Context-based urban terrain reconstruction from UAV-videos for geoinformation applications

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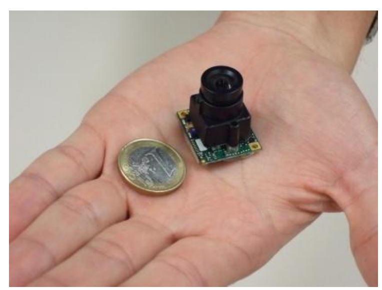
Introduction: Sensors

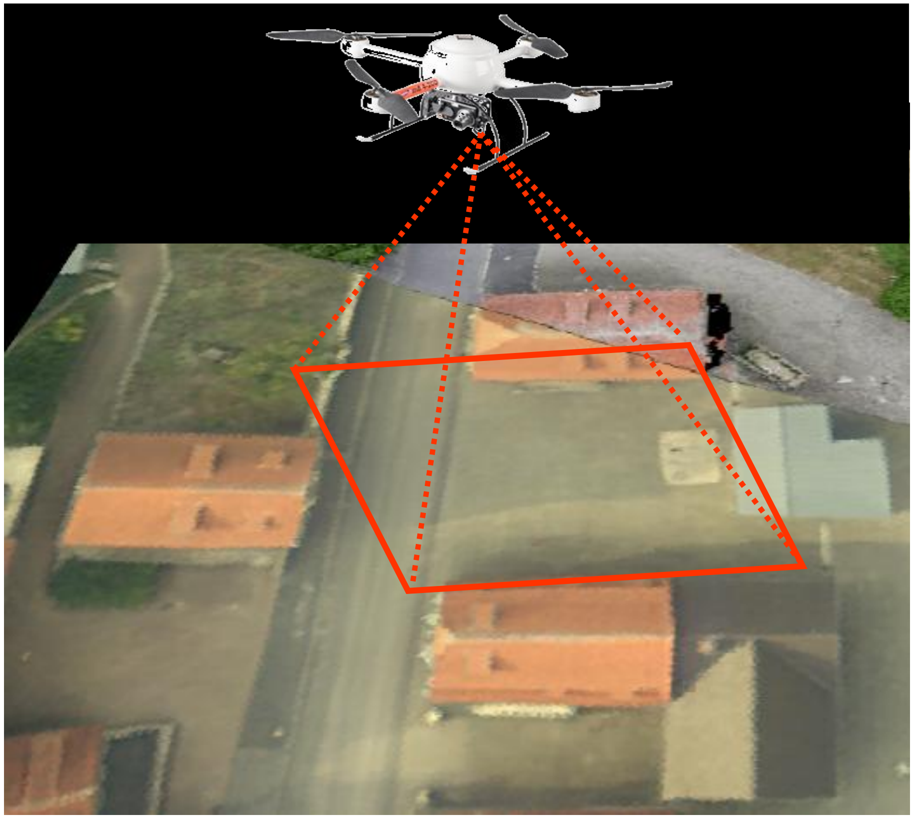
With daylight or infrared camera onboard

Reduced to minimal weight → GPS-data often not available

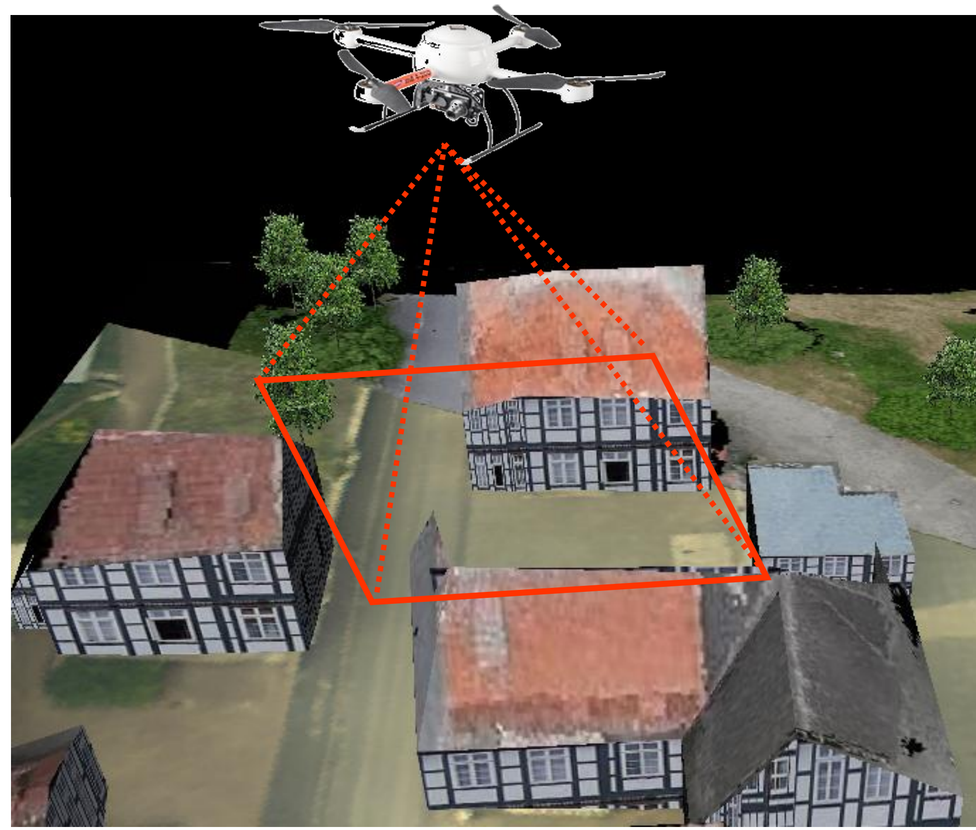


Introduction: Example of a mUAV-video

Introduction: 2D or 3D?



Our previous work (Solbrig et al. 2008)



Current work

Overview of the procedure

Step 1: Computation of camera orientation parameters

Step 2: Depth maps extraction

Step 3: Urban terrain reconstruction

Step 4: Registration and geo-referencing

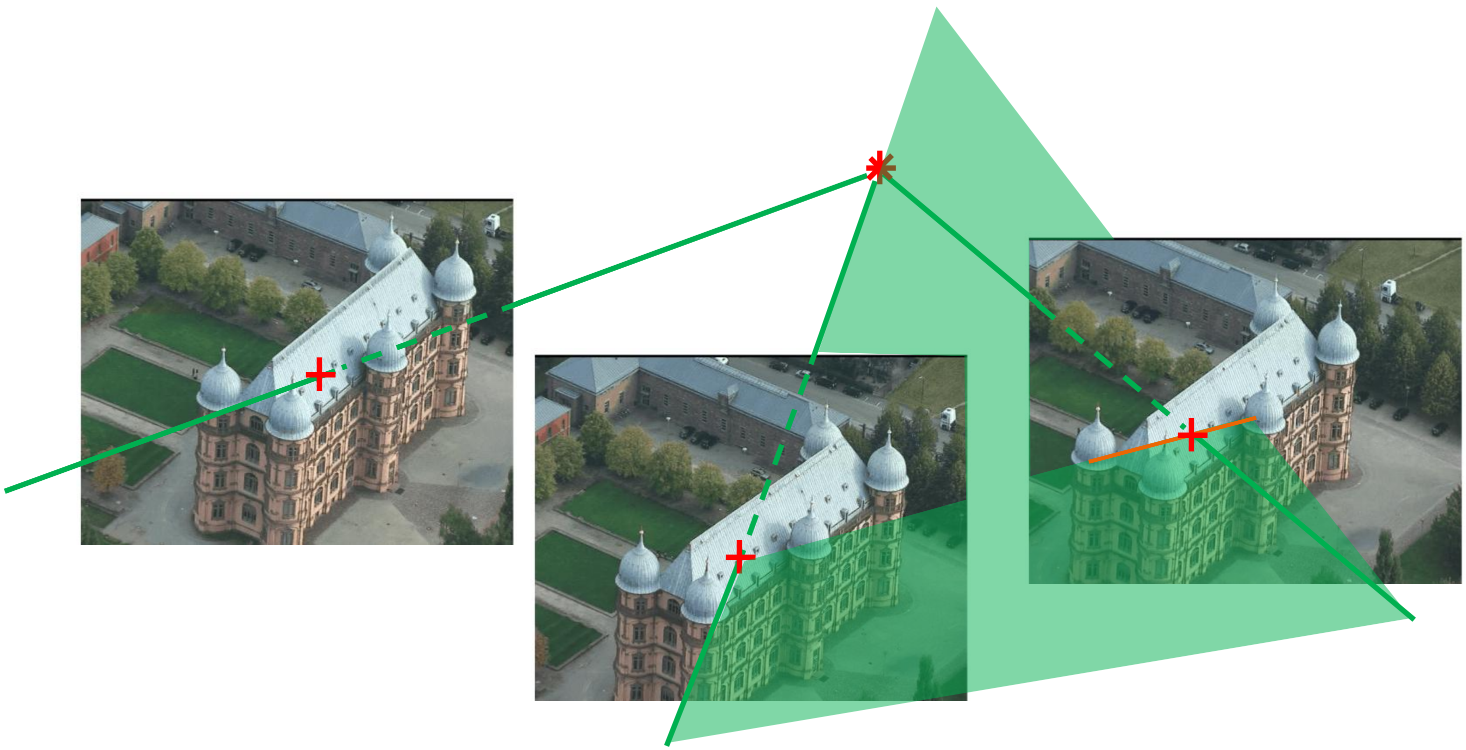
Step 1: Orientation

Computation of camera orientation parameters and a sparse 3D point cloud by means of a structure-from-motion approach (Bulatov 2008)

- Detecting and tracking characteristic points from frame to frame
- Computation of fundamental matrices and 3D points in a projective coordinate system (triangulation)
- Computation of camera matrices in the same coordinate system (camera resection)
- Self-calibration → transformation into an Euclidean coordinate system
- Bundle adjustment

Step 2: Multi-view depth map computation

Given a subsequence of 5-10 images, compute for each pixel of the reference frame the depth value of the corresponding 3D point:



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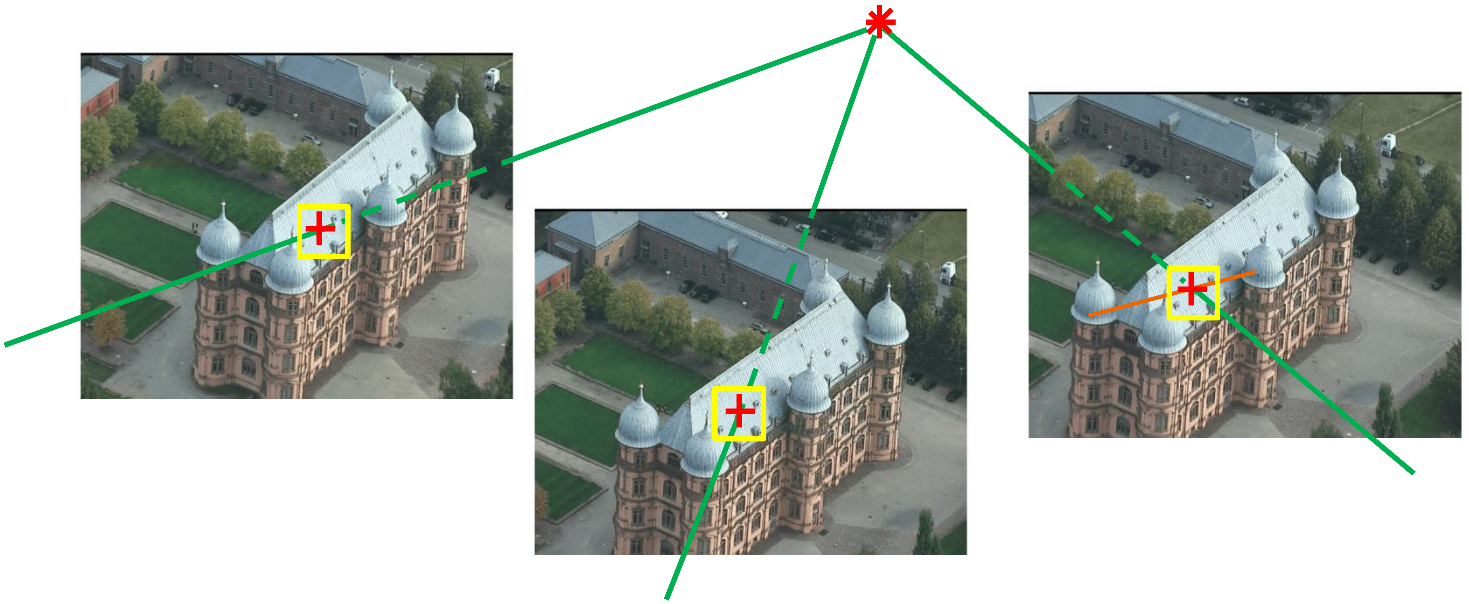
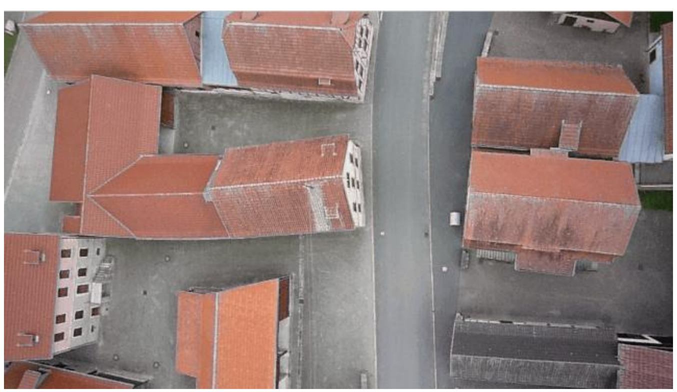
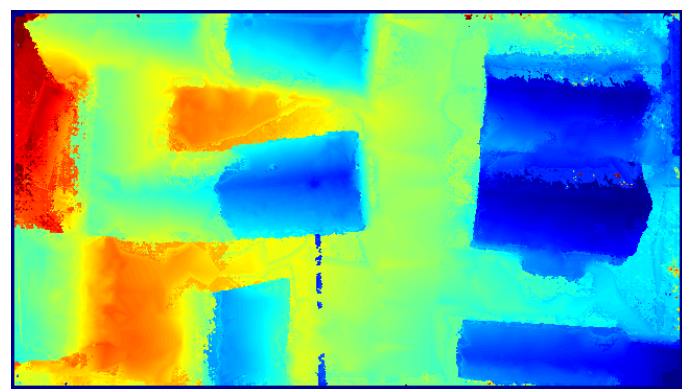


Step 2: Multi-view depth map computation

Our approach (Bulatov et al. 2011):

- Depth values discretization
- Data cost computation (e.g. gray values difference) and aggregation of low cost values
- Triangle-based smoothing (towards the depth map based on the triangular interpolation from already available 3D points)
- Semi-global optimization with 16 smoothness paths (Hirschmüller, 2005)
- Evaluation on triangles





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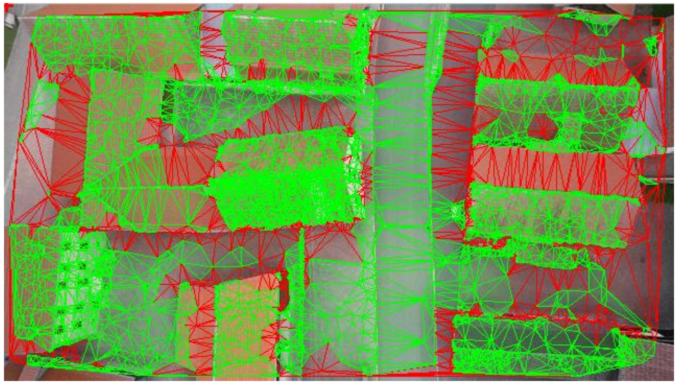
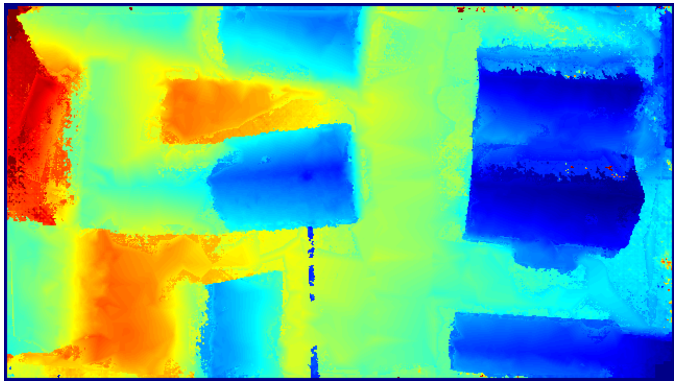
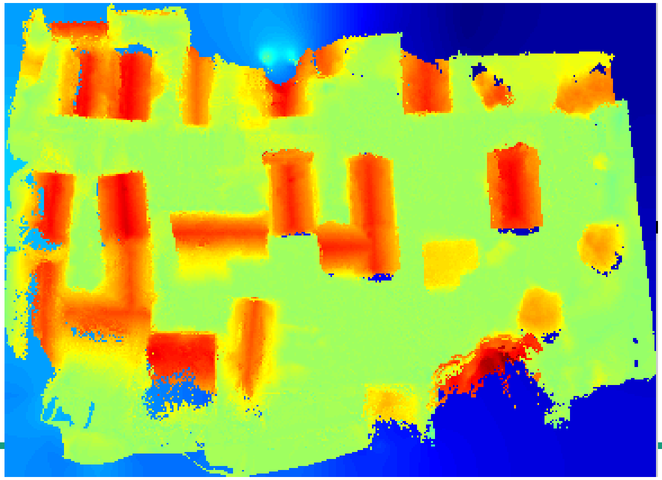




Step 3: Urban terrain modeling

Texture image rendering, DTM and DSM generation

- DSM generation with the median value of the *z*-coordinate in each cell of a rasterized image $z(x, y)$, the same with the texture image
- DTM is obtained by setting ground cells and then minimization of a suitable functional (our current choice: Neumann differential equation with border condition)
- Cells that satisfy the condition DSM – DTM > threshold are supposed to belong either to buildings or to vegetation



Step 3: Urban terrain modeling

Identification of vegetation

- Straight lines computation (Burns et al. 1986) in reference images
- Each region R is assigned *lineness*-measure $lm(R) = {}^{1}\!/\!\sqrt{\text{area}(R)} \sum_{l \in \underline{R}} \text{length}(l)$, so that isolated trees are given low lineness measures
- Identification of tree-like pixels by means of color distribution

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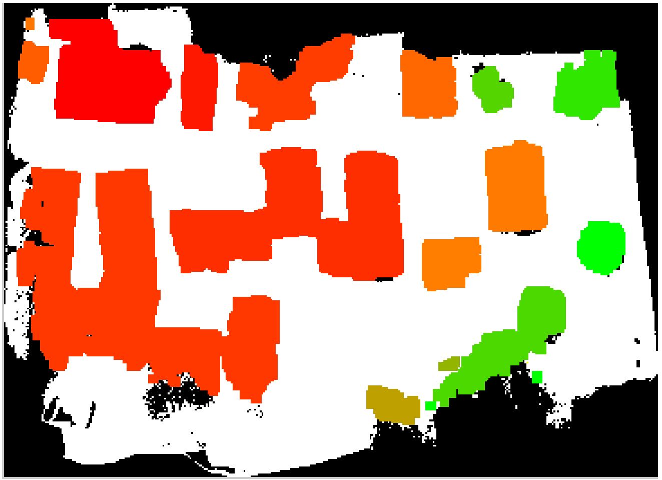
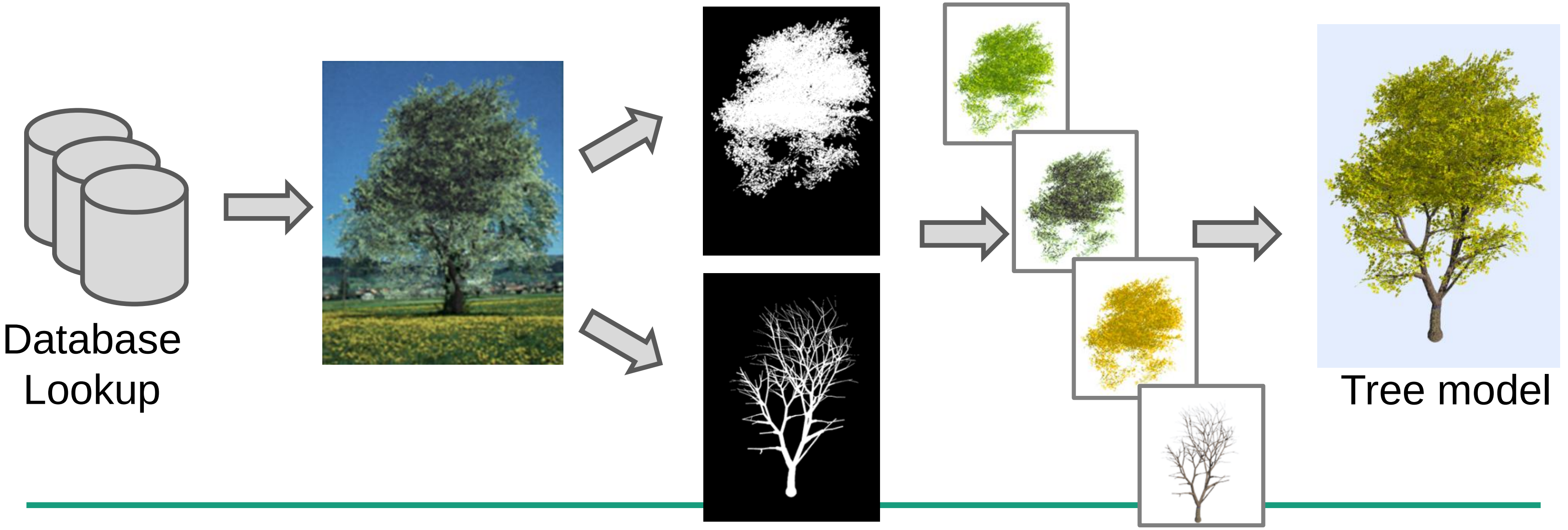


Step 3: Urban terrain modeling

Modeling Trees

- Default: Creating an artificial image where all pixels that do not belong to the tree are completely transparent, then superposition of 2-3 such images
- Database lookup (search for an appropriate model), model representation, and model adaption (e.g. seasonal changes) are optionally possible
- Height of the tree is given by the DSM



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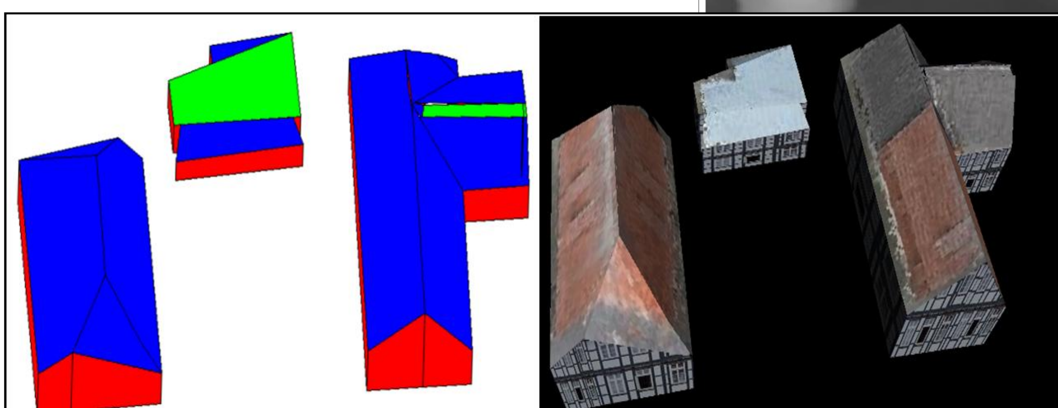
Step 3: Urban terrain modeling

Modeling buildings (Groß et al. 2005)

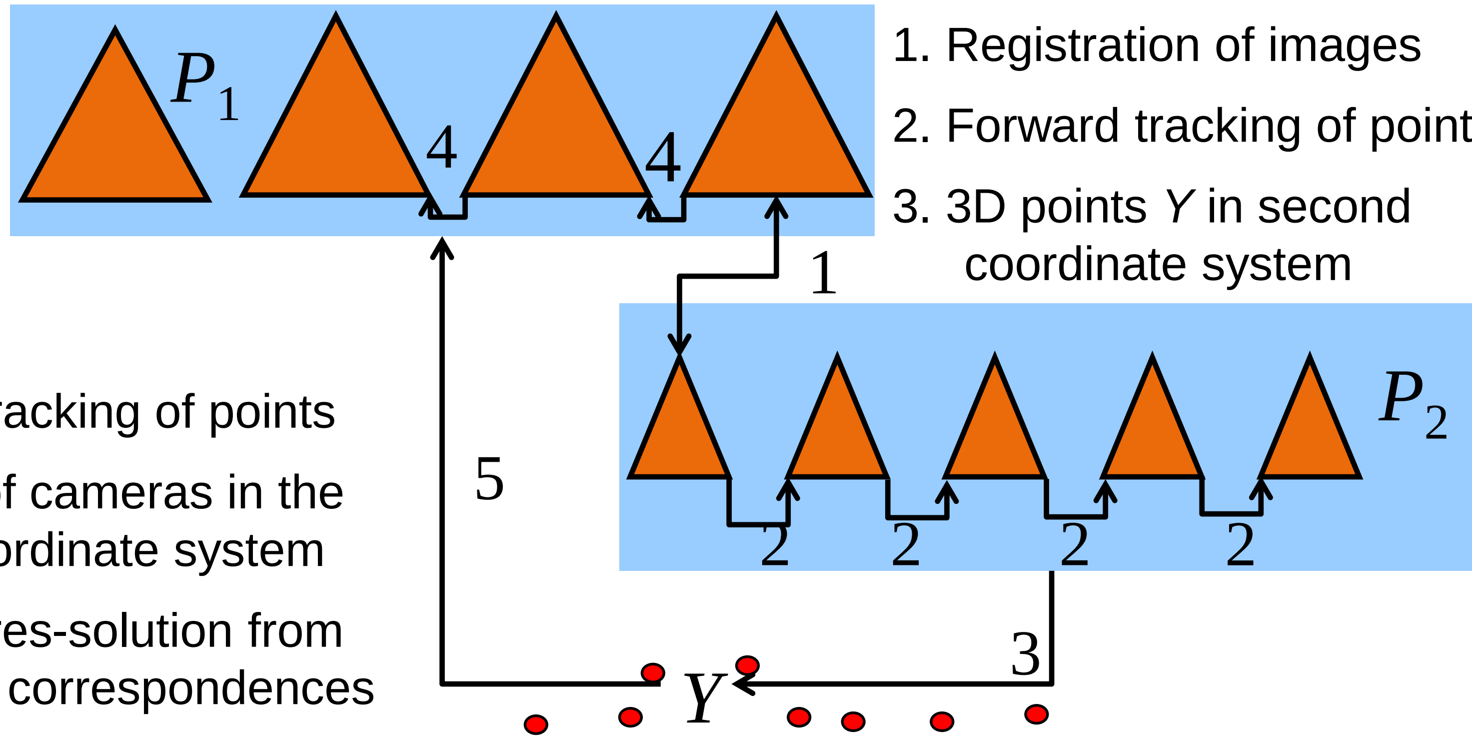
- Description of building outlines with rectangular polygons
- Roof detail analysis by means of normal vector computation and clustering, morphological operations and polygonization of roof surfaces
- Texturing



Step 4: Registration and geo-referencing

Registration of two different UAV-flights

- In absence of any internal navigation data, it is possible to obtain the spatial transformation connecting two Euclidean reconstructions from a pair of images covering the same region of the terrain.



1. Registration of images
2. Forward tracking of points
3. 3D points *Y* in second coordinate system
4. Backward tracking of points
5. Resection of cameras in the second coordinate system
6. Least-squares-solution from ≥2 camera correspondences

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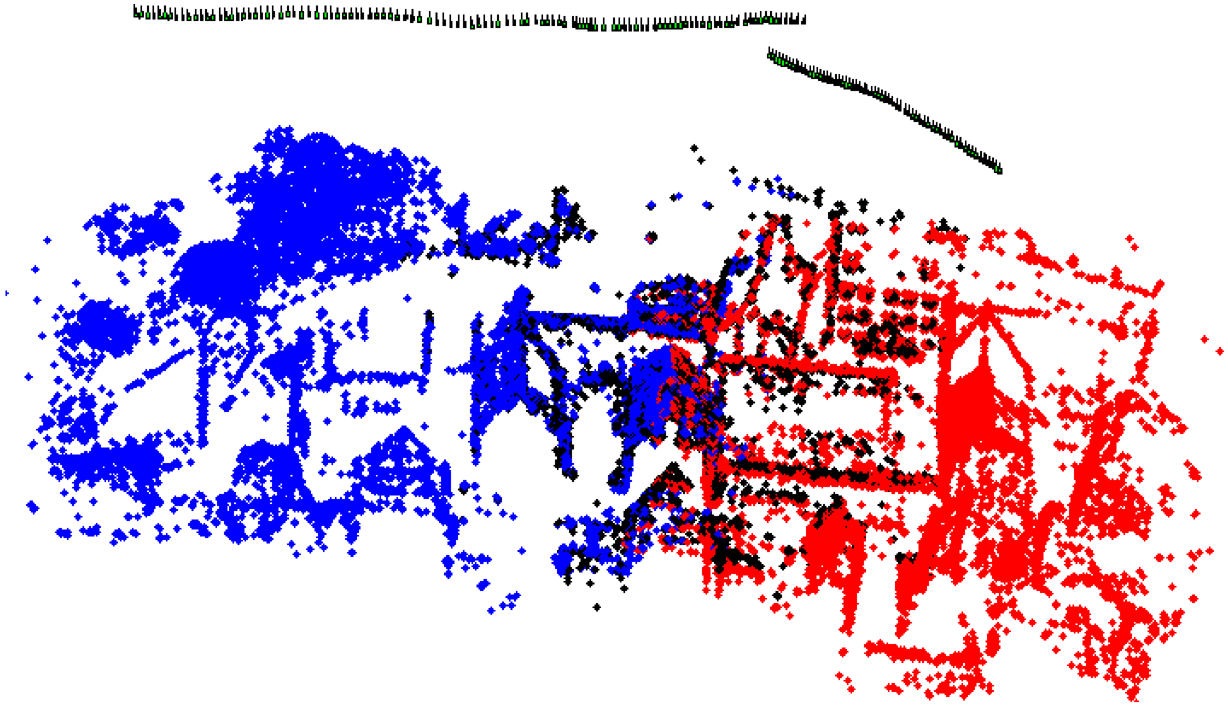

Step 4: Registration and geo-referencing

Automatic geo-referencing of the synthetic color image

- In case of Nadir videos, a 2D homography is a suitable registration tool with an orthophoto
- Because of different radiometry, a descriptor-based approach must be applied. Our choice: (Shechtman and Irani 2007)

Result

Outlook

- Quantitative evaluation of several reconstruction procedures
- Applications of 3D urban terrain reconstruction (e. g. change detection)

Conclusions

- A robust procedure for geo-referenced urban terrain modeling from UAV-based Nadir videos has been developed at Fraunhofer IOSB
- It is possible to model DTMs, buildings and vegetation. These components are easily exchangeable depending on season, day-time etc. This makes our tool suitable for AR and VR applications
- The modular structure of the procedure allows modifying parts of the programs without dismissing the entire concept
- Integration of new sources of information (GIS-data, short-wave infrared, LIDAR point clouds etc.) is suggestible
- Geo-referencing and parameter choice still require user's interaction, but these draw-backs can be corrected in the future

References

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