Description of the Dataset of Zurich, Hoengg

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NOTE: This data can be freely used and distributed for non-commercial scientific and research purposes, under the condition that the following statement is made in every written report or oral presentation: ã Institute of Geodesy and Photogrammetry, ETH Zurich

1. Purpose

This document describes a test data set prepared for use in the project AMOBE II (Automation of Digital Terrain Model Generation and Man-Made Object Extraction from Aerial Images) being conducted at ETH Zurich between the photogrammetric (IGP) and computer vision (IKT) groups. We are distributing this data with the purpose of providing a basis for comparison and evaluation of image understanding techniques, in particular those dealing with the reconstruction of man-made objects. Features of this data set include provision of the full photogrammetric information, four-way image overlap and ground truth.

2. Dataset

The dataset covers an area nearby the center of Zurich (Switzerland) and the ETH Hoenggerberg. The region comprises the center of the quarter of Hoengg, different residential areas with different types of buildings (flat roofs, hip roofs etc.), other man-made objects like squares, bridges and streets, different kinds of vegetation (forest, single trees, meadow, vineyard, gardens etc.), and the Limmat river. The region is situated in the Limmat Valley so that the mapped area has a strong slope.

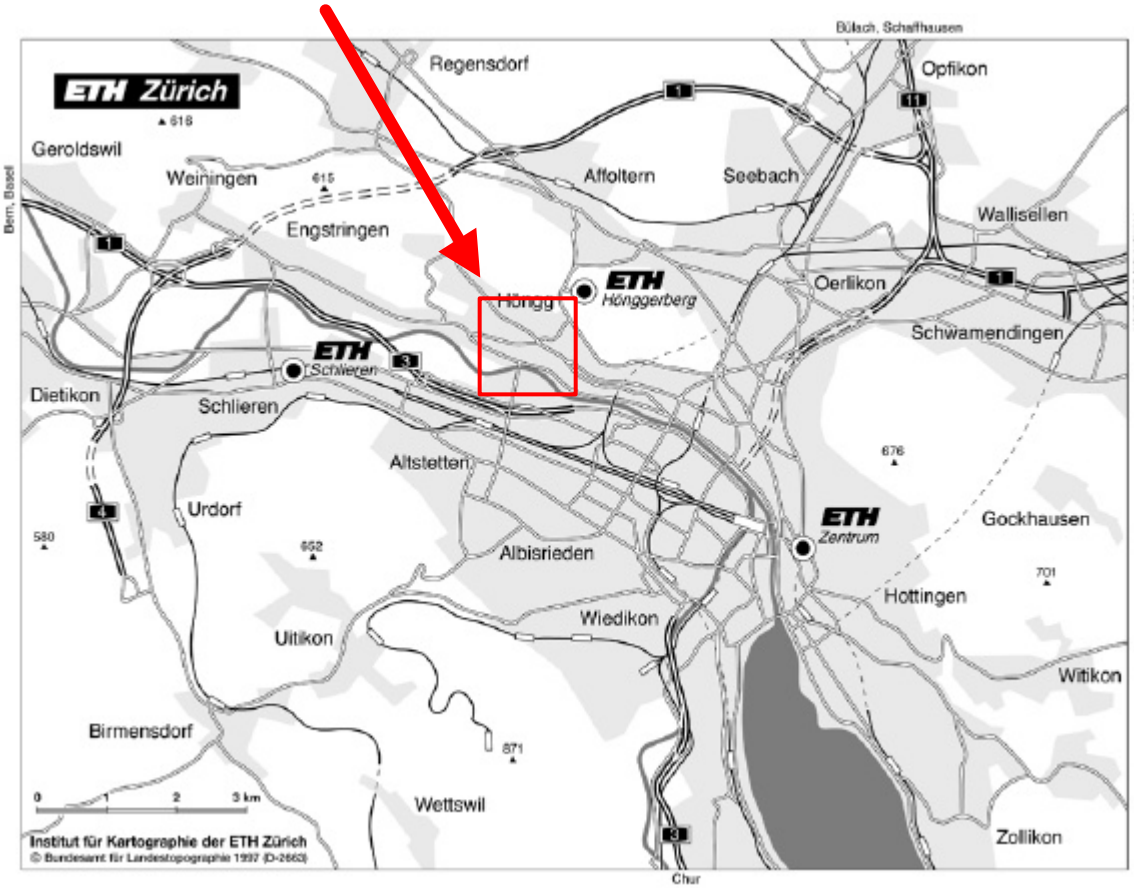


Fig. 1: Map of the environment of the aerial images of the Zurich Hoengg dataset

2.1. Photography

The Zurich Hoengg data set is based on aerial photography collected over Zurich in 1995. The data is based on a 2x2 image block collected for the Surveying Office of the City of Zurich at an average image scale of ca. 1:5000. It consists of two models from two neighbouring strips flown directly over Hoengg. The 23cm x 23cm colour photographs were scanned at 14 µm giving colour images of about 840Mb. This photography was flown ca. 1050 over ground with 65% forward and 45 % sideward overlap. The camera was a Leica RC20.

2.2. Scanning

The 23cm x 23cm original colour diapositives of Zurich Hoengg were scanned with 14 µm at a Zeiss SCAI scanner at the Swiss Federal Office of Topography, Bern. This scanner has a nominal geometric accuracy of ca. 2 microns RMS in x and y. A full photograph scanned at 14 µm produces images of (RGB) about 840Mb! The pixel footprint is ca. 7 cm.

2.3. Files

The dataset consists of the following files:

Filename	Description	Format
47008_2087.tif (i3.tif)	Colour, scanned with 14 µm, 842 MB	Tiled Tiff
47008_2088.tif (i4.tif)	Colour, scanned with 14 µm, 842 MB	Tiled Tiff
47009_2058.tif (i1.tif)	Colour, scanned with 14 µm, 824 MB	Tiled Tiff
47009_2059.tif (i2.tif)	Colour, scanned with 14 µm, 824 MB	Tiled Tiff

Table 1. Description of the files of the Zurich Hoengg dataset

2.3.1. Aerial Images

The dataset consists of 4 aerial images in colour (Figures 2-5), scanned with 14 µm, the format is Tiled Tiff , each image is about 16500 x 16400 pixels.

47009_2058.tif (i1.tif)	Colour, scanned with 14 µm Image Width: 16530 Image Height: 16369	Tiled Tiff

Fig. 2: Aerial image 2058.tif (i1.tif) of Zurich Hoengg dataset

47009_2059.tif **i2.tif**	Colour, scanned with 14 µm Image Width: 16530 Image Height: 16433	Tiled Tiff

Fig. 3: Aerial image 2059.tif (i2.tif) of Zurich Hoengg dataset

47008_2087.tif (i3.tif)	Colour, scanned with 14 µm Image Width: 16562 Image Height: 16433	Tiled Tiff

Fig. 4 ***Aerial image 2087.ti (i3.tif) of Zurich Hoengg dataset***

47008_2088.tif (i4.tif)	Colour, scanned with 14 µm Image Width: 16594 Image Height: 16433	Tiled Tiff

Fig. 5 ***Aerial image 2088.tif (i4.tif) of Zurich Hoengg dataset***

2.3.2. **Digital surface models (DSM)**

Two DSMs (one for each stereo pair) are distributed as examples of the results obtainable automatically without manual editing with commercial software. As opposed to a DTM, the DSM includes modelling of the surface of all entities e.g. buildings, and not just the terrain. It was computed using a pyramid-based cross-correlation and subsequent relaxation matching techniques on the Virtuozo digital photogrammetric station. Figures 6 and 8 illustrates these DSMs represented as grey level images, and Figures 7 and 9 show the same data shaded and artificial coloured to better show the elevation variations. The bright blobs in the grey level images represent the higher points, e.g. houses and tree stands. The colour tables of both DSMs are different, dark green signalises less elevation. Then comes bright green, yellow or brown. The DSM was generate with a cross-correlation patch size of 15 by 15 pixels and an image grid spacing of 15 pixels, i.e. the average DTM spacing in x and y is ca. 1m. Both files contain irregularly distributed data. Some statistics about the DSMs are listed below.

	58_59_hoeng.dat	**87_88_hoeng.dat**
Xmin	679179	679554
Xmax	680145	680621
Ymin	250065	250471
Ymax	251184	251664
Zmin	385	444
Zmax	515	554
Number of points	507416	615888

Table 2. Some statistics of the DSMs (in m).

58_59_hoeng.dat	DSM from 47009_2058.tif and 47009_2059.tif made with Virtuozo	ASCII (x,y,z)

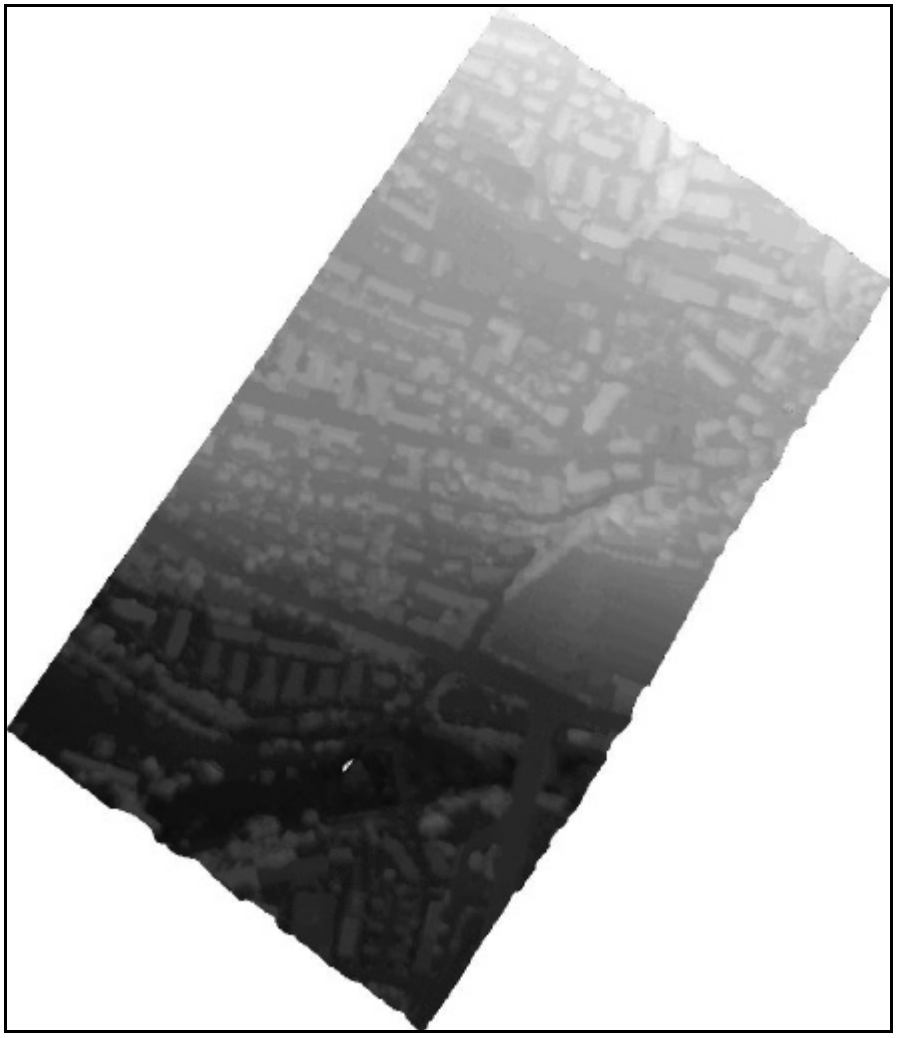


Fig. 6 Computed DSM with Virtuozo Software 58_59_hoengg.dat

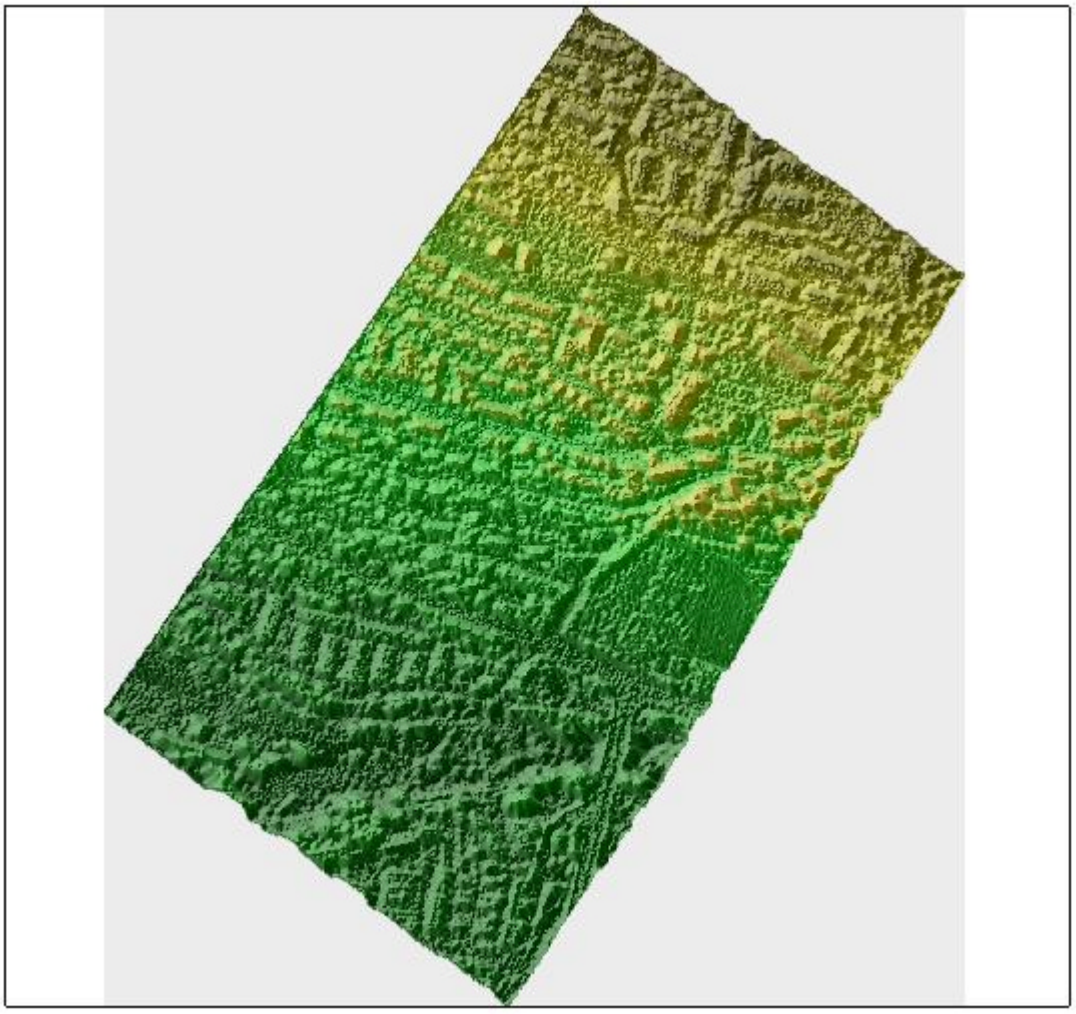


Fig. 7 ***Computed DSM with Virtuozo Software 58_59_hoengg.dat***

87_88_hoeng.dat	DSM from 47008_2087.tif and 47008_2088.tif made with Virtuozo	ASCII (x,y,z)

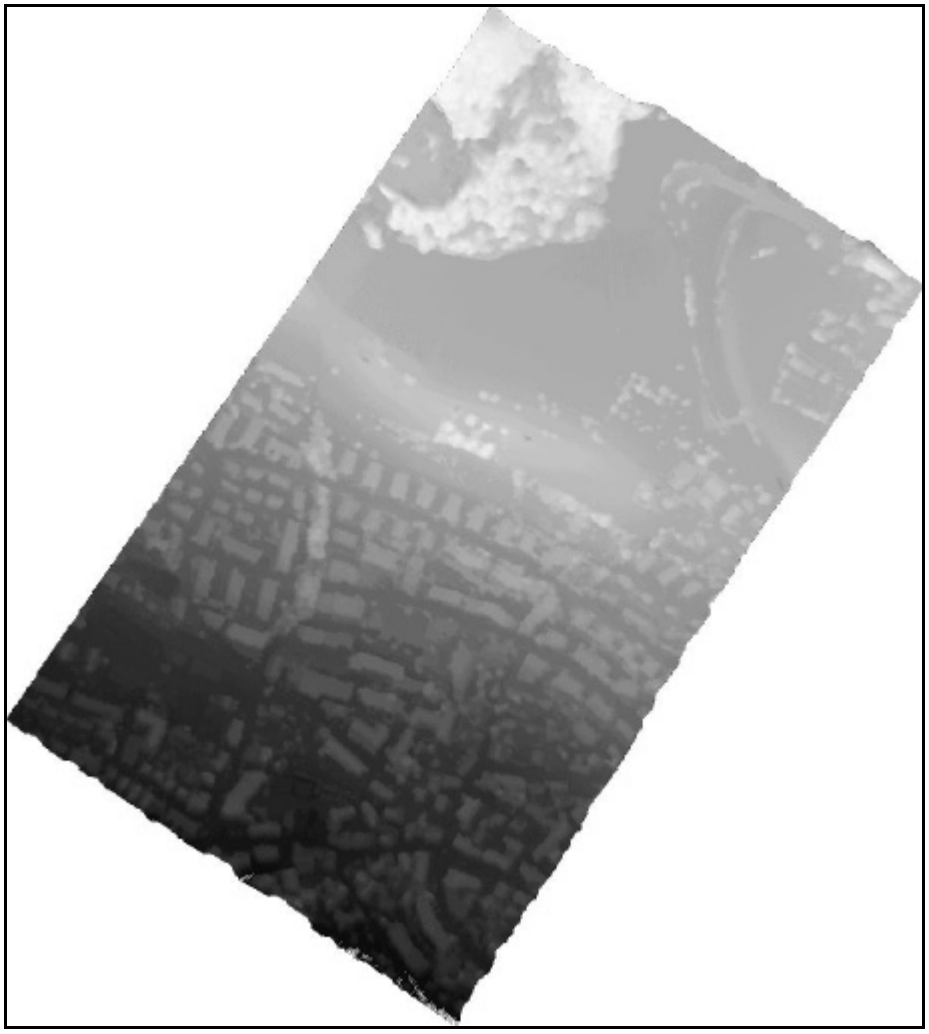


Fig. 8 Computed DSM with Virtuozo Software 87_88_hoengg.dat

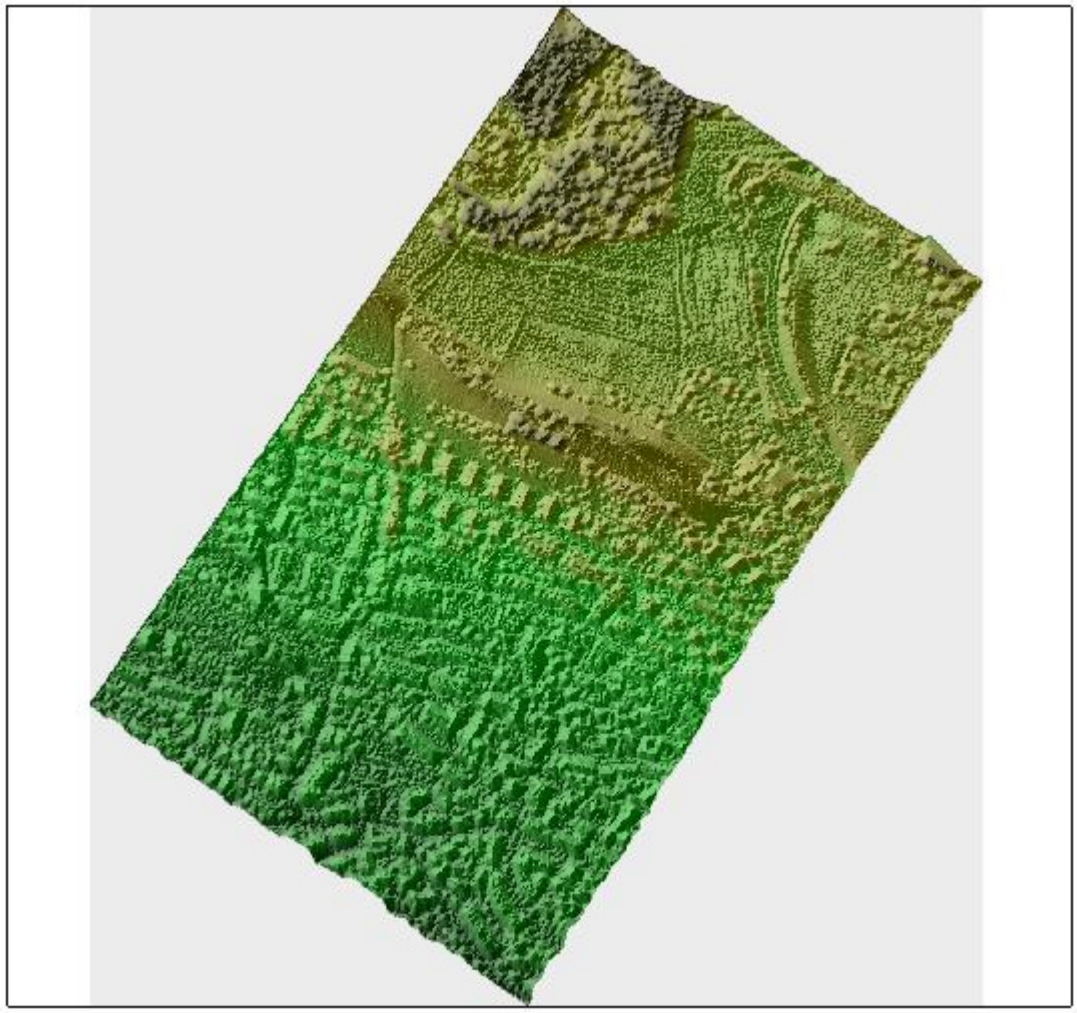


Fig. 9 Computed DSModels with Virtuozo Software 87_88_hoengg.dat

2.3.3. **Digital Terrain Model (DTM):**

A separate ASCII file contains DTM information. The data was manually measured at an AC1 analytical plotter to an expected accuracy of 0.1-0.2 m. The DTM models only the terrain and does not include 3D objects. The file includes irregularly distributed points.
The slope of the terrain from the top of the hill at ETH Hoenggerberg down to the Limmat River is observable in the figure below.

Fig. 10 DTM data shown as regular DXF grid (not distributed)

Xmin	Xmax	Ymin	Ymax	Zmin	Zmax	Number of points
679145	680624	250039	251525	393	531	4021

Table 3. Some statistics of the DTM (in m)

2.3.4. Buildings

The roof points were first measured modelwise at the AC1 analytical plotter as an unstructured point cloud and then the topology was built using CyberCity-Modeller (Gruen and Wang, 1998). A separate DXF file contains building roof models (no DTM included), represented in terms of line entities. This file can be imported in AutoCAD v.13 on Unix but not in Microstation. For Microstation, we provide a DGN and a DWG file. If you use the DWG file in Microstation to make measurements, the coordinates will be wrong because Microstation shifts the coordinate origin. To avoid this, you should use the following commands in Microstation before importing the DWG file:
For=$
Reset
For=679000,250000
In both DGN and DWG files the building data lie at the bottom left of “View 1”.

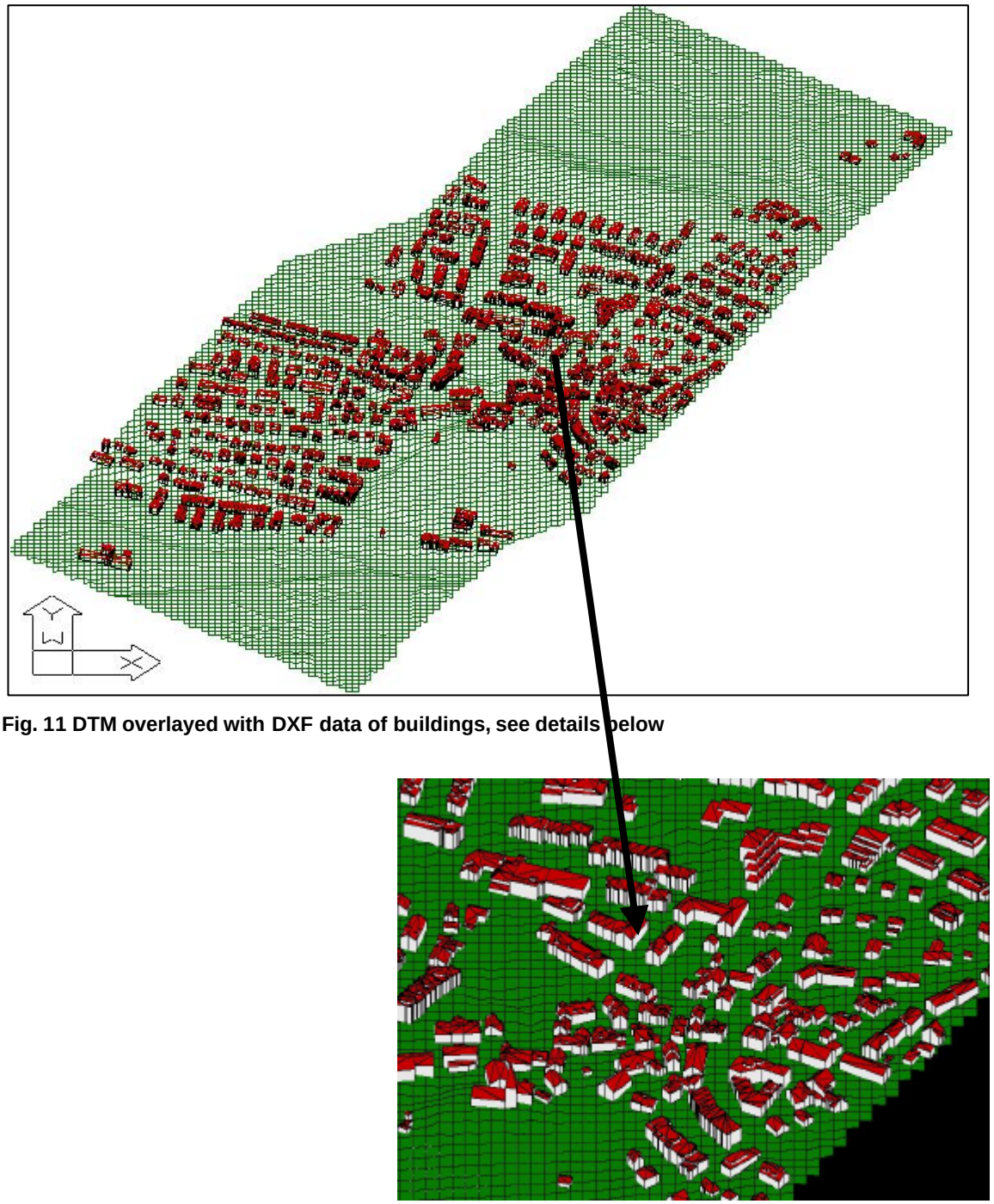


Fig. 11 DTM overlayed with DXF data of buildings, see details below

2.3.5. Point coordinates

Due to a request, we also provide for each cut-out 6 object points and the respective object and pixel coordinates. They are included in the files *.pix and *.obj. The standard deviations in the *obj files should not be taken into account. The pixel coordinates refer to the pixel coordinate system of each cut-out with 0/0 at the center of the top left pixel. The points were selected in cut-out ic1 and then measured in the remaining 3 with constrained least squares matching and manual determination of the approximate (starting) positions. The object coordinates are the result of the constrained matching and they are influence by matching inaccuracies (small errors possible, but no gross errors). Thus, these points are given here only as an additional check for everybody who wishes to use this dataset., and should not be used as a substitute of the interior and exterior orientation given below to transform from object to pixel coordinate systems and vice versa.

3. Transformations

3.1. Orientation Parameters:

3.1.1. Interior Orientation

From the camera calibration protocol of the Leica RC20 the principal point of autocollimation (PPA) is given as (-0.012 mm, -0.005 mm) and the camera's principal distance as 214.74 mm (note that in some programs the camera constant should be used with negative sign). Radial lens distortion is on the order –2.3 to 4.8 µm. For object reconstruction purposes the given calibration values can be adopted. By ignoring radial distortion and other additional parameters (APs) the camera model required is simplified without significant loss of accuracy. The units of the image coordinates used in all affine transformations below should be mm. The pixel coordinates refer to the original (whole) images, not the cut-outs that are distributed.

xpixel= a1 + a2 ximage + a3 yimage
ypixel= a4 + a5 ximage + a6 yimage
ximage= a1 + a2 xpixel + a3 ypixel
yimage= a4 + a5 xpixel + a6 ypixel

NOTE: for the image data distributed (i.e. the cut-outs) only the affine transformations in Section 4 are needed. The transformations below are given only for reasons of completeness and checking purposes.

image i1.tif (58.tif)

image-to-pixel

a1	8.329527609919551e+03
a2	-7.131895000839620e+01
a3	-1.036116634861065e-01
a4	8.152161292799678e+03
a5	-3.924209332739440e-02
a6	7.133126806809679e+01

pixel-to-image

a1	1.169585609137468e+02
a2	-1.402150661116614e-02
a3	-2.036692570944883e-05
a4	-1.142215949791606e+02
a5	-7.713675664492936e-06
a6	1.401908550985939e-02

image i2.tif (59.tif)

image-to-pixel

a1	8.353152746731206e+03
a2	-7.132979651782341e+01
a3	-1.269540643978518e-01
a4	8.173286265284157e+03
a5	-5.173753905724950e-02
a6	7.133285795793748e+01

pixel-to-image

a1	1.173098540248075e+02
a2	-1.401936824581864e-02
a3	-2.495075398965650e-05
a4	-1.144944560973392e+02
a5	-1.016831275230263e-05
a6	1.401876672957178e-02

image i3.tif (87.tif)

image-to-pixel

a1	8.378277511392196e+03
a2	-7.133905273469587e+01
a3	-9.270610876739746e-02
a4	8.152536246787537e+03
a5	-2.061460558348070e-02
a6	7.134228728912908e+01

pixel-to-image

a1	1.175915260093767e+02
a2	-1.401756220274022e-02
a3	-1.821517097916253e-05
a4	-1.142395682945267e+02
a5	-4.050447714802842e-06
a6	1.401692683238062e-02

image i4.tif (88.tif)

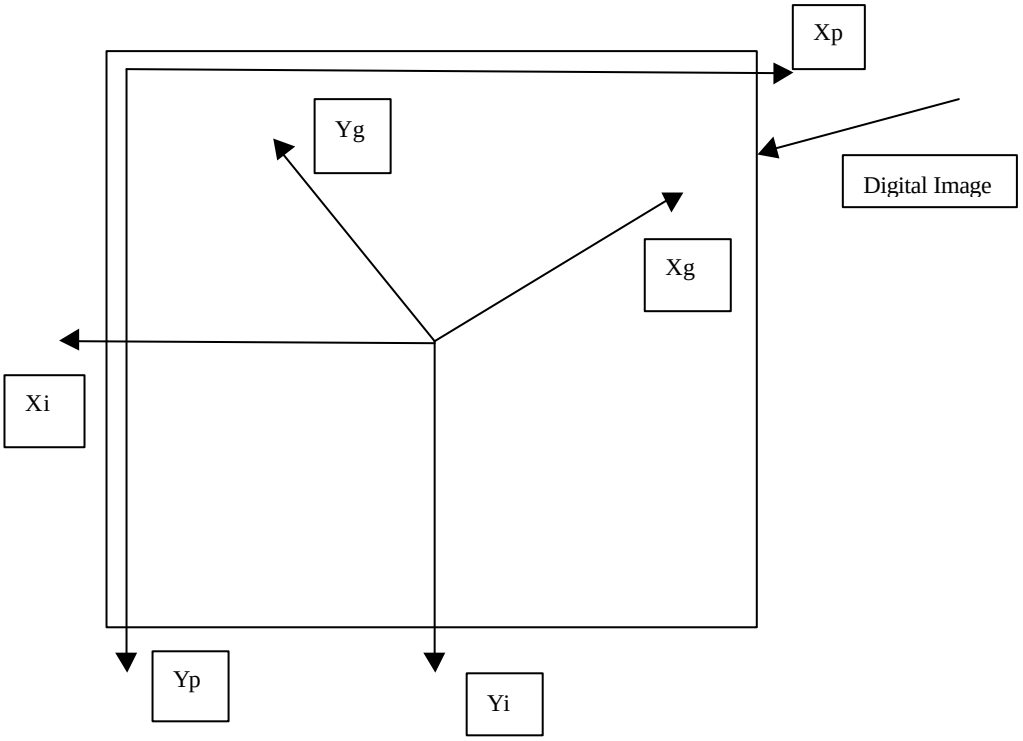
image-to-pixel

a1	8.384152687643529e+03
a2	-7.133598652485367e+01
a3	-1.191730770556034e-01
a4	8.232286234717112e+03
a5	-5.167976333985249e-02
a6	7.133757280189678e+01

pixel-to-image

a1	1.177231200153173e+02
a2	-1.401815309518250e-02
a3	-2.341804707217700e-05
a4	-1.153137391919102e+02
a5	-1.015530256864328e-05
a6	1.401784140019694e-02

The definition of the pixel, image and ground (object) coordinate systems, Xp/Yp, Xi/Yi and Xg (Easting) / Yg (Northing) respectively are as shown below. Note that these definitions refer to the digital images (original or cut-outs) as viewed on a computer screen. The origin (0/0) of the pixel coordinate system is the center of the upper left pixel. The origins of the other two systems below are arbitrary. Only the direction of the axes are of value.



3.1.2. Exterior Orientation:

In this section the (six) exterior orientation parameters of each of the four images is given in the form of the location of the perspective centers in the Swiss Landeskoordinatensystem in meters and the rotation angles (in grad). They were derived by orientation of single models (57 and 58 pair, 87 and 88 pair) at an AC1 analytical plotter. The used ground control points were measured by GPS with an accuracy of ca. 1 dm. The orientation is the same, as the one used for manual measurement of the DTM and the buildings. The rotation system is $\omega\,\varphi\,\kappa$ (omega primary, phi secondary), i.e. $R = R\omega * R\varphi * R\kappa$
The angles describe the rotation from the object to the image coordinate system. Since the orientation was derived modelwise, it is natural that the orientation of 57 and 58 fit better to each other than to the orientation of 87 and 88, and the opposite.

X_o, Y_o and Z_o are in [m]
ω, φ, κ in [grad]

Image 2087: (i3)

X_o	Y_o	**Z_o**	w	j	k
679933.474	251161.625	1521.868	0.7991	-0.9116	162.3969

Image 2088 (i4):

X_o	**Y_o**	**Z_o**	w	j	k
680240.899	250956.277	1523.270	0.4837	-0.9689	162.2631

Image 2058 (i1):

X_o	**Y_o**	**Z_o**	w	j	k
679523.670	250761.547	1480.194	0.3027	-0.7627	162.1962

Image 2059 (i2):

X_o	**Y_o**	**Z_o**	w	j	k
679848.592	250524.205	1479.335	0.9050	-1.0488	162.9081

Table 4. Exterior Orientation parameters

Rotation matrices from object space to image space (if you need the matrices from image to object space, just transpose the matrices given below):

Image 2058 (i1)

-0.82874945040034	*0.55957261750566*	*-7.2687137107032D-03*
-0.55949157618360	*-0.82876768821270*	*-1.0644019643250D-02*
-1.1980176990855D-02	*-4.7544413385653D-03*	*0.99991693187326*

Image 2059 (i2)

-0.83490062959293	*0.55036873139974*	*-5.9328073262180D-03*
-0.55015411814990	*-0.83480071971154*	*-2.0933338285978D-02*
-1.6473766662252D-02	*-1.4213298931736D-02*	*0.99976327055230*

Image 2087 (i3)

-0.83048363095098	*0.55702146613348*	*-4.9015292497599D-03*
-0.55685896608796	*-0.83040325642386*	*-1.8399011062902D-02*
-1.4318889968121D-02	*-1.2550617003155D-02*	*0.99981870926830*

Image 2088 (i4)

-0.82930040776616	*0.55874023625479*	*-8.3774738929639D-03*
-0.55859575726820	*-0.82930792480912*	*-1.4803574256046D-02*
-1.5218858066555D-02	*-7.5969887937012D-03*	*0.99985532559487*

4. Cut-Outs

Four cut-outs are selected in the region with four-way overlap. We provide the cut-outs as TIFF format files and the pixel coordinates of the upper left and lower right corners of each cut-out with respect to the pixel coordinate system of the original images (see figure 12). The affine transformations listed below for each cut-out in all 4 images are between the image coordinates (ximage/yimage) (in mm) of the whole original images and the pixel coordinates (xpixel/ypixel) of the cut-outs in their local pixel coordinate system. They were derived by the formulas below (with a1, a2 etc. as listed in section 3.1.1).

Pixel-to-Image

$x_{image} = (a_1 + a_2 x_{lu} + a_3 y_{lu}) + a_2 x_{pixel} + a_3 y_{pixel}$

$y_{image} = (a_4 + a_5 x_{lu} + a_6 y_{lu}) + a_5 x_{pixel} + a_6 y_{pixel}$

Image-To-Pixel

$x_{pixel} = (a_1 - x_{lu}) + a_2 x_{image} + a_3 y_{image}$

$y_{pixel} = (a_4 - y_{lu}) + a_5 x_{image} + a_6 y_{image}$

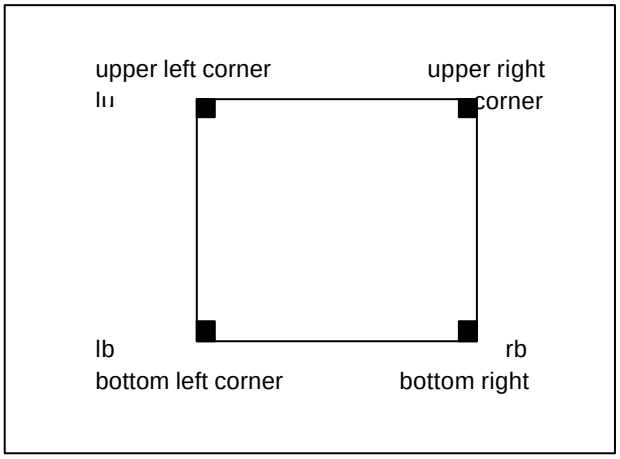


Figure 12: Pixel coordinates of the cut-outs

Cut-out i2_c1.tif

i1_c1.tif

Corner	x	y
lu	9696	5272
rb	12460	6864

i2_c1.tif

Corner	x	y
lu	3743	5135
rb	6527	6767

i3_c1.tif

Corner	x	y
lu	8064	13688
rb	10688	15148

i4_c1.tif

Corner	x	y
lu	2580	13704
rb	5312	15220

Sequence of affine parameters below is:
a1 a2 a3
a4 a5 a6

pixel to image 58_1

-19.101341620460325	-0.01402150661116614	-2.036692570944883E-5
-40.38776797042482	-7.713675664492936E-6	0.01401908550985939

image to pixel 58_1

-1366.472390080449	-7.131895000839620e+01	-1.036116634861065e-01
2880.161292799678	-3.924209332739440e-02	7.133126806809679e+01

pixel to image 59_1

64.70723655897146	-0.01401936824581864	-2.49507539896565E-5
-42.54614893561997	-1.016831275230263E-5	0.01401876672957178

image to pixel 59_1

4610.152746731206	-7.132979651782341e+01	-1.269540643978518e-01
3038.286265284157	-5.173753905724950e-02	7.133285795793748e+01

pixel to image 87_1

4.304575146116783	-0.01401756220274022	-1.821517097916253E-5
77.59146337672703	-4.050447714802842E-6	0.01401692683238062

image to pixel 87_1

314.277511392196	-7.133905273469587e+01	-9.270610876739746e-02
-5535.463753212463	-2.061460558348070e-02	7.134228728912908e+01

pixel to image 88_1

81.23536411266933	-0.0140181530951825	-2.3418047072177E-5
76.76055867576154	-1.015530256864328E-5	0.01401784140019694

image to pixel 88_1

5804.152687643529	-7.133598652485367e+01	-1.191730770556034e-01
-5471.713765282888	-5.167976333985249e-02	7.133757280189678e+01

Cut-out i2_c2.tif

i1_c2.tif

Corner	**x**	**y**
lu	13640	760
rb	16440	2528

i2_c2.tif

Corner	**x**	**y**
lu	7615	671
rb	10383	2415

i3_c2.tif

Corner	**x**	**y**
lu	11856	9528
rb	14528	11072

i4_c2.tif

Corner	**x**	**y**
lu	6352	9504
rb	9072	11064

Sequence of affine parameters below is:
a1 a2 a3
a4 a5 a6

pixel to image 58_2

-74.31026812609855	-0.01402150661116614	-2.036692570944883E-5
-103.67230452773114	-7.713675664492936E-6	0.01401908550985939

image to pixel 58_2

-5310.472390080449	-7.131895000839620e+01	-1.036116634861065e-01
7392.161292799678	-3.924209332739440e-02	7.133126806809679e+01

pixel to image 59_2

10.535622876971502	-0.01401936824581864	-2.49507539896565E-5
-105.16529532340532	-1.016831275230263E-5	0.01401876672957178

image to pixel 59_2

738.152746731206	-7.132979651782341e+01	-1.269540643978518e-01
7502.286265284157	-5.173753905724950e-02	7.133285795793748e+01

pixel to image 87_2

-48.77424561540081	-0.01401756220274022	-1.821517097916253E-5
19.265688456289126	-4.050447714802842E-6	0.01401692683238062

image to pixel 87_2

-3477.722488607804	-7.133905273469587e+01	-9.270610876739746e-02
-1375.463753212463	-2.061460558348070e-02	7.134228728912908e+01

pixel to image 88_2

28.4572464353441	-0.0140181530951825	-2.3418047072177E-5
17.847318993645473	-1.015530256864328E-5	0.01401784140019694

image to pixel 88_2

2032.152687643529	-7.133598652485367e+01	-1.191730770556034e-01
-1271.713765282888	-5.167976333985249e-02	7.133757280189678e+01

Cut-out i2_c3.tif

i1_c3.tif

Corner	**x**	**y**
lu	13472	2872
rb	16376	5984

i2_c3.tif

Corner	**x**	**y**
lu	7551	2831
rb	10415	5887

i3_c3.tif

Corner	**x**	**y**
lu	11728	11352
rb	14528	14384

i4_c3.tif

Corner	x	y
lu	6288	11376
rb	9064	14392

Sequence of affine parameters below is:
a1 a2 a3
a4 a5 a6

pixel to image 58_3
-71.99766996252097 -0.01402150661116614 -2.036692570944883E-5
-74.06270003339648 -7.713675664492936E-6 0.01401908550985939

image to pixel 58_3
-5142.472390080449 -7.131895000839620e+01 -1.036116634861065e-01
5280.161292799678 -3.924209332739440e-02 7.133126806809679e+01

pixel to image 59_3
11.378968816086228 -0.01401936824581864 -2.49507539896565E-5
-74.88410841551413 -1.016831275230263E-5 0.01401876672957178

image to pixel 59_3
802.152746731206 -7.132979651782341e+01 -1.269540643978518e-01
5342.286265284157 -5.173753905724950e-02 7.133285795793748e+01

pixel to image 87_3
-47.01322212531604 -0.01401756220274022 -1.821517097916253E-5
44.83308145585889 -4.050447714802842E-6 0.01401692683238062

image to pixel 87_3
-3349.722488607804 -7.133905273469587e+01 -9.270610876739746e-02
-3199.463753212463 -2.061460558348070e-02 7.134228728912908e+01

pixel to image 88_3
29.31056964931666 -0.0140181530951825 -2.3418047072177E-5
44.08936803417856 -1.015530256864328E-5 0.01401784140019694

image to pixel 88_3
2096.152687643529 -7.133598652485367e+01 -1.191730770556034e-01
-3143.713765282888 -5.167976333985249e-02 7.133757280189678e+01

Cut-out i2_c4.tif

i1_c4.tif

Corner	x	y
lu	9288	600
rb	13024	3992

i2_c4.tif

Corner	x	y
lu	3215	479
rb	6943	3983

i3_c4.tif

Corner	x	y
lu	7520	9336
rb	11136	12736

i4_c4.tif

Corner	x	y
lu	1920	9424
rb	5696	12704

Sequence of affine parameters below is:
a1 a2 a3
a4 a5 a6

pixel to image 58_4
-13.285412646189972 -0.01402150661116614 -2.036692570944883E-5
-105.88178829281678 -7.713675664492936E-6 0.01401908550985939

image to pixel 58_4
-958.472390080449 -7.131895000839620e+01 -1.036116634861065e-01
7552.161292799678 -3.924209332739440e-02 7.133126806809679e+01

pixel to image 59_4
72.22563370333953 -0.01401936824581864 -2.49507539896565E-5
-107.81215795937297 -1.016831275230263E-5 0.01401876672957178

image to pixel 59_4
5138.152746731206 -7.132979651782341e+01 -1.269540643978518e-01
7694.286265284157 -5.173753905724950e-02 7.133285795793748e+01

pixel to image 87_4
12.009401408508785 -0.01401756220274022 -1.821517097916253E-5
16.59200124576344 -4.050447714802842E-6 0.01401692683238062

image to pixel 87_4
858.277511392196 -7.133905273469587e+01 -9.270610876739746e-02
-1183.463753212463 -2.061460558348070e-02 7.134228728912908e+01

pixel to image 88_4
90.58757439695871 -0.0140181530951825 -2.3418047072177E-5
16.770899982613955 -1.015530256864328E-5 0.01401784140019694

image to pixel 88_4
6464.152687643529 -7.133598652485367e+01 -1.191730770556034e-01
-1191.713765282888 -5.167976333985249e-02 7.133757280189678e+01

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References

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