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# RECENT DEVELOPMENT OF INDUSTRIAL PHOTOGRAMMETRY IN JAPAN

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## § 1. General Remarks

The author has been engaged in the application of photogrammetry since 1949, originally in map-making, measurement of excavation volumes for dam construction, etc., but recently the photogrammetry has extended their application to the various kind of fields and played the important role in planning and surveying of social and engineering field, especially in the field of industry. This paper deals with the some recent achievements in the industrial field in Japan, especially on the developed fields after Helsinki Congress in 1976.

## § 2. Historical Background in Japan in the field of Industrial Photogrammetry

The author has started to study the camera calibration of terrestrial phototheodolite in 1948 in the field and the optical bench. In 1949, the terrestrial photogrammetry was applied in the field of dam construction for making the large scale maps such as 1 : 500 and 1 : 300 and used for planning of big dam construction. In 1950 at the Niigata beach facing the Japan Sea, specially designed two stereocameras were used for catching behavior of the wave pattern in the sea with the cooperation of Hydraulic Department, Transportation Ministry.

In the next year, precise measurement of the Great Buddha was done by the short-range photogrammetry for computing the center of Gravity and weight. This procedure gave the weight as about 120 tons as compared with the actual figure of  $121 \pm 2$  tons obtained when the statue was lifted to rebuild the base. In 1959 Indian Mission for Archaeology and History engaged in studying and measuring the historical architectures and remains of medieval time in India by the terrestrial photogrammetric method and the author directed this program. It was continued until 1964 and during this period four study groups were organized under the sponsorship of the University of Tokyo, Inst. of Oriental Culture and Japanese Government.

In 1962, the author was engaged in projects relating to the application of photogrammetry to engineering projects. Among these were application of photogrammetry to automobile models for obtaining body line drawings and for checking the complicated surface of hydraulic turbine runners. The results of this project were discussed as a presented paper at the I. S. P. Congress in 1964. Since then various achievements have been made in the field of industrial photogrammetry in both software and hardware.

In 1966 at the Comm. V Symposium of I. S. P. in Tokyo, the author presented

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a paper on short-range photogrammetry for objects in motion and this was the first proposal for four-dimensional photogrammetry in the field of industrial photogrammetry.

The Meteorological Research Institute started to measure the air turbulence phenomena at Mt. Fuji to determine the cause of the BOAC airplane crash in 1966 under actual conditions in the field and experimentally in the wind tunnel. I was involved in this project for the photogrammetric works and analysis. Flash balloons equipped with a light mechanism with a time interval of 15 seconds were dropped from an airplane in the vicinity of Mt. Fuji. Three P 30 phototheodolites took photos at fixed triangulation points which were appropriately distributed throughout the area and the space coordinates of the flash at each 15 seconds were calculated by computer and also model tests inside a wind tunnel were carried out to determine the conditions of air turbulence by tracing the smoke trails.

In 1967, in Kobe harbour, ship positions in sailing were determined by photogrammetric method : terrestrial method and aerial method. Two P 30 phototheodolites in the terrestrial photogrammetry were used for taking the successive photos each 6 seconds. In the same year from fixed points on the beach placed two phototheodolites, the positions of a ship, on which the instruments of seismic reflection recorder are carried, was determined.

The year 1967 was the first year in Japan when the terrestrial photogrammetry was applied to the traffic accident surveying with the shortrange photogrammetry. As the result, the specially designed cars to carry the stereo-camera mechanized with the automatic function have been popularly used among the accident management centers belonged to national police and all local police headquarters in which police men stay whole day and night and deal with the all kind of works related to the accidents including the stereo-photographing works in urgent case. There are all 3000 police men working there totally in whole Japan. Nowadays this management techniques have been extended to apply not only for the traffic accident sites but also the criminal sites and many works related to the police business. As of the 1975 calender year, there are 279 stereocameras and 66 plotting machines belonging to the police stations.

The body measurement of human being has been doing extensively from the needs of various kind of fields such as human being engineering, cloth design field, anatomy field and so on, not only using the photogrammetric method but also the moirè topography, holographic method. As you all know, Prof. Takazaki, originator of moirè topography, has succeeded the technique for visualizing contour lines in situ on an object and its extended application on an object with large size and depth.

Several applications in the field of of medical and industrial engineering were discussed exclusively at the 14th Japan Annual Meeting of the Medical Engineering Society in 1975 on the boundary problems between medical and engineering fields.

The terrestrial photogrammetric techniques were also effectively used for the model test for civil and architectural engineering field such as plastic buckling test of catching I-beam flange and web behavior under loading (refer to the Invited Paper of ISP 1968

“Short Range Photogrammetry of Objects in Motion”) and the model test of suspension roof deformation of the national indoor stadium catching the roof behaviors under the various load conditions. The model test of the Taiseiki Temple by photogrammetric techniques controlled for the measurement of deformation under the various loading conditions and earthquake conditions. The two SMK-120 stereo-cameras were used for analytical short-range photogrammetry.

On the way of applying actually this terrestrial photogrammetry, many hardware such as specially designed devices for storing the input data and data processing instruments have been developed and also a series of system for analyzing the images has been established.

### § 3. Several Problems on the way to develop Industrial Photogrammetry

In the Helsinki Congress, the author has remarked on the several examples of new development of industrial photogrammetry in our country such as analytical short-range photogrammetry for the measurement of a tire rotating at high speed, measurement of subsidence of the launching ways at the Mitsubishi Dock, measurement of marine “model propeller cavitation in hull pressure and so on.

In industrial photogrammetry, precise measurement is sometimes important for design construction with severe criteria. This is combined with the stereo-camera, comparator, computer and so on and the problems in this case are the distribution and number of control points. Size and marking of control points, geodetic measurement of control points, position and direction of stereo-camera and its selection, transformation and adjustment of control and the check of physical condition of camera and plates, and especially the mathematical formulas for checking the control points are the key factor for this measurement. The inner orientation factors have an important effect upon the result. These must be considered in synthetic ways.

After Helsinki Congress, we’ve proceeded the more systematized program on the way of analyzing the data gained by the analytical terrestrial photogrammetry. In the calculation of the analytical photogrammetry, the theory of the projection geometry must be severely considered including the various kinds of camera errors.

The conventional method only uses the inner orientation data given from factory. As far as the terrestrial photogrammetry is concerned, photo-taking conditions are always changeable, for example the plate has not been kept in a same position because of invariable pressure force, that means, the camera has always variable inner orientation data. Therefore we must adjust always these data to accommodate to the precise central projection geometry. The more difficult things in the process of analytical photogrammetry is the fact that objects are in the deep range. From the point of optical and mathematical geometry, the real correct focussed range must be checked and examined.

As the fundamental formula, we consider the following principle :

$$\sum_{i,j} (\cos \alpha - \cos \beta) \text{ —— minimum}$$

herewith  $\alpha$  : incoming angle through lens

$\beta$  : outgoing angle through lens

and in case of the least square method solution, the following coefficient determinant formula must be considered.

$$\begin{pmatrix} dX \\ dY \\ dZ \end{pmatrix} = \begin{pmatrix} A_1 & A_2 & A_3 \\ A_4 & A_5 & A_6 \\ A_7 & A_8 & A_9 \end{pmatrix} \begin{pmatrix} dx \\ dy \\ df \end{pmatrix}$$

and the important point in the short-range photogrammetry is that all control points must be arranged to be situated not only in the plane (X,Z) but also in depth direction (Y) that means three dimensionally. The above-mentioned program is considered very precisely for each plate and as the numerical model is formulated in the systematized way, the most reliable data can be gotten.

The actual measurement for an architectural model was tried by this analytical means using two SMK-120 stereo-camera which were used for photographing from the upper side on aspecially designed platform. The object was the model of a famous temple, about eight meters by seven meters in cross section and three meters high. The distance between cameras and object was eight meters. The mean square error of measurement was about  $\pm 0.2$  mm in plane coordinate and  $\pm 1.5$  mm in height :

The next important problem is to do fairing adjustment on the entire whole surface of the measuring object. The fairing methods are divided into five points method, spring thory method, and fourier series method. These theory is not difficult but the related problems arisen on the process are not so simple. Therefore we must perform more research in order to find the integrated techniques in considering economical and easily applicable conditions.

#### § 4. Several Examples of Industrial Photogrammetry in Japan after the Helsiki

##### 4-1 Measurement of Atomic Bomb Buddha Statue by Close-range Photogrammetry geodetically controlled

The purpose constructing this buddha is to console and worship the soul of the dead persons by the atomic bomb. At first the original buddha sculpture was made by the famous sculptor. For the reconstruction of ten times buddha in the field, the precise space coordinates on the original buddha body were needed. The height of original buddha is 4.00 m. The works of photo-taking, measurement, fairing were done by using the control points which were measured by the method of trilateral triangulation.

##### 4-2 Measurement of a Tire rotating at High Speed

In conjunction with the increased speed of motor cars due to the construction of super highways, the development of new tires has become an urgent problem. The measurement of tire deformation by the classical method is very difficult to carry out

in a laboratory because of the high velocity. The short-range photogrammetric method cannot be replaced by any other conventional method for this purpose. A series of measurements has been developed to accomplish systematically and automatically for measurements of deformation by using a specially designed stereo-camera, comparator, computer, and automatic plotter at the Bridgestone Tire Co. Ltd. with the cooperation of the Sokkisha Co. Ltd., and Hosei University. The flow chart for the measurement operations is shown in Figure 1 and stereophotos in Figure 2. The final mean square error of measurement was  $\pm 0.25$  mm.

The coordinate data on the plate taken from a SKB-40 stereo-camera, can be trans-

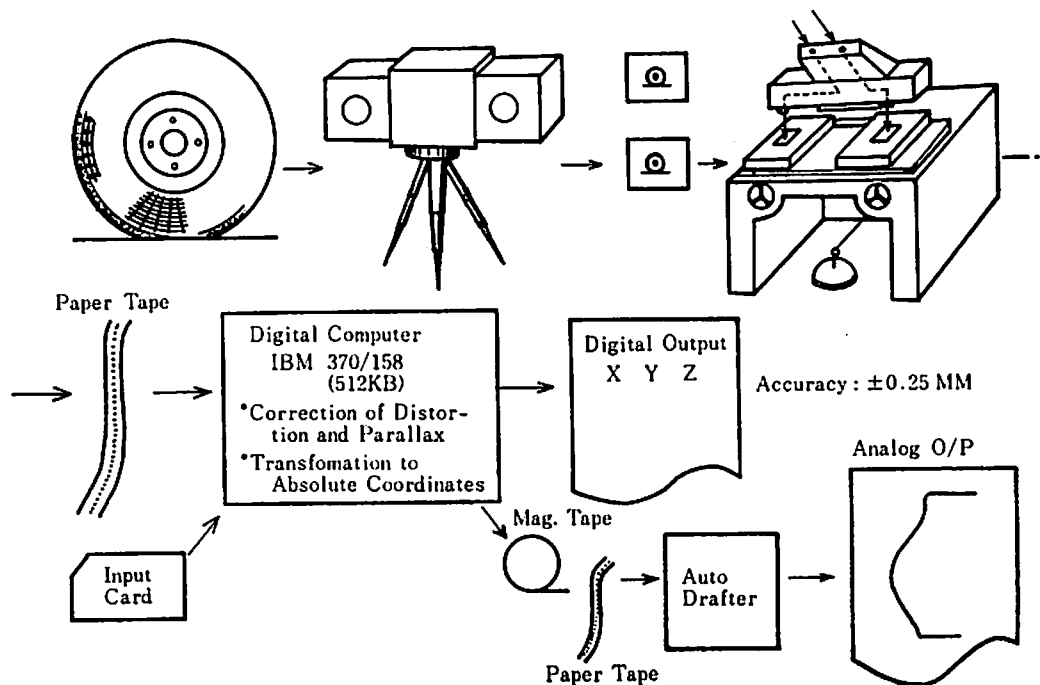


FIG. 1. Analytical short-range photogrammetry for measurement of tires.

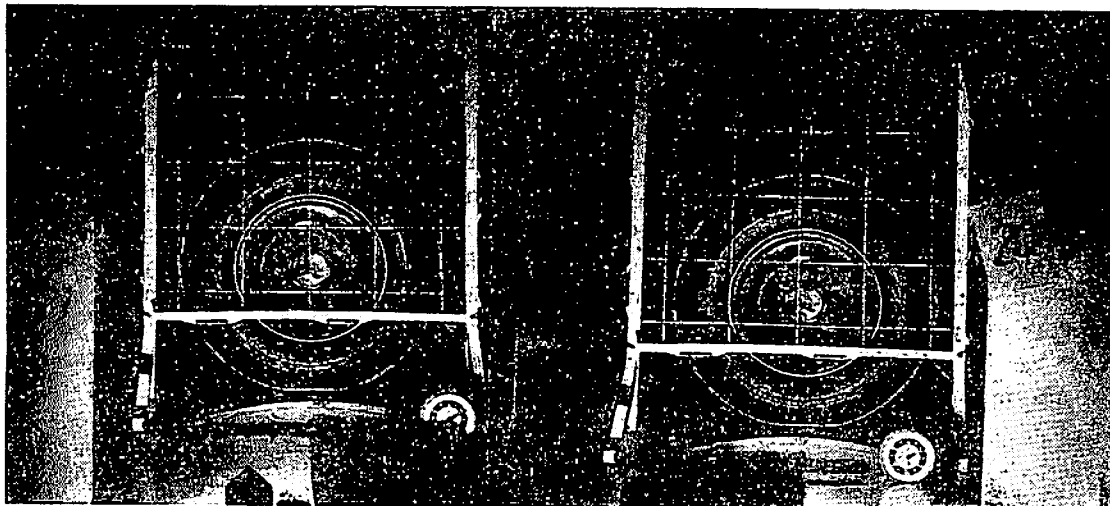


FIG. 2. Stereopair of tire.

formed to the plate coordinates from the fiducial mark coordinates ; six points on the plate can be selected for relative orientation ; and absolute orientation can be done from the control points set on the front of the fixed frame. The coordinate data calculated by the computer can be plotted automatically with the on-line system and the result gives the clear influence area of the inner stress on the tire.

The newly developed systematized method was done for measurement of a tire rotating at high speed. The Röntgen photogrammetry was applied for analyzing the inside of the tire.

4-3 Specially designed Microscope for Stereophotomicrograms with an annexed stereocomparator

This microscope as well as stereocomparator were constructed for the purpose of measurement of the volume and surface area of neurons stained by Coigi's method. These apparatus will also be useful for obtaining the three-dimensional data on various industrial objects.

## § 5. Conclusion

Short-range Photogrammetric methods have played an important role in the field of industrial photogrammetry and the results have been most satisfactory. But there are various problems which must be solved if short-range photogrammetry is to be applicable systematically. Since only a few examples have been given, we must perform more research in order to find integrated techniques.

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