1. Introduction

The surface and the feature changes more often during the exploitation of the open or underground pit. For example:
(1) The roads, pipes, buildings and facilities will be build up following the production development of the coal mine.
(2) The geographical feature of district will be destroyed after the exploitation of the open pit, then according to the exploitation norm, the land and plant have to be recovered.
(3) In the case of underground exploitation, we must to remove the residence which are built upper the pit.

So that the surveying work in the coal mine not only various but also frequently. The topographic surveying work in the coal mine list as following:
(1) At the exploration stage, the basic control network and 1:5000 scale mapping are needed.
(2) 1:2000 and 1:1000 scale topographic map is mostly used in the coal mine design stage.
(3) In construction stage, the surveyor must work on the 1:500 and 1:200 scale.
(4) In the production stage, the planimetric and elevation control network will re-survey periodically, which will be used for monitor the changes of the terrain surface.
(5) Above all different kinds of scale topographic maps should be revised periodically as a pre-requisite for the production management of the coal mine.

Due to the characteristics of the variety and repeatability in the coal mine surveying work, so that the photogrammetry becomes a efficient methods. Especially, following by technology development in camera, materials, instruments and digital aspects, the photogrammetry can almost resolve all terrain survey tasks in the coal mine. Using the digital data collected from the photo, the people can get the graphic files and digital information altogether, including topography, geology, hydrology, transportation, pipes and environment etc.

2. Practivities

Recently years, the photogrammetry work has been done in the more than ten coal mine. It includes topography mapping by airphoto, engineering surveying and construction surveying by terrestrial and close range photogrammetry, the lower class control network by aerotriangulation.
2.1 In the aerophotogrammetry work, the photo-scale is selected according following formulae:

\[ M_h = \frac{1}{K} \sqrt{1.66m_q^2 + (0.7m_c)^2} \]  for the planimetric accuracy

\[ M_e = \pm \frac{H}{b} \sqrt{1.21m_q^2 + (0.17m_c)^2} \]  for the elevation accuracy

In the formulae:
- \( m_q \) - mean error of instrument measurement
- \( m_c \) - mean error of orientation of the model
- \( K \) - the scale ratio for photo to map
- \( H \) - the flight height
- \( b \) - the photo base

The map accuracy has been verified by field survey. Its result as following:

<table>
<thead>
<tr>
<th>AREA</th>
<th>PHOTO SCALE</th>
<th>MAP SCALE</th>
<th>INSTRUMENT</th>
<th>CALCULATE ACCURACY</th>
<th>VERIFIED ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( M_h )</td>
<td>( M_h )</td>
</tr>
<tr>
<td>A</td>
<td>1:300000</td>
<td>1:5000</td>
<td>A10</td>
<td>1.30m</td>
<td>1.33m</td>
</tr>
<tr>
<td>B</td>
<td>1:25000</td>
<td>1:5000</td>
<td>A8</td>
<td>1.09</td>
<td>1.11</td>
</tr>
<tr>
<td>C</td>
<td>1:20000</td>
<td>1:5000</td>
<td>B8s</td>
<td>1.09</td>
<td>1.11</td>
</tr>
<tr>
<td>D</td>
<td>1:14000</td>
<td>1:5000</td>
<td>A10</td>
<td>1.09</td>
<td>1.11</td>
</tr>
<tr>
<td>E</td>
<td>1:12000</td>
<td>1:2000</td>
<td>A10</td>
<td>0.52</td>
<td>0.48</td>
</tr>
<tr>
<td>F</td>
<td>1:8000</td>
<td>1:2000</td>
<td>B8s</td>
<td>1.09</td>
<td>1.11</td>
</tr>
<tr>
<td>G</td>
<td>1:12000</td>
<td>1:1000</td>
<td>A10</td>
<td>0.43</td>
<td>0.40</td>
</tr>
<tr>
<td>H</td>
<td>1:10000</td>
<td>1:1000</td>
<td>A10</td>
<td>0.43</td>
<td>0.40</td>
</tr>
<tr>
<td>I</td>
<td>1:8000</td>
<td>1:1000</td>
<td>A10</td>
<td>0.43</td>
<td>0.40</td>
</tr>
</tbody>
</table>

The camera taken for the test area is RC10 with \( F=152\)mm

2.2 For terrestrial photogrammetry, 1:2000 and 1:1000 map has been made using JENA 19/1318 Photo-theodolit and Topocart and Autostereograph 1318 instrument. The accuracy as following:

<table>
<thead>
<tr>
<th>TEST AREA</th>
<th>AVERAGE PHOTO-SCALE</th>
<th>MAP SCALE</th>
<th>INSTRUMENT</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( M_h )</td>
</tr>
<tr>
<td>A</td>
<td>1:4500</td>
<td>1:2000</td>
<td>TOPOCART</td>
<td>0.45m</td>
</tr>
<tr>
<td>B</td>
<td>1:3100</td>
<td>1:1000</td>
<td>1318</td>
<td>0.38</td>
</tr>
</tbody>
</table>

2.3 Engineering survey
(1) The deformation monitor of the coal preparation building:
The photo taken by JENA 19/1318 Photo-theodolit is measured on P5K-2 Comparator. The data is proceeded with the Coplanar and Direct Linear Transformation. When we introduce the radial distortion of the lens in to the equation, the method is based on the following pair of equation:
\[
\begin{align*}
x + x'r^2K - & \frac{l_1 x + l_2 y + l_3 z + l_4}{l_5 x + l_6 y + l_7 z + l_8} = 0 \\
y + y'r^2K - & \frac{l_1 x + l_2 y + l_3 z + l_4}{l_5 x + l_6 y + l_7 z + l_8} = 0
\end{align*}
\]

where
- \( r \) is the radial distance of the image, \( r = \sqrt{(x-x_0)^2 + (y-y_0)^2} \)
- \( K \) is the radial distortion coefficient
- \( l \) is the function of orientation element, principle distance and linear correction

Above equation can be reduced to the following matrix equation:
\[
\begin{bmatrix}
X & Y & Z & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -xX -xY -xZ -xr \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -yX -yY -yZ -yr
\end{bmatrix}
- L \cdot \begin{bmatrix}
X \\
Y \\
Z \\
1
\end{bmatrix}
= \begin{bmatrix}
V_x \\
V_y
\end{bmatrix}
\]

where
- \( L = \begin{bmatrix} 1 & 1 & 1 & \ldots & 1 & K \end{bmatrix}^T \)
- \( A = \frac{1}{l_5 x + l_6 y + l_7 z + l_8} \)

We have 12 unknown elements in the equation, so more than 6 control points are needed. The results of the monitor points approach 1-2cm.

(2) The measurement of strip of an open-pit mine:
The stereophoto is taken periodically at the fixed station with \( B = 31 \) m, \( y = 400 \) m. Using the 1318 Autostereograph measures top-line, base-line and hight points every 2-3 cm. The area is calculated by integrant. At last the quantity of strip could be heted. For this kind of work, photogrammetry methor is much better than old one. It is more efficient, accuracy and less laboured work.

(3) The acquisition of geology information by the method of the close-up photogrammetry. Using SMK-120 stereo-camera and Comparator measures 4-6 points on the geological body plane, then calculate the strike-dip on the plane by following formula:

\[ P_1 y + P_2 x + P_3 z = 1 \]

When getting the coefficients \( P_1, P_2, P_3 \), following formulae is used for calculation of the elements of strike-dip:

- Dip-angle: \( \alpha = \arctan \left( \frac{P_1^2 + P_2^2}{P_3} \right) \)
- Strike: \( \delta = \arctan \left( \frac{P_1}{P_2} \right) + A \); \( A \) is the azimuth of photo-base

The close-up is not only to get the strike-dip but we can get the interval of fault and the thickness of the different geological bodies at same time.

2.4 The lower class control network of coal mine can be established by analytical aerotriangulation. Using independent model method, the area is 9km \( \times \) 11km. The control points are set up as follows:
LMK AERIAL CAMERA with compensation of linear image motion is used. Photo scale is 1:11000. The focal length of photo camera \( f_x = 152 \text{mm} \). The fore-and-aft overlap is 60%. The lateral overlap is 55%. Whole test area has 11 strips. All control points are marked. The photo coordinate are taken on the PSG-2 Comparator. The results of block are: \( M_e = 0.15 \text{m} \). It can be met the requirement for the lower class network of coal mine.

3. Conclusion and perspection

Based on the experiment for years. The photogrammetry can resolve various terrain survey task economically, especially for repetition task and map revision. We also can expect, taking digital technology for data collection and setting up mining data base, can make the photogrammetry information directly for application of mining planing, design, construction and administration.