PHOTOGRAMMETRY

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Summary

Photogrammetry is a formed word from the Greek “photos”, “gramma” and “metron” and is defined as the science of obtaining information on objects through measuring and interpreting imagery and photographs. Photogrammetry has a 150-year history and its popular name has evolved according to advances of technology such as analog, analytical and digital photogrammetry, respectively. Analog photogrammetry requires a skilled human operator. With the appearance of the computer, analog methods were

computerized. Analytical photogrammetry was subsequently transformed to digital photogrammetry by the transition from photographs to digital images. The common principles in these three categories of photogrammetry are the same, but there are considerable differences in the fields of application. Following a description of the basic principles in photogrammetry, selected current topics in digital photogrammetry are introduced.

1. Introduction

Photogrammetry is the science, art, and technology for obtaining from imagery the position, size and shape of objects, as well as interpretation of these object features. Photogrammetry is divided into aerial and terrestrial categories. Aerial photogrammetry has two distinct areas: metric photogrammetry and interpretative photogrammetry. The common applications of metric photogrammetry are the compilation of planimetric and topographic maps, and uses of interpretative photogrammetry include land classification, and preparation of forestry maps and disaster maps. Terrestrial photogrammetry (the term Close Range is used instead of Terrestrial by the International Society of Photogrammetry and Remote Sensing), is applied to metrology of construction sites, recording structures of architectural significance and measuring historical objects. It is also employed in traffic accident sites and measurement of industrial objects and the human body. With the transition of imaging from film to Charge Coupled Device (CCD) digital sensors, real-time imaging and image processing are now common applications, and the term digital photogrammetry has achieved wider acceptance for the photogrammetric field. Application fields of digital photogrammetry have expanded to embrace machine vision, robot vision, computer vision and virtual reality modeling. In particular, image sequence analysis makes possible dynamic analysis such as human motion studies in the field of sports training and medical rehabilitation, and in facial expression analysis.

Digital photogrammetry is now developing as a comprehensive technology for obtaining and recording 3D object model position, size and shape via real time imaging, and for reconstructing and visualizing developments in sensor and image processing technologies.

2. Orientation

2.1 Stereoscopic instruments

Aerial photographs in photogrammetry are usually taken with a 60% forward overlap. The overlapping pair of photographs is called a stereopair. Stereoscopic instruments are the photogrammetric instruments that provide rigorously accurate analog solutions for the stereo image projection which creates a 3D model of the overlap area. This model is called a stereomodel. Determining the parameters of this projective transformation between 2D image space and 3D object space is called exterior orientation, and the process of creating the stereomodel independent of a chosen reference coordinate system is called relative orientation. Stereomodel data is transferred to planimetric or topographic maps through the absolute orientation process. Electro-mechanical instruments which enable stereomodel projection and 3D analysis are called analog stereoplotters or simply photogrammetric plotters. The basic concepts of an analog stereoplotter are illustrated in Figure 1.

An analog stereoplotter consists of projectors (1), a reference table (2) and a tracing table (3). Projectors with illumination lamps(5) are set on the projector bar(6), and six screws enable setting of correct perspective center positions and tilt angles for the projectors. After the orientation is completed, all light rays for corresponding or conjugate points on the diapositives intersect within a 3D model space in which measurements of position can be made. Intersection points are tracked using a platen (4) and elevations are determined for the intersected object point. A map is then created on the reference table (2) by tracing the intersected points of interest using a tracing table (3). An analog stereoplotter is shown in Figure 2.

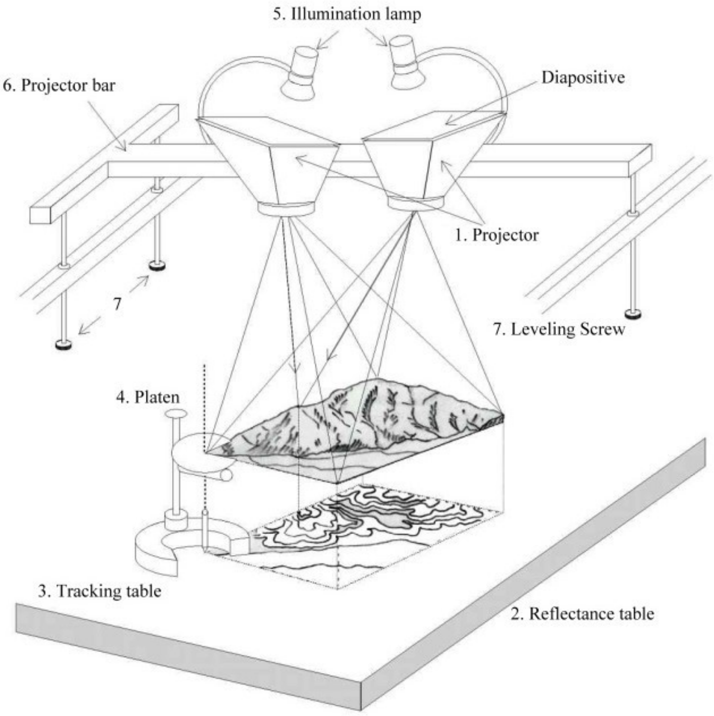

Figure 1: Basic concepts of analog stereoplotter

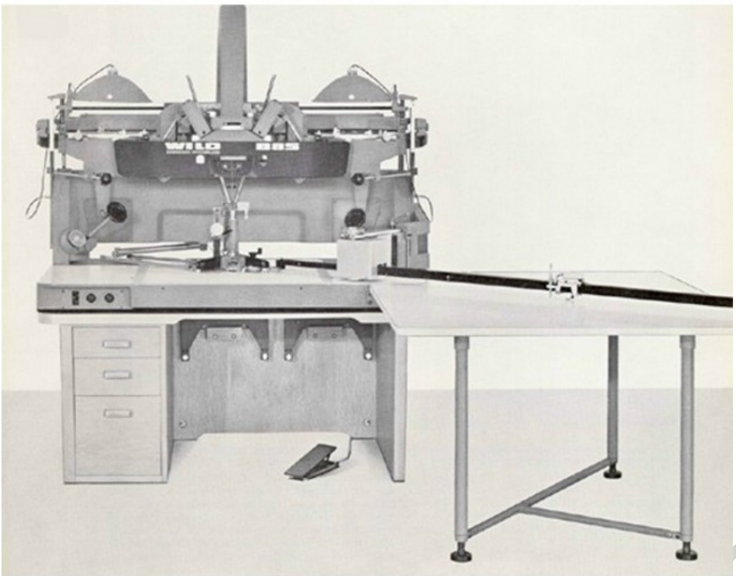

Figure 2: Wild Aviograph B8 (Courtesy LH Systems LLC)

2.2 Exterior orientation

For a given image, X, Y and Z coordinates of the perspective center, and the tilt angles about these three mutually perpendicular axes, constitute the exterior orientation parameters. The x-rotation is called omega (ω), the y-rotation phi(φ) and the z-rotation kappa(κ). The exterior orientation process for an analog stereoplotter is conducted in two sequential stages, namely relative and absolute orientation.

2.3 Interior orientation

In general, aerial cameras are carefully calibrated by the camera manufacturer to determine precise values for the interior orientation parameters. These are the principal point location, focal length, lens distortion, fiducial mark coordinates or inter-fiducial distances, and flatness of the camera focal plane. There are usually four fiducial marks on the focal plane frame. These marks are exposed onto the negative when the photograph is taken. The principal point is defined as the point of intersection of the lines joining opposite fiducial marks. Fiducial marks enable corrections for film shrinkage or expansion which may occur in the developing or subsequent storage of film. Lens distortion is classified as either radial or tangential. Radial distortion is the distortion in image position along radial lines outwards from principal the point, and tangential distortion is distortion in image position perpendicular to such radial lines. Tangential distortion can usually be neglected since it is normally quite small.

2.4 Relative orientation

The process of relative orientation is used to create the stereomodel shown in Figure 1. In general, six corresponding image points (at least five are needed), called pass points, are conventionally used in relative orientation. There is no requirement to know the XYZ object space coordinates of pass points, the relative orientation takes place independently of the reference coordinate system of the object space. The stereo model is formed when y-parallax is cleared at all image points, which indicates that corresponding rays will intersect within the model space. Parallax is a displacement in position caused by a shift in the position of the observer. When parallax (x-parallax) varies parallel to the flight direction, it indicates a change in the elevation of the intersected object point and thus x-parallax is an important element for calculating XYZ ground coordinates of points by aerial photogrammetric measurement. The existence of y-parallax means that the relative orientation needs to be refined.

2.5 Absolute orientation

The transformation on an analog from the stereomodel coordinate system to the ground coordinate system through a scaling and leveling is called absolute orientation. This requires at least three control points (commonly four points) distributed in the model so that they form a large triangle. Scaling is performed by means of parallel movement of projectors along the X axis, since expansion and reduction of the projected map on the reflectance table changes model scale. After the scaling is completed, leveling is performed by tilting the projector bar around X and Y axes using leveling screws, (7) in figure 1. After absolute orientation, control points in the model will coincide with corresponding marked positions established on the reference table.

2.6 Successive orientation

If there are more than two stereomodels within a flight line, the adjacent stereomodels can be connected to one another using an analog plotter. This is called successive orientation. After the orientation is completed for the first stereopair, the third photograph is set on the left projector instead of the first photograph, and the orientation for the third photograph with respect to the second, which is on the right projector, is performed by relative orientation. The successive orientation procedure is implemented in practice by a concept called the Zeiss parallelogram. The connecting of stereomodels by repeated, successive orientation is called analog aero-triangulation.

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Biographical Sketch

Prof. Dr. Hirofumi Chikatsu is currently a professor at the College of Science and Engineering, Tokyo Denki University, Japan, a position he has held since 1995. He graduated with a Master of Engineering (Civil Engineering) from Chuo University in 1975 and obtained his doctorate in Photogrammetry from the University of Tokyo in 1988. From 1989 to 1991 he was an associate researcher at the Institute for Applications of Geodesy in Civil Engineering at the University of Stuttgart in Germany, and since 1992 he has also been an associate researcher at the Institute of Industrial Science at University of Tokyo.

Prof. Chikatsu is a member of the Japan Society of Civil Engineering, the Japan Society of Photogrammetry and Remote Sensing, and the Japan Association of Surveyors. He served from 1996-2000 as President of Commission V (Close Range Techniques and Machine Vision) of the International Society of Photogrammetry and Remote Sensing (ISPRS), and has been Vice President of the Japan Society of Photogrammetry and Remote Sensing (JSPRS). He is currently a council member of JSPRS, and since 1994 has been on the council of the Association of Real-time Imaging and Dynamic Analysis (ARIDA). He also currently serves as chairman of ISPRS Working Group V/4 (Integration of image analysis and spatial information system for applications in cultural heritage).

Professor Chikatsu's current research interests include automated object detection and reconstruction using digital photogrammetric and videogrammetric techniques, building and line feature extraction from imagery, 3D city modeling, image matching, human motion analysis, and imaging techniques for the generation and control of virtual reality modeling.

He serves on the editorial boards of several scientific journals and is Editor in Chief for the Journal of Survey. Prof Chikatsu has published more than 100 research articles and technical papers.