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The 4D-CH Calw Project – Spatio-temporal Modelling of Photogrammetry and Computer Graphics

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ABSTRACT

The 4D -Cultural Heritage Project takes advance of Imagery from the wild (Internet) and existing repositories to reconstruct 3D Models of Monuments, Places and Landscapes. This method however can not always reproduce a complete dataset of an object since the obliged views are depending on the prominent positions of the recording. We would like to present two different approaches to a work-flow which overcomes this issue through a semi – automated reconstruction as well as the use of simulation with a grammar based modelling.

1. INTRODUCTION TO THE 4D-CH PROJECT

The advent of technology in digital cameras and their incorporation into virtually any mobile device has led to an explosion of the number of photographs taken every day. Today, the number of photographs stored online and available freely has reached unprecedented levels. It is estimated that in 2011, there were over 100 billion photographs stored in just one of the major social media sites. This number is growing fast. Moreover, advances in the fields of Photogrammetry and Computer Vision have led to significant breakthroughs such as the Structure from Motion algorithm which creates three-dimensional models of objects using their two-dimensional photographs. The existence of powerful and affordable computational machinery has now made possible not only the reconstruction of complex structures but also entire cities.

2. THE CASE STUDY OF THE CITY OF CALW

Within the 4DCH project, the city of Calw has been chosen as a test site for 3D reconstruction where different approaches were applied to model the central square of the settlement in different time settings (see Dieter Fritsch and Michael Klein, 2014). According to the project plan not only the central square of the town, but also the somewhat larger historical settlement core was modeled.

The results will be made accessible in an interactive virtual 3D realtime environment, powered by a game engine allowing the user to walk or fly-through the 3D model of the settlement and retrieve additional information on places and buildings on his demand. Further the switch into different time periods of the environment or a building will be possible depending on the accuracy and quantaty of the source material which is necessary to model out the complete set of structures.

3. PRODUCTION PIPELINE FOR (MODELLING FOR 3D REALTIME AND VR ENVIRONMENTS)

The results of a computer generated 3D model through SfM and/or dense matching is bound to the quality and quantity of the source images available. It reflects the time epoch for which all images were taken. Missing features of a model as well as anomalies in the resulting 3D model can be substituted through a camera matched, manual modelling approach. This technique also allows the

3D reconstructions using historic photos. However, the results obtained might be subjective and are depending on the operator's personal perception and his skills in 3D modelling. Nevertheless a comparison between a SfM calculated structure and the para-metrical model can lead to an adequate accuracy level. As once defined by Paul Debevec (1996), an expert of computer vision, his interpretation of photogrammetry is as follows: "A method for interactively recovering 3D models and camera positions from photographs."

The modern digital breakthrough work done by Debevec, part of the Computer Vision Group at the computer science division of UC Berkeley, was the first research that raised interest in photogrammetry as a tool for architectural reconstruction from a single view source.

Through the manual alignment of the vanishing points in an image its distortion and perspective can be used to calculate the position of the camera which collected it. Using the alignment of the camera the geometry can be adjusted to fit to the camera matched image in the background through orthogonal translations and extrusions respecting the coordinate system of the modelling environment, modelling out the features of the desired structure.

In order to automate the process of image rectification one could also use the calculated camera positions generated by a SfM processing and therefore bypass the manual alignment of the vanishing points as described above, eliminating subjective factors in the rectification process. This however requires more than one view to allow for the the simultaneous image data processing in a bundle block adjustment.

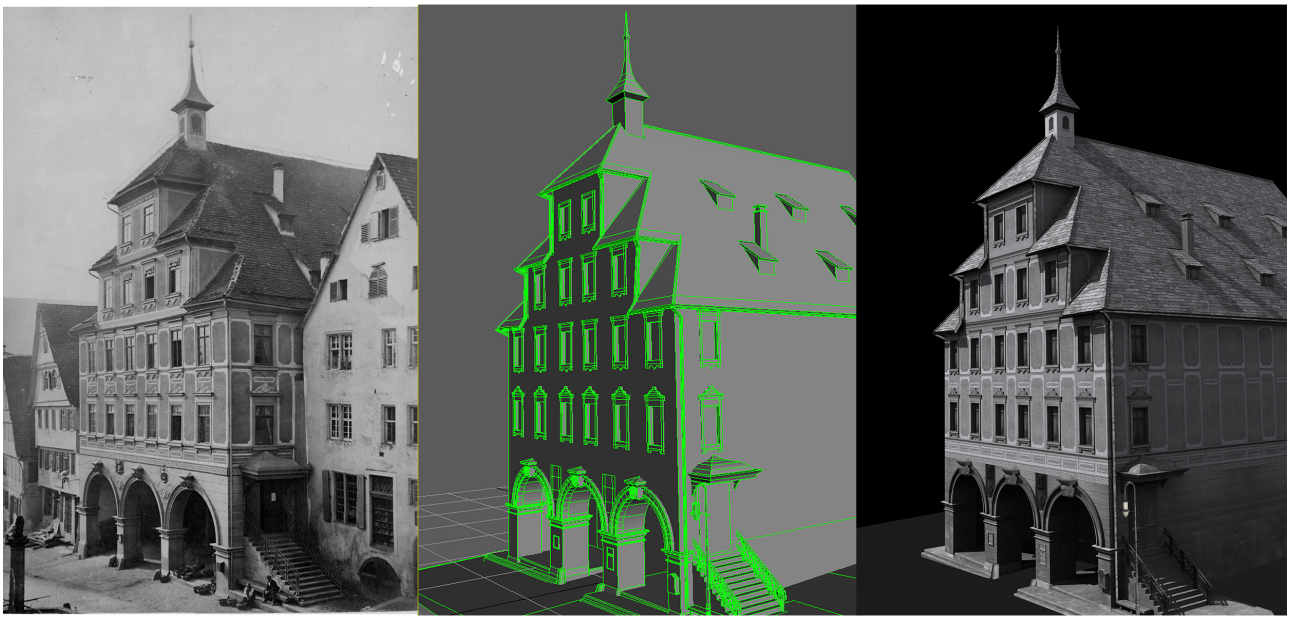


Figure 1: Historical Image and the resulting 3D Model of the City Hall of Calw.

To illustrate this process we set up a test scene consisting a 3D model of the Hermann-Hesse Birthplace building, which was previously constructed through a manual camera match approach, from which several rendered images from different viewpoints were taken to provide a source for the SfM model generation. Any SfM sofware, such as VisualSfM, will deliver the camera positions, orientations and a sparse 3D model, which can be reimported to a 3D modelling program (eg. Autodesk 3ds Max). Inside the 3d modelling program one of the reconstructed camera views was chosen to verify the matching of the perspective with the background image, which served as a template for a newly constructed geometry, representing the outlines of the object (house). Since the constructed geometry, matched seamlessly with the vanishing points of the projected background image it can be confirmed that the camera match calculated from the SfM procedure is adequate for this purpose.

The accuracy of the models generated through this procedure is highly dependent on the comprehension, skills and precision of the modeller in charge. Using this modelling technique historical images or even illustrations can be used to recreate a periodic morphology of the chosen monument in order to compare the changes occurring in this time range. Utilizing the manual approach of 4D modelling together with other automated modelling techniques like laser scanning, SfM and dense image matching in combination, will lead to an optimized model of a monument, which can be produced and delivered for dissemination.

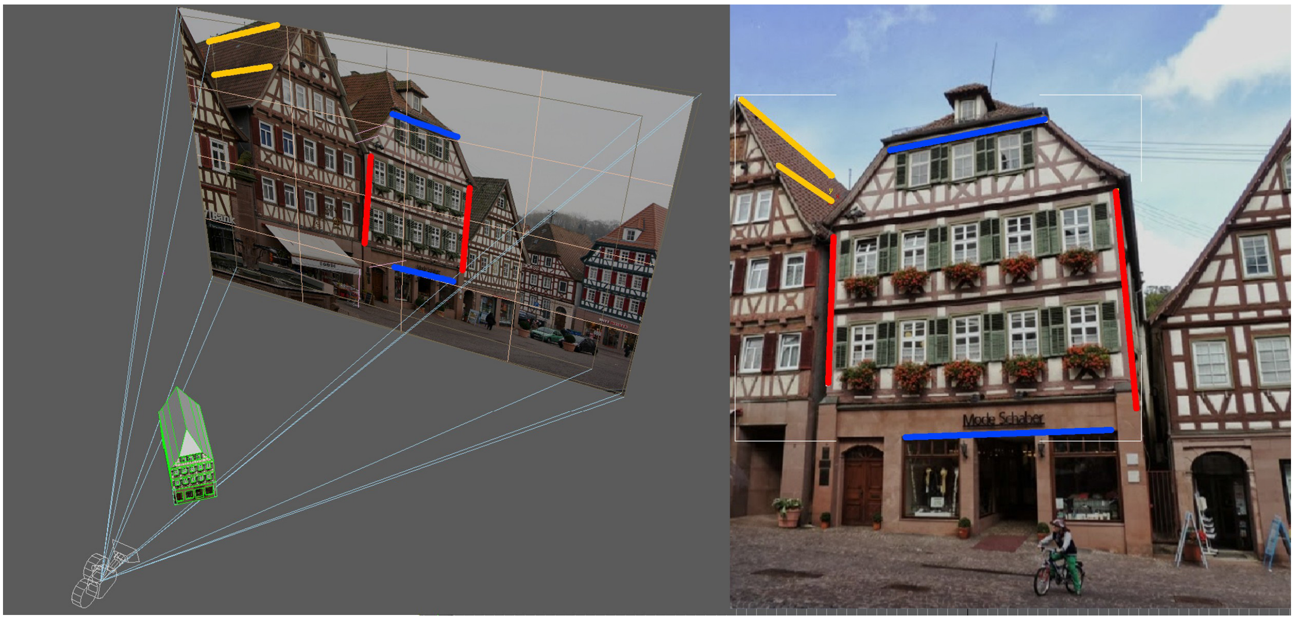


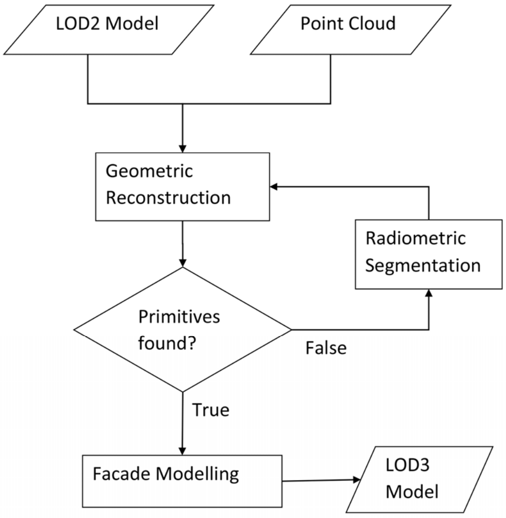
Figure 2: Set -up with the calculated camera position and the 3d Model of Hermann Hesses Birthplace.

4. OPPORTUNITIES USING GRAMMAR BASED MODELLING

It is obvious that computer algorithms will never reach the capability to reconstruct and model geometrically and semantically accurate buildings in a level of detail an experienced modeler with background knowledge of the target of interest can produce. Nevertheless, there are many cases where buildings have to be modelled with almost no data basis at all. Every time a building has not completely been covered by data acquisition methods regardless of whether LiDAR or image based, the modeler lacks of information for the remaining building. In these cases grammar-based model completion can be an opportunity, since knowledge from the existing reconstructed structure can be derived and architecturally consistent applied to the remainder of the building.

5. ALGORITHM OVERVIEW

Figure 1 gives an overview of the processing pipeline which is an extension of the work of (Becker, 2011), so that it is capable of generating and processing building models compliant with CityGML. A GUI was implemented which gives users the possibility to select façades of interest for the reconstruction process (Tutzauer and Haala, 2015). Coarse building model and point cloud serve as input for the geometric reconstruction. First a plane is fitted to the façade point cloud to perform a pre-segmentation into façade points and non-façade points. Additionally, a radiometric segmentation process is under investigation, which can bypass the initial geometric segmentation step if geometric data information is too limited.



Subsequently, horizontal and vertical edge points located at the borders of primitives like windows and doors are searched. By means of the extracted edges and the estimated window depth the coarse building model is divided into three dimensional cells. Initially, these cells only have geometric information and are then classified into façade and window cells with help of a point availability map. This results in the reconstructed façade (figure 2 top right), serving as input for a grammar based modeling approach. By horizontal and vertical divisions along the primitives and floors the façade is segmented into tiles. Tiles either contain a geometry object or consist of a homogenous wall part. Thereby tile strings emerge, which are further investigated. Different tile types are assigned with according symbols. The objective is to compress the tile string in a way that redundant sequences can be replaced by new symbols. This way hierarchical relations between the tiles become apparent and can be expressed as replacement rules and at the same time production rules can be derived. Subsequently, the façade grammar – represented by the entirety of afore-derived rules – can be used to model the remaining façades of a building synthetically, enriching it from CityGML LoD2 to LoD3.

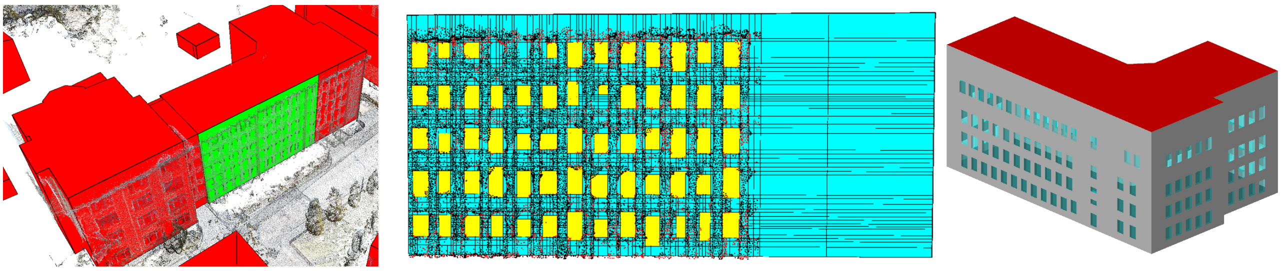


Figure 3: From Left to Right: Coarse building model with selected façade of interest, 3D cell decomposition with reconstructed primitives, enriched CityGML LoD3 model.

6. DISCREPANCY OF EXISTING DATA PRE AND POST PROCESSING

Within the photogrammetric and GIS community some standard data formats have established. For point based representation of data the las format is very common. For semantic building and city models the OGC standard CityGML is well-known. However, the computer graphics community deals with completely different data formats, such as Collada or 3ds max. Suitable data conversion therefore have to be performed to fuse information given by modelling exports with photogrammetric processing steps. Figure 3 exemplarily shows the Hermann Hesse birthplace, which has been selected for testing purposes and has been simplified as input for the reconstruction algorithm. Top left depicts the textured model of the building, top right the corresponding point cloud. The reconstructed façade is shown on the bottom left and the suggested completion of the model in CityGML is depicted on the bottom right.

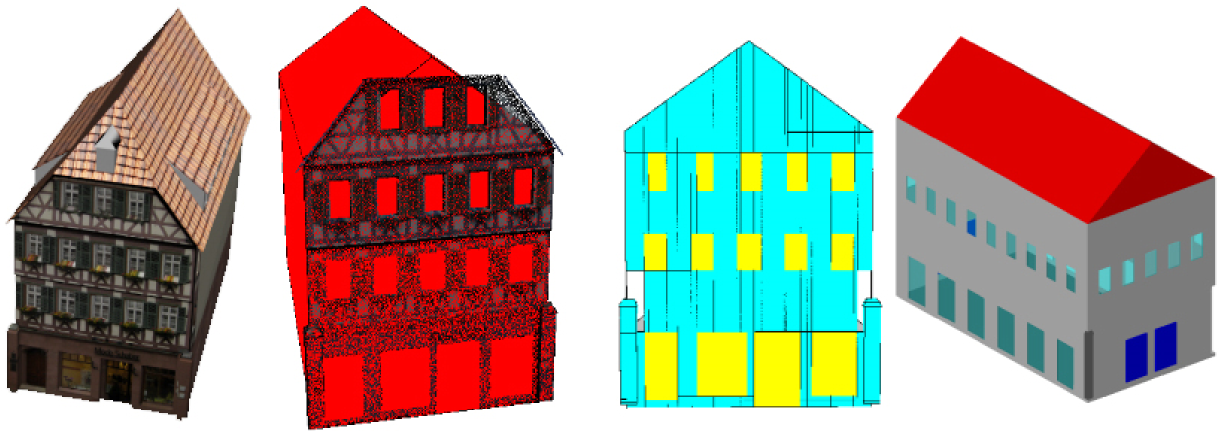


Figure 4: From Left to Right: Textured model of the Hermann Hesse birthplace, simplified CityGML model with an overlying point cloud, reconstructed primitives, bottom right: grammar based completion.

7. CHALLENGES FOR COMPLEX ARCHITECTURAL STRUCTURES

Point clouds delivered by dense image matching often have limited geometric accuracy. However, the described reconstruction of doors and windows presumes, that they differ significantly from the main façade plane in depth. Which means that main façade and primitives should not be coplanar. Further, complex architectural buildings in many cases do have main façades with several layers in depth which additionally aggravates the reconstruction process. Historic constructions often contain very complex building primitives which can be quite cumbersome to recreate even for a manual modeler.

8. REFERENCES

Becker, S., 2011. Automatische Ableitung und Anwendung von Regeln für die Rekonstruktion von Fassaden aus heterogenen Sensordaten. Dissertation, Universität Stuttgart.

Tutzauer, P. and Haala, N., 2015. Façade Reconstruction Using Geometric and Radiometric Point Cloud Information, ISPRS – International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-3/W2, 2015, pp. 247-252, DOI:10.5194/isprsarchives-XL-3-W2-247-2015.