Toegepaste en Technische Wetenschappen

Building Changes in 3D point clouds using Very High Resolution Stereo-Images

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Introduction

Currently: 3D city model combines

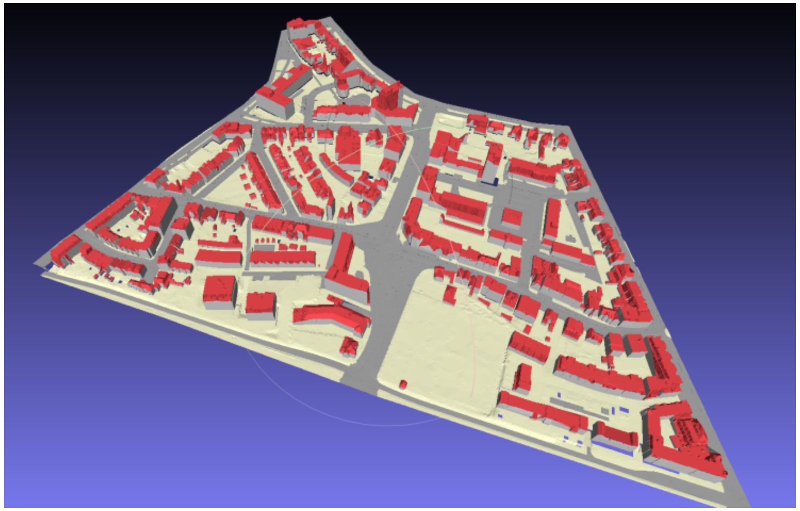
- BGT: 2D Dutch large scale base map
  updated every 1 to 2 years
- AHN: 3D Dutch LIDAR archive
  updated every 5 to 10 years

Goal: 3D city model – Annual Update

- Annual VHR, aerial stereo-images

Required: change detection

- 3D Model vs. VHR stereo-Images



Building changes:
Geometric change indicators

A) Shadow change in a single VHR image

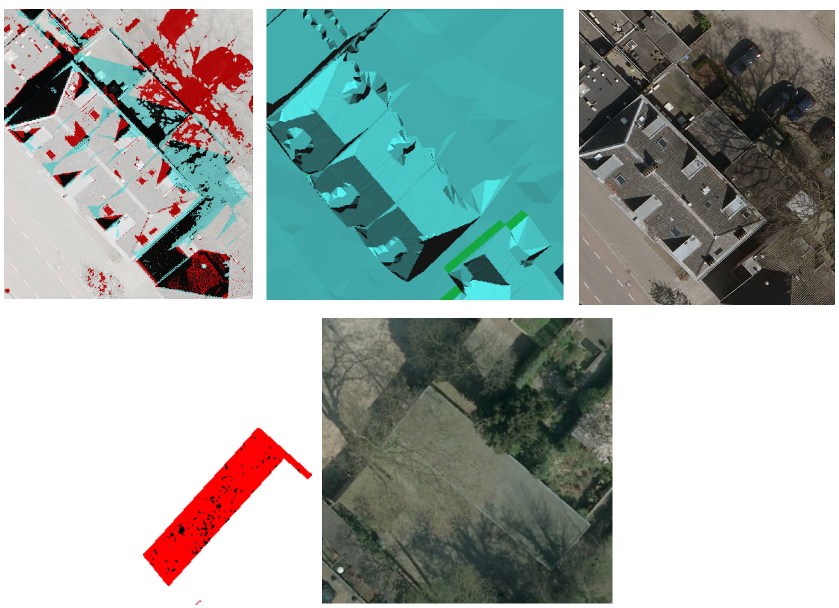
B) Direct height change in VHR image stereo-pair

C) Projection based geometric differences from VHR image stereo-pairs

Shadow change

+ Shadow is relatively easy to detect
+ Often possible to identify geometric change in areas that are occluded or in the shadow

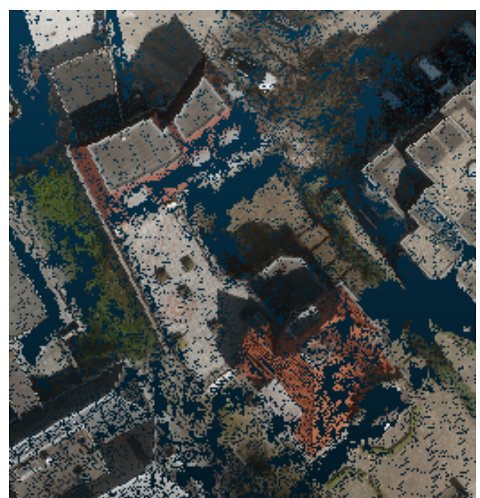
- Affected by quality 3D model and by trees (left image)
- Not all changes result in a shadow change (right image)



Direct height change

+ Full change detection
+ No 3D model needed. Works directly on raw LiDAR data

- Stereo pair detection is affected by occlusions (right image) and low texture (left image)
- Corresponding points are needed for comparison


Projection based geometric differences

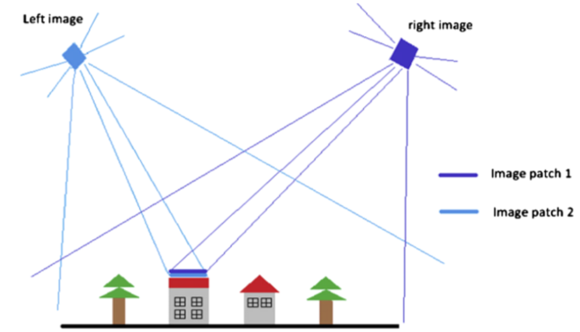
Use existing height and camera geometry to project Image pairs to check for pixel similarity

+ Finding stereo pairs is guided by existing height
+ Corresponding geometry between LiDAR and images is determined from height and camera geometry

True Ortho approach:

- Existing 3D heights near edges are very noisy
- Changes are not detected due to homogeneity surroundings

(a)



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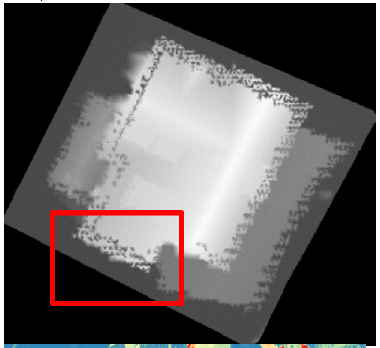
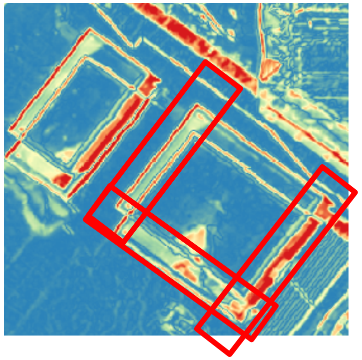
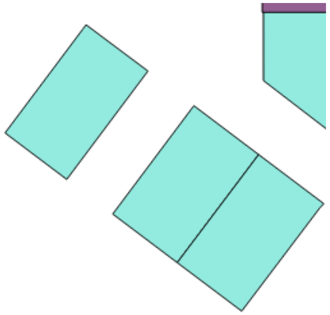
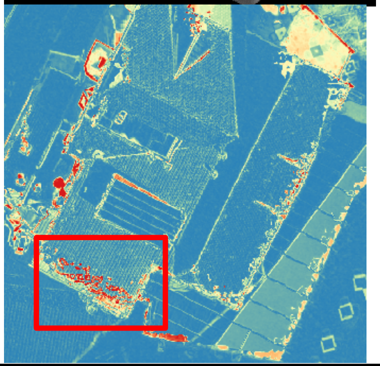
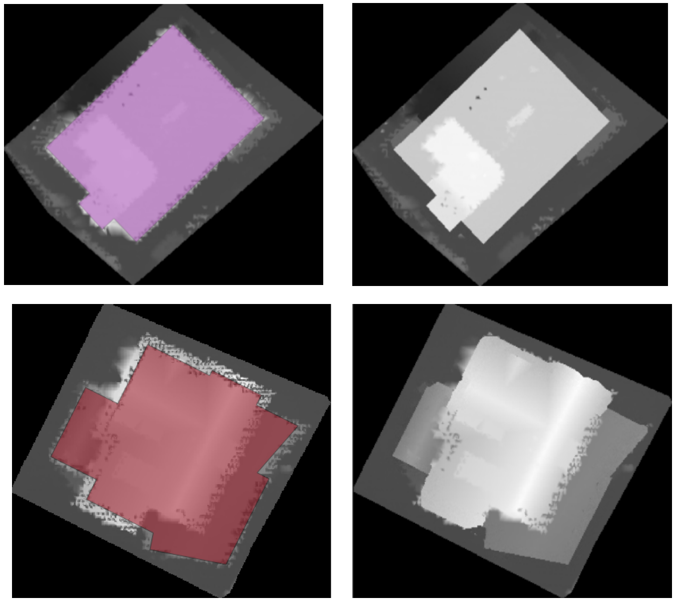








1st try: Edge Optimization



Adjust 3D heights near edges using 2D base map

Criteria for adjustment:

AP: Do not deviate from DSM heights

IP1: Planarity and continuity on roofs

IP2: Discontinuities at the 2D base map boundaries

- **Continuous Markov random field (**Kumar, S., & Hebert, M. (2006)**)**

$$P(\mathbf{y}|\mathbf{h}) = \frac{1}{Z} \prod_{i \in n} \boxed{\psi_i(h_i, \mathbf{y}_i)} \prod_{i \in n} \prod_{j \in N_i} \boxed{\psi_{ij}(\mathbf{y}_i, \mathbf{y}_j)}$$

$\mathbf{y}_i = (\alpha_i, \beta_i, \gamma_i)$ the pixels forming planarity trend

$norm_i = (\alpha_i, \beta_i, 1)$ presents the normal of the planarity information in the pixel

γ_i presents the height the pixel

h_i presents the height of pixel i in the DSM

$\boxed{\psi_i(h_i, \mathbf{y}_i) \text{ presents the association potential}}$

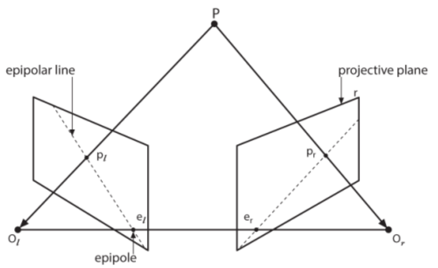
$\boxed{\psi_{ij}(\mathbf{y}_i, \mathbf{y}_j) \text{ presents the interaction potential}}$

Remaining problems:

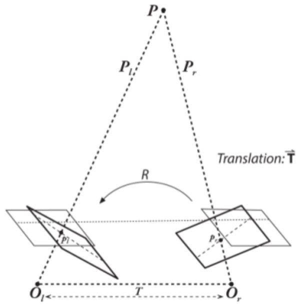
- Too many candidate states in MRF
- Internal edges are not enhanced

2nd try: Epipolar projection approach

Epipolar geometry



Stereo rectification



Source: Learning OpenCV

Optimize **discrete disparities** (nr. of pixel displacements), instead of **continuous height**

Two step approach:

1) Verification - (Solves: Existing heights near edges are very noisy)

- **New AP**: Corresponding pixels should have the same colour
- **New IP1**: Neighboring disparity values are similar
- **New IP2**: Pixels have different colours across edges+Base map boundaries

2) Change propagation – (Solves: Changes are not detected due to homogeneity surroundings)

- High matching costs -> Change candidate -> Real disparity
- Propagate real disparities to surrounding pixels

Verification (on going)

DSM-Disparity

DSM

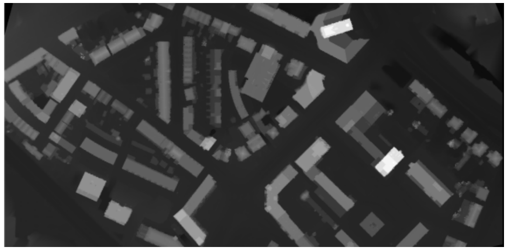
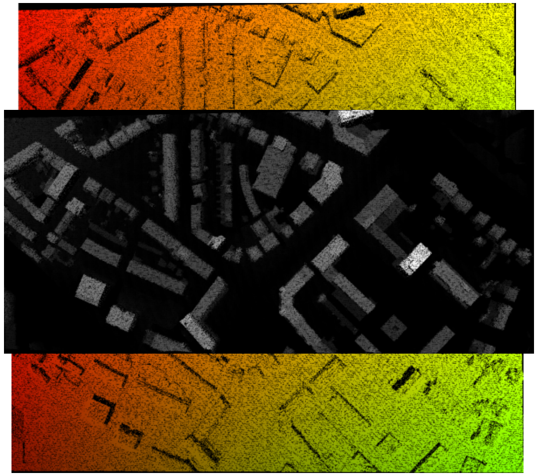


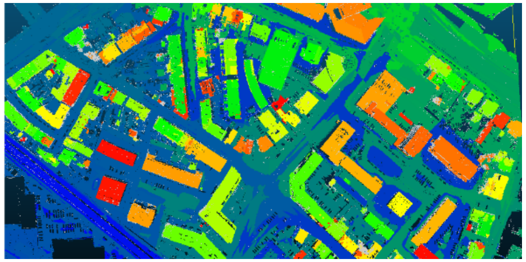
Image stereo pair

Resulting disparities

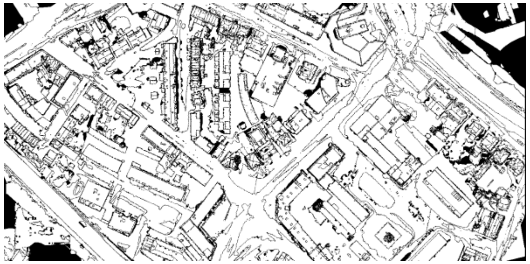


Plane- candidate states

Extracted planar segments



edges from interpolation

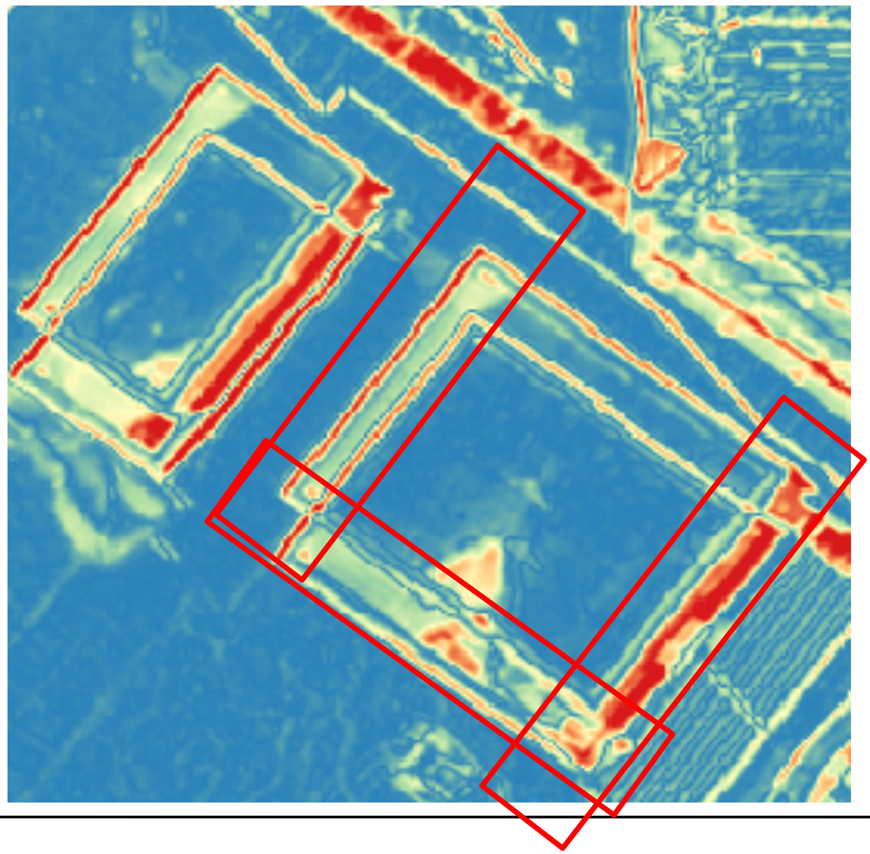


Epipolar projection for possible states

2D base map and color difference from image -> Edge constraint for Markov Random Field

Change propagation (Ongoing)

- In red boxes: high matching costs: Likely changed
- True disparity value within red boxes is found to be five
- Propagate this true disparity values to surrounding pixels



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Questions?