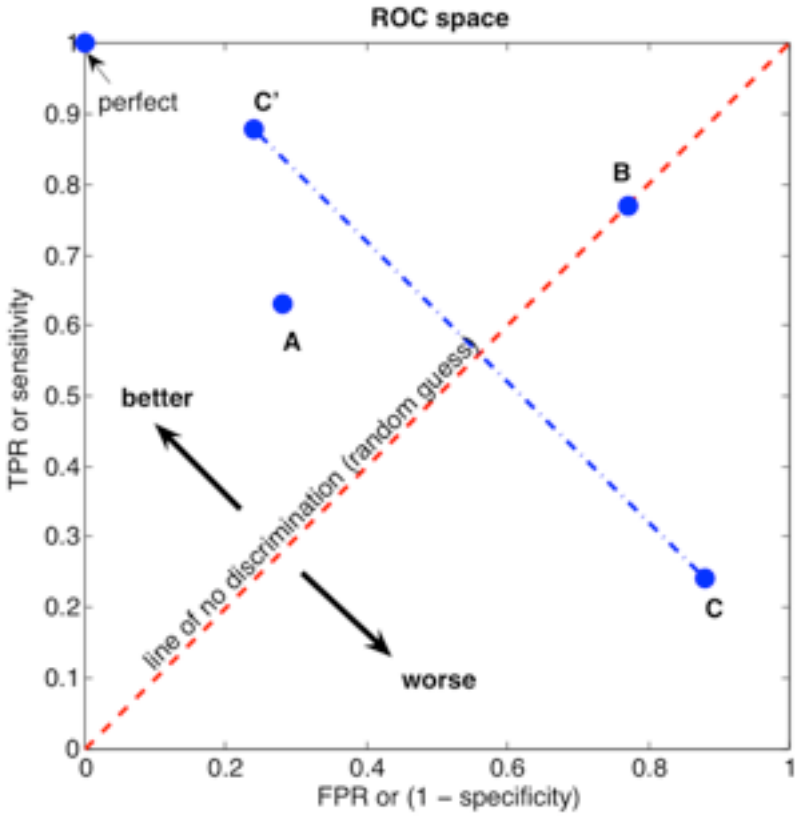
Experimental Evaluation
Data Set

- 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

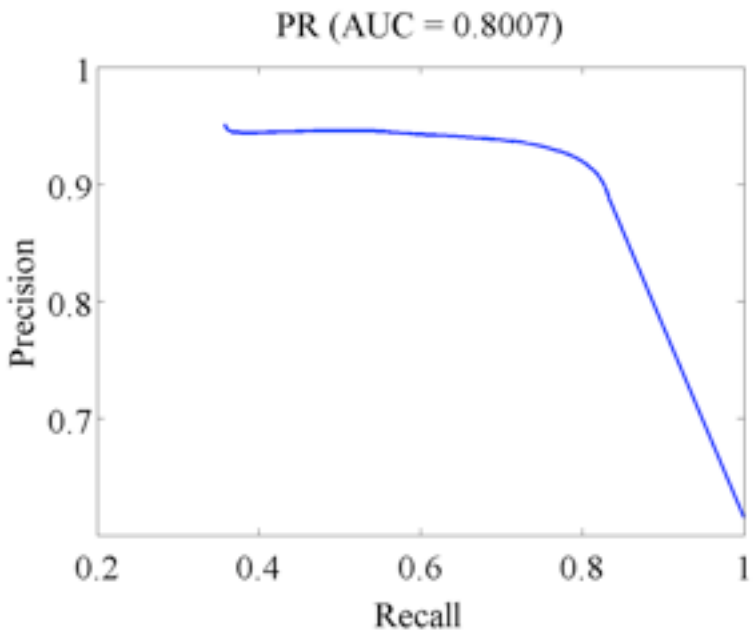
- Precision-Recall
- Receiver Operating Characteristic
- F_β-Scores: combine precision and recall into a single value (weighting determined by β)

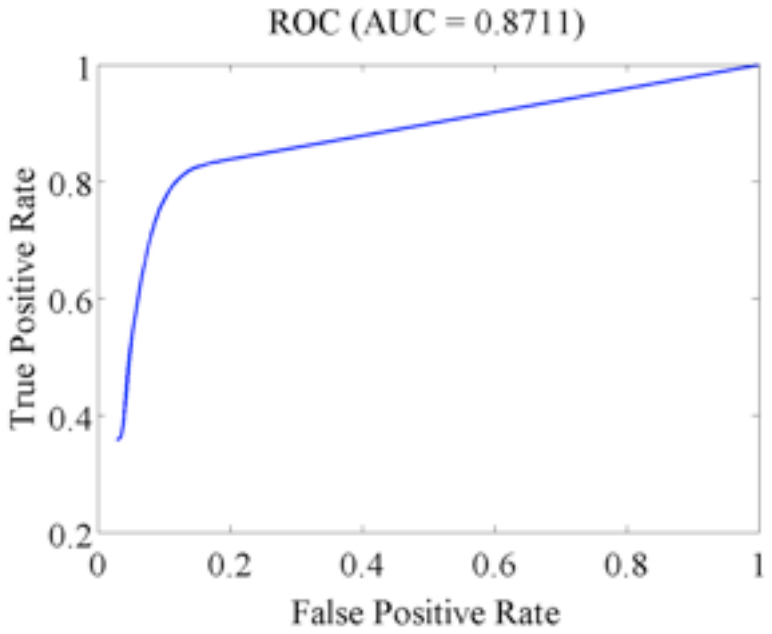
$$F_\beta = (1 + \beta^2) \cdot \frac{\text{precision} \cdot \text{recall}}{(\beta^2 \cdot \text{precision}) + \text{recall}}$$



- 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

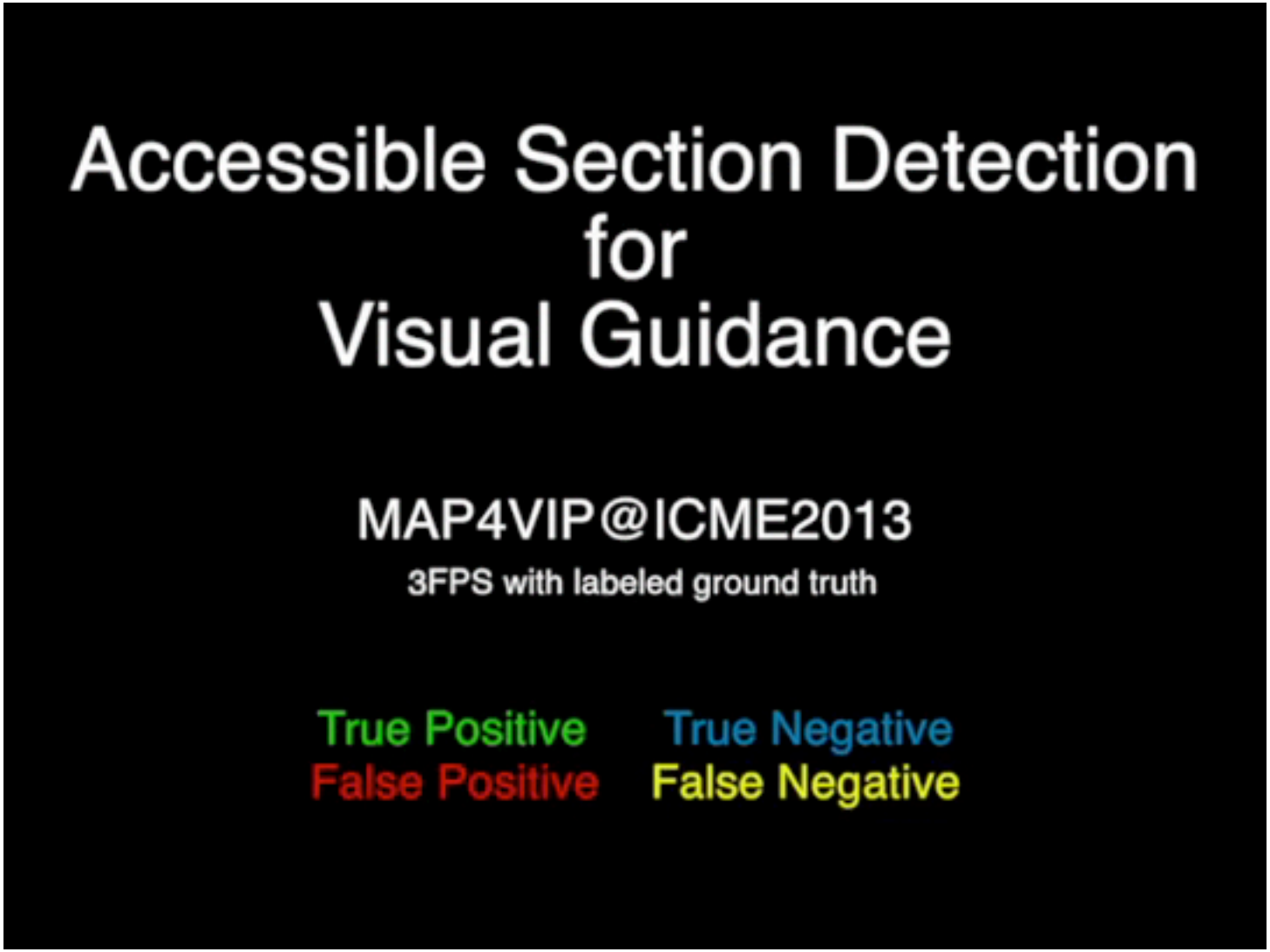




OVERALL ACCURACY = 91.74 %

$F_{0.5}$ = 0.861

$F_{1.0}$ = 0.828


Accessible Section Detection
for
Visual Guidance
MAP4VIP@ICME2013
3FPS with labeled ground truth
True Positive
True Negative
False Positive
False Negative

Conclusion

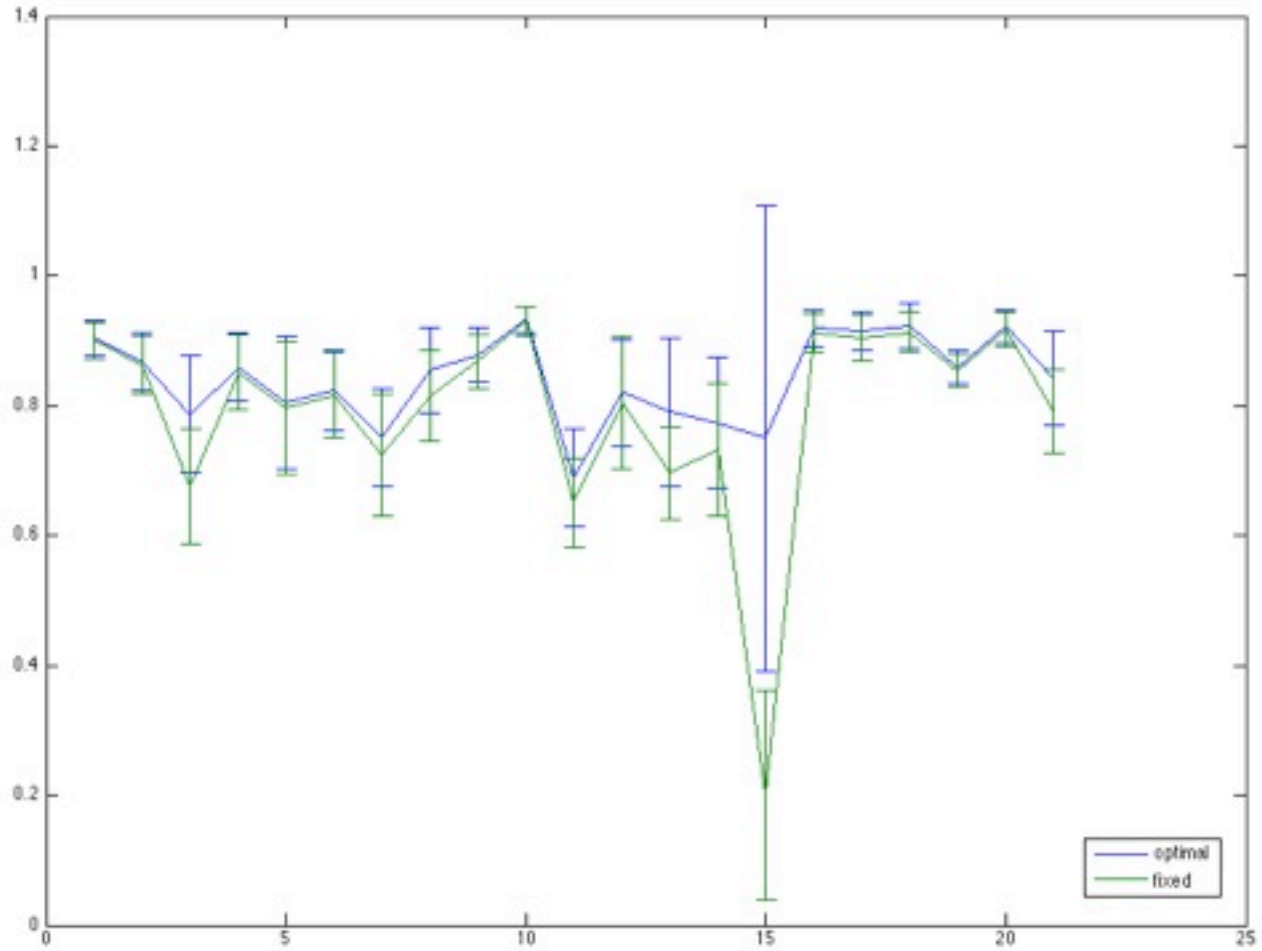
- Efficient method to determine accessible section
- Derive section not blocked by obstacles

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

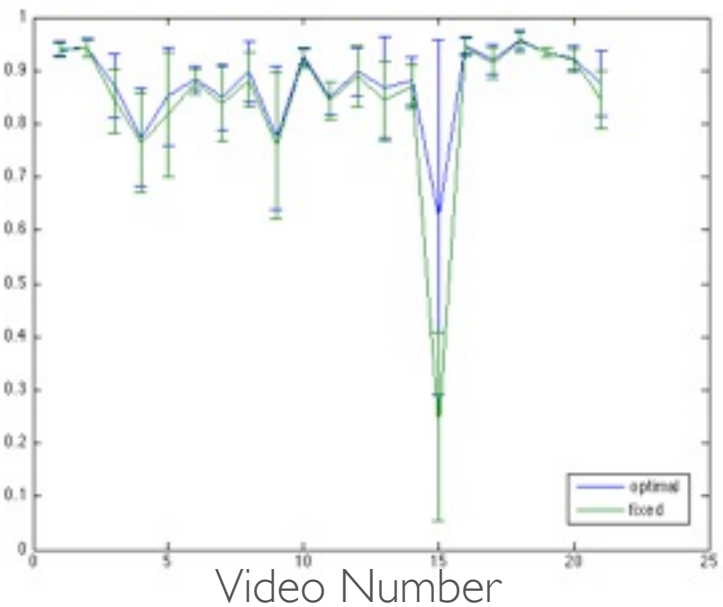
Experimental Evaluation
Results Overview

Name	$\int$ROC	$\int$PR	$F_{0.5}$	F_1	Acc.
Alley	0.928	0.882	0.937	0.916	0.901
Alley L.	0.892	0.856	0.941	0.911	0.862
Bicycle	0.753	0.629	0.843	0.869	0.676
Car	0.850	0.679	0.763	0.739	0.851
Corridor	0.819	0.665	0.816	0.750	0.796
Fence	0.855	0.750	0.878	0.834	0.815
Flower-box	0.783	0.607	0.838	0.789	0.724
Hedge	0.836	0.827	0.882	0.872	0.814
Ladder	0.836	0.629	0.757	0.736	0.868
Narrow	0.958	0.924	0.922	0.928	0.929
Pan	0.759	0.548	0.843	0.861	0.650
Passage	0.850	0.733	0.889	0.821	0.805
Railing	0.760	0.626	0.842	0.852	0.696
Ramp	0.803	0.680	0.870	0.839	0.731
Ridge	0.854	0.622	0.230	0.304	0.199
Sidewalk	0.929	0.945	0.943	0.947	0.913
Sidewalk 2	0.947	0.914	0.913	0.912	0.904
Sidewalk L.	0.889	0.942	0.954	0.950	0.912
Sign	0.890	0.835	0.933	0.899	0.854
Street	0.940	0.885	0.919	0.904	0.917
$\bar{x}$	0.852	0.753	0.861	0.828	0.784

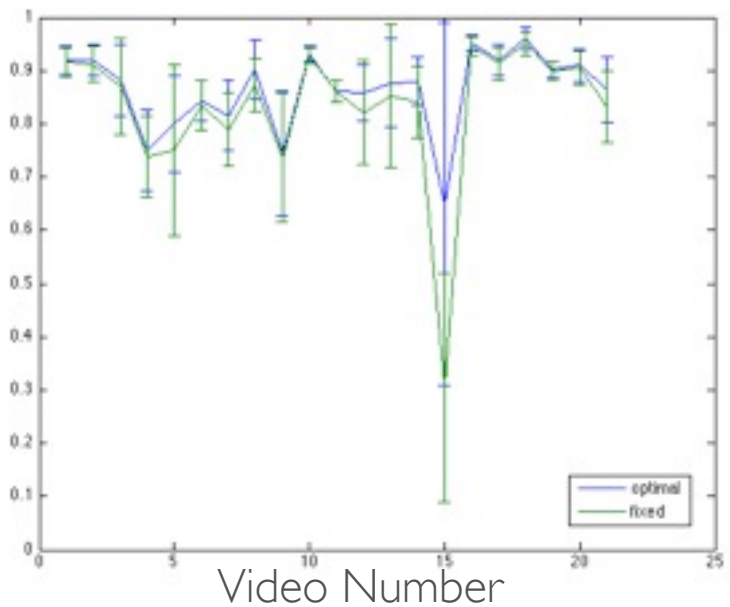
Experimental Evaluation
Accuracy



Experimental Evaluation
F_β-Scores



$F_{0.5}$ SCORE
PRECISION > RECALL



F_1 SCORE
PRECISION = RECALL