Reconstructing Textured CAD Model of Urban Environment using Vehicle-Borne Laser Range Scanners and Line Cameras

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Outline

- Overview
- Experimental Setup
- Geo-referencing Data Outputs
- Creating Geometric Models
- Texture Mapping
- Results

Overview

Current Techniques

- aerial based imageries for reconstruction of 3D urban models: UMass Radius Project
  - [+] can cover relatively wide area
  - [-] cannot capture details: facades of buildings
- demonstration at small scale, using simple objects under controlled light conditions

Overview

Current Techniques

- image-based approach
  - interactive method of rendering scenes using sparse sets of still photographs [Debevec et al.]
  - MIT City Scanning Project: extraction using feature correspondence on spherical mosaic images.
  - captured image streams are geo-referenced to existing 2D map using GPS data [Uehara and Zen]

Overview

Current Techniques

- range-based approach
  - large-scale reconstruction of indoor environments [Sequeira and El-Hakim]
  - generating 3D model of urban out-door objects using stationary platforms [Allen, Zhao and Shibasaki]

Objective

generate an efficient reconstruction method exploiting ground-based survey technique at large-scale, for complicated unexpected object geometries, under uncontrolled light-conditions using vehicle-borne systems

Approach

- 3 single-row laser range scanners and 6 line cameras are mounted on a measurement vehicle equipped with a navigation system.

- geometric model is generated using geo-referenced laser range data where urban features are extracted in a hierarchical way.

- texture of urban features is generated by projecting and re-sampling line images on the geometric model.

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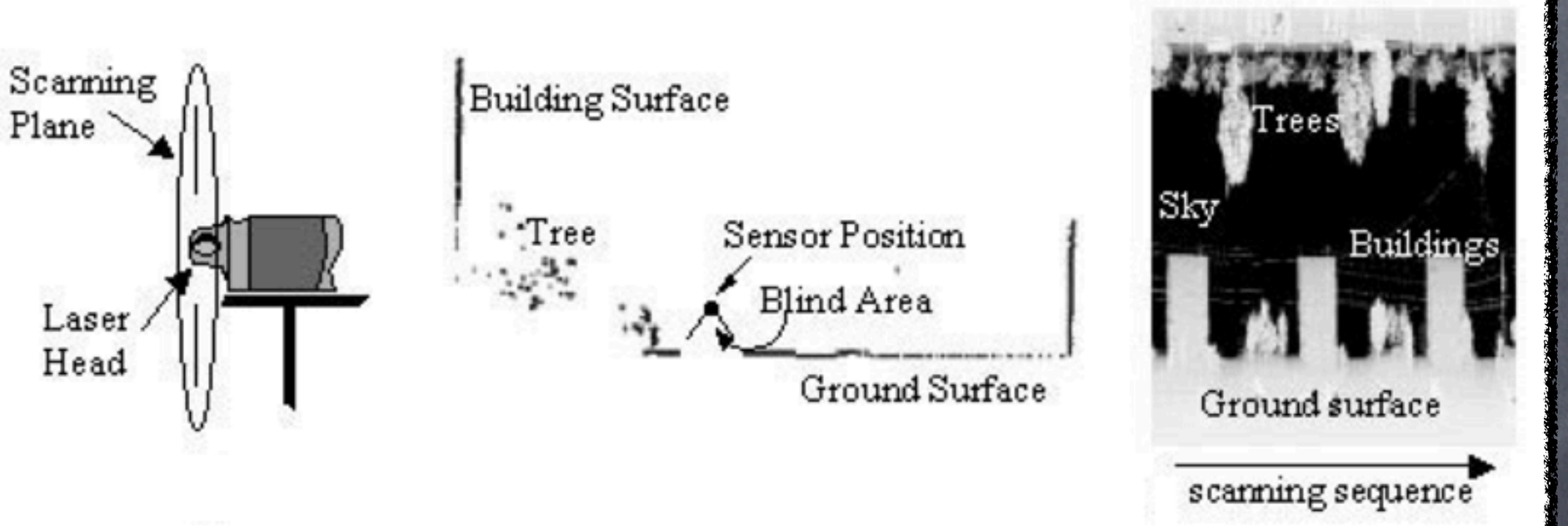
Experimental Setup

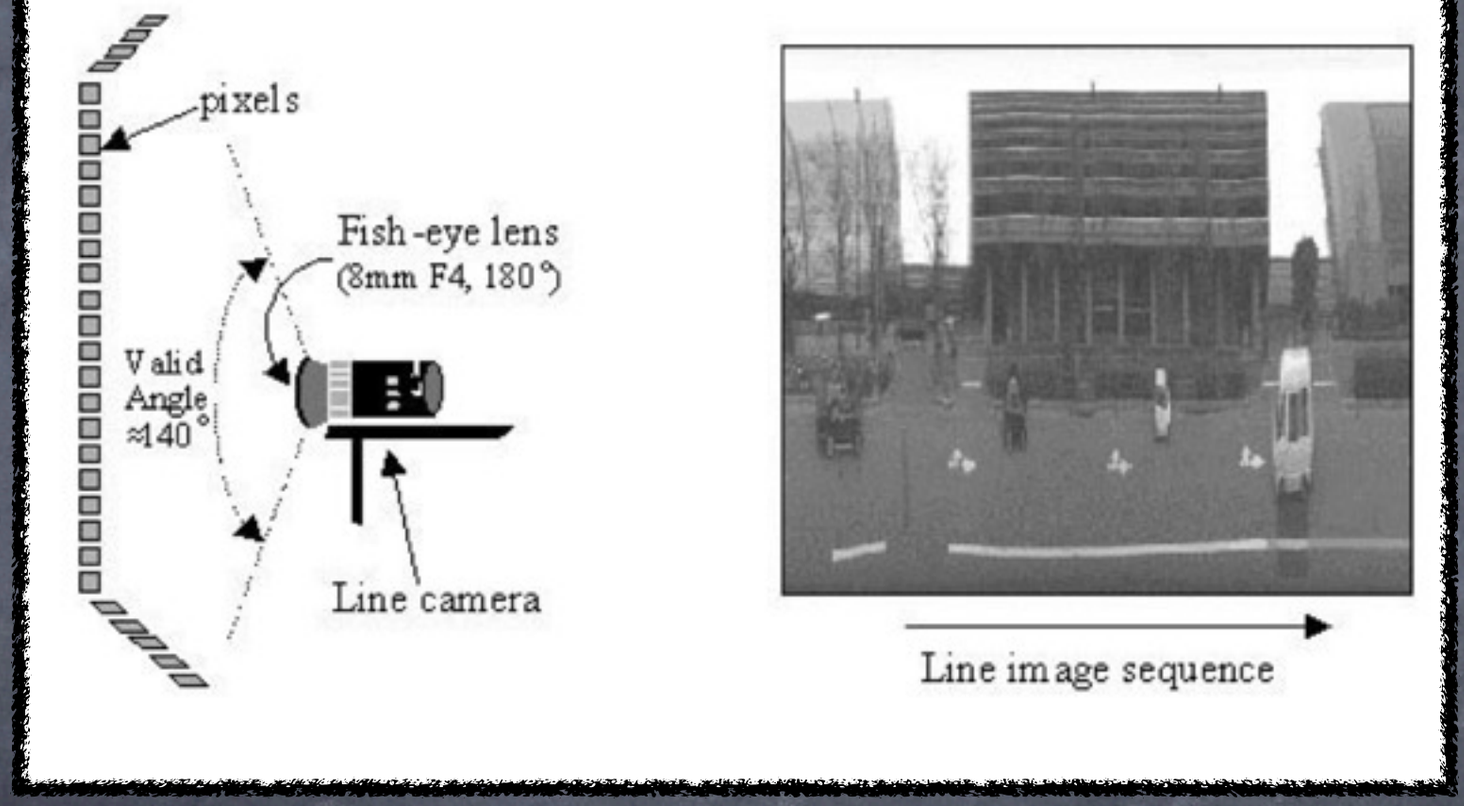
Laser Range Scanner



- sensor for measuring object geometry
- a blind area of 60 degrees exists

Experimental Setup

Line Cameras



- sensor for capturing object texture
- lens has a vision field of 180 degrees.

Experimental Setup

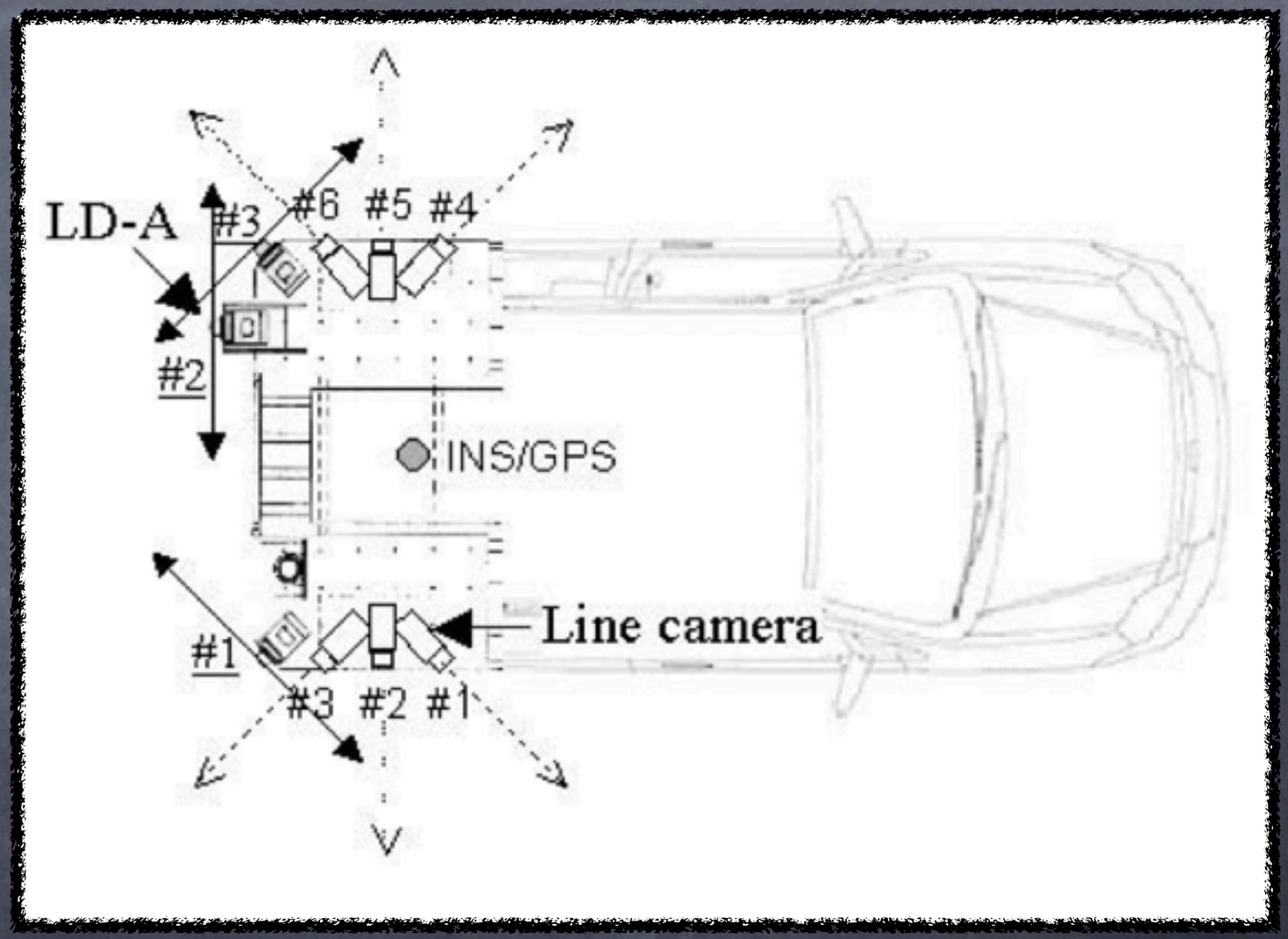
geoMaster

- moving platform
- equipped with a GPS/INS/Odometer navigation system

Experimental Setup

Sensor Alignment

- line cameras are installed at different angles to reduce occlusion
- navigation data is associated to each line image and range scan line using sensor' local clock



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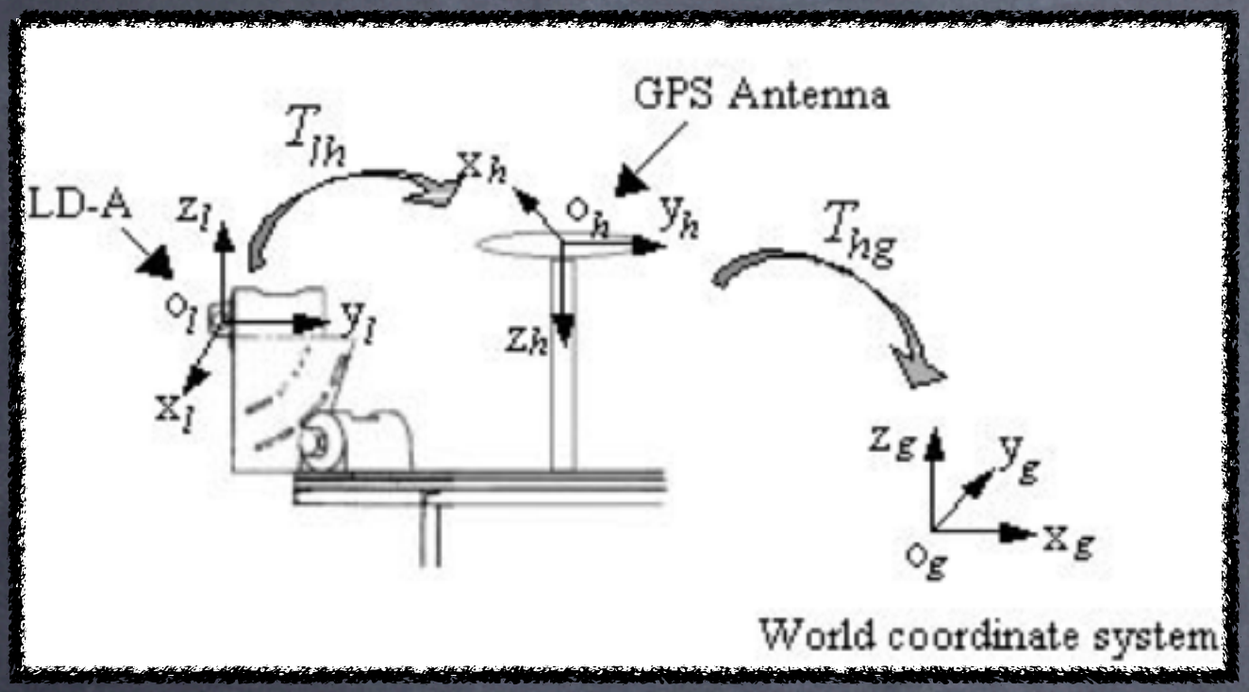
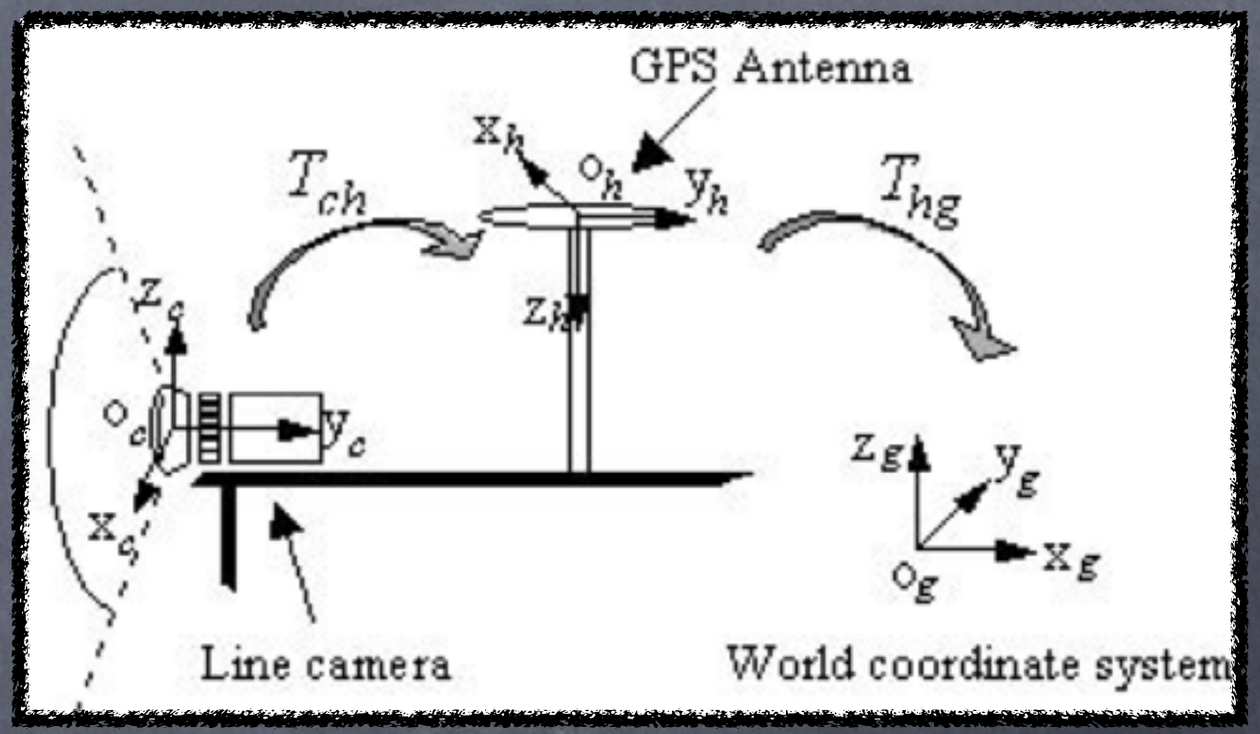
Geo-referencing Data Outputs





range scan line

line image

T_{lh} and T_{ch}: calculated based on exterior calibration parameters

T_{hg}: calculated based on navigation data associated to each range line scan and line image

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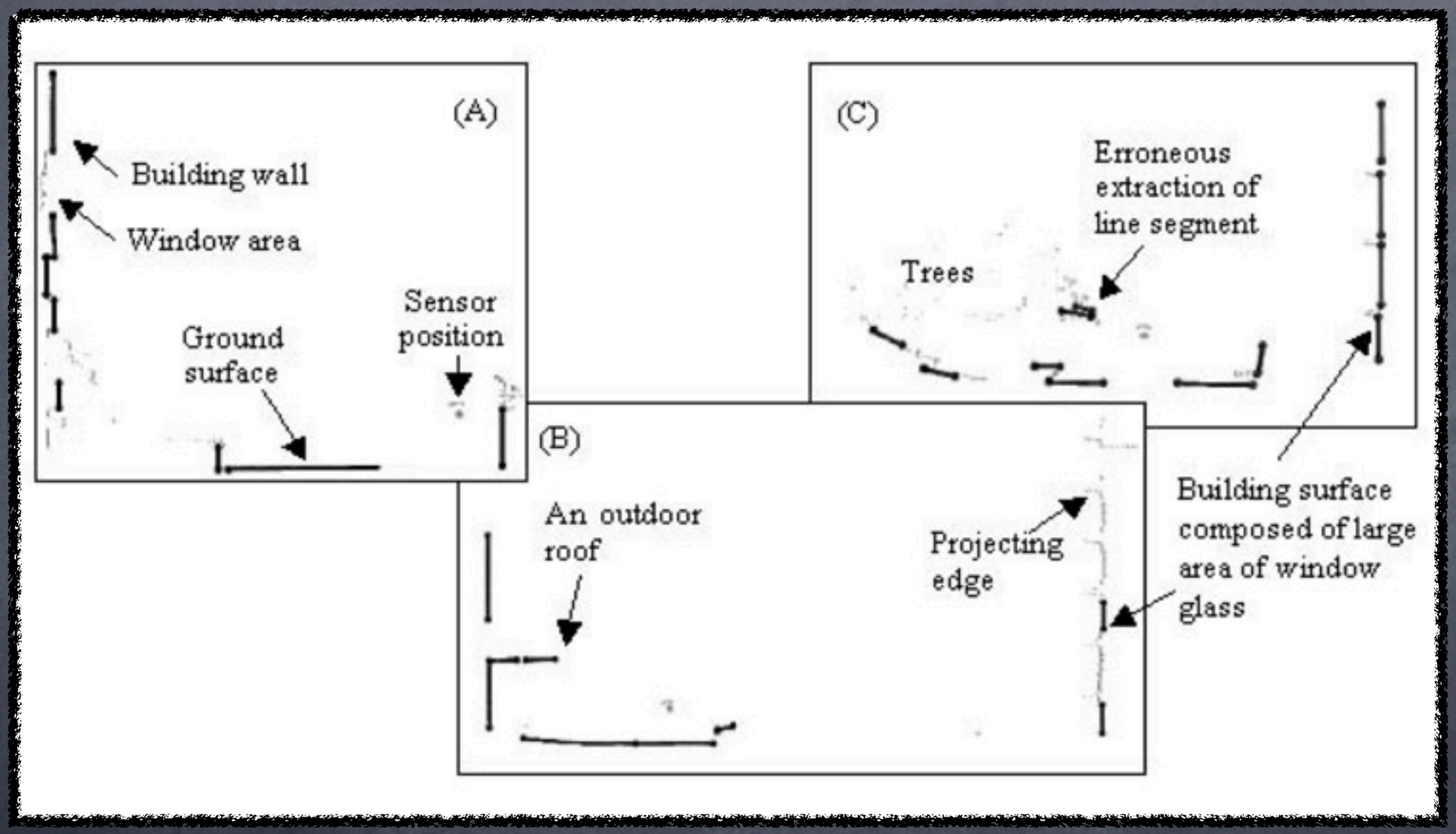
Creating Geometric Models

- classification of range points
  - segmenting each range scan line into line segments
  - grouping the range points in a hierarchical way
- geometrical feature extraction and modeling
  - z-image for vertical and ground surface extraction
  - USF segmentation for non-vertical buildings

Classification of Range Points

Segmentation of Range Scan Lines



method based on: "non-parametric segmentation of curves into various representations, Rosin et al., IEEE PAMI, 1995"

Classification of Range Points

Grouping the Range Points in a Hierarchical Way

- rules
  - vertical buildings: vertical linear features of range scan line
  - ground surfaces: small gradients, elevation < thresh
  - trees: non-vertical surfaces with large clusters
- misclassifications can occur

Classification of Range Points

Grouping the Range Points in a Hierarchical Way

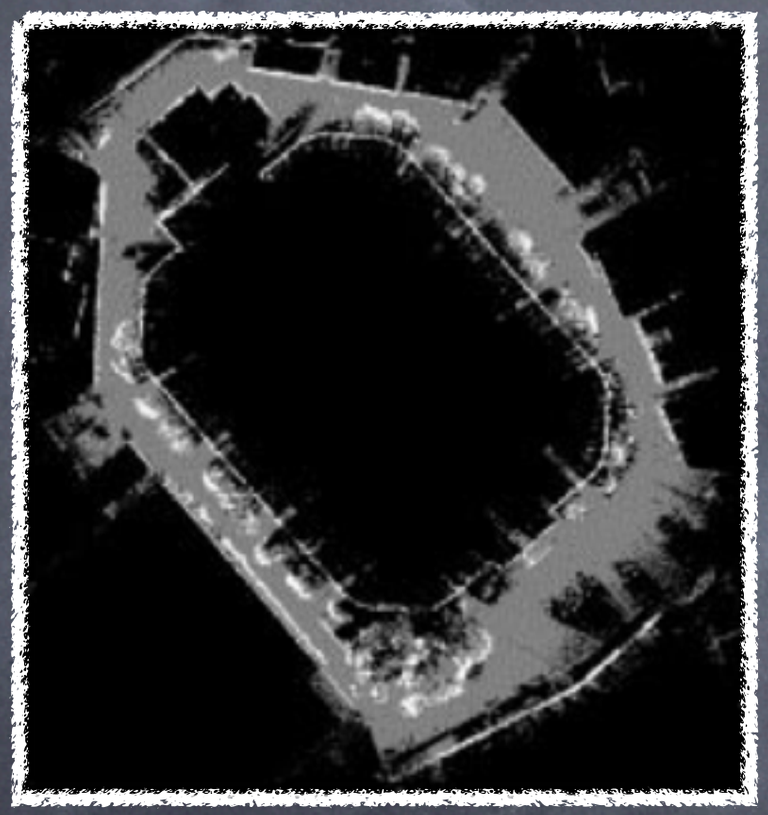
- problem: misclassifications can occur
- solution: validation using extracted geometric features
  - example: discard range points belonging to vertical line segments if no vertical planar surface is extracted from range points.

Creating Geometric Models

- classification of range points
  - segmenting each range scan line into line segments
  - grouping the range points in a hierarchical way
- geometrical feature extraction and modeling
  - z-image for vertical and ground surface extraction
  - USF segmentation for non-vertical buildings

Geometrical Feature Extraction

z-images: vertical surface extraction



z-image: all range points

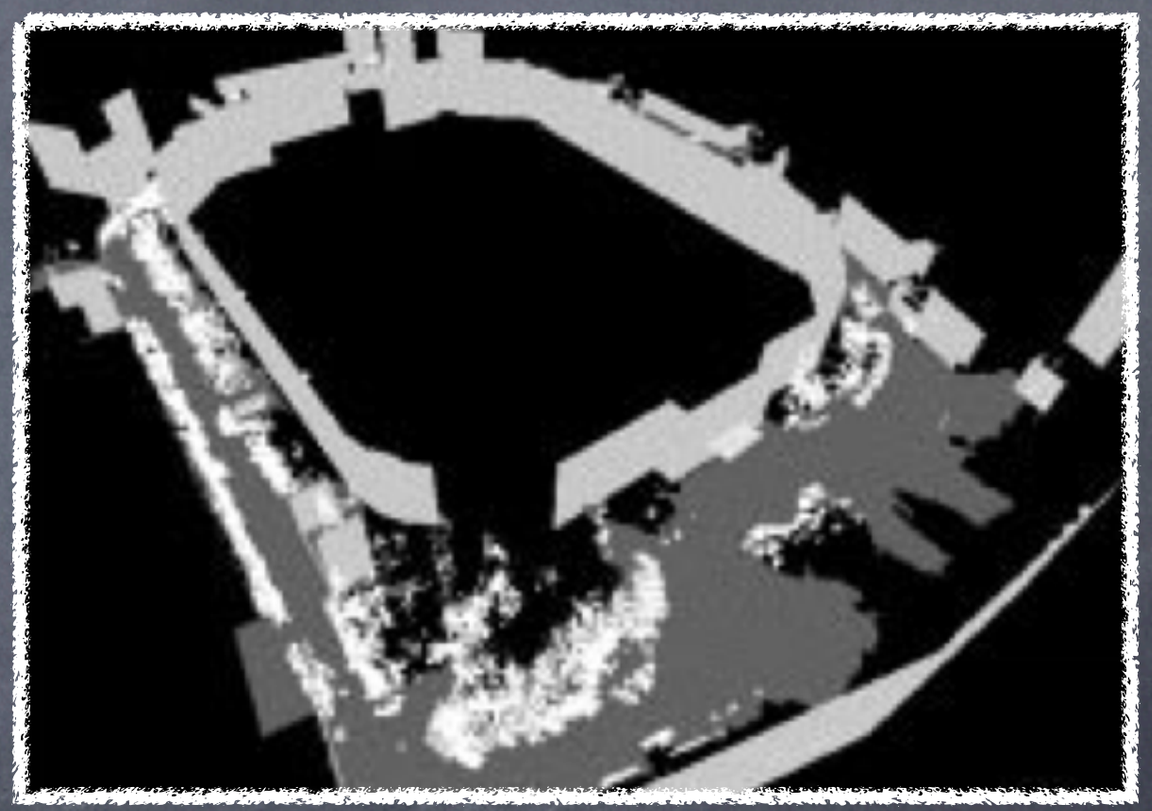
z-image: vertical surfaces

extract line segments from z-image of range points belonging to group of vertical buildings

Geometrical Feature Extraction

z-images: vertical surface extraction

vertical surfaces: z-image



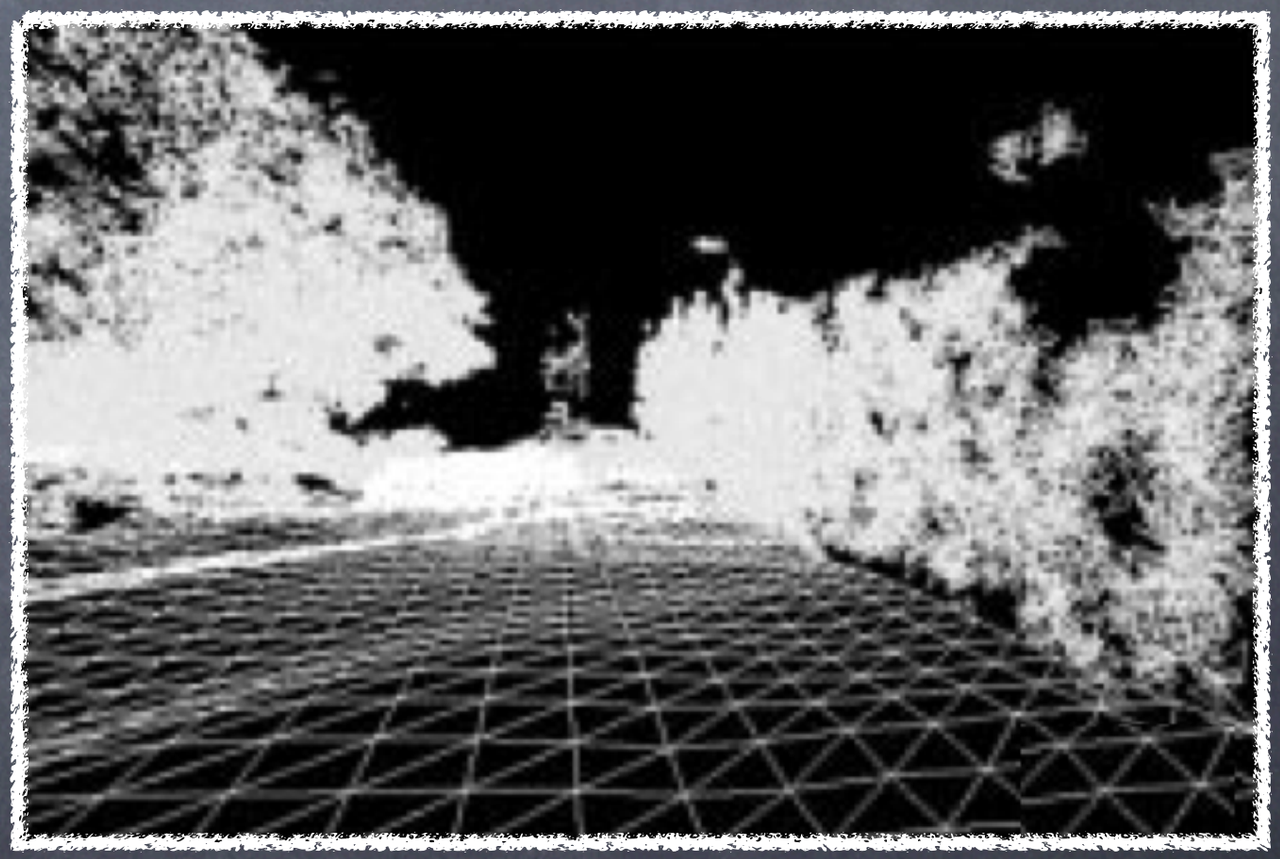
vertical surface: geometrical model

recover the line segments to vertical polygons using corresponding range points to define boundaries

Geometrical Feature Extraction

z-images: ground surface extraction

- range points are projected onto a regularly tessellated horizontal plane.
- an elevation map of ground surface is generated using minimal z-value in each grid cell.

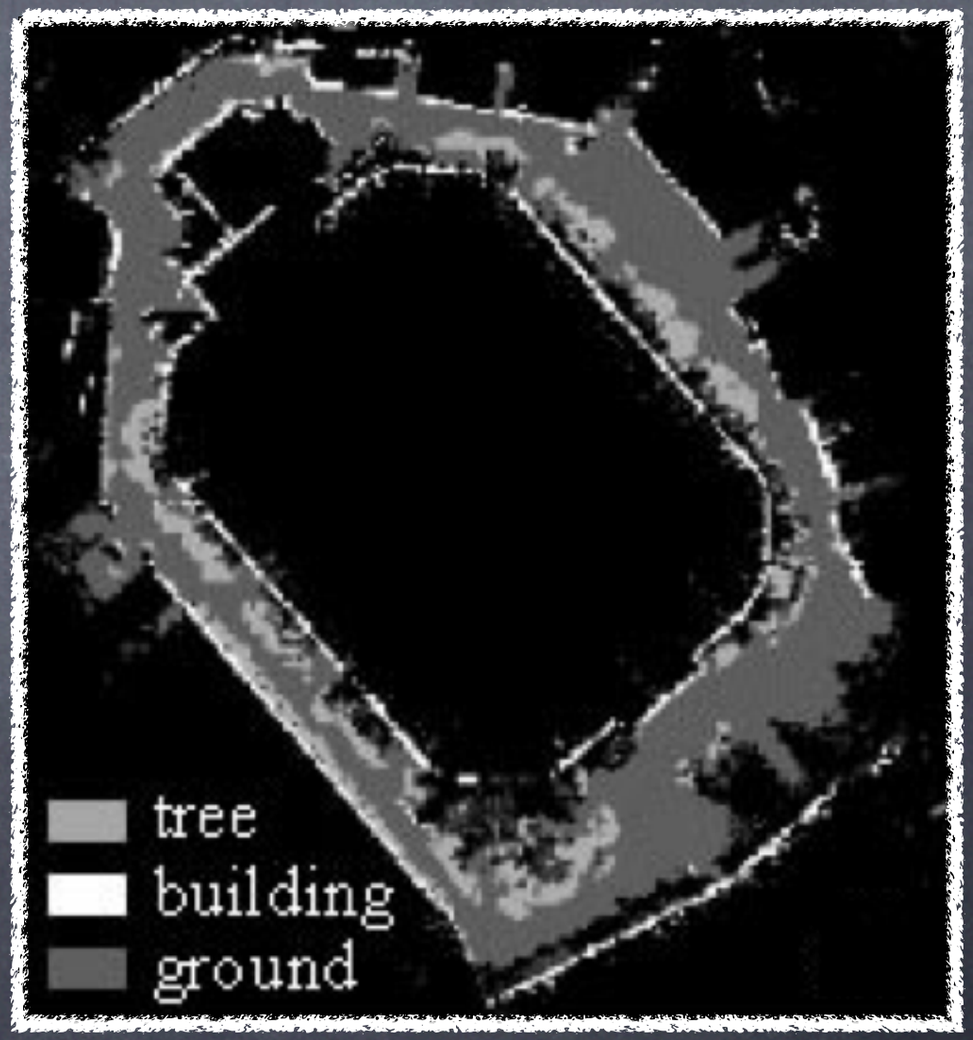


ground surface: TIN model

Geometrical Feature Extraction

USF segmentation: non-vertical surface extraction

- mixed data of trees, parking cars, utility poles etc.
- generate a z-image of range points
- range points corresponding to small clusters are removed.
- trees are modeled using triangular cells



classification result

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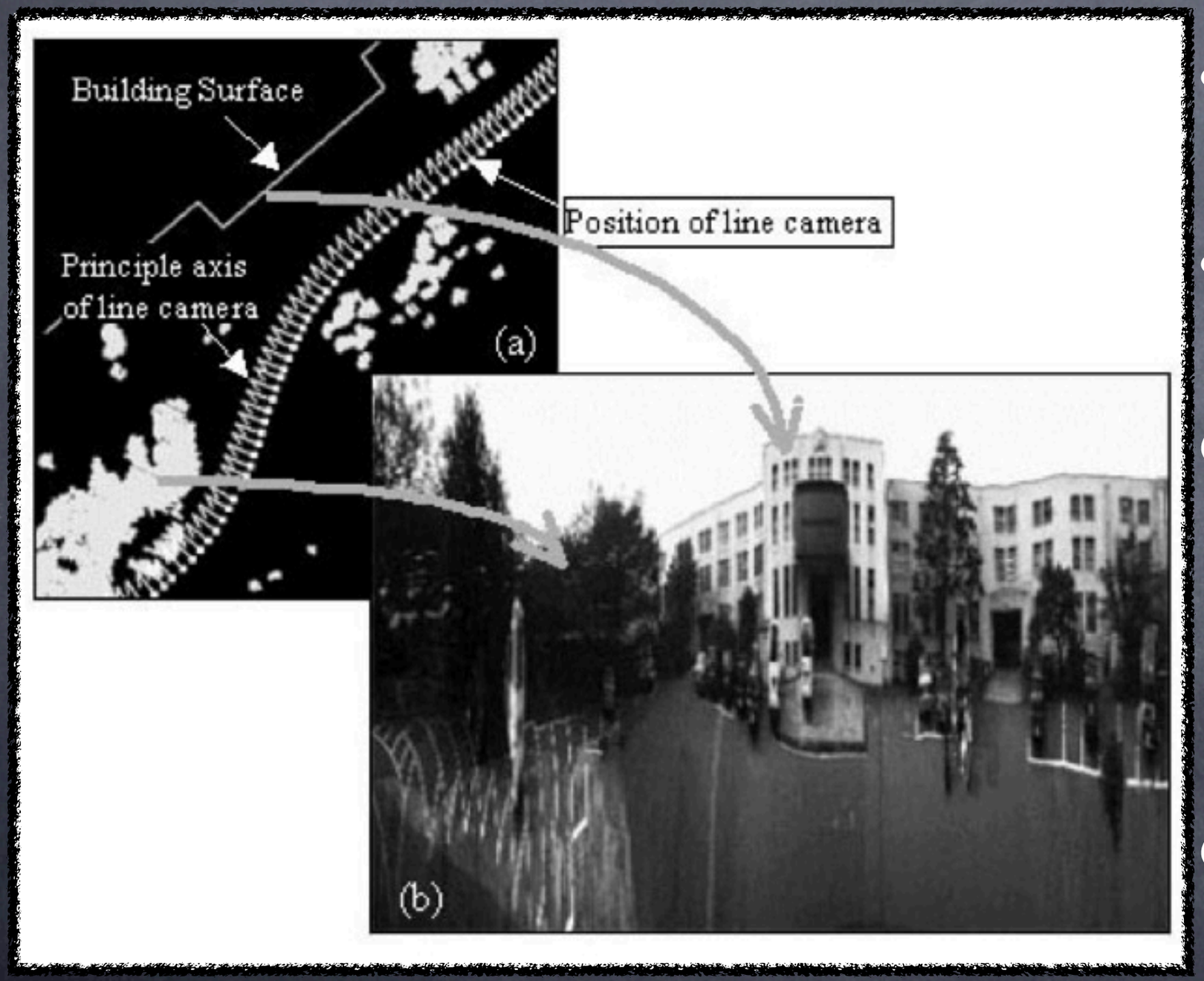
Texture Mapping



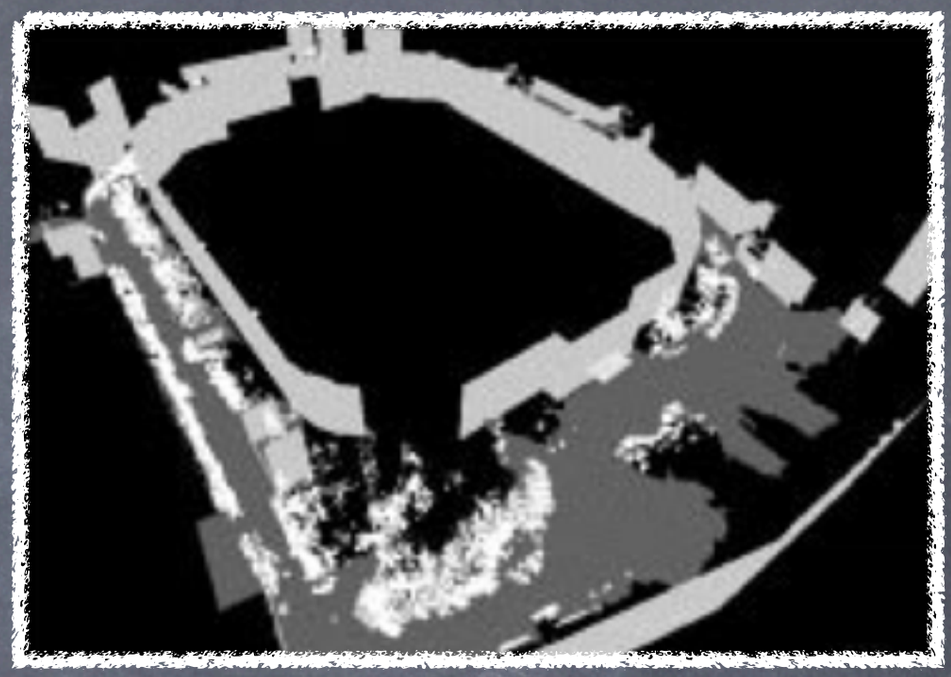
trajectory of line camera

distorted strip of line image

Texture Mapping

- problem: distortion in line image strip, due to change of relative distance and direction from line camera to object

- solution: resample the line image!



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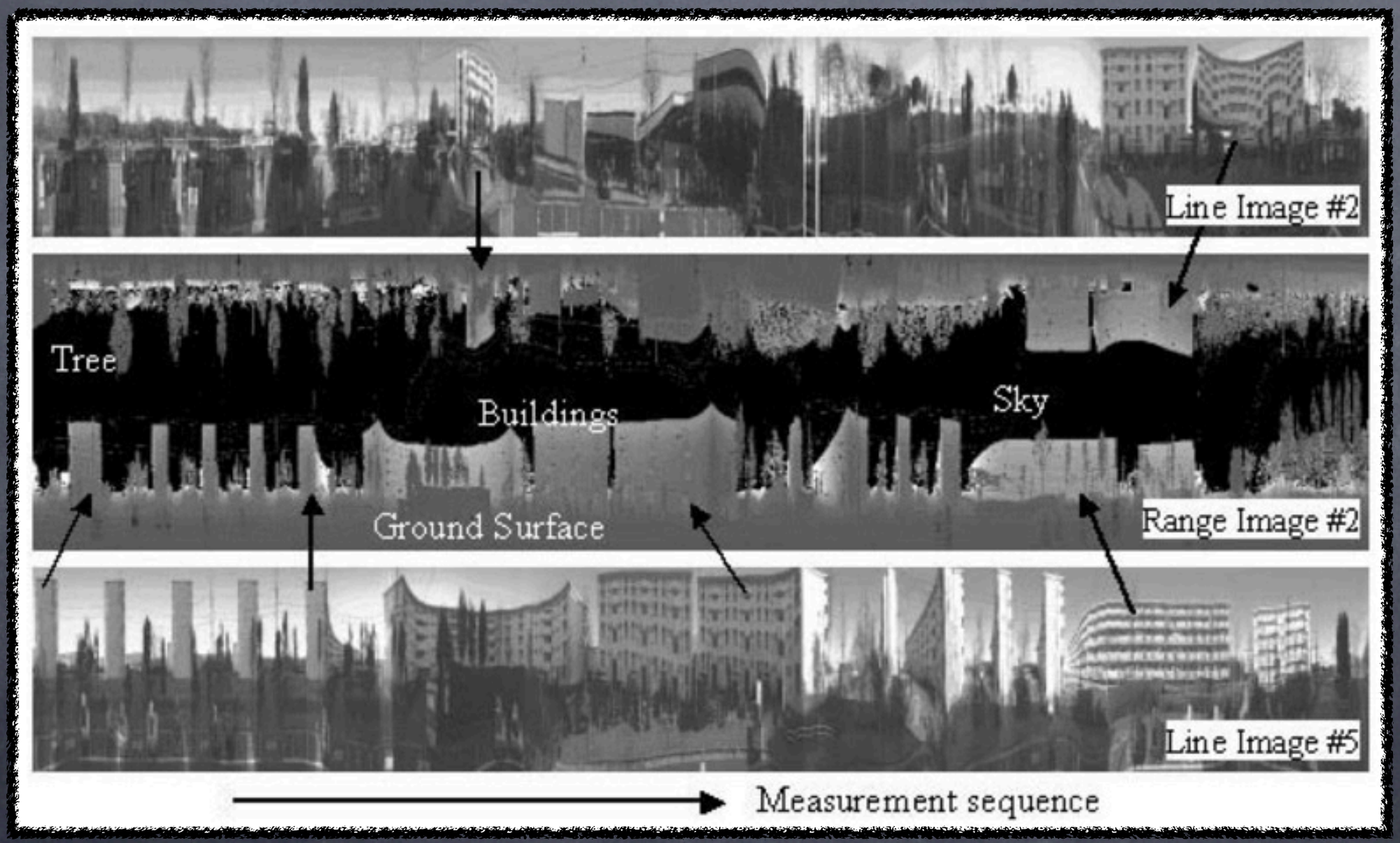
- Results and Future Work

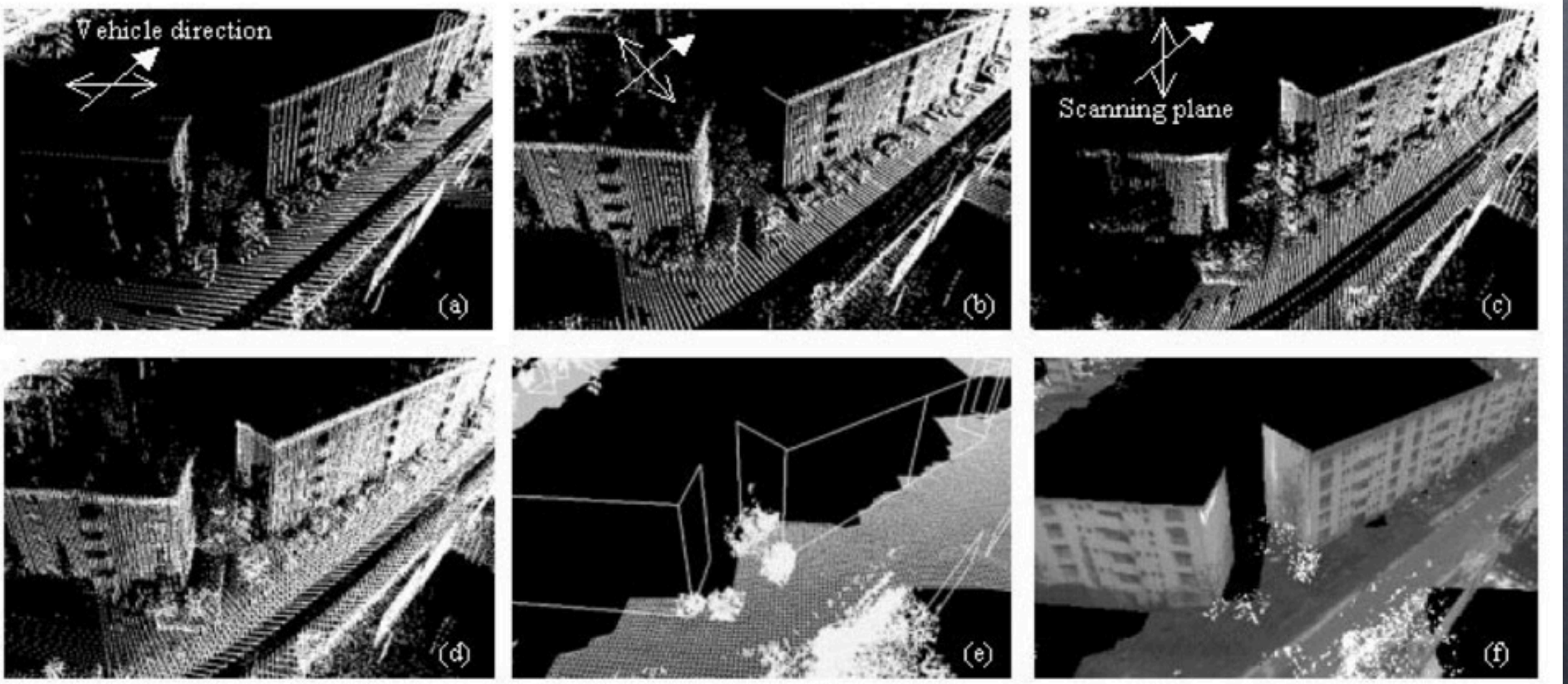
Results



- over 30K line images measured by each line camera
- over 7K range scan lines measured by each LD-A

Results

Reducing Occlusion using Multiple Laser Range and Line Images



Future Work

- extracting and modeling other urban features: parking cars, telegram poles ...
- fusing the textured CAD model by vehicle-borne system with that by aerial survey

References

- Zhao and Shibasaki. Reconstructing a textured CAD model of an urban environment using vehicle-borne laser range scanners and line cameras. Machine Vision and Applications (2003) vol. 14 (1) pp. 35-41