ifp

Universität Stuttgart

EuroSDR Image Matching Benchmark - Results IFP

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Overview

- Algorithm
  - Matching (Semi-Global Matching, Hirschmüller 2008)
  - 3D Point and DSM Generation
- Results of Dataset ‘Vaihingen Enz’
- Results of Dataset ‘Marseille’
- Problems and Possible Improvements

Dense Stereo Matching

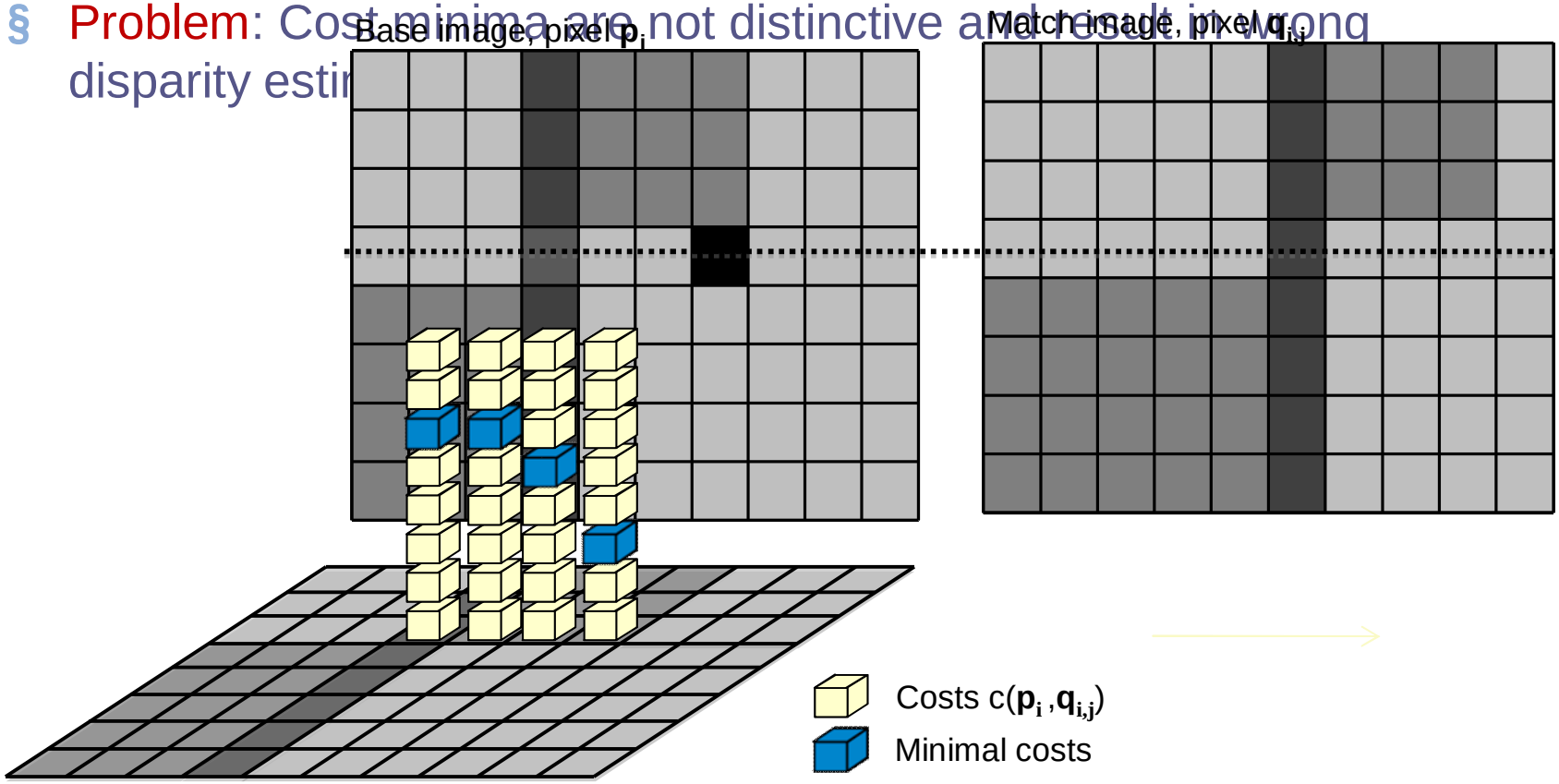
- Dense Stereo Matching: for each pixel in the base image find the corresponding pixel in the match image

Base image Match image Parallax image

- Local algorithms
  - Window based algorithms, parallax estimation by analyzing similarity of proximate intensity values of potential correspondences
- Global algorithms
  - Parallax estimation such that a global energy function is minimized, smooth surfaces are forced by introducing penalty terms for discontinuities

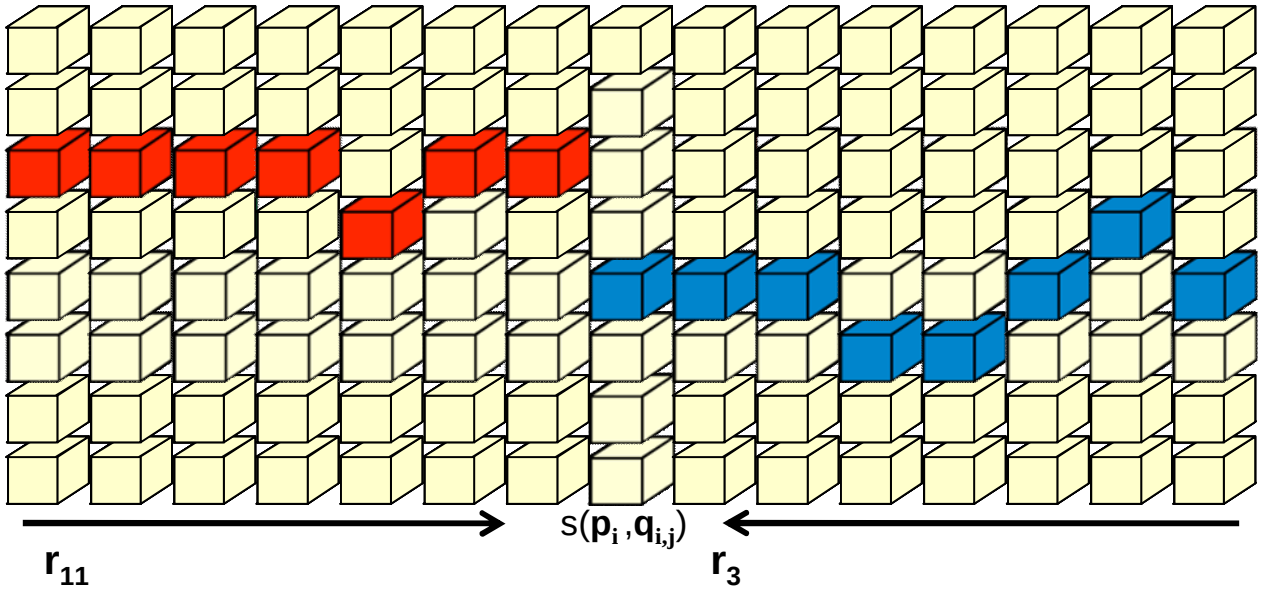
Algorithm - Semi Global Matching

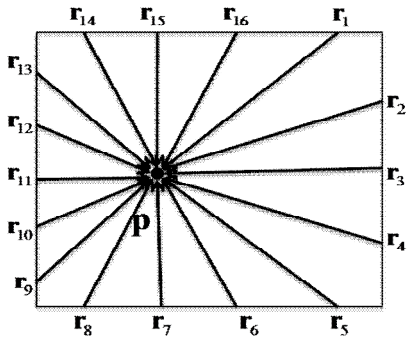
- Goodness of the assignment of a base image pixel $\mathbf{p}_i$ and a potential correspondence in the match image $\mathbf{q}_{i,j}$ is estimated by a cost function $c(\mathbf{p}_i, \mathbf{q}_{i,j})$
- For each base image pixel $\mathbf{p}_i$ and its potential correspondences in $\mathbf{q}_{i,j=1,\ldots,d}$ the matching costs are assigned to a 3D cost structure
- Problem: Cost minima are not distinctive and result in wrong disparity esti



SGM – Cost Accumulation

- Solution: Final matching costs $s(\mathbf{p}_i, \mathbf{q}_{i,j})$ are derived by accumulation of minimal costs along 16 image paths
- Penalty terms are introduced to force proximate disparities to be smooth

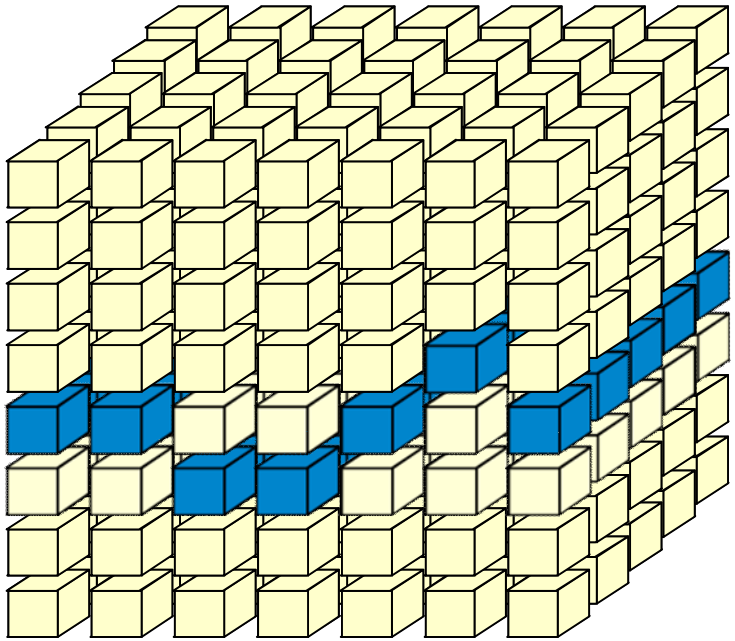


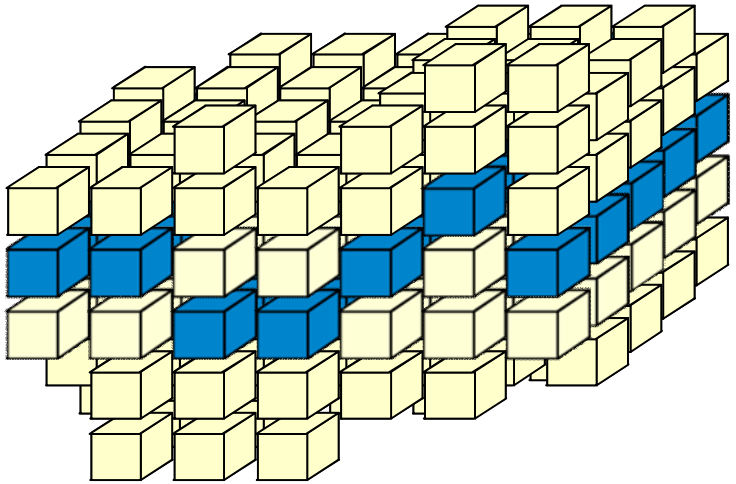


- Minimum $\min(s(\mathbf{p}_i, \mathbf{q}_{i,j}))$, $j=1\ldots n$ determines the final assignment $(\mathbf{p}_i, \mathbf{q}_i)$
- Result: Parallax image

Generation of point clouds and DSM

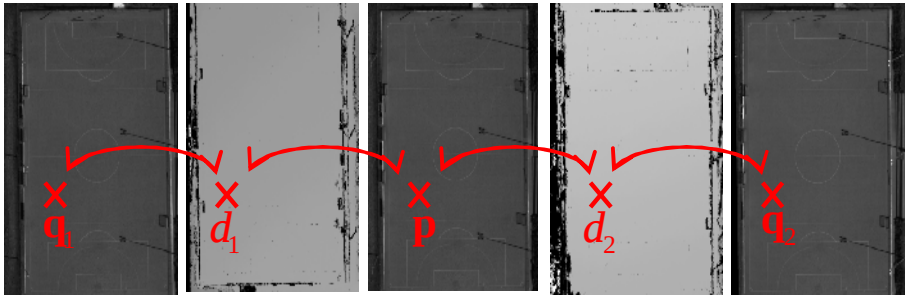
- Hierarchical approach: dynamically adapt disparity search range using disparity estimations of matching the previous pyramid level





Generation of point clouds and DSM

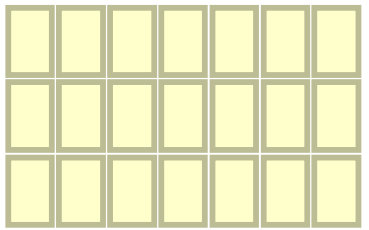
- Object point triangulation – Multi Stereo approach:
  - Matched based image against multiple match images, used redundant parallax estimations



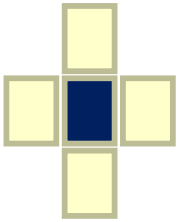
  - Mismatches are rejected by evaluating their consistency in object space
- DSM generation
  - Triangulated object points were assigned to grid
  - If more than one point is assigned to grid cell Z-components are averaged
  - Cells to which no points were assigned were interpolated

Results of Dataset ‘Vaihingen Enz’

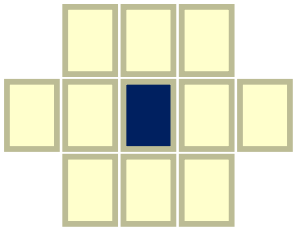
- UltraCamX , ground sampling distance: 0.08m, 16bit
- Overlap:
  - front/back 80%
  - right/left 70%
- Block structure of provided 21 images:



- Used matching configuration:
  - -> 64 image pairs matched



- Possible configuration:



Base Image

Match Image

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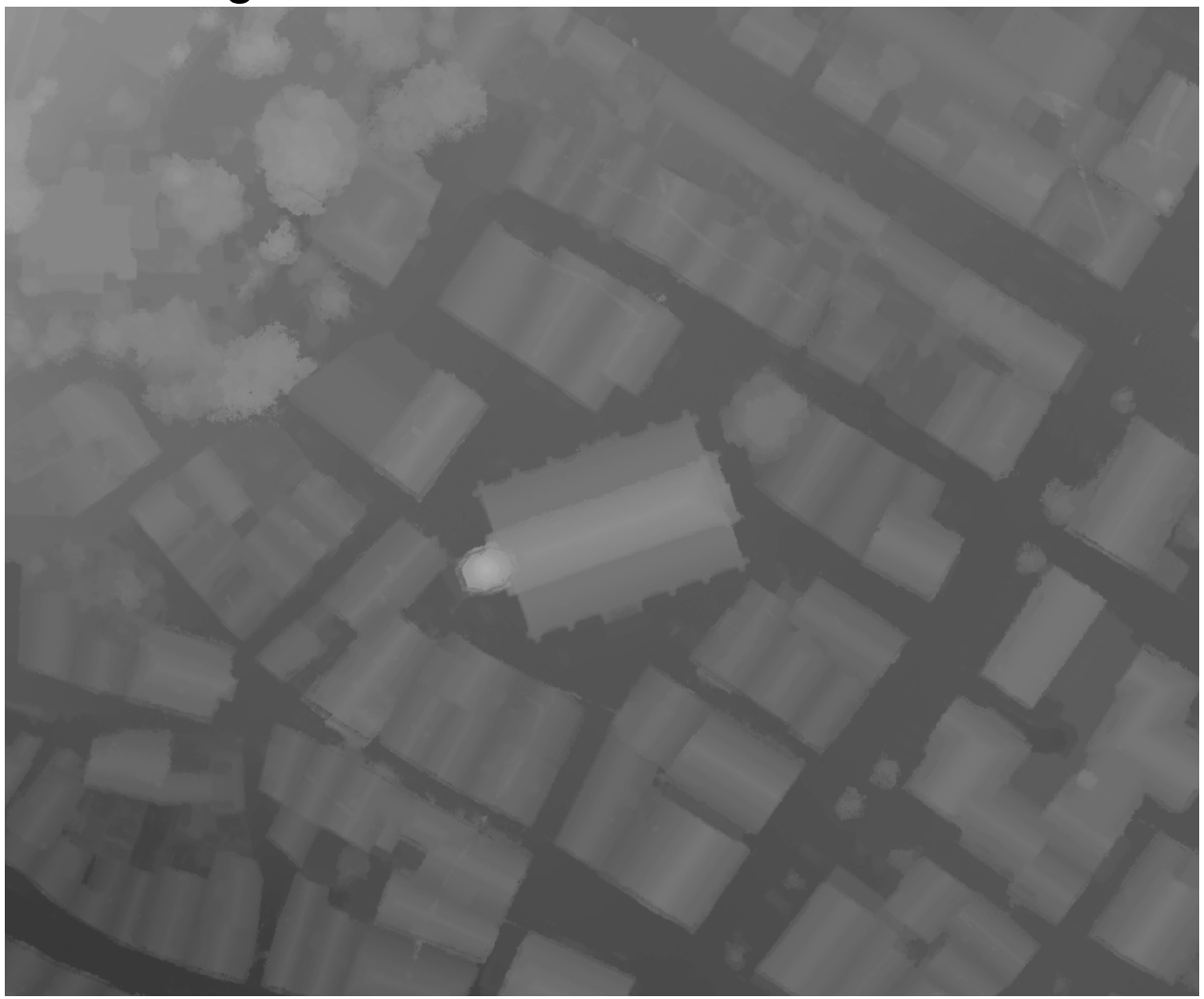
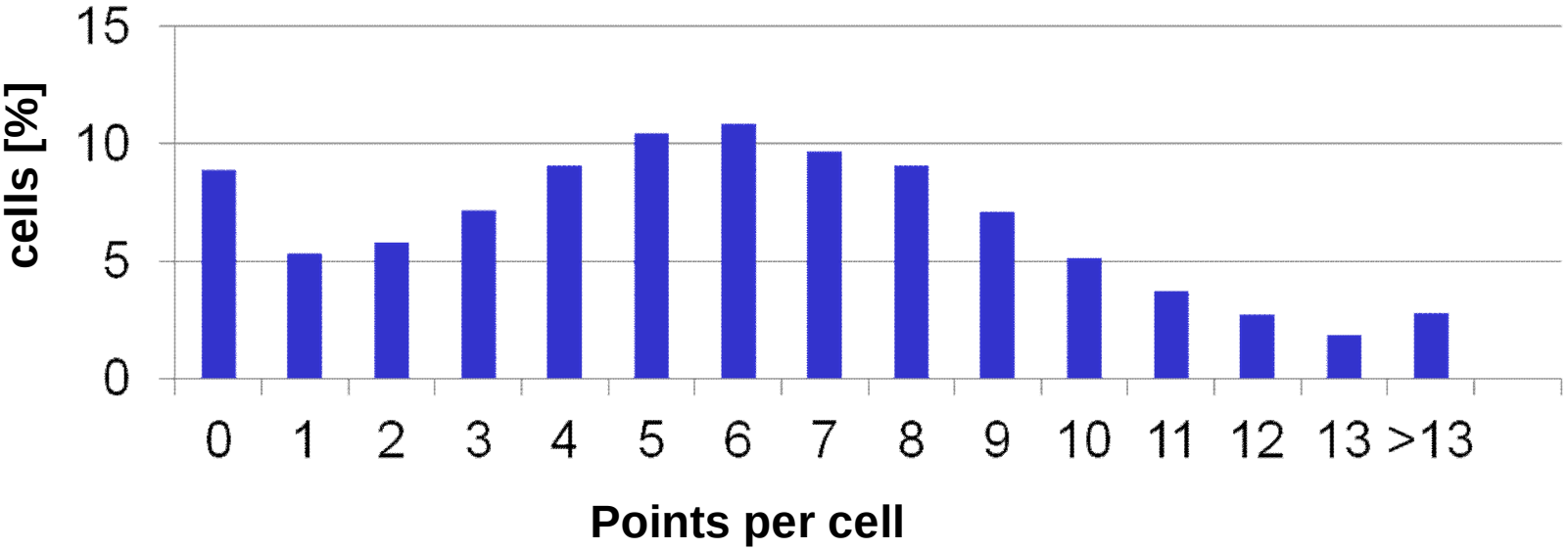
Results of Dataset ‘Vaihingen Enz’

- Resulting DSM



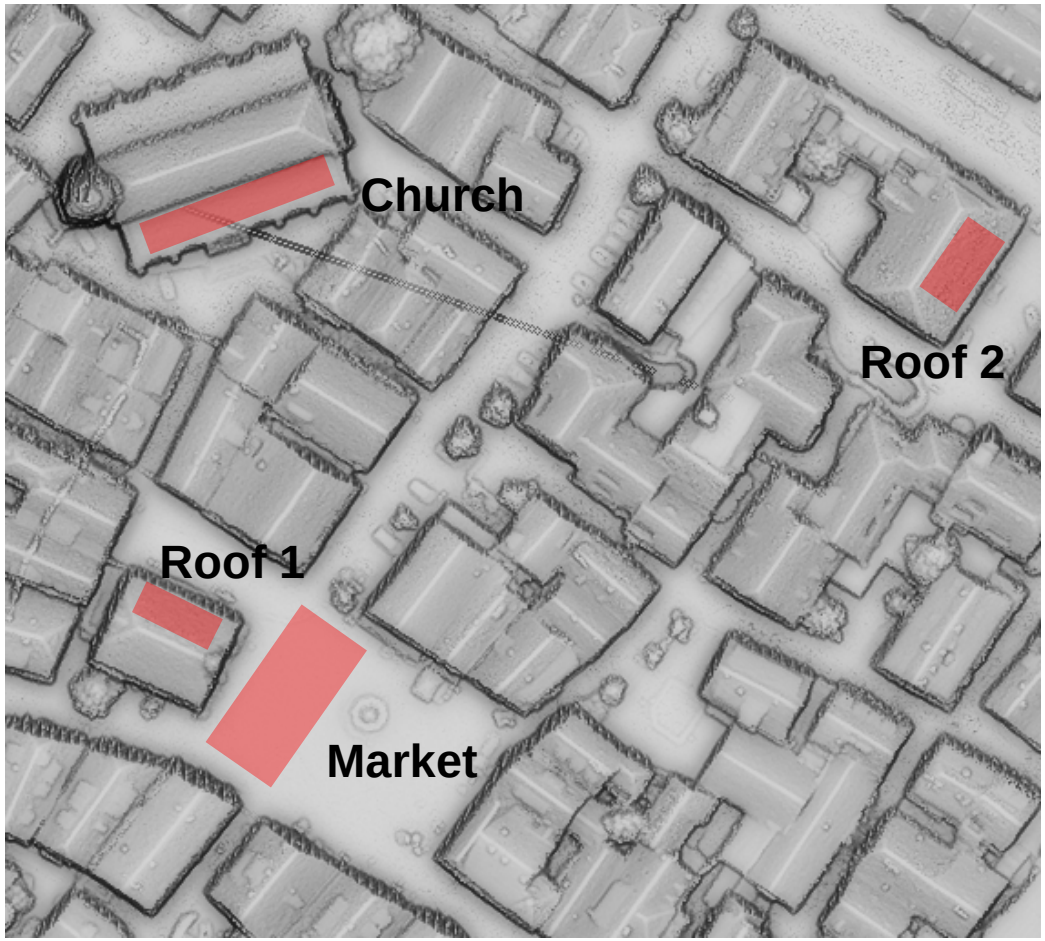
Results of Dataset ‘Vaihingen Enz’ – Point Densities

- Percentage of cells for which height value is available: 91.1%
- Average number of points in grid cell: 7.5



Results of Dataset ‘Vaihingen Enz’

- Accuracy of surfaces by evaluation planes fitted into point patches cut from generated point clouds



RMSE of point-to-plane residuals:

Church: 4.5cm

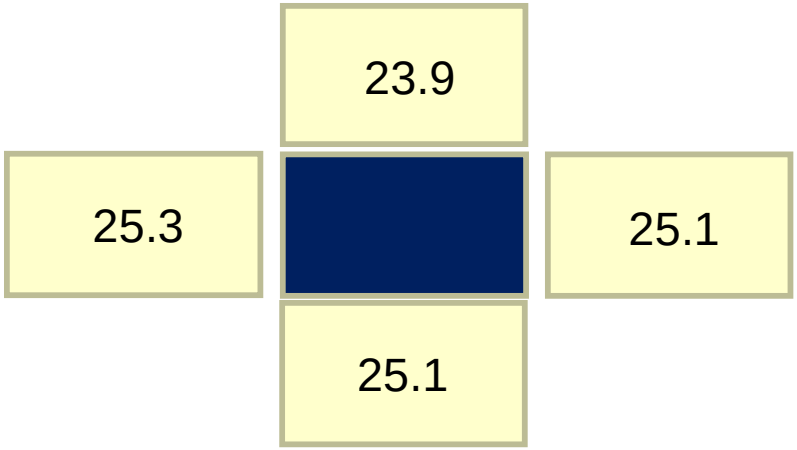
Market: 3.4cm

Roof 1: 2.4cm

Roof 2: 23.9cm

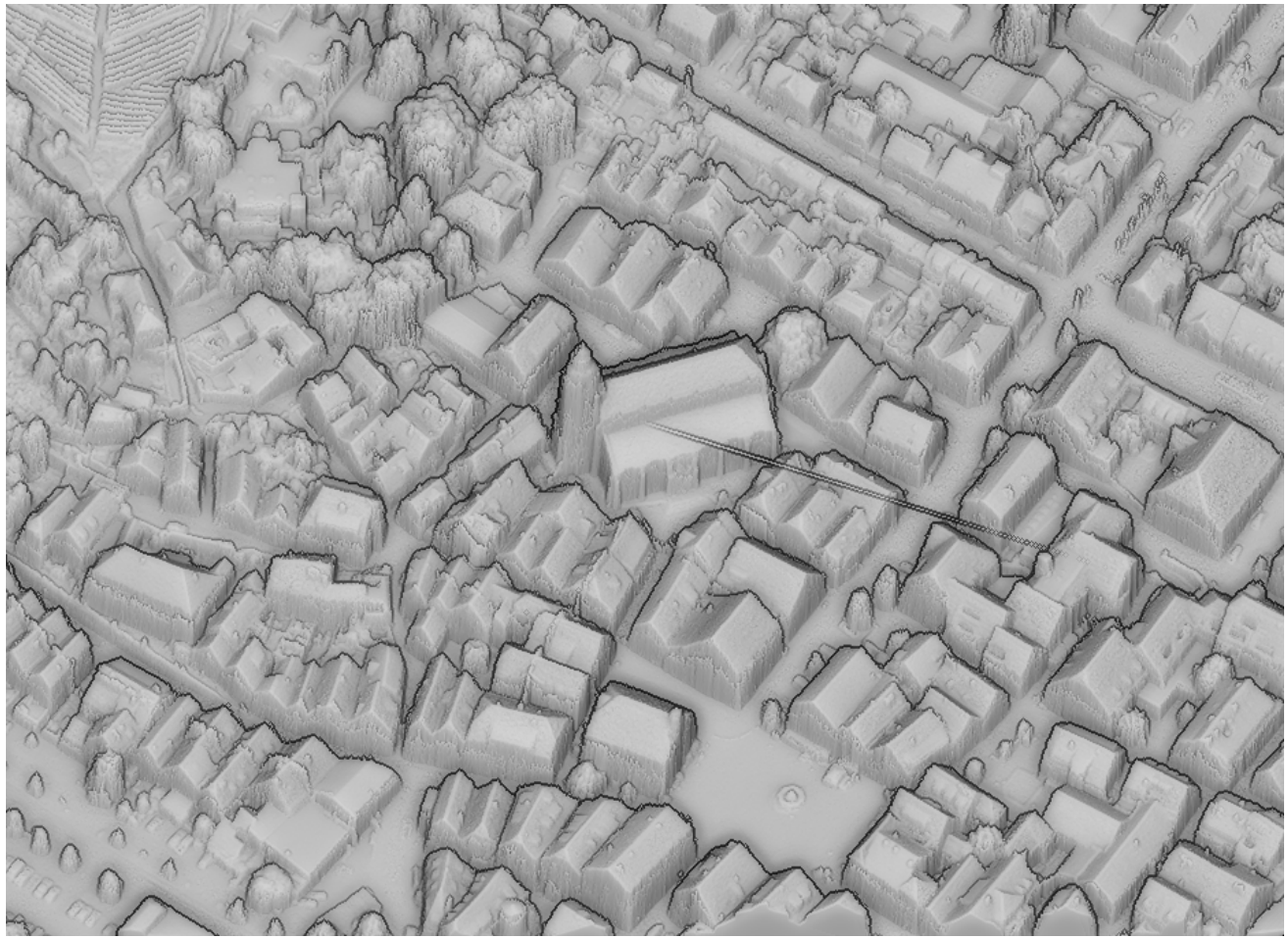
Results of Dataset ‘Vaihingen Enz’ – Computation Times

- CPU: i3, dual core, 3.07GHz
- Computation time for exemplary configuration (in minutes):



- Computation time for all images: 26.5 h
- Average computation time for single image 1.3h

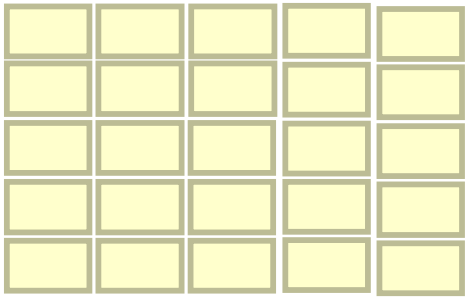
Results of Dataset ‘Vaihingen Enz’



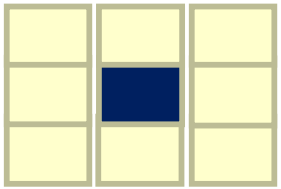
- Detailed surface
- Sometimes sharp roof break lines hindered due to reconstructed facade points and interpolation errors

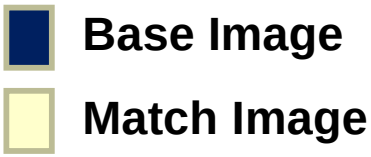
Results of Dataset ‘Marseille’

- DMC, ground sampling distance: 0.1m
- Overlap
  - Front/back 60%
  - Right/left 60%
- Block structure of provided 25 images:



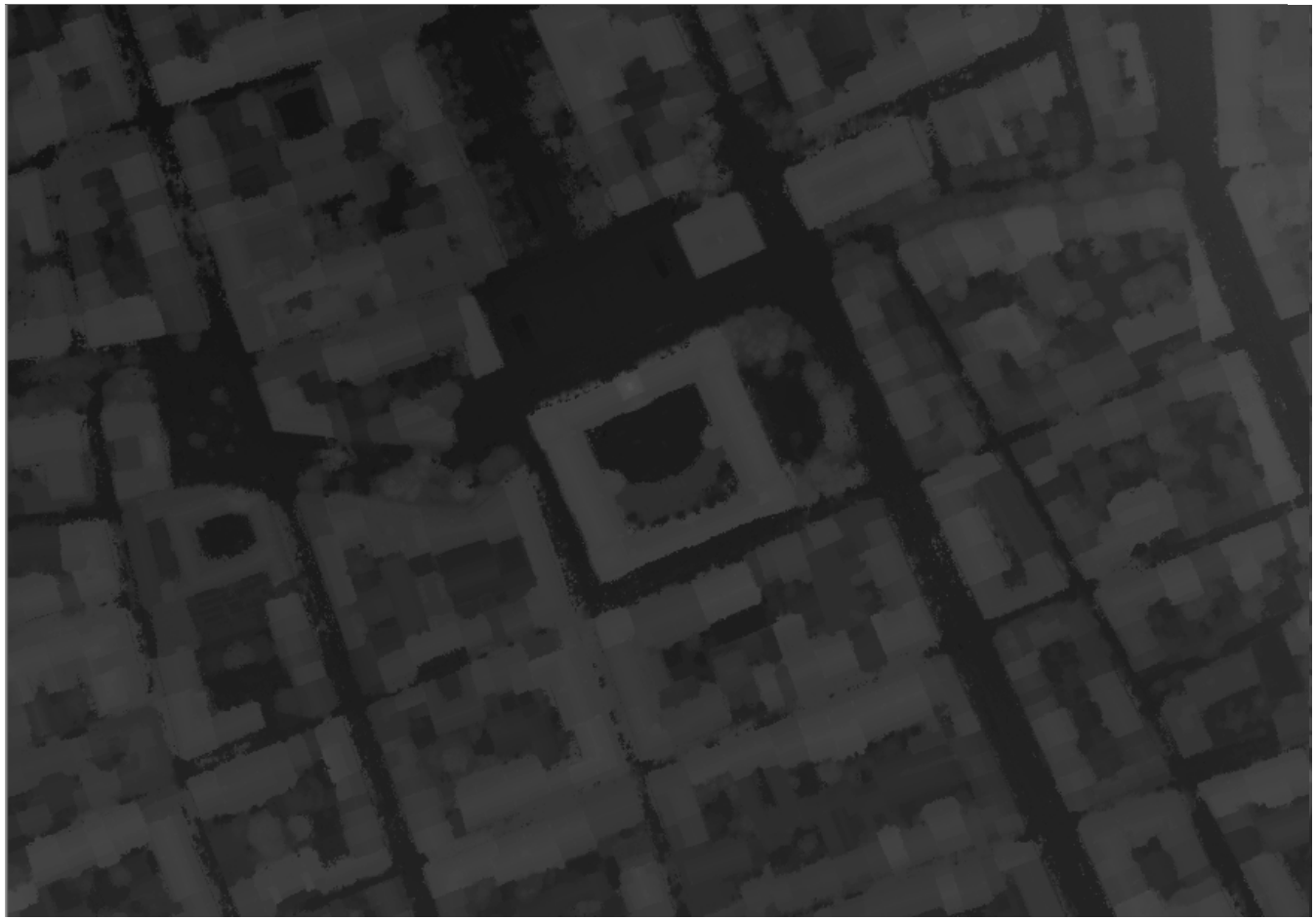
- Used matching configuration:
  - -> 144 image pairs matched





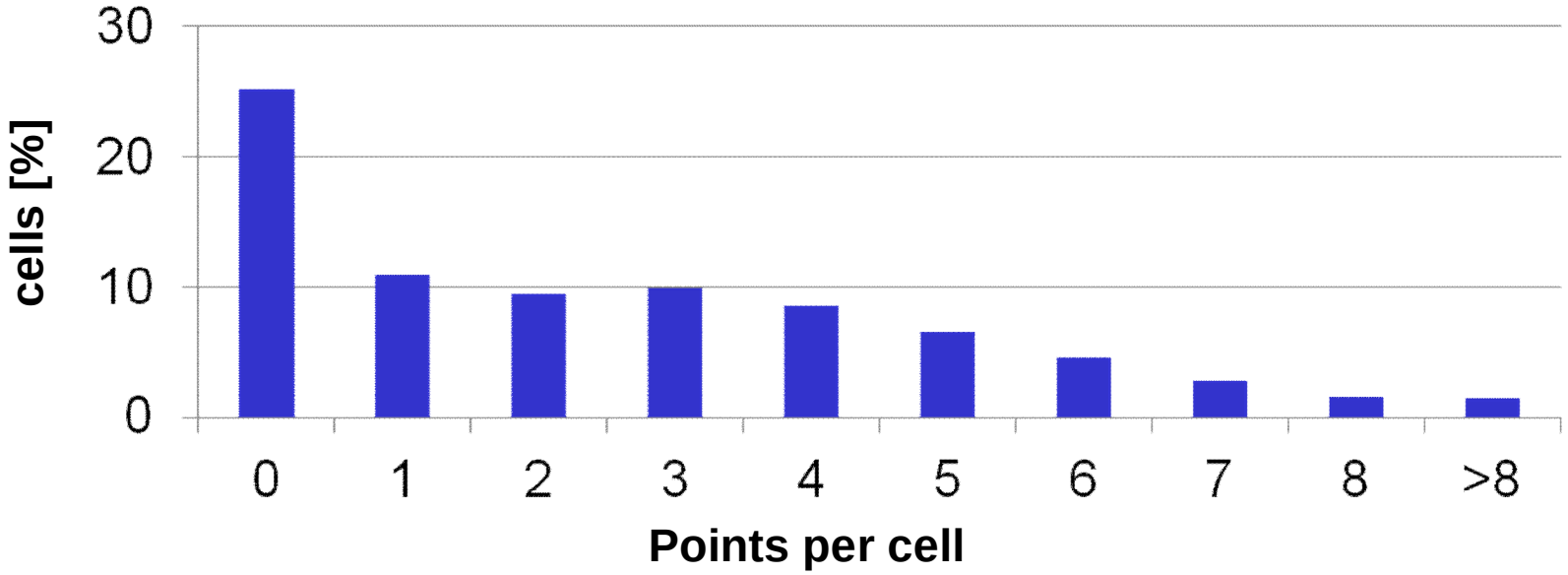
Results of Dataset ‘Marseille’

- DSM



Results of Dataset ‘Marseille’ – Point Densities

- Percentage of cells for which height value is available: 74.8%
- Average number of points in grid cell: 3.4



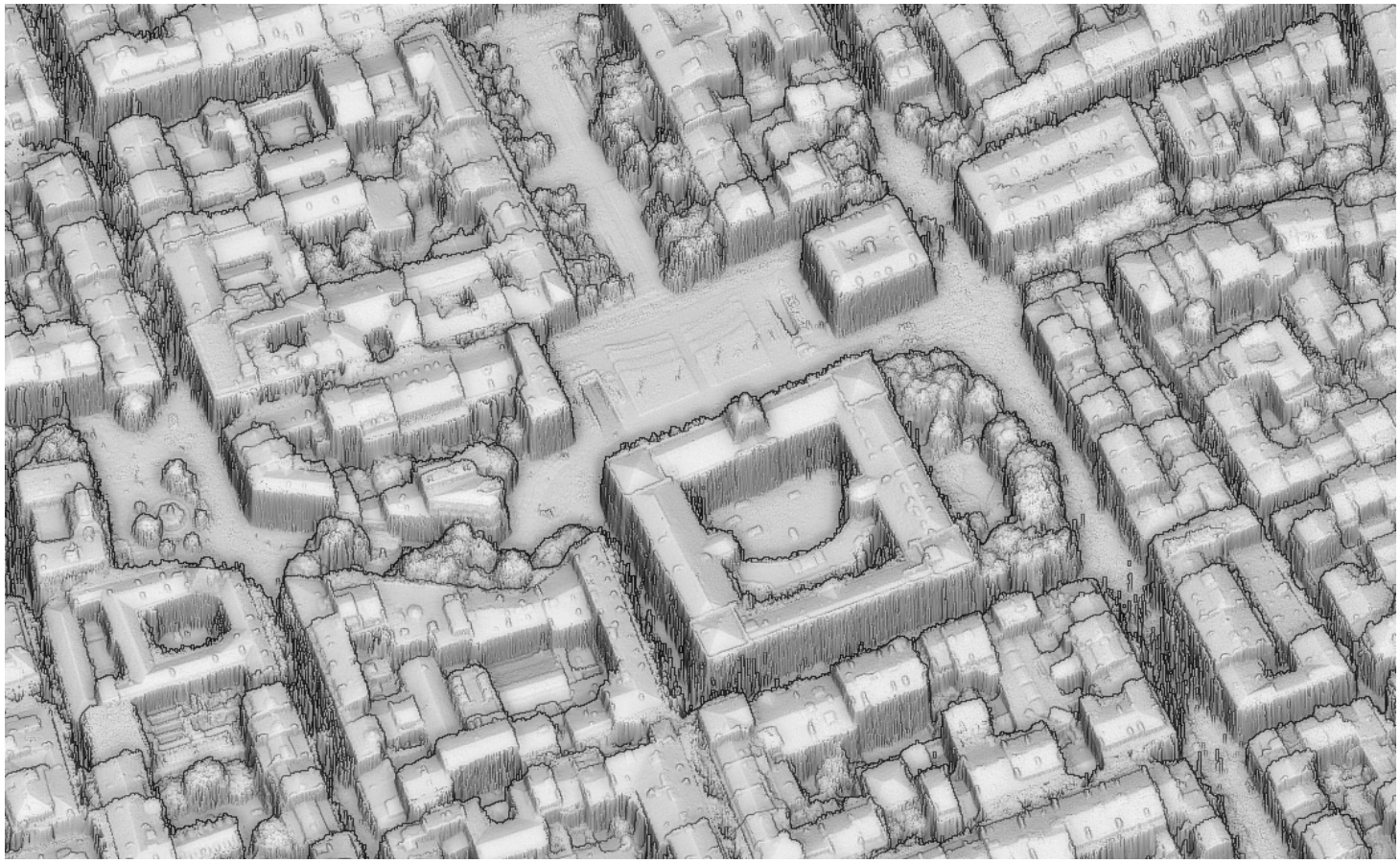
Results of Dataset ‘Marseille’ – Computation Time

- CPU: i7, quad core, 3.4 GHz
- Computation time for exemplary configuration (in minutes):

23.3	17.1	22.4
17.4		17.3
23.9	17.9	23.0

- Computation time for all images: 47.9 h
- Average computation time for single image: 1.9 h

Results of Dataset ‘Marseille’



- Roof surfaces ok
- Major interpolation errors in narrow streets providing only low point density due to occlusion
- Unfiltered mismatches caused by low texture in narrow streets

Problems and Possible Improvements

- **Main Problems**:
  - Matching problems in narrow streets due to occlusions and low texture
  - Problem of 3 dimensionality: Reconstructed facade points hinder sharp steps in height

- **Possible improvements:**
  - Tune smoothness parameters to match roof break lines more reliably
  - Implementation of a smarter interpolation techniques for DSM generation

Thank you for your attention! Questions?