

APPLICATION OF STEREO PLOTTING SYSTEM TO UNDERGRADUATE PROGRAM TO FOSTER NON-PHOTOGRAMMETRIST

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ABSTRACT:

As spatial information becomes more popular in various fields in recent years, more engineers capable of processing spatial information obtained by using digital stereo images have been required. Accordingly, Department of Network and Computer Engineering, Tokai University (TU for short) planned to provide undergraduate students with lectures and practical works on spatial information processing. TU started two subjects on spatial information processing in the 2007 fall semester in collaboration with Research and Development Division, Kokusai Kogyo Co., Ltd. (KKC for short). TU and KKC adopted the simplified spatial information acquisition system K-Scope with SSM (Stereo-Set-Manager) developed by KKC as a training tool. This paper reports on an experiment to evaluate effectiveness of K-Scope with SSM as a training tool on spatial information acquisition to an undergraduate program the aim of which is to foster non-photogrammetrist. The experiment results show that K-Scope with SSM has a potential to be a good spatial information acquisition tool for undergraduate students of TU. However, it is found that K-Scope with SSM does not have two necessary functions for the undergraduate program of TU. One is the function of exterior orientation by using control points, and the other is the function of real-time verification of acquired spatial information. Therefore, TU and KKC will add these functions to K-Scope with SSM or develop a new piece of software possessing these functions to improve the subjects on spatial information processing at the undergraduate program of TU.

1. INTRODUCTION

In recent years, the needs for 3-D measurement and spatial information acquisition using digital stereo images have been increasing in response to the current of digitization of aerial photographs and the trend to higher resolution of satellite images. Accordingly, it is urgent to train many engineers capable of executing 3-D measurement by using digital stereo images. Moreover, as spatial information becomes more popular in the field of application research, more researchers are becoming eager to acquire spatial information by themselves.

Therefore, Department of Network and Computer Engineering, School of Information and Design Engineering, Tokai University (TU for short from now on) planned to provide undergraduate students with lectures and practical works on spatial information processing. TU aims to foster information processing engineers. TU provides not only the basics in information technology, but also some lectures on computer graphics and image processing.

TU decided to start two subjects on spatial information processing in the 2007 fall semester. One is the subject "Spatial Information Processing," which consists of 15 lectures of 80 minutes. The other is the subject "Exercises on Information Technologies," which consists of 30 exercises of 160 minutes. Since TU does not aim to foster photogrammetrists, three or four lectures of the former subject deal with photogrammetry, and two or three exercises of the latter subject deal with

photogrammetry as well. Another lectures of the former subject deal with ground survey, remote sensing, GPS, GIS and so on.

TU decided to conduct both the subjects in collaboration with Research and Development Division, Kokusai Kogyo Co., Ltd. (KKC for short from now on), which is one of Japan's leading engineering consultant firms. KKC is a multidisciplinary engineering firm, offering innovative global solutions through consulting and engineering services, and the use of surveying and geospatial information technologies.

TU and KKC discussed the contents of the subjects, and decided to adopt the spatial information processing system developed by KKC as a training tool (Takeda, 2006). The system named K-Scope with SSM (Stereo-Set-Manager) was developed as a simple and low cost stereo plotter system, and the main function of K-Scope with SSM is to acquire spatial information. Although K-Scope with SSM was originally designed for business use, we believed that K-Scope with SSM has a potential to be a good training tool for undergraduate students of TU.

TU and KKC decided to conduct an experiment to evaluate effectiveness of K-Scope with SSM as a training tool on spatial information acquisition to an undergraduate program the aim of which is to foster non-photogrammetrist. This paper reports on the experiment executed by the TU undergraduate students.

2. OUTLINE OF K-SCOPE WITH SSM

2.1 Features of K-Scope with SSM

Major features of the current full-function version of K-Scope with SSM as a stereo plotter are as follows:

- (1) Easy operation: The major advantage of K-Scope with SSM is that it is easy for beginners to operate. Short-term training allows beginners to execute accurate 3-D measurement.
- (2) Small scale and low cost hardware: The second advantage of K-Scope with SSM is that necessary hardware is compact and not expensive for business use. The hardware system components are mainly a personal computer, a stereo viewing device such as 3-D LCD glasses and a 3-D pointing device.
- (3) Provision of products of the requested quality: K-Scope with SSM can provide highly precise spatial information. Precision of spatial information acquired by K-Scope with SSM depends on the skill of an operator.
- (4) Cooperation of the stereo plotting software and the image-database management software: K-Scope with SSM is composed of the stereo plotting software K-Scope and the image-database management software SSM (Stereo-Set-Manager). SSM manages stereo pairs of digital aerial images acquired directly by a digital camera or obtained through digitization of analog photographs. K-Scope is able to display a pair of stereo images around the specified point immediately with the assistance of SSM.
- (5) Points cloud processing function: K-Scope with SSM can process points cloud data acquired by a LIDAR.
- (6) No orientation function: K-Scope with SSM has no orientation function for easy operation and system simplification. Orientation parameters (the position and attitude of each image) are provided with digital stereo images by KKC.

2.2 Hardware of K-Scope with SSM

The typical hardware of K-Scope with SSM is shown in Figure



Figure 1. Hardware of K-Scope with SSM

1. The minimum hardware components of K-Scope with SSM are as follows:

- (1) Personal computer: K-Scope with SSM works on a Windows-based personal computer with a keyboard, a pointing device such as a mouse, an OpenGL stereo-ready graphics card with quad buffer support, and a stereo-ready CRT monitor. The graphics card should support stereo on Microsoft Windows 2000/XP with a stereo connector. The CRT monitor is required to be able to display with vertical refresh rate of 100 Hz or more at a resolution of 1024 × 768, to avoid noticeable flicker.
- (2) Stereoscopic viewing equipment: K-Scope with SSM will provide an operator with stereoscopic visualization. K-Scope with SSM works currently with StereoGraphics Monitor ZScreen that enables stereoscopic viewing on a CRT monitor. StereoGraphics Monitor ZScreen produced by REAL D, USA is a stereoscopic visualization system comprising a high speed modulating stereoscopic panel and circular polarized eyewear (REAL D, 2008) as shown in Figure 1.

2.3 Software of K-Scope with SSM

The major functions of the current full-function version of K-Scope with SSM are as follows:

- (1) K-Scope with SSM can acquire spatial information by using stereoscopic viewing. Figure 2 shows the main window of K-Scope with SSM to acquire spatial information, and the aerial image on the right side of the window is stereoscopic viewing.
- (2) K-Scope with SSM can manage stereo data sets. K-Scope with SSM shows thumbnail images as an index map by using digital aerial images and results of POS (Position and Orientation System) processing or aerial triangulation.
- (3) K-Scope with SSM can manage layers of both raster and vector datasets. The overlapping order of layers and visibility of each layer are controllable.
- (4) K-Scope with SSM has three graphics modes such as the ortho view mode, the perspective view mode and the stereo view mode. The ortho view mode provides vertical

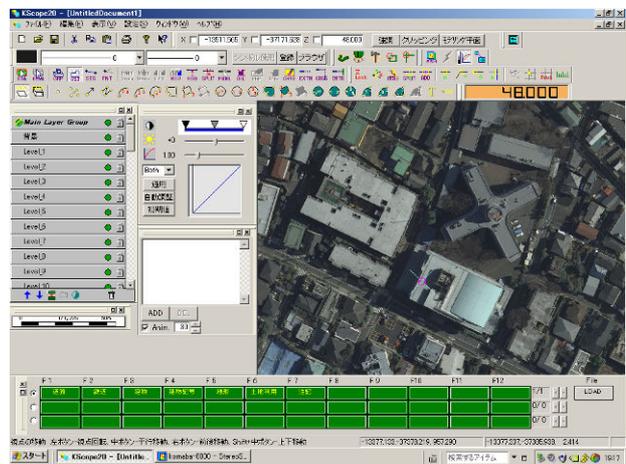


Figure 2: Main window of K-Scope with SSM to acquire spatial information (right aerial image: stereoscopic viewing)

viewing that is not stereoscopic viewing to see a 2-D map image. The perspective view mode can provide 3-D viewing from any viewpoint. The stereo view mode can provide stereoscopic viewing from any viewpoint. The perspective view mode and the stereo view mode can help to inspect quality of acquired spatial data of 3-D objects.

- (5) K-Scope with SSM can input and edit the various types of spatial information. K-Scope with SSM processes three types of objects such as primitive objects, parametric objects and informative objects. Primitive objects include the types of point, points cloud, vectors, poly-lines, and polygons. Parametric objects include the types of circle, arcs and sectors. Informative objects equal to the text objects that can add to some explanation on the layer as an annotation.
- (6) In order to join the editing vector data to existing vector data or grid points, K-Scope with SSM can snap to a line, a vertex, an end point of a poly-line, an intersection point and so on.
- (7) K-Scope with SSM can design the original symbol marker by oneself. K-Scope with SSM includes a fishing port, a police station, a ruin of castle, a temple, a hospital and a city office and so on. K-Scope with SSM will provide management function that is selection of symbol and adjustment scale.
- (8) K-Scope with SSM has the editing function of LIDAR data such as removing and clustering by using the stereo view mode. LIDAR points and 3-D objects can be seen as digital mapping data or DEM data.

Although K-Scope with SSM is a simplified spatial information acquisition system, K-Scope with SSM has too many functions for the undergraduate program of TU. Therefore, TU decided to adopt the function-limited edition of K-Scope with SSM as a training tool.

On the other hand, the current K-Scope with SSM does not have the following functions:

- (1) K-Scope with SSM cannot process stereo pairs of aerial images, GPS data and IMU data directly.
- (2) K-Scope with SSM cannot execute POS processing, in which the position and attitude of each image will be obtained from GPS data and IMU data.
- (3) K-Scope with SSM cannot conduct an aerial triangulation by using ground control points to obtain the position and attitude of each image.
- (4) K-Scope with SSM cannot process close range images such as digital still camera images.

2.4 Workflow of spatial information acquisition

Workflow of spatial information acquisition by using K-Scope with SSM is as shown in Figure 3. The workflow is divided into three steps such as the pre-processing step, the K-Scope with SSM step, and the post-processing step.

The main task of the pre-processing step is to obtain the position and attitude of each image in preparation for spatial

data acquisition at the K-Scope with SSM step. GPS data and IMU data obtained during aerial image acquisition are processed with a piece of POS software such as POSpac of Applanix Corporation. When GPS data and IMU data are not available, or if POS processing results are not accurate enough, an aerial triangulation is conducted by using ground control points with a piece of orientation software such as ImageStation of Intergraph Corporation.

Next at the K-Scope with SSM step spatial data are acquired by using stereo images and the position and attitude of each image obtained at the pre-processing step.

Finally at the post-processing step building a topologic structure of spatial data acquired at the K-Scope with SSM step will be conducted, if the application requires topologically structured spatial data. The structuring process can be conducted by using geographical script language such as ArcGIS of ESRI.

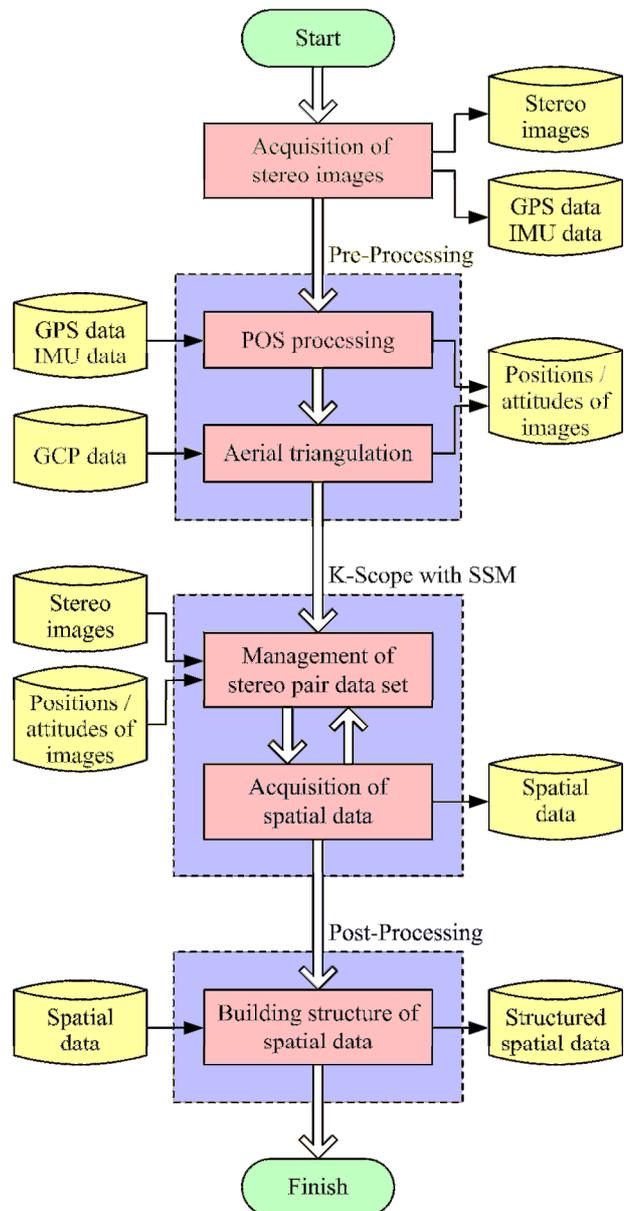


Figure 3. Workflow of spatial information acquisition

3. EXPERIMENT

We have conducted an experiment to evaluate effectiveness of K-Scope with SSM as a training tool on spatial information acquisition to an undergraduate program. Three TU undergraduate students engaged in the experiment.

3.1 Stereo images used in the experiment

KKC provided two datasets of aerial stereo images around the Yoyogi campus of TU. Both datasets consist of images acquired by DMC and the orientation parameters (position and attitude) of each image. Image scales of the two datasets were 1/8,000 and 1/30,000 respectively.

3.2 Experiment of stereo plotting

The students plotted the buildings of TU and surroundings, and roads around the Yoyogi campus of TU by K-Scope with SSM using the provided aerial stereo image datasets. Figure 4 shows a scene of the experiment and Figure 5 shows the result of the stereo plotting.

Although StereoGraphics Monitor ZScreen utilizes lightweight eyewear to be worn for extended periods without fatigue, a student who was not used to wearing glasses felt tired after not so long work.

3.3 Experiment of 3-D measurement

The students conducted 3-D measurement of 78 points in the five districts of five different stereo pairs to evaluate precision of 3-D measurement by K-Scope with SSM as well. Clearly visible points such as corners of buildings and a swimming pool, and ends of lines on schoolyards and parking lots were selected to be measured.

Figures 6 and 7 show 1/8,000 and 1/30,000 images of District-01 of the Yoyogi campus of TU and District-02 of an elementary school in the neighbourhood of the campus respectively. District-01 and District-02 have 16 points and 14 points respectively.

Table 1 shows discrepancies of horizontal and vertical positions of points between students. The left-lower and right-upper triangle parts show discrepancies of horizontal ($X-Y$) and vertical (Z) positions respectively. The upper and lower value



Figure 4. Stereo plotting using K-Scope with SSM

Z	Student A	Student B	Student C
X-Y			
Student A		4.32	5.58
Student B	1.30	9.00	10.00
Student C	2.23	1.65	7.00
	4.38	4.42	

(a) Image scale: 1/8,000

Z	Student A	Student B	Student C
X-Y			
Student A		6.77	3.59
Student B	1.27	28.00	11.00
Student C	1.35	1.32	11.00
	3.75	3.51	

(b) Image scale: 1/30,000

[Upper: RMS (m), Lower: Maximum (m)]

Table 1: Discrepancies of horizontal ($X-Y$) and vertical (Z) positions of points between students

of each cell indicates the RMS (root mean squares) value (in meters) and the maximum value (in meters) respectively.

The measurement precision of vertical positions was much worse than that of horizontal positions. The reason would be that it was difficult to place the measuring mark on the target point in stereoscopic viewing, because a stereoscopic viewing observed by an operator was somewhat dark. Since a ray from a CRT monitor to an operator's eye should pass a high speed modulating stereoscopic panel and circular polarized eyewear, the intensity of the ray is rather weakened.

4. CONCLUSION

Through the experiment, we concluded the followings:

- (1) Students can acquire spatial information by K-Scope with SSM after short-term training. This shows that K-Scope with SSM has a potential to be a good spatial information acquisition tool for undergraduate students of TU.

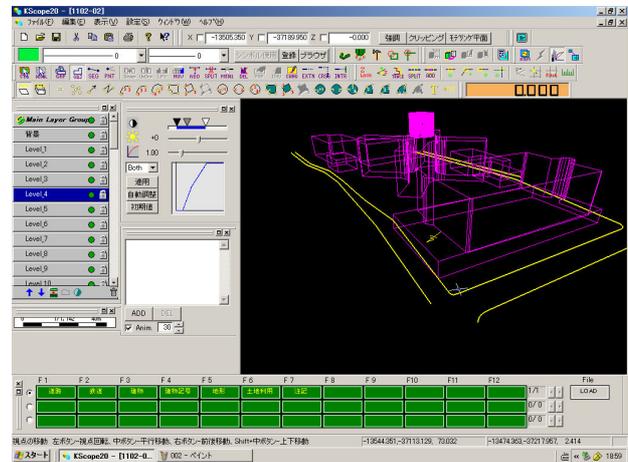


Figure 5. Result of stereo plotting

- (2) The quality of acquired spatial information was not so good as expected. The reason would be that a stereoscopic viewing observed by an operator was somewhat dark, because a ray of light should pass through the high speed modulating stereoscopic panel and the circular polarized eyewear.
- (3) The hardware of K-Scope with SSM is more compact and less expensive than that of a spatial information acquisition tool designed for professional use. However, StereoGraphics Monitor ZScreen costs more than US \$3,000 in Japan, and the total cost of the hardware of K-Scope with SSM exceeds US \$6,000. It would be too expensive for the undergraduate program of TU.
- (4) It is found that K-Scope with SSM does not have two necessary functions for the undergraduate program of TU. One is the function of exterior orientation by using control points, and the other is the function of real-time verification of acquired spatial information. We should add these functions to K-Scope with SSM or develop a new piece of software possessing these functions.
- (5) On the other hand, K-Scope with SSM has many unnecessary functions for the undergraduate program of TU. We will prepare the function limited edition of K-Scope with SSM.

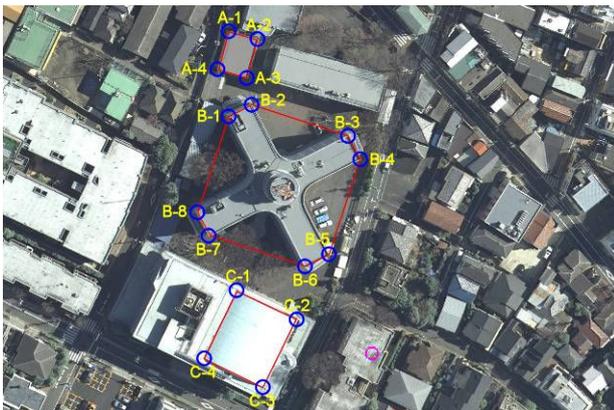
- (6) Furthermore, it is to be desired that K-Scope with SSM can process close range images such as digital still camera images, which are more familiar to undergraduate students of TU.
- (7) Stereoscopic viewing would be of great use in the education of spatial information processing. A stereoscopic viewing in presentation of acquired spatial information would be more attractive to TU students than one in spatial information acquisition.

Following the above-mentioned conclusion, we are going to modify the implementation plan of the subjects of the undergraduate program of TU.

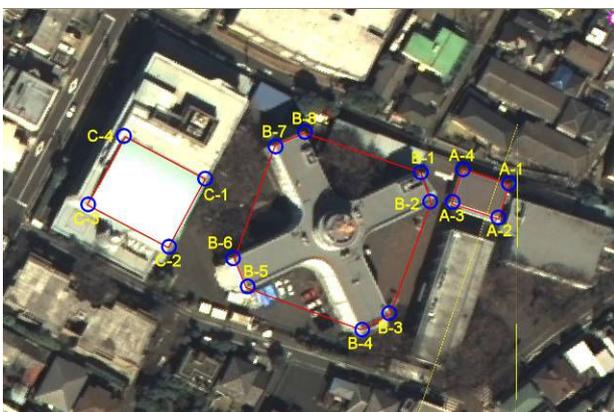
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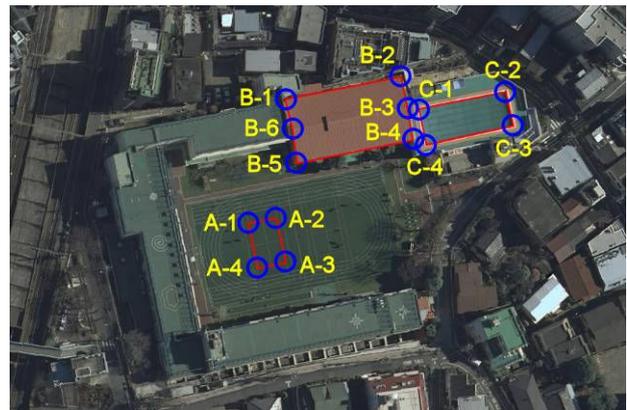


(a) 1/8,000 image

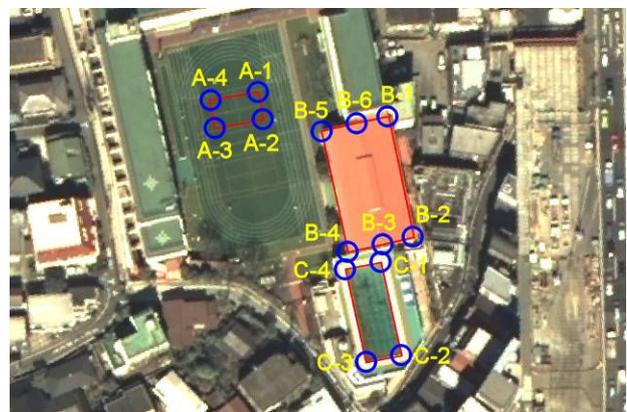


(b) 1/30,000 image

Figure 6. Points for evaluation of 3-D measurement precision (District-01)



(a) 1/8,000 image



(b) 1/30,000 image

Figure 7. Points for evaluation of 3-D measurement precision (District-02)

