

Technical Report Series of DCGI, Volume 2, Year 2012

Department of Computer Graphics and Interaction

Czech Technical University in Prague, CZ

Faculty of Electrical Engineering

Website: <http://dcgi.fel.cvut.cz>

3D Reconstruction Data Set - The Langweil
model of Prague (Technical Report)

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Funding Acknowledgements

This work has been partially supported by the Grant Agency of the Czech Republic under research program P202/11/1883, and the Grant agency of the CTU Prague, grant No. SGS10/291/OHK3/3T/13. The authors thank to The Prague City Museum for the special data provided.

Technical Report Series of DCGI, available at <http://dcgi.fel.cvut.cz/techreps>,
Department of Computer Graphics and Interaction, Czech Technical University in Prague,
Faculty of Electrical Engineering, Czech Republic.

ISSN 1805-6180

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Abstract

A large data set of input RAW photos for 3D reconstruction of historical paper model of Prague is presented in this paper. The data acquisition process and its organisation are described in detail together with color and camera calibration algorithms used. Moreover, a complete reconstruction work-flow together with several cultural heritage applications are briefly presented. The subject of this 3D reconstruction has been the Langweil model of Prague, originally created in the first half of 19th century. Three parts of this model with different characteristics are afforded for computer scientists through the internet.

Keywords

3D reconstruction, Langweil model of Prague, cultural heritage, digitisation, data set

Contents

1	Introduction	2
1.1	The Langweil model of Prague	3
2	Workflow	5
3	Data acquisition	6
3.1	Coordinate System Definition	6
3.2	Data organisation	7
3.3	Camera	8
3.4	Colour preservation	9
4	Calibration	11
5	Geometry reconstruction	12
6	Texturation	13
7	Reconstructed models	15
8	Cultural Heritage Presentation	16
8.1	Applications for museum experts	16
8.2	Applications enriching the original model	16
8.3	Applications for the public	17
9	Conclusion	18
	Bibliography	19

1 Introduction

The cultural heritage reconstruction is really popular in these days. It is mainly due to the high improvement in computer vision methods and in capabilities of current graphics hardware, which are able to present huge amount of data photo-realistically. One of cultural heritage monuments are scale city models. The reconstruction of such models enables walk through the ancient cities and simulates their behaviour. This is interesting both for historians and public. Several projects have already started with scale city model reconstruction. One of the most famous is Rome Reborn project [GMR⁺05] whose first part has ended at 2007, followed by reconstruction of other scale city models like Prague, Toul [CJP10] or Beijing [ZMMS09]. Each of these city models have different properties like material, colours, scale, and size. All of them have one common attribute – they are complex. Due to this, the reconstruction of these models reminds reconstruction of real cities and the reconstruction techniques are similar with little differences. The collection of data necessary for cities reconstruction requires a lot of resources (time, money, etc.), thus data owners do not want to share them or scientists are limited by non-disclosure agreements. So the reconstruction methods are mostly suited for just one case, they are not robust and general.

The purpose of this paper is to allow a comparison among similar reconstruction techniques and to enable testing on real data for all scientists who do not have the opportunity to work with these unique inputs. The fraction of the Langweil model of Prague is described in the paper. The originally taken data are provided on the web site managed by CTU in Prague with the permission of City of Prague museum. Three parts of scale city models are provided in original RAW format, representing more than 7000 photos. We present a complete documentation describing data organisation, scanning equipment and processes necessary for testing and improving current computer vision algorithms. These data are suitable for testing colour preservation, camera calibration, multiview stereo, geometry reconstruction, image based modelling, texture extraction, and many others.

The Langweil model of Prague is a historical coloured paper model of the Prague city center. The model digitisation process has been started in 2006 for the purpose of model conservation and collection of complex materials about the model enabling detailed studies by the museum experts. The uniqueness of the model is mainly in its historical importance, level of details, rich textures and large number of objects like houses, shelters or trees. These properties make described digitization project unique in a world scale. Similar comprehensive cultural heritage digitisation projects are the Rome reborn project [GMR⁺05], the Parthenon project [Deb05], and the project of digitisation Michelangelo's David statue [LPC⁺00]. The main differences from these projects are in the applied reconstruction method (here the photogrammetric reconstruction) and in the fact that individual textures are created for all reconstructed objects.

The photogrammetric reconstruction technique was chosen for two reasons. Firstly, it is necessary to generate detailed textures for the resulting 3D model. Secondly, the museum experts prohibited any type of intensive lighting (e.g., laser scanning or high-powered flashing) and model touching, while requiring the precision of the reconstructed model to be better than 1 mm. The basic idea of photogrammetric reconstruction method lies in observing projections of a real model point on several photos taken from different positions. The model point is marked

on the photos where it is visible. When the camera properties are known (camera position, orientation, focal length, CCD chip size), a virtual 3D point can be computed by intersecting the rays projected from camera centers to the markers on the photos. A detailed description of photogrammetric reconstruction can be found in [HZ04].

In this paper we briefly present the entire reconstruction process from data acquisition through geometry reconstruction and texture creation to the final presentation. The reconstruction process consists of several steps which required development or customization of current algorithms and tools. The length of the paper prohibits us from describing all parts of the process in detail. Thus, we single out the parts of the project that are necessary to understand the data collection, mainly model scanning process, color and camera calibration, and texture extraction. The detailed description of the reconstruction process is the basis for another article currently in preparation.

Model reconstruction was carried out in 2006-2010 by Visual Connection a.s. company, currently known as Visual Unity a.s. ¹, in cooperation with the Czech Technical University in Prague.

1.1 The Langweil model of Prague

The oldest model of Prague was created by Antonín Langweil between years 1826-1837 and is placed in the City of Prague Museum ². It is made of paper and illustrated by pen-and-ink drawings. The model's size is about 3.5 m × 6 m in the scale 1:480, thus the real covered area is about 1.6km × 2.6km. There are more than 2000 buildings corresponding to land register and almost 7000 other unique objects like shelters, small walls, statues and trees. The ground captured in the model varies throughout the area – the Old Town part of Prague is mostly planar, while the rest of the model, located on the other side of the river Vltava, offers hilly terrain dominated by the Prague Castle and its gardens. The model itself consists of 57 parts, each with different number of objects and complexity, see Fig. 1.1.

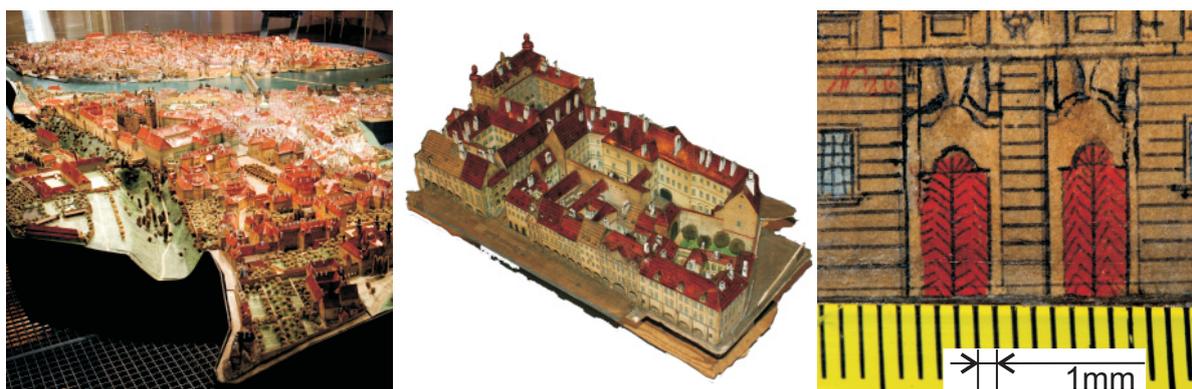


Figure 1.1: From left to right: the Langweil model of Prague at City of Prague Museum, a single model part, a wall with millimetre ruler.

We have chosen 3 parts of the Langweil model and afforded them for a scientific purposes

¹<http://www.visualunity.com>

²<http://www.muzeumprahy.cz>

with the permission of the City of Prague museum. The data sets are provided for free after submission of registration. Data and registration form are located on the page ³. The model parts were selected with respect to the model size, reconstruction complexity and variety of terrain, see Fig. 1.2.

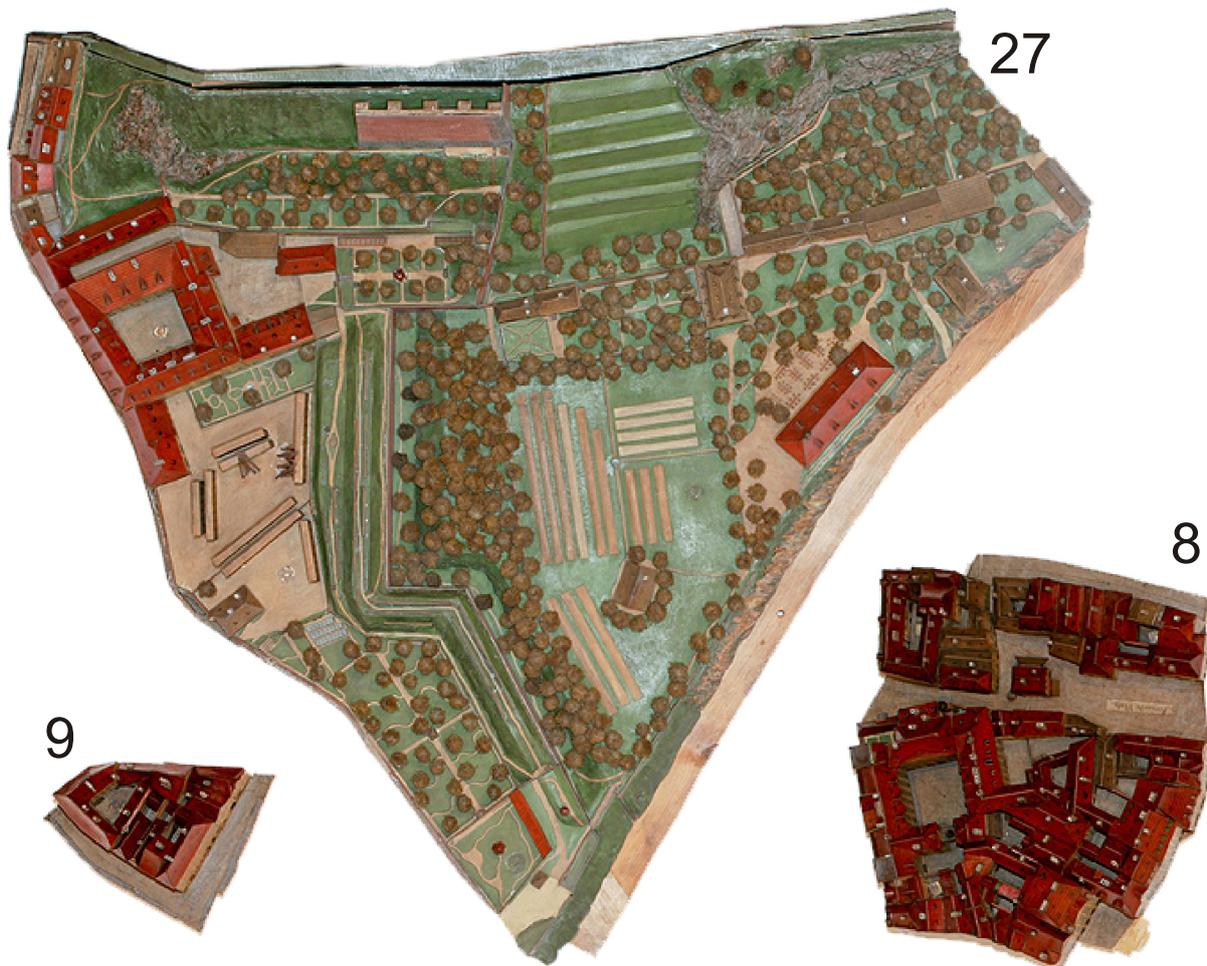


Figure 1.2: Three provided separate parts of the Langweil model.

Part 9: small, compact piece. It is suitable for study of 3D reconstruction algorithms. Terrain: **flat**.

Part 8: more exacting piece, with streets and complex geometry. Dealing with current state-of-the-art in 3D reconstruction. Terrain: **flat**.

Part 27: this piece contains a lot of occlusions caused by terrain variations and a huge number of trees. Suitable for the most robust algorithms testing. Terrain: **hilly, a lot of rough surfaces**.

³<http://dcgi.felk.cvut.cz/langweil3d>

2 Workflow

The model reconstruction can be divided into five consecutive steps, see Fig. 2.1. Firstly, the photos of each part from different positions and angles are taken. This data acquisition process (together with a specially designed image browser) is described in section 3. The following step of the process is camera calibration described in section 4. An approximate reconstruction of the model was carried out in parallel to the calibration in order to save time. When the camera calibrations are known, this approximate reconstruction is upgraded to precise and detailed metric reconstruction of the model. Different kinds of objects (buildings, chimneys, trees, ground) are created using various automatic or semi-automatic approaches described in section 5.

Once a 3D model is created, the textures are generated for each face of the model. The texture creation process (called texturation, see section 6) takes information from many different photos and combines them into a final texture for each face of the model. The final step of the reconstruction process is the model completion where all separately reconstructed parts are transformed into one global space.

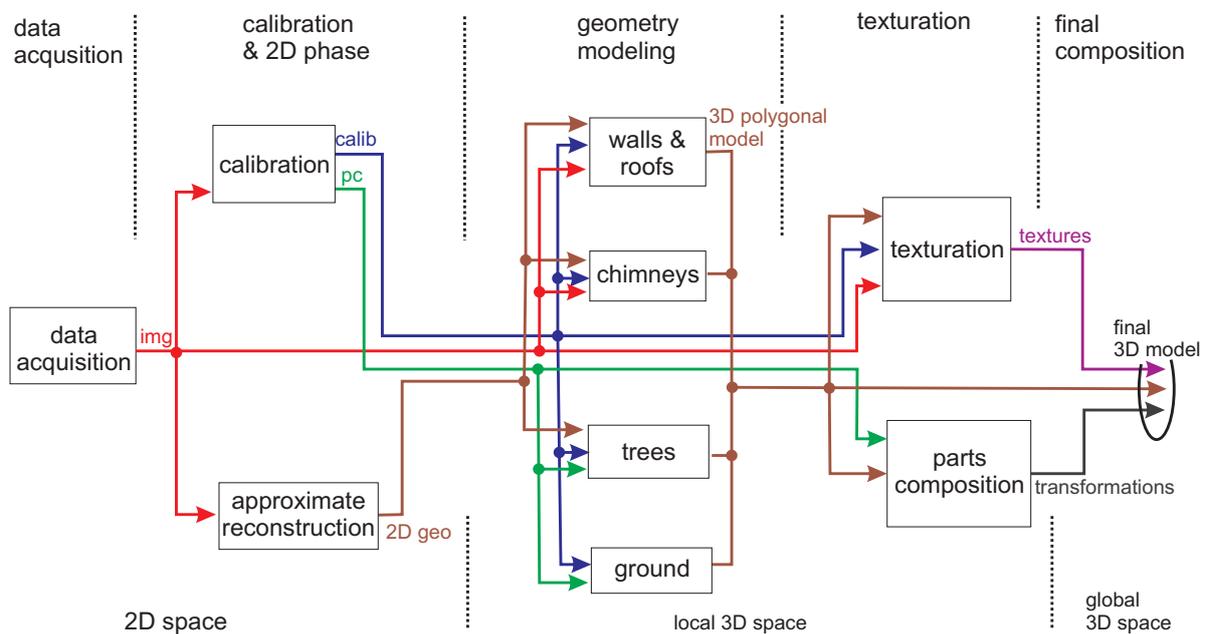


Figure 2.1: Reconstruction workflow.

3 Data acquisition

Due to the paper nature of the model, museum experts prohibited standard types of scanners, lasers, high-powered flashing and model touching. For this reason, a special robot was developed for the acquisition purposes. The robot automatically took photos of one model part from several camera positions and orientations, see Fig. 3.1a. For the remainder of this paper, the photos looking parallel to the z -axis are referred to as *top views*, while the photos taken under a non-zero angle δ from the z -axis are referred to as *side views*. Notice that the character of the model prevented us from taking bottom views and photos perpendicular to the model's walls. The whole scanning took two months of non-stop operation, during which almost 300 000 photos in 4K resolution (4096 x 4094 pixels) were obtained.

This chapter describes facts necessary to fully understand the acquired data collection. Firstly, the coordinate system common for each part is described, see section 3.1, then the organisation of provided data is depicted, section 3.2. The camera description is in section 3.3 followed by section dedicated to develop of RAW images.

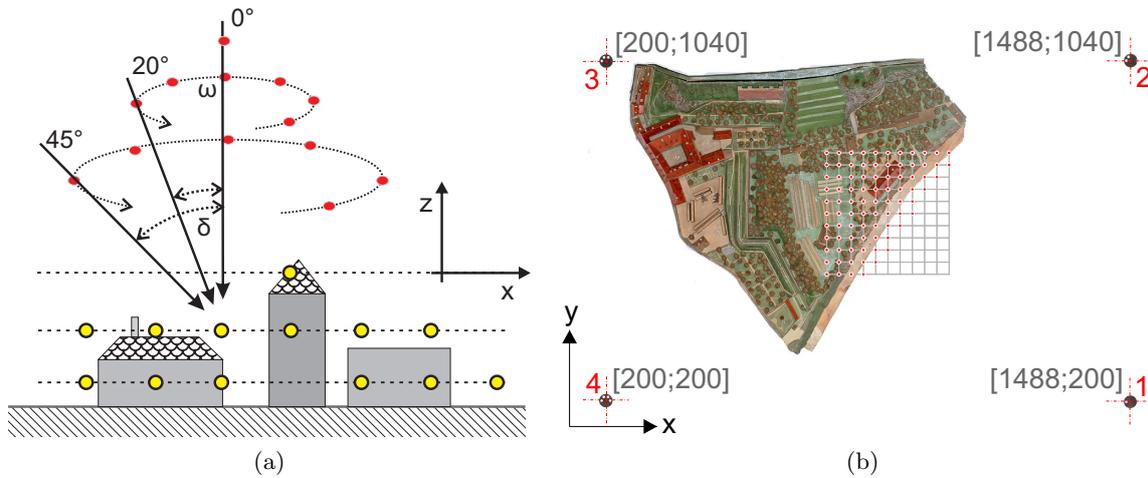


Figure 3.1: Data acquisition process: (a) Schematic view of automatically captured photos. Yellow points depict viewing points, red points are cameras looking at the same viewpoint from several directions. (b) Orto-photo coordinate system. Part of the image is covered by a grid with 30mm step to show the scale of acquired data. The grid corresponds to the distance between viewing points which are marked by dots.

3.1 Coordinate System Definition

Each model part was photographed in the perpendicular view on the table with 4 calibration marks, see Fig. 3.1b. The coordinates $[X, Y, Z]$ are derived from the centres of calibration marks. The coordinate system origin is computed from the marks positions, while the table plane gives the zero height, i.e. $z = 0$. The marks positions are in the Fig. 3.1b. The marks

are in the image distinguished by a count of white dots.

The X, Y distance between viewing points is always 30mm for $\delta = 0$ and 45mm for $\delta \neq 0$. The Z axis (the height) distance is 40mm, only in the case of part 27 the Z axis step is smaller in the hilly areas. The discrete Z axis viewing points naturally forms the layers, as refereed in this text, which corresponds to the focus plane. Each viewing point was captured from 17 different angles. Three different elevation angles δ [0; 20; 45] were used and 8 different azimuths ω for non-zero δ [0–315, step 45], see Fig. 3.1a. Due to used shift lens (sec. 3.3), the focus plane at side views ($\delta \neq 0$) is parallel to the table plane and not to the plane of camera chip. The viewing points was planned before scanning start to take only photos containing objects in the focus plane and to avoid collisions of the robot with tall model parts. For this reason some viewing points are "missing" at lower layers (smaller Z position).

3.2 Data organisation

Each image file is named by combination of several attributes obtained during scanning process. The file name and path structure are as follows:

`\PART\ELEVATION_AZIMUTH\X_Y_Z_PART_ELEVATION_AZIMUTH_UID.tif`

where each attribute corresponds to the Table 3.1.

attribute	description	digits
PART	part number	2
ELEVATION	δ angle	3
AZIMUTH	ω angle	2
X	x axis coordinate	4
Y	y axis coordinate	4
Z	z axis coordinate	3
UID	unique picture number	6

Table 3.1: File naming conventions. Angles are in degrees. Axis coordinates are in millimetres and correspond to the viewing points, see Fig. 3.1a.

We can analyse for example the file `0210_0060_030_27_120_20_689456.tif`. The model part is 27. Viewing point has coordinates [210, 60, 30], camera orientation is 120° in elevation and 20° in azimuth. The system path to this file is `\27\120_20\`.

More photo properties are available additionally to the file name. The additional data are stored in the csv format, the file name is `db.csv`. Table 3.2 summarizes database columns.

Closer explanations:

UID unique file identification

captured date and time of photo capture

piece number of Langweil model part

axis_a–e robot articulated positions in IRC pulses

description	database columns
UID	uid
part	piece
date and time of capture	captured
manipulator coordinates	axis_a--e [IRC]
camera orientation	elevation, azimuth [°]
viewing point coordinates	x,y,zpos [mm]
part placing	x,y,zshift [mm]
calibration ID	calid

Table 3.2: Values in the database

elevation camera orientation - elevation

azimuth camera orientation - azimuth

x-y-zpos coordinates of viewing positions, see Fig. 3.1b.

x-y-zshift part placing in the scanning plane

calid robot calibration identification — it is 5 for all available parts

3.3 Camera

The project conditions made impossible to use a standard camera. The specially designed macro camera was built from standard accessories. The digital camera back P20 from Phase One ¹ was used together with macro shift lens. The image resolution of the camera back is 16Mpx, 16bit/channel, while the chip size is 36.9×36.9 mm. The focal length of the lens is 120mm, more precisely the RODENSTOCK Apo-Macro-Sironar digital, 1:5.6, f=120mm was used. All photos were taken with the same camera settings, see Table 3.3.

camera aperture	22
exposure time	1/30
ISO speed rating	ISO 50

Table 3.3: Camera exposure settings

The photos taken under different elevation angles had set front lamella differently. Due to this, the photographs had always focus plane parallel to the table plane. The distance between front and back lamella was $\delta = 15.5$ mm, see Fig. 3.2. The angles for different elevations are in Table 3.4.

Image Format Specification

All photos are stored in compressed RAW format produced by CaptureOne application which is supplied together with digital back P20. The RAW images are stored together with $254 \times$

¹<http://www.phaseone.com>

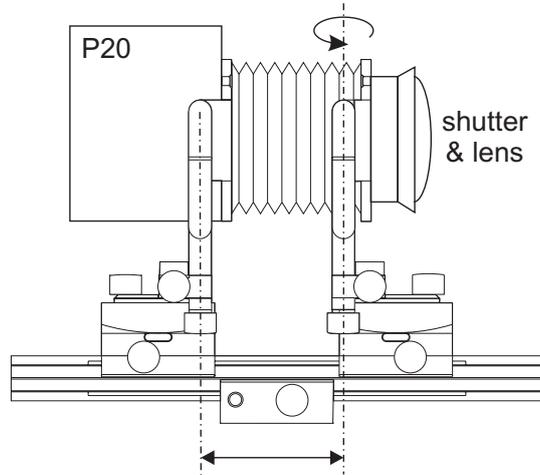


Figure 3.2: Camera schematic view

elevation	0°	20°	45°
α	0°	4.8°	13°

Table 3.4: Lamella angles

255px thumbnail which is viewable by standard image browsers. The file size of each RAW image is approximately 20MB, uncompressed to TIFF format occupies 96MB. The resolution of each photo is 4096×4094 px.

3.4 Colour preservation

The lighting conditions was controlled during the scanning process. The paper model was scanned in the black room hiding all disturbing lighting. The only light source was the camera lighting device with controlled light intensity.

The RAW image develop can be set by one calibration photo and applied to the whole photo set, due to the controlled lighting. The calibration photo consists of several useful calibration charts, see Fig. 3.3. The 18% grey matt plane is in the top left corner (GC18²). Colour&Grey Contour Chart with millimetre ruler (BST1³) is on the right side of the image. Finally, one model part for size referential is in the bottom left corner. The millimetre rule on the calibration chart is in the same height as the ground in the referential model, i.e. 60mm above the table. The focus plane is in the first scanning layer, i.e. 75mm above the table.

The first necessary step for the use of data is the RAW image develop. For this reason we present a usable settings and guideline, how photos can be developed. The Dave Cofins ddraw⁴ will be used.

Firstly, it is necessary to find multiplicative constants for white balance. We develop the

²<http://www.danes-picta.com/>

³<http://www.danes-picta.com/>

⁴<http://www.cybercom.net/~dcoffin/dcrow/>

image without any color or brightness correction, see Fig. 3.3 left.

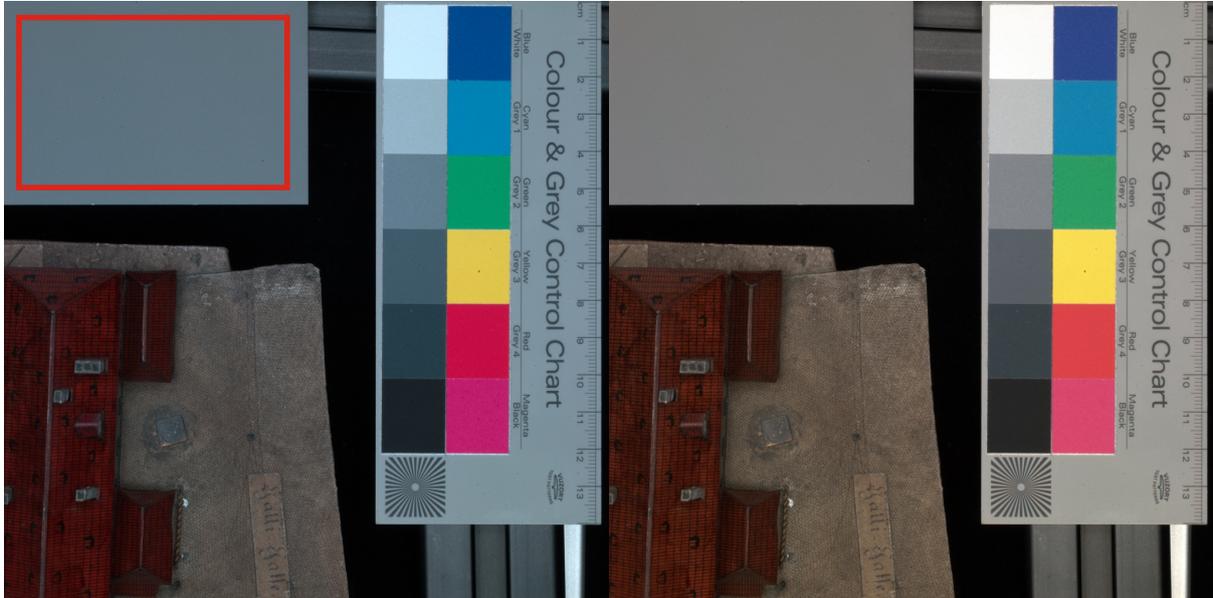


Figure 3.3: Photo used for color calibration. On the left is an un-calibrated image with highlighted rectangular region used for white balance estimation. On the right is truth-colour image.

```
dcraw -j -t 0 01.tif
```

Then the rectangle with constant grey is found and used as parameter for white balance estimation, Fig. 3.3 red outlined rectangle in left corner.

```
dcraw -v -A 100 100 1800 1200 01.tif  
output: 3.45 1 1.193 1.0132
```

Now, we can use multiplication constants for develop of truth-colour image.

```
dcraw -v -r 3.45 1 1.193 1.0132 01.tif
```

The last step is brightness adjustment. The brightness correction was set to 1.185, which is a value where the measured grey values have similar step in the Grey chart. Final photo is in Fig. 3.3 right, the dcraw developing parameters are following. These settings may be used for all tiff photos in the data set.

```
dcraw -W -b 1.185 -r 3.45 1 1.193 1.0132 *.tif
```

The `-W` parameter turns off the automatic brightness adjustment and uses the `-b` value. It is necessary to turn off automatic brightness, because the model was scanned on the dark velvet and in the boundary model parts there is more black and the automatic brightness fails. On the other hand, the lighting device was little unstable and more sophisticated brightness estimation for each photo individually would be helpful. We have solved the small differences in the brightness in the texturation phase, see section 6.

4 Calibration

Photogrammetric approach to camera calibration proceeds by marking projections of some of the model points on the photos and estimating the camera parameters (such as camera position, orientation or focal length) from these projections. The total amount of 300 000 photos divided into 57 parts, each with up to 14 000 photos, poses two problems.

Firstly, given the nature of the scene, we need to precisely mark millions of model points (each on more than 3 photos) for the problem to be well conditioned. It is intractable to perform this task manually. We therefore apply an automatic matching algorithm, namely one based on SIFT [Low04], which gives us point correspondences among image pairs. Typically, we end up with 2 to 6 thousand point matches for one image pair. After matching all image pairs, we simultaneously synthesize these image-pair matches into longer tracks (a track is defined as a set of projections of a single model point) and filter them by various methods, such as *feature space outlier rejection* described in [Low04], RANSAC or the following novel topological filtering method, we describe below.

For every track, we define a graph $G(V, E)$, whose vertex set V is the set of all the photos this track goes through. To define the edge set E of this graph, we add an edge for every pair of photos between which a correspondence has been detected. For an ideal matching algorithm, this graph would be complete (with $E = \binom{V}{2}$). In practice, however, the application of current matching algorithms (like SIFT) results in graphs that tend to be rather sparse. A graph with a lot of missing edges points at difficulties with matching the underlying model point and thus indicates a higher probability of the track being corrupted by false matches. For example, the presence of a bridge in this graph implies that there is a significant probability that this bridge-edge is a result of a mismatch of the automatic matching algorithm (a bridge is an edge in a connected graph, whose removal leads to the graph being disconnected). Thus, whenever we have a choice, we prefer to use tracks with high edge-connectivity in the input for the camera calibration estimation. The algorithm [NI92] is used to calculate the edge-connectivity for a given graph.

Secondly, it is not possible to apply a general camera calibration algorithm on inputs of this size. We exploited the topology of the scene and started by calibrating only the top views. All of the top view cameras differ mostly only by translation, so matching these images is trivial for the SIFT algorithm. Along with some basic filtering, this results in an outlier-free input for the calibration process. We then apply a modified version of a commercial calibration tool (RealVIZ MatchMover) to calibrate the scene. We continue by triangulating [HZ04] the points visible on more than 2 of the currently calibrated cameras. After that, we use resection to estimate the uncalibrated cameras on which sufficient amount of triangulated points are marked. These last two steps are repeated until all cameras are calibrated (occasionally, we perform several iterations of bundle adjustment with fixed cameras or fixed 3D points to stabilize the result). In this way, the camera calibration is obtained along with a 3D point cloud model. The camera calibrations represent essential information for the reconstruction, since we use it to triangulate the points forming the resulting 3D model and for texturation. The 3D point cloud is used as an input for various semi-automatic algorithms, see section 5.

5 Geometry reconstruction

Due to the variability of the 3D objects, we have separated the geometry reconstruction into 4 different processes using different approaches and algorithms. It is divided into house/wall modelling, which is fully human controlled process, and three different automatic algorithms for reconstruction of the chimneys, trees, and ground. The reconstruction of walls and roofs were mostly done in the commercial photogrammetric software Image Modeller.

The chimneys reconstruction is based on image processing algorithms. The randomized colour segmentation method was developed for chimneys contour detection. While the chimneys reconstruction algorithms works in the image space, the trees and ground reconstruction works with 3D point cloud. The tree reconstruction algorithm finds the exact position of tree-top and estimates the properties of a tree. All trees in Langweil model are modelled as an instances of template tree, so they vary only in the size.

A supervised process was used for the ground reconstruction. The user-guided segmentation method based on graph-cut algorithm [BK04] was applied to select ground points from the 3D point cloud obtained in section 4. 2D Voronoi triangulation was applied to automatically generate the final mesh. Further details about segmentation process can be found in Sedlacek et al. [SZ09].

6 Texturation

The task of texturation process is to acquire textures for each model face from photos with known camera calibrations and model geometry. This process consists of 3 steps:

1. texture extraction from photos by raycasting
2. texture registration via deformation models
3. building-up the final textures from extracted and registered ones

Due to the nature of reconstruction the polygons are not necessarily planar. We divide these polygons into parts that are sufficiently planar. Every such part is then fitted using single plane for which a corresponding texture array is defined by a projection of this polygonal part into the plane. Textures are extracted from photos by casting a ray from the camera center to each pixel of the texture array. Resolution of the extracted textures is programmable, although it is limited by the resolution of the photos and affected by the angle of view of the face.

During texture extraction we do not acquire only color values of the texture, but also other properties important for further processing. We have chosen following properties similarly as Callieri et al. [CCCS08]:

- level of focusing/blurriness from information about camera point of view and depth of field,
- occlusion by other model faces, see Fig. 6.1,
- observation angle of faces relative to camera, see Fig. 6.1,
- reflections caused by illumination of specular surface of model during making of photos.

In the second phase, image registration method is used for more accurate (at the level of pixels) matching of the textures corresponding to one model face. This step has to be done before building-up the final texture from the textures acquired from the photos made from different views. A deformation model described by Shekhovstov et al. [SKH08] is used to find the 2-dimensional discrete mappings. Textures are transformed to referential ones using this mapping and bilinear interpolation.

During the third phase, the final texture for model is built-up from extracted textures. The values mentioned above like focusing, occlusion and reflections define weights of each pixel. Contribution to the final texture is influenced by these weights. Textures are sorted according to them and the final texture is composed of the best evaluated texture by sequentially adding better valued pixels from the other ones. By this process we can get textures which are sharp and without reflections and occlusions over whole their area.

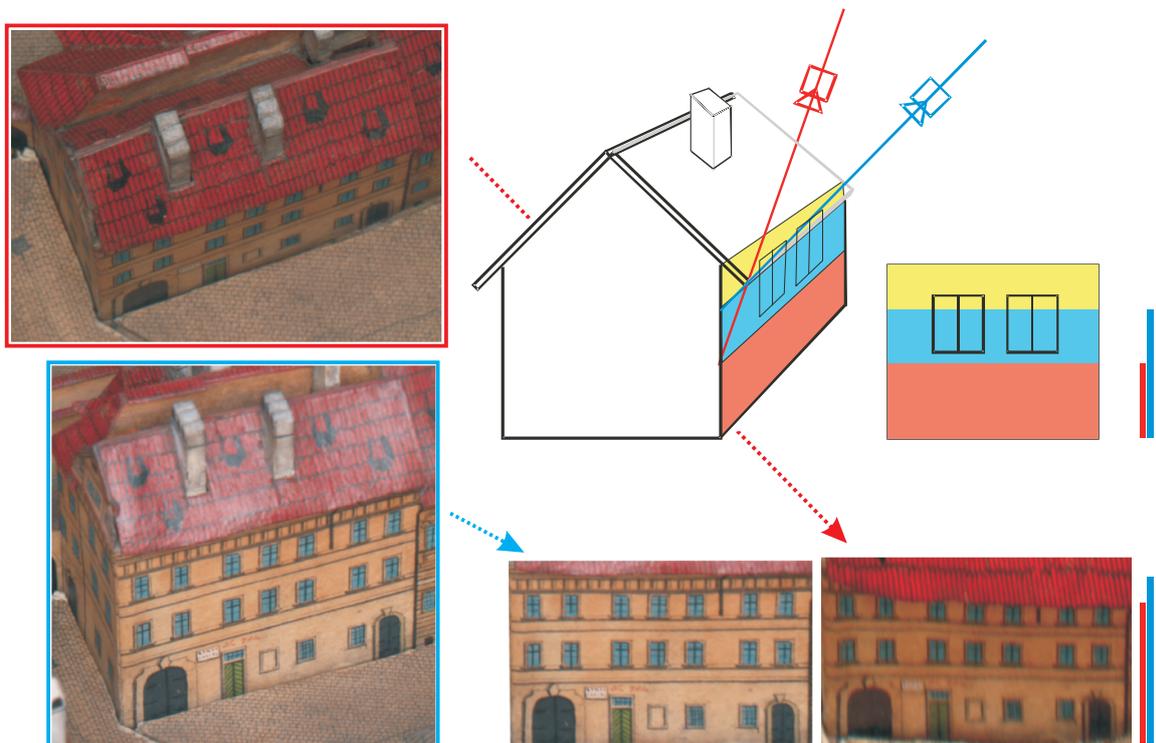


Figure 6.1: The model self occlusion. The visibility is depicted by color areas. The red area is visible even in photos with narrow observation angle (photo in red rectangle). The blue area is visible only on side photos (photo in blue rectangle). The yellow part is not visible in any photo. The blurriness caused by narrow observation angle is visible on the texture obtained from the photo in red rectangle.

7 Reconstructed models

The reconstructed models are provided with input photos together. The models are in VRML and X3D format with PNG textures in highest possible resolution. The models can be used for algorithms verification. Due to high amount of manual refinements (geometry and texture), they can be considered as a ground truth. The models are completely annotated using following name conventions.

general objects	<code>_XX_YYYY_Z</code>
automatically generated chimneys	<code>_XX_YYYY_Z_x</code>
ground	<code>_XX_baseY</code>

Where capital letters stand for:

XX	model part number
YYY	building unique identification number in one model part
A	letter distinguishing the same geometry type in one building
Z	geometry type, see next table.

The following geometry types are distinguished in the model:

0	roof
1	building wall
2	chimney
3	small wall, fence
9	special geometry, like statues, fountains

In the model part 8 the chimneys were created manually for testing purposes, while in the other two parts the chimneys were generated automatically and marked with letter `_x` at the end of the name. Trees are in the part 27, they do not have assigned any special name and ID neither. The trees are grouped into one group named `_Trees`. The trees are transformed instances of one tree, which is stored in directory `.\common\vege`.

One texture exists for each mesh, the texture name is the same like a mesh name. All textures are stored in the folder `.\XX_maps` where `XX` is the model part number. Each manually created chimney (part 8) has own texture, on the other hand, other chimneys (part 9 and 27) are typified during automatic process and several chimneys share the same textures stored in `.\common\chimneys`.

Several meshes are grouped together by identical ID to form a building entity. For example small house (ID = 1256) in model part 9 is made of roof (`_09_1256_0`) house wall (`_09_1256_1`) and two automatically generated chimneys (`_09_1256a_2_x`, `_09_1256b_2_x`).

8 Cultural Heritage Presentation

Several applications and presentations of 3D Langweil model have been created. The presentation techniques have reflected different demands of the target users.

8.1 Applications for museum experts

Two applications were designed specifically for the museum historians and for the architects, who compare the current state of Prague in historical context of Langweil model. The first application is the IBR viewer, which allows browsing almost 300 000 high quality photos of the model. The second application is GIS (Geographic Information System) with a wide number of functions, including annotations, 3D data filtering, interactive presentation and navigation, measurement of distances, and comparison with other digital resources, see Fig. 8.1.

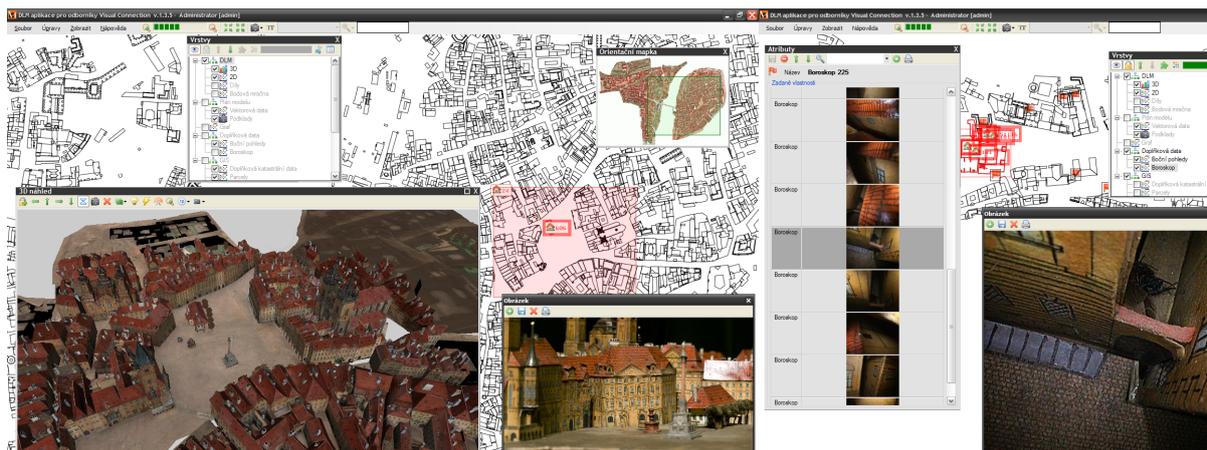


Figure 8.1: The application for museum experts is a kind of GIS.

8.2 Applications enriching the original model

These are presentations expanding the experience from the real model directly in the museum. Two kiosks with touch screens have been installed in the room with the Langweil model. Visitors can use them to investigate hidden, hardly accessible or distant parts of the model or to simulate a fly over the old Prague. Similar application is used for educational lectures about historical Prague organised for special groups of visitors. Finally, a short 3D movie (about 7 minutes) of the model fly-through was created. The movie is projected in a small 3D cinema which was build directly in the museum using passive stereo projection. These applications, mainly the 3D movie, extremely increased the interest in the original paper model. The final 3D Langweil model is shown in Fig. 8.2.



Figure 8.2: The whole reconstructed 3D Langweil model of Prague.

8.3 Applications for the public

A lot of museum visitors all over the world wish to take some part of the exhibit back to their homes. This is not different in the case of the Langweil model. The visitors can buy a DVD copy of the 3D model where they can virtually fly over Prague. The adventure game unfolding Prague myths within the Langweil model was developed for kids, see Fig. 8.3 left. One fragment of the model was created as a paper puzzle and postcard together.

Finally, the resulting 3D model is available on the internet ¹ in VRML format, see Fig. 8.3 right. For this purpose, the whole model is subdivided into four parts. While the geometry is unchanged, textures were significantly reduced in order to save bandwidth from server to clients.



Figure 8.3: The game (left) and the on-line model presentation (right).

¹<http://www.praha.eu/jnp/en/maps/langweil/index.html>

9 Conclusion

Three parts of unique historical scale city model were presented in this paper together with detailed description of acquisition process and data organisation. The model reconstruction processes were briefly presented. For the full understanding and further utilization of the input photos, the RAW photos development and camera calibration processes were described more precisely.

All three parts of Langweil model are accessible for scientists on the web site. Providing these data to further research, we expect improvements in algorithms for data reconstruction, mainly in the process automation and in higher precision of reconstruction. We believe that these data will be used for a comparison of computer vision algorithms, too. We plan publishing the most advanced algorithms used for the whole model reconstruction in more details, and to compare them with current state-of-the-art algorithms tested on these 3 model parts.

Acknowledgments

This work has been partially supported by the Grant Agency of the Czech Republic under research program P202/11/1883, and the Grant agency of the CTU Prague, grant No. SGS10/-291/OHK3/3T/13. The authors thank to The Prague City Museum for the special data provided.

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Technical Report Series of DCGI, Volume 2, Year 2012

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