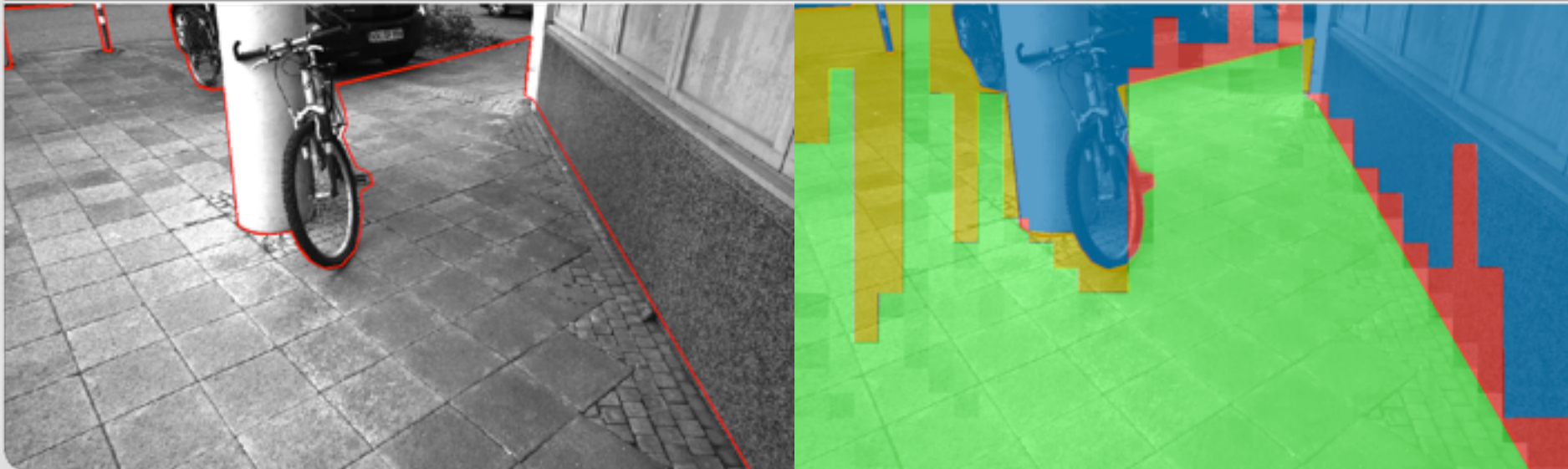


Accessible Section Detection for Visual Guidance

Daniel Koester, Boris Schauerte, Rainer Stiefelhagen

Institute for Anthropomatics
Computer Vision for Human-Computer Interaction Lab



Introduction



Südostschweiz.ch



“Seeing Guide Cane” by ETH Zürich

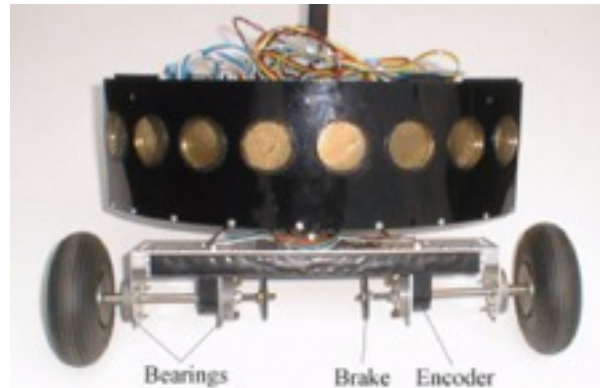
- Navigation and exploration
- Urban areas, indoor, outdoor
- Autonomy and mobility
- Obstacles and hazards

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

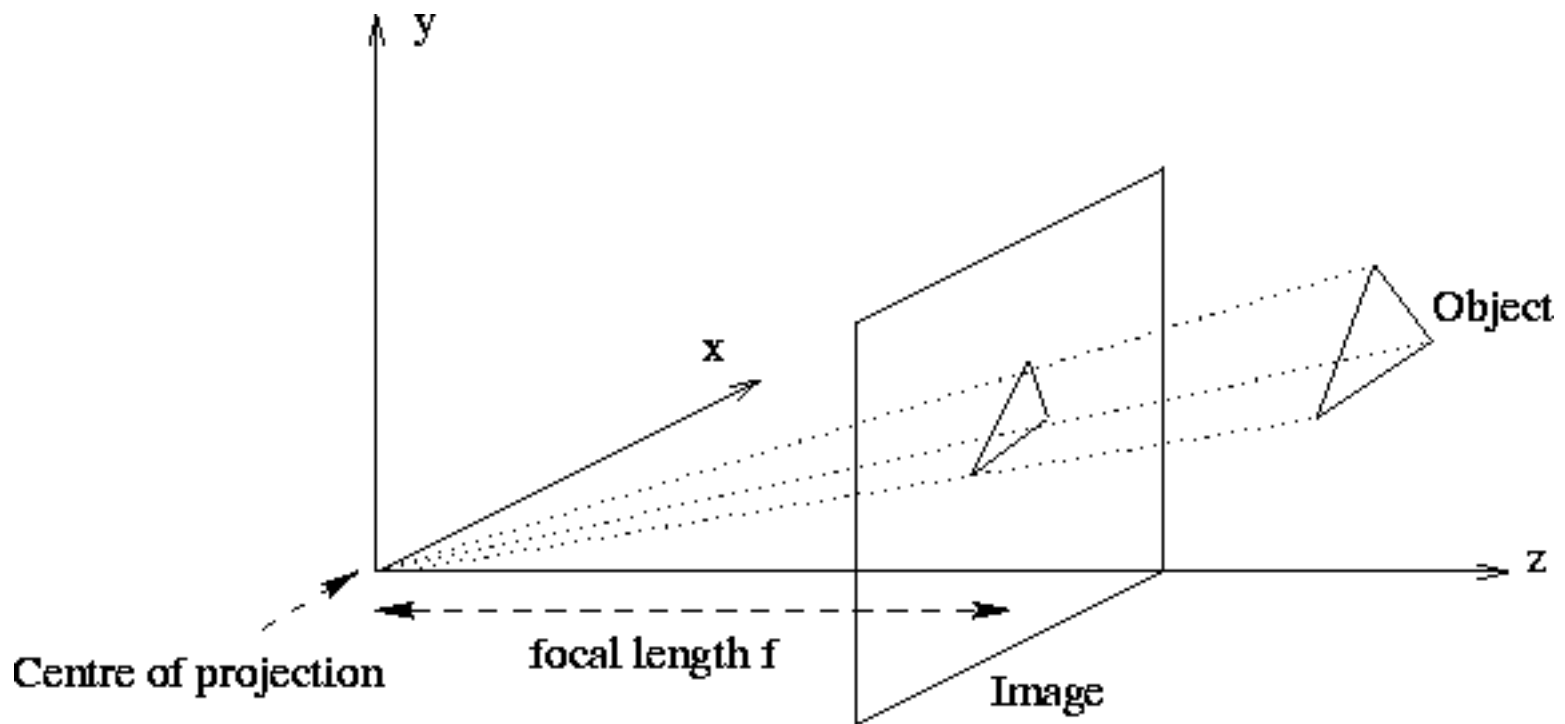
Approach Overview

- 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 :

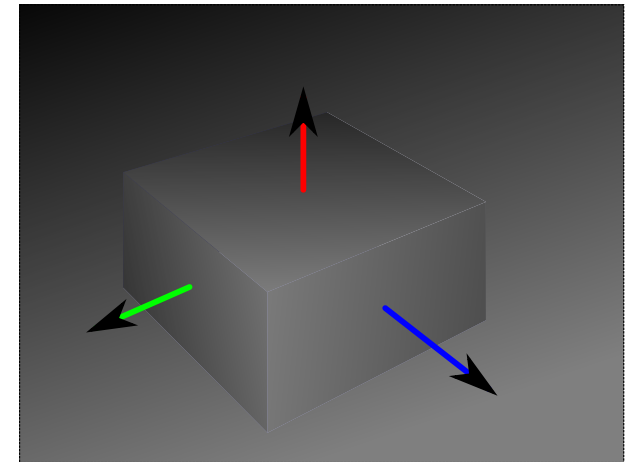
$$D = \frac{f_{focal} * b}{x_{i_{left}} - x_{i_{right}}} \quad \Delta = \{(x_i, y_i, \delta_i)\}$$

- Convolution:

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

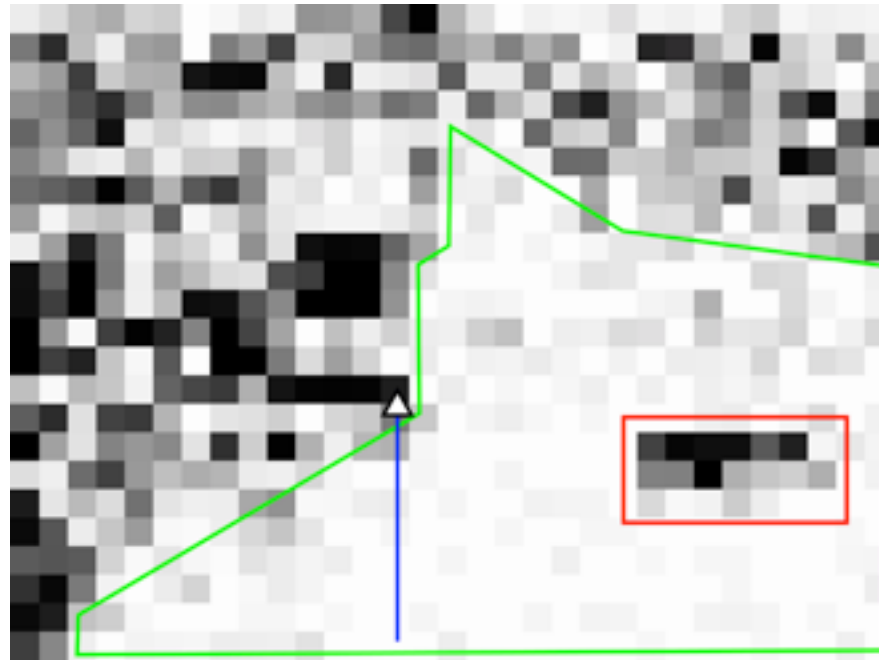
- Map Φ of gradient directions:

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



Accessible Section Detection

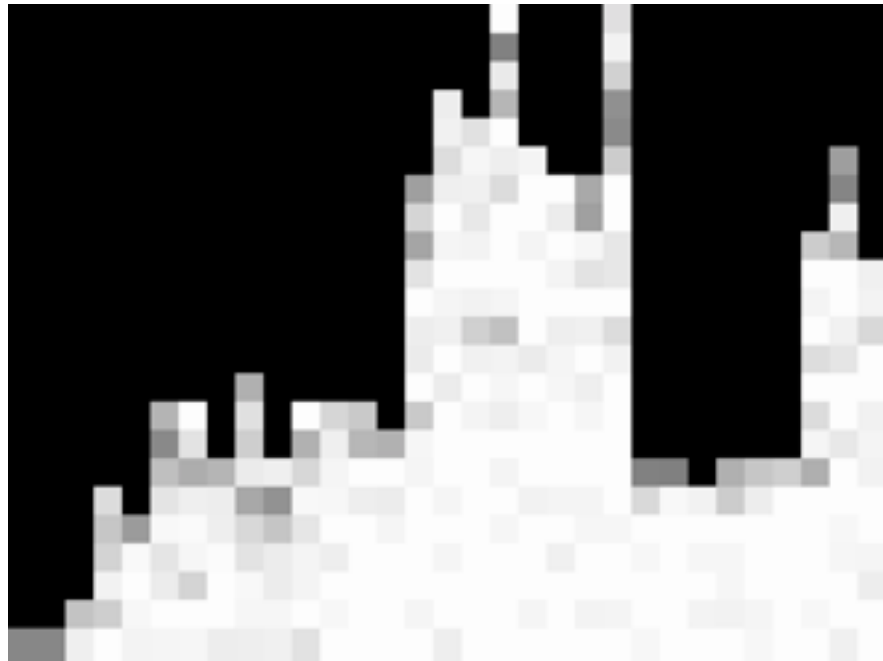
Block-Wise Selection Process



- 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

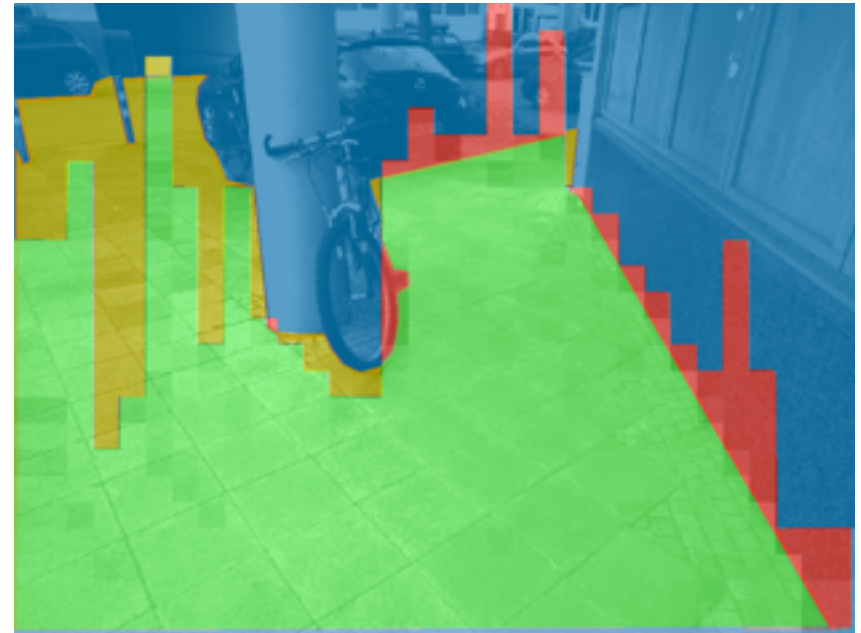
Accessible Section Detection

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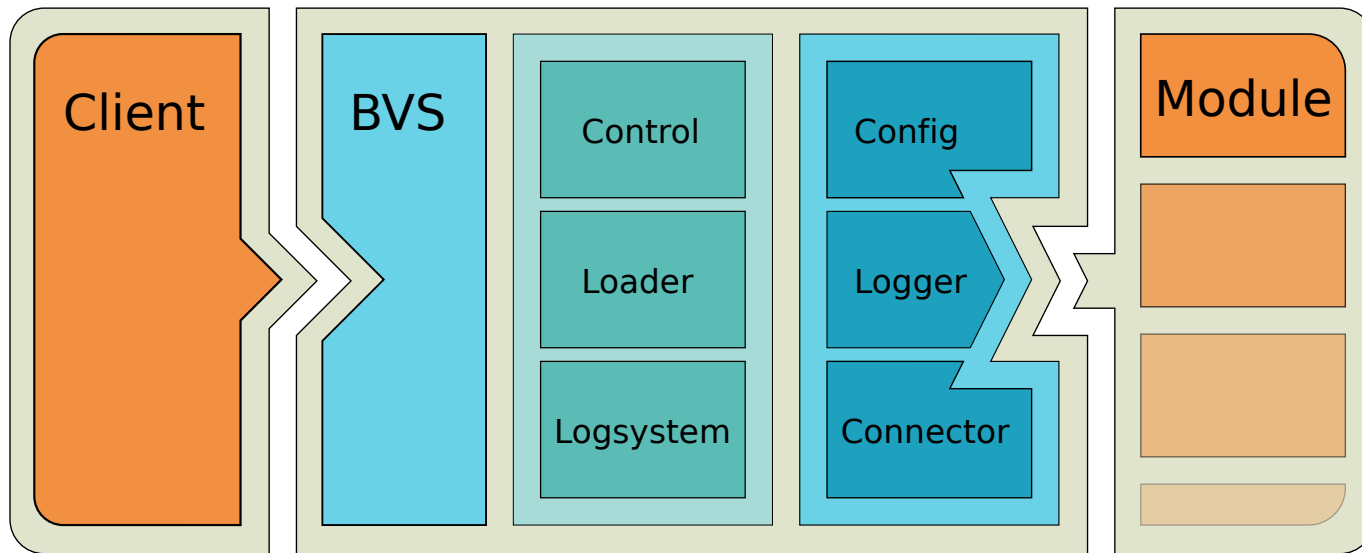
Accessible Section Detection Example



- Labeled accessible section and recognition classes: true positive (TP), false positive (FP), false negative (FN), true negative (TN)

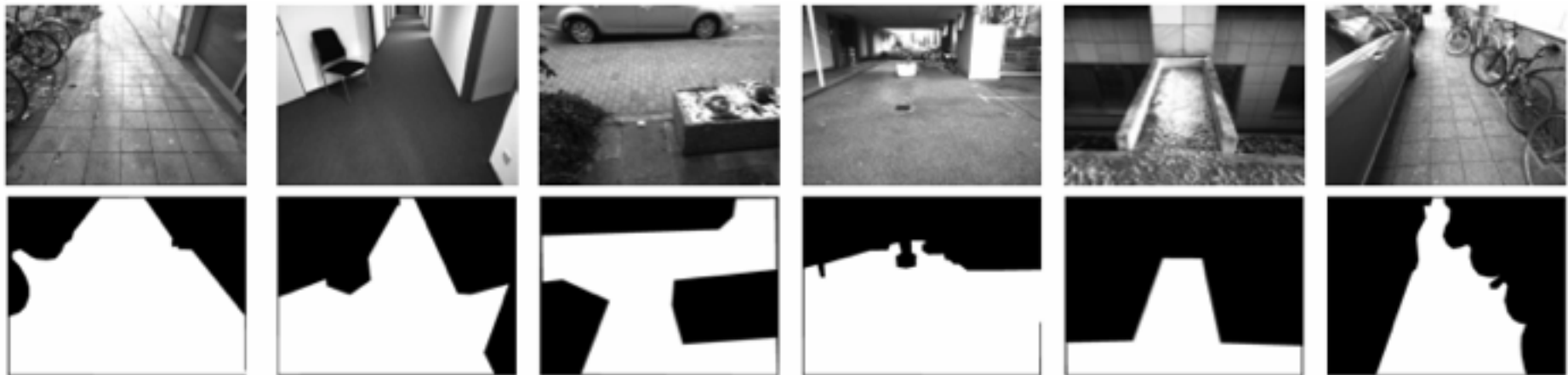
Accessible Section Detection

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



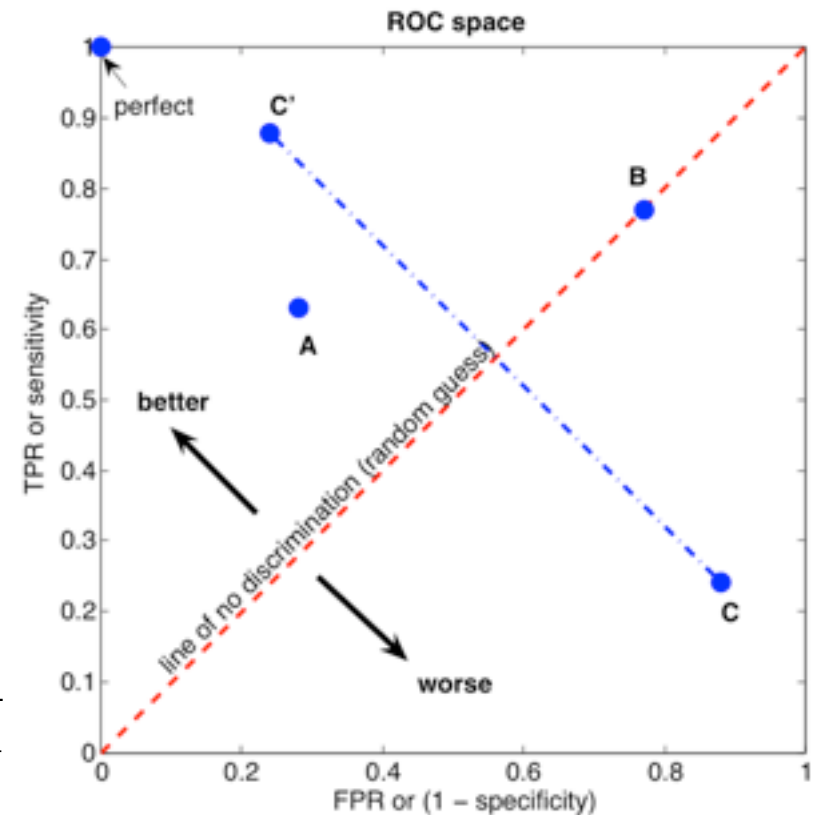
- Data set (20 videos) to evaluate system
- Challenges: intense ego motion, lighting variations
- Common urban scenes: walkways and side-walks, floors, static and moving obstacles

Experimental Evaluation Measures

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

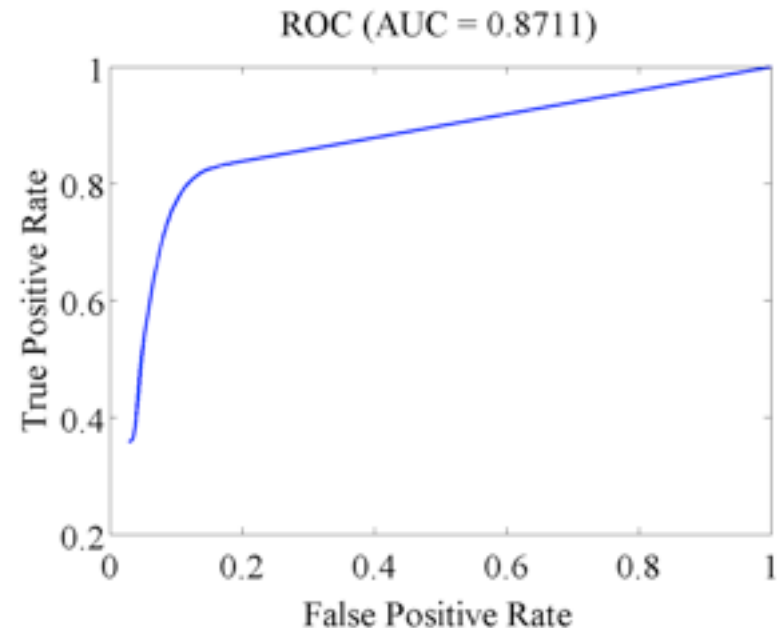
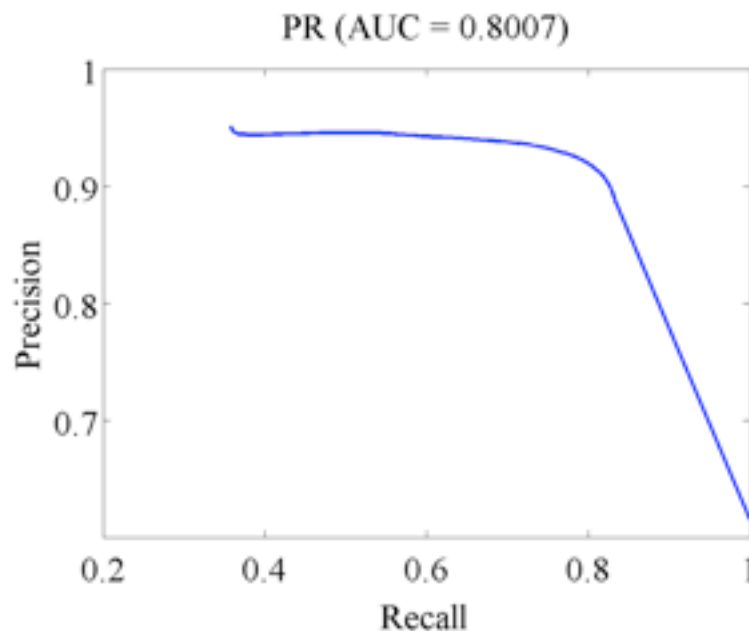
$$F_\beta = (1 + \beta^2) \cdot \frac{\text{precision} \cdot \text{recall}}{(\beta^2 \cdot \text{precision}) + \text{recall}}$$

- 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

Conclusion



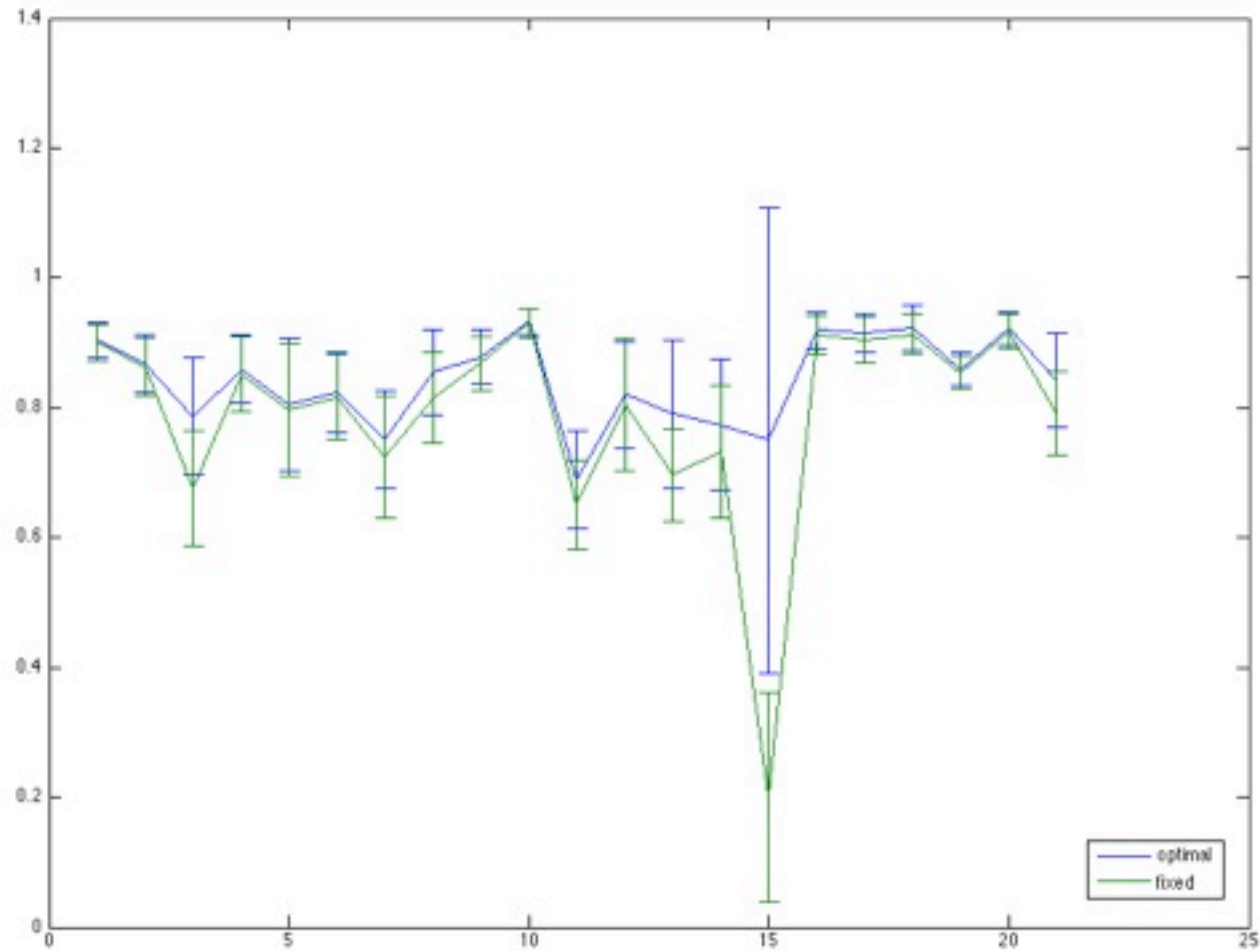
- Efficient method to determine accessible section
- Derive section not blocked by obstacles
- Navigational aid using a mobile platform
- System that helps in everyday situations
- Investigate haptic or auditory output modalities

Experimental Evaluation

Results Overview

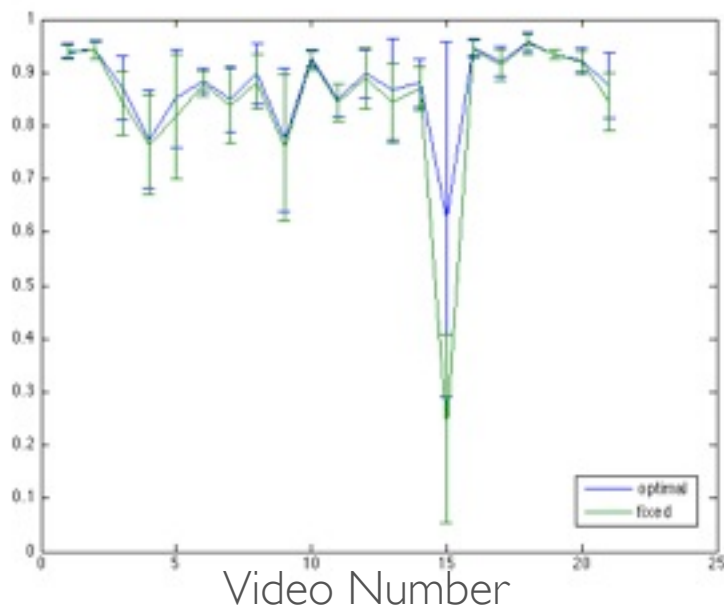
Name	$\int \text{ROC}$	$\int \text{PR}$	$F_{0.5}$	F_1	Acc.
Alley	0.928	0.882	0.937	0.916	0.901
Alley L.	0.892	0.856	0.941	0.911	0.862
Bicycle	0.753	0.629	0.843	0.869	0.676
Car	0.850	0.679	0.763	0.739	0.851
Corridor	0.819	0.665	0.816	0.750	0.796
Fence	0.855	0.750	0.878	0.834	0.815
Flower-box	0.783	0.607	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

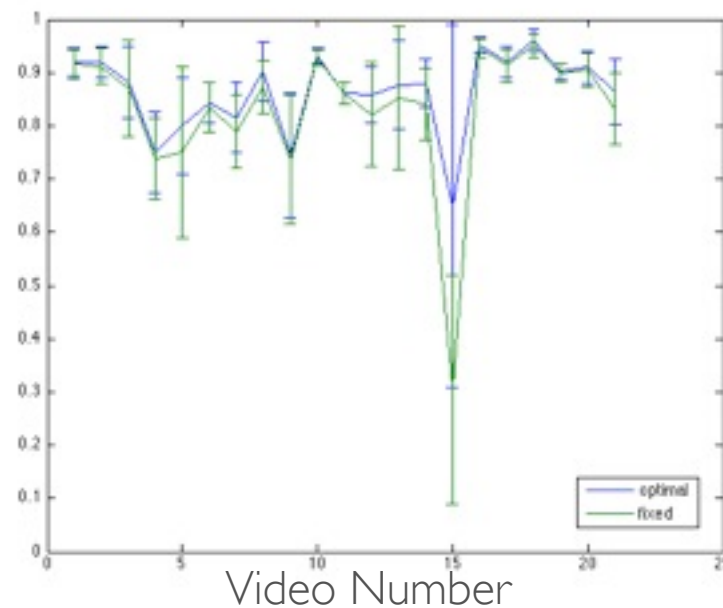


Experimental Evaluation

F_β -Scores



$F_{0.5}$ SCORE
PRECISION > RECALL



F_1 SCORE
PRECISION = RECALL