AUTOMATIC MEASUREMENT OF SEWER MAN-HOLES
IN LARGE SCALE AERIAL IMAGES

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ABSTRACT

The geometric changes of the surface (subsidence and horizontal displacement) caused by coal mining can be determined by photogrammetry with a sufficient accuracy. As long time stable targets sewer manholes can be used. They can be identified in large scale aerial images without additional effort for targeting. They also can be measured semi-automatic in digital images. Especially for periodically performed photogrammetric evaluations of the same area these aspects can lead to a significant cost reduction against a manual measurement. The program DPLX developed by the University of Hannover resulted in a precision and completeness of the automatic image point determination similar to those by manual measurement with analytical plotters. Digital images with the full resolution can be handled also on standard PC's.

1   INTRODUCTION

In coal mining areas the ground surface shows subsidence and horizontal displacements. They are causing problems, mostly concerning damaged buildings, traffic lines or supplying facilities. The mining companies have the duty to monitor surface changes. Photogrammetry with large scale aerial images allowing a high point determination accuracy can be used for this purpose. The need for economic data acquisition is especially caused by the large size of affected areas. By this reason a higher degree of automation is required, especially for the very time consuming measurement of image coordinates. State-of-the-art aerial triangulation and DTM extraction software systems using natural targets have been examined and cannot reach the accuracy limits of $\leq \pm 3$ cm on the ground. Another possibility is the use of clearly identifiable objects like sewer manholes. In aerial images with a scale of 1:4000, scanned with a pixel size of 12 μm, they do have a diameter of about 10 pixel. They follow the local surface changes, but they are defined very stable in their neighborhood (as long as they are not the object of road-constructions) by this reason they are used since several years by the Deutsche Steinkohle AG (DSK) for a photogrammetric point determination based on computer supported measurement with analytical plotters (Jacobsen 1986). In a common project together with the DSK an automation of the image measurement for a re-survey of in former period determined points has been established. In the following a system is presented which provides the environment required for image handling, data organization and semi-automatic point measurement.

2   PROGRAM DPLX

For the automated measurement of manholes in blocks of digital images the program DPLX has been developed. It provides a project management with progress control, large image display, semi-automatic point measurement and manual coordinate registration at sub-pixel accuracy for verifying and completing results. Some details of the functionality are described below. The appearance of the user interface is shown in Fig. 1.

2.1   Software Development

DPLX is coded mostly platform-independently, using the freeware TCL/TK script language for the entire user interface. The image display is done by a loadable extension called IMG.

Image processing including the automated measurement routines is realized with easy portable stand-alone low-level C-routines. This was necessary because of the slow executing TCL interpreter. Communication between the different processes is done by the streaming and piping mechanisms of TCL.

Fig.1: User Interface

2.2 Image handling

As mentioned before, the aerial images showing sewer manholes in an appropriate size for precise measurement should have an image scale of 1:4000 or larger. This leads to a minimum size of 20.000 × 20.000 pixel or 370 Mbytes if scanned at a resolution of 12μm and 8-bit gray scale.

It is not reasonable to hold a complete image in the main memory, even if this is large enough. The loading procedure would be very time consuming on most standard computers, and not all of the image information is really required. For display purposes a size-reduced overview image together with a quite small and from the overview selectable tile at the original resolution is sufficient (see Fig.1). Also the measurement routines, including preprocessing, only do need small image regions containing the objects. By these reasons DPLX works with a special tile technique generating small sub-images offline and loading them into the display or the processing routines.

2.3 Evaluation steps and progress control

Data preparation consists of scanning, generating overview images and providing the interior orientations.
The next step for each photo is the manual measurement 4 to 5 of the up to 800 points in the images, well distributed over the whole image area to calculate the exterior orientation parameters based on the object coordinates determined during the preceding period 2 or more years ago. After the transformation of all covered objects into image coordinates and a visual quality control of the approximate values, the automatic measurement is starting. Fig. 4 shows the window containing a list of results and some control elements. The additional messages for some of the points indicate errors in

the identification based on the above mentioned quality parameters. They will be collected in a separate list which later is used to go to the related approximate position for a manual measurement or a skipping.

Fig. 2: menu for creating overview image

For each image DPLX tracks the evaluation progress and shows the actual state of it in a separate window (see Fig. 3). So the operator has a fast overview of the progress of the actual image. The steps shown are "overview image ok", "interior orientation ok", "exterior orientation ok", automatic measurement ok" and "manual post-processing missing".
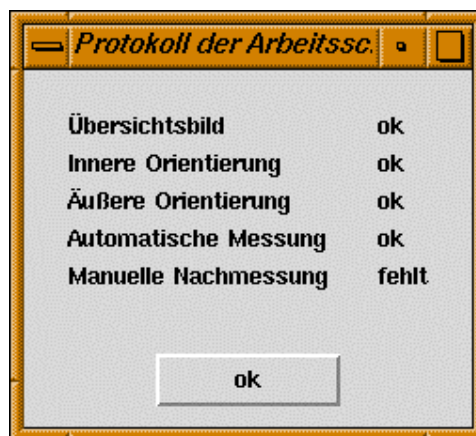

Fig. 3: Evaluation progress control

2.4   Interior and exterior orientation

DPLX is able to load orientation data from ZEISS PHODIS and in this way to take advantage of the comfortable PHODIS automatic interior orientation tool, but the inner orientation can be measured also manually, supported by an ellipse operator for the precise pointing.

The approximate exterior orientation data is required, because up to now the semi-automatic measurement of the manholes needs approximate image coordinates, which have to be obtained for example from a data set of a previous epoch. These 3D-object coordinates have to be transformed into the image system. Tests for the automatic identification of manholes in the digital images without any pre-information of the location failed. The diameter of just 10 pixel and the very often not clear structure was leading to a very high number of objects which could be manholes.

2.5   Automatic manhole measurement algorithm

Because of the mentioned modular concept of DPLX it is simple to implement different algorithms for the automated point determination. Up to now one method is realized. It is based on a edge detection. It uses several quality parameters in order to reduce the number of wrong point determinations. The detected edge has to be a closed figure, the size in x- and y-direction have to be closely identical and there is a limit for its minimum and maximum size. If these checks are successful, the center of gravity is calculated from the coordinates of the identified edge pixels.

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┌──────────────────────────────────────────────────────────────────────────────────────────┐
│ ▭  Automatische Messung                                                          ▫  □ │
├──────────────────────────────────────────────────────────────────────────────────────────┤
│ 363:   921941662    9.311  -42.784      6    13    24    9    9   ok                      │
│ 364:   921941663   83.265   73.187     20    -2    25    9    9   ok                      │
│ 365:   921941664   76.150   78.194     16    -6    25    8    8   ok                      │
│ 366:   921941665   69.059   83.084     27     3    23    8    9   ok                      │
│ 367:   921941666           Punkt schon gemessen                                          │
│ 368:   921941667   36.265   86.163     21    23    15    3    7   ok                      │
│ 369:   921941669   22.086   92.381      8     7    36   12   11   ok                      │
│ 370:   921941670    8.918   78.246     16   -12    27    9    9   ok                      │
│ 371:   921941676  -46.689   50.761     -9    -6    31    9   10   ok                      │
│ 372:   921941678  -62.922   33.306      1     6    16    7    6   ok                      │
│ 373:   921941681   -9.368   -1.157     11    -9    20    7    7   ok                      │
│ 374:   921941682  -20.881   52.484     -1    -6    22    9    9   ok                      │
│ 375:   921941683  -22.849   47.352      0    -6    24    9    9   ok                      │
│ 376:   921941684  -58.699   74.465    -94   -13    23    5    9      DX zu groß           │
│ 377:   921941685  -63.096   57.676      1   -11    23    6    8   ok                      │
│ 378:   921941733   46.518   93.357     15     3    26   10    9   ok                      │
│ 379:   921941734   47.423   93.947     13    -8    34   12   12   ok                      │
│ 380:   921941735   30.594   97.291      6   -34    22    7   10   ok                      │
│ 381:   921941736   34.751   92.202     29   -36    19    7    6   ok                      │
│ 382:   921941737   18.133   99.668                            Kante zu lang              │
│ 383:   921941739    4.623  110.589     11   -19    25    8   10   ok                      │
│ 384:   921941792    3.147   85.133     32   -14    33   12    9   ok                      │
│ 385:   921941794   47.283   94.106   -181    51    35    9    9      DY zu groß           │
│ 386:   921941796   50.635  100.337   -134   -17    22    6    8      DX zu groß           │
│ 387:   921950101 -109.980   66.241     14    -9    23    7    8   ok                      │
│ 388:   921950102  -96.790   50.077      7   -16    26    8   10   ok                      │
│ 389:   921950106 -111.360   39.374    -14   -15    25    6   11   ok                      │
│ 390:   921950111   12.476   45.335      7     1    25    9    8   ok                      │
│ 391:   921950113   46.438   26.912     30     0    24    8    9   ok                      │
│ 392:   921950135 -111.701   89.901    -88    -3     8    3    2      Ziel zu klein        │
├──────────────────────────────────────────────────────────────────────────────────────────┤
│  Ok: 317  Fehler: 67  │  Start  │  Optionen  │  Stop  │  Speichern  │  Schließen          │
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Fig. 4: Listing of automatic point determination with quality parameters

This algorithm has been shown as very robust and not detected objects are difficult or not to measured by a human operator. The achieved accuracy is on the same level like the manual measurements with analytical plotters. The main limitation is the accuracy of the image itself and the quality of the photos.

3   QUALITY OF RESULTS

The automatic point determination of manholes has been checked in comparison to manual measurement with the analytical plotter Planicomp P1.

image number	points / image of the previous period	automatic point determination				manual reference measurement with DPLX
		reference points for image orientation	points with status OK	not identified	additional manual measurement	
52	224	8	178	43	13	161
51	392	8	326	66	21	335
50	616	8	493	115	42	499
57	273	7	226	40	14	216
58	459	6	370	83	48	377
59	591	7	462	122	51	448
mean [%]	**100 %**		**80.4 %**	**19.6 %**	**7.4 %**	**79.7 %**

Table 1: check of the automatic determination of manholes in aerial images with a scale 1 : 4000

The possibilities of DPLX has been checked by means of a group of images of a real project. The object coordinates of the period before have been available, changes in the range of 1m occurred, but this has not affected the approximate pointing because the change of the location within one image is smaller. In table 1 the results of 6 typical images are shown. In the mean 426 manholes have been measured in every image during the preceding period 3 years ago. The image orientation has been computed by a resection based on 7 points. With the image orientation the ground coordinates of the preceding period have been transformed into image coordinates, used for the automatic pointing. Based on this, 80.4% of the manholes have been detected automatically. After termination of the automatic pointing, DPLX goes to the position of the not automatic determined points, allowing a manual pointing, which usually takes place in a zoom window to allow a sub-pixel-accuracy. So additional 7.4% could be measured, that means finally 12.2% of the points of the preceding period could not be identified. This is caused by cars located above the manholes, trees covering the view, shadows and dirt on the roads. The objects which could be measured manually in addition to

the automatic pointing have been partially covered by shadows or they could be seen through the branches of trees – such points in general cannot be identified automatically. In comparison a computer supported manual measurement has been made, that means, DPLX went to the individual approximate positions of the image points and the positions have been measured in a zoom window. By this method with 79.7% a smaller number than with the automatic process has been measured. This shows the sufficient quality and also robustness of DPLX.

Another topic is the geometric quality. A bundle adjustment with program BLUH, using image coordinates of 524 object points determined by manual measurements with the Planicomp P1, was leading to an accuracy of the image coordinates of σ_o = 6.45μm. With the automatic process of DPLX 452 object points have been determined with σ_o = 7.17μm, together with the additional manual measurements a σ_o = 6.99μm has been achieved and with the only manual measurements with DPLX a σ_o = 6.89μm has been reached. That means, there is only a negligible difference in the accuracy of the image coordinate quality determined by measurements with the analytical plotter Planicomp P1, the automatic determination by DPLX and the manual measurement in the zoom window of DPLX.

4 CONCLUSIONS

The automatic determination of image coordinates of manholes by program DPLX, developed by the University of Hannover, can be done with a similar precision and completeness like the manual measurement in digital images or with analytical plotters using photos. It is not possible to determine 100% of the points identified in a period 3 years before – this also cannot be done by manual measurement. In addition to this special topic, the program can be used also in general for the determination of image coordinates in digital images with manual approximate pointing and a point operator or totally manual measurement in a zoom window. Full size digital images (e.g. 20 000 x 20 000 pixel) can be used also on PC's. Based on the script language TCL/TK it is platform independent, only the included programs have to be compiled and linked for the different platforms.

DPLX will be continuously improved. The point measurement algorithm will be investigated in detail. The quality parameters for the internal check of the point identification are subject for a further test. Also the set of used quality parameters may be extended. An improvement of the geometric quality by different image filters before edge detection and a least squares adjustment for the determination of the ellipse parameters has been checked (Freitag 1999) and will be further investigated.

The very sophisticated problem of finding manholes in a digital image automatically without having approximate coordinates is a further field of research in future. It is yet not possible to predict if a solution could be found. Some existing methods do have low efficiency, but there are still some possibilities.

Because of the modular structure of DPLX it possible to implement batch processing for the automatic point measurement. A stereo display could increase reliability and accuracy of manual operations. The integration of data organization tools e.g. from the program system BLUH could be done and would increase efficiency.

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