Microscope and X-Ray Photogrammetry and Their Medical Application

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1. Introduction

In the medical application of photogrammetry, the measurement of the visual form of human body by photogrammetry is neither so difficult nor new and already has been being practised considerably in the fields of orthopaedic surgery, dentistry,human morphorogy, etc.

This paper covers the application to fields which require approaches fundamentally different from those made in the conventional photogrammetry; one is stereoscopic measurement by use of microscopic photogrammetry and the other is streoscopic measurement by use of X-ray photogrammetry.

The sterescopic measurement by microscopic photogrammetry must solve the following new problems. Since a greatly enlarged image must be photographed in a narrow field of view, it is very difficult to obtain a stereo-photo sufficiently containing a base inevitable for accurate measurement and the conventional lighting used for observation alone does not allow the surface of the specimen to be confirmed and is unsuitable for stereophotogrammetry. Furthermore, since the focussing depth is shallow, a slight difference in depth makes the image fuzzy, not allowing accurate measurement, and any method for detting control points to be reffered to for measurement must be considered. These various difficult problems must be solved.

X-ray photography is basically different in nature from ordinary photography. The differences are that while ordinary photography forms images by reflected light, X-ray photography forms images by X-rays emitted form a source, and that sufficient conditions must be satisfied to treat the light source as a point source.

This report describes methods for solving these problems and several examples. Studies of this kind require positive cooperation of medical doctors needless to say, and the present study can be said to have borne fruit with earnest cooperation of Prof. Dr. Mannen, Tokyo Medical and Dental University, the late Dr. Ohtsu and Dr. Inoue, Branch of Tokyo University Hospital, Dr. Tokorazawa, Nagasaki University, et al. These method can be applied not only to photogrammetry for the human body but also to the photogrammetry used widely industrially. However, problems of higher accuracy and problems for wider practical application need studies to be continued further.

2. Microscopic photogrammetry

2-1. Stereophotographing method

The measurement of the positions by stereophotogrammetry can be executed either by processing two photos of an object (a specimen for a microscope, in this case) taken from two points apart from each other by a certain distance and using a plotting instrument,or by calculating from the coordinates measured on photos of the points to be measured.

However, in the case of a microscope, since photographing is made using a camera fixed on one microscope, the object must be moved horizontlly to obtain stereo-photos with a proper base. however, a microscope is very narrow in the field of view since an enlarged image is observed, and a slight horizontal movement of the object causes it to go outside the field of view. thus, it is almost impossible to obtain stereo-photos with a parallax required for measurement by this method.

A method usually taken in such a case is to elongate the base by slightly revolving the object, but it is very difficult to fabricate such a revolving table . In addition, the correct setting of the specimen is another problem to be solved.

The present study has used the convergent photography to solve the above problem. In this method, the specimen is fixed, and only the objective lens of the microscope is tilted toward both sides for photographing (See Fig. 2).

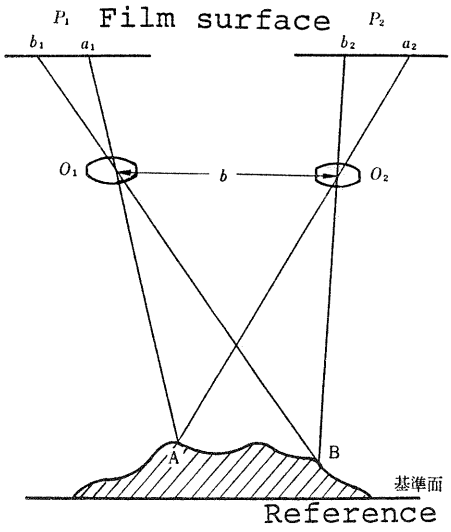


Fig.1 Photography of Microscope

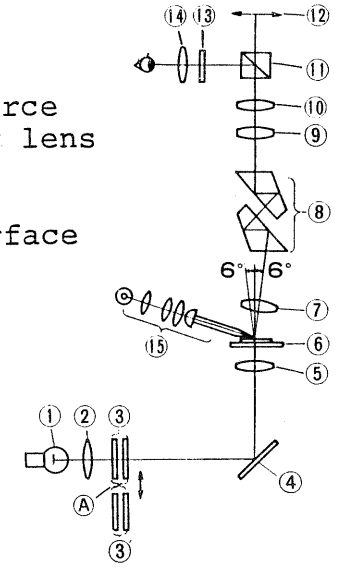


Fig. 2 Internal mechanism of microscopic photographing instrument

2-2. photographing instrument

The outline of the photographing instrument is showan in Fig. 2. The instrument consists of a microscope proper, special stroboscopic reflected illumination unit, measurement reference scale setter, and transformer. The microscope proper uses the body of Nicon L type microscope, and an object, in this case, a specimen with a Golgi-stained nerve cell held between slice glasses by balsam is set on a standard square mechanical stage mounted on the body as in the case of ordinary microscopy. The objective lens

portion alone is tilted by 6 degrees to let the light fall accurately on the vertical optical axis of the microscope by prisms. Photo 1 shows the general view of microscopic instrument. The Objective lens portion can be rotated by 180 degrees, and two stereo-photos can be taken with the specimen kept stationary as mentioned before. The objective lens portion can be simply removed for exchange.

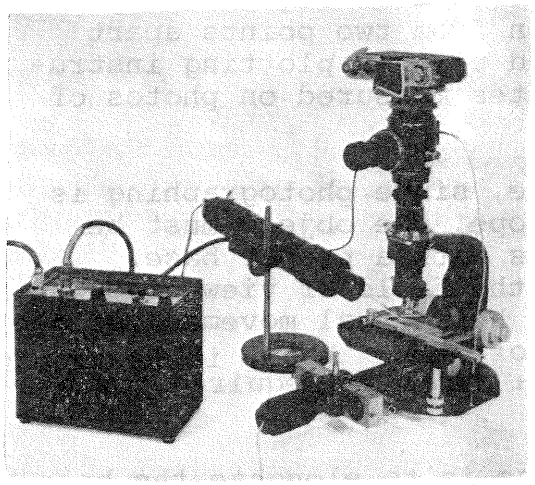


Photo 1 Microscopic photographing instrument

2-3. Reflected illumination unit

Stereophotogrammetry can be used only when the surface of the object can be clearly confirmed. In the conventional observation of a tissur specimen by a microscope, illumination is given from below in most cases. For this reason. the photo obtained gives a silhouette image as shown in Photo 2-a.

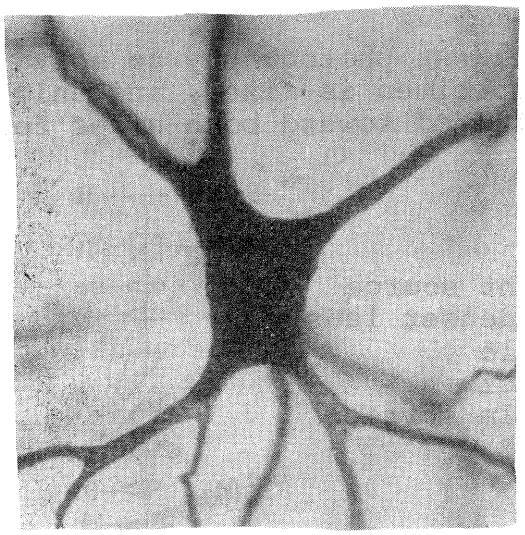


Photo 2-a A Golgi-stained nerve cell by ordinary illunination (upward illumination only)

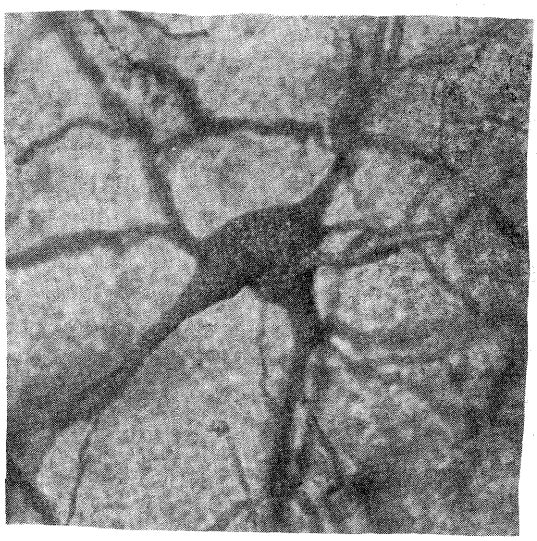


Photo 2-b With both upward and downward illumination(Even only one photo gives a stereo feeling)

In this case, it is impossible to stereoscopically measure the surface of the cell. To overcome this difficulty, it has been decided to use downward illunination in addition to upward illunination. A photo taken by this method is shown in Photo 2-b.

For the downward illunination, at first a condenser for microscope was mounted at the tip of the standard illumination unit for microscope, and the condensed light was guided by a glass rod onto the specimen. However, this method was insufficient in the quantity of light and could not avoid flare, etc.,not allowing the surface to be clearly displayed. Therefore, a relay lens was used for the standard illumination unit, to set a conjugate point of the conventional light source image, and a 200W xenon discharge tube was used for stroboscopic illumination for improvement. As a result, clear photogrphing became possible.

2-4. Reference scale for measurement and its setter

For measurement as absolute values as in ordinary aerial photogrammetry, microscopic photogrammetry must also have a measurement reference simultaneously set in the photo, to decide the reference plane and scale. In the case of photomicrographs, the lenses are fixed and the convergent angle is decided. Therefore, it is sufficient only if a scale for the length on the reference plane of the object and a scale for the height perpendicular to it are provided. However, since microscopic photogrammetry uses a very small specimen of microns, especially highly accurate scales must be photographed simultaneously under the same condition as for the specimen. Photo 3 shows the appearance of the reference scale setter designed for this purpose. The reference scale consists of a bright frame illuninated by a 6V 18W tungsten lamp used at a low voltage of 2 to 3V and black line marks, and two small holes are provided in addition. The reference scale can be changed in 3 steps from outside.

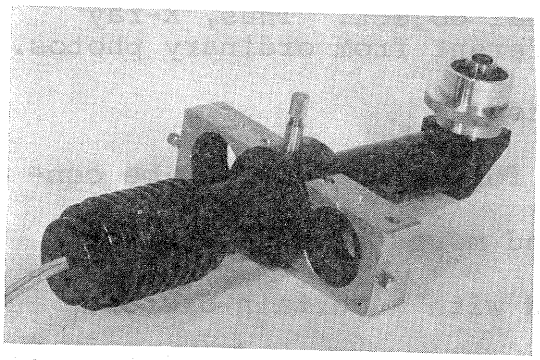


Photo 3. Measurement reference scale setter

The reference scale is designed to accurately coincide with the optical axis of the microscope proper, if accurately set on the optical axis beforehand. The X-Y scale is arranged to be photographed with the specimen by inversely using the microscopic system. In this case, since a 20X objective lens accurately regulated in magnification is inversely used for reduction, the actually 3 mm square scale is photographed simultaneously with the specimen as a 150 μ square on the specimen surface, with each division on both sides as 10 μ.

As the reference for the depth, a point image scale is set above the X-Y scale at an accurate distance of 6 mm, with the marked surfaces facing each other. Fig. 3 shows the images. Two pairs are provided, considering the case where one should disappear under the specimen. The vertical magnification in the microscope is smaller by a factor of the square of the magnification. Therefore in this case,

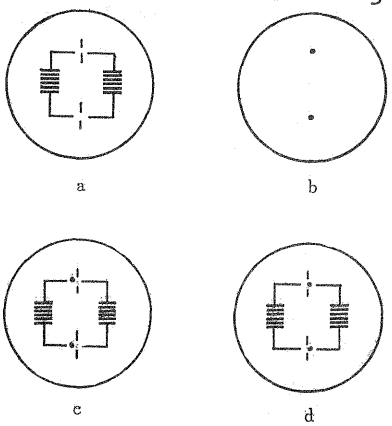


Fig.3 Measurement reference scale

$$6 \text{ mm} / 20^2 = 0.015 \text{ mm} = 15 \mu$$

Thus on the specimen, it is photographed as a reference with a height of 15 u. The physical focussing depth of an objective lens is obtained by $S' = n\lambda / 2A^2$. If $\lambda = 550 m\mu$ and A=0.40, then $S' = 1.7 \mu$. Since the point image used as a reference for height must be sufficiently clearly shown, it is desirable to photograph with a point image kept in the focussing depth. However, for use in stereo-photos, 1.7 μ cannot provide a sufficient parallax. For this reason, as a result of various experiments, it has been

decided to use a height of 15 μ on the specimen for the reference. If photographing is made with the objective lens tilted by 6 degrees each toward both sides, the point images are indicated on both sides of the center line and the difference is a parallax corresponding to the height of 15 μ.

3. X-ray photogrammetry

An ordinary photo gives an image formed by the light reflected through a lens from an object, while an X-ray photo gives and image directly formed on the film surface by the X-ray emitted from an X-ray source. Therefore, if a contrast medium,etc. is used on the way to intercept the X-rays, its silhouette is projected on the film surface. This is often used for measurement. The image formed on the film is always larger than its real object. Thus, X-ray photogrammetry must use photos very different from ordinary photos.

3-1. Method for taking X-ray stereo-photos

To obtain X-ray stereo-photos, the following four can be considered.

(a) One X-ray emission source is used and moved in a device for photographing at two optional points.

(b) Two X-ray emission sources are fixed with a certain distance kept between them.

(c) One X-ray emission source is used, while the object and film are moved horizontally by required distances.

(d) One emission source is used, and a table with the object fixed is tilted at a certain angle toward both sides.

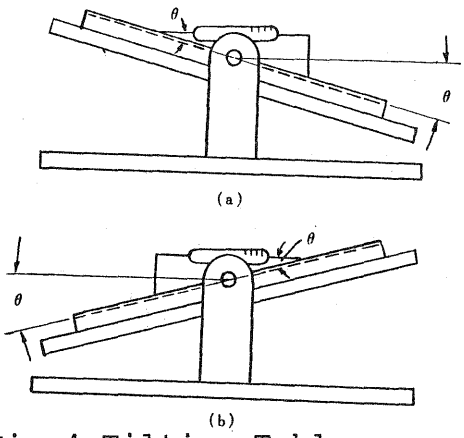


Fig.4 Tilting Table

In general, the method(d) is simplest, economical and easy to use. Also the study of this time by the authors used this method, and the device is shown in Fig. 4. The table can be tilted by 6 degrees each toward both sides, and the reference points used for height and horizontal position are yen coins placed at the four corners and on both sides of the center. In addition, a lead grid is placed as a reference plane of the object, in consideration to use the intersection of the grid as the reference for measurement.

3-2. Equation for obtaining the difference in height in an object

The spatial position of an object can be measured from a pair of stereo-photos by two methods; (1) using a plotting instrument or (2) measuring the coordinates on the photos and calculating. Let's consider an equation for obtaining a relative height in an object from stereo-photos obtained by the method shown in Fig.4. When photographing is made from one emission source by tilting table at a certain angle on both sides, it can be considered, as shown in Fig.9, that photographing is made from the two points of the photographic base b decided by the tilting angle and the distance between the emission souce and the film surface.(See Fig. 5)

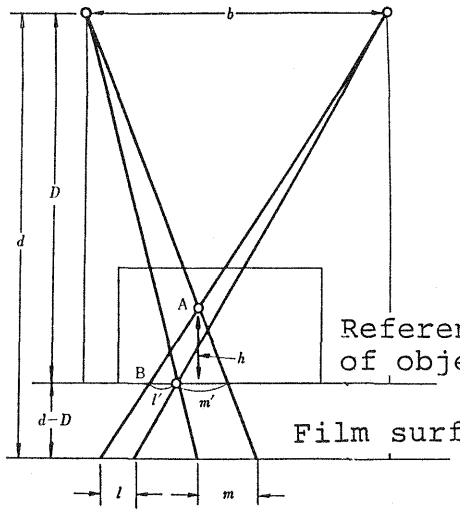


Fig. 5 Geometric relation in photographing of X-ray photogrammetry

In this Fig.5, if the X-rays emitted from two points apart from each other by distance b are transmitted through AB in the object and give images l and m on the film surface, the relative height between A and B can be obtained from the following equation.

$$h = (\Delta p.D)/(bd/D + \Delta p)$$

Where Δp = l + m, parallax difference
b = base length
D = height from object reference plane to X-ray tube
d = height from film surface to X-ray tibe

Considering $D \fallingdotseq d$ and that Δp is small compared with b,

$$h = (p.D)/b$$

To simply measure a height from X-ray photos, the above equation can be used. However, in the case of X-ray photos, since it is difficult to secure sufficiently high accuracy in the measurement of parallax difference, the height obtained in this way cannot be expected to be highly accurate.

3-3. Spatial position of X-ray tube against film surface

In either case of measuring the height using the above equation or using a plotting instrument, the spatial position of the X-ray tube against the film surface must be decided. The following method is used for this purpose. As shown in Fig. 6, five lead pieces are placed on a cylinder made of stainless steel with a known height. One is placed at the center and the others are arranged on mutually perpendicular lines with a certain distance kept.

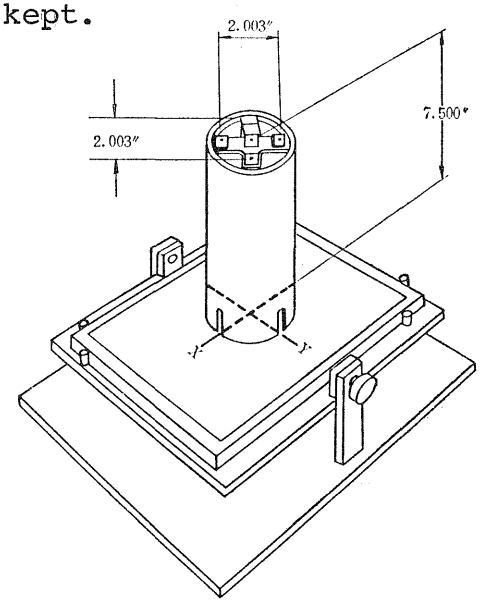


Fig. 6 Calibrator

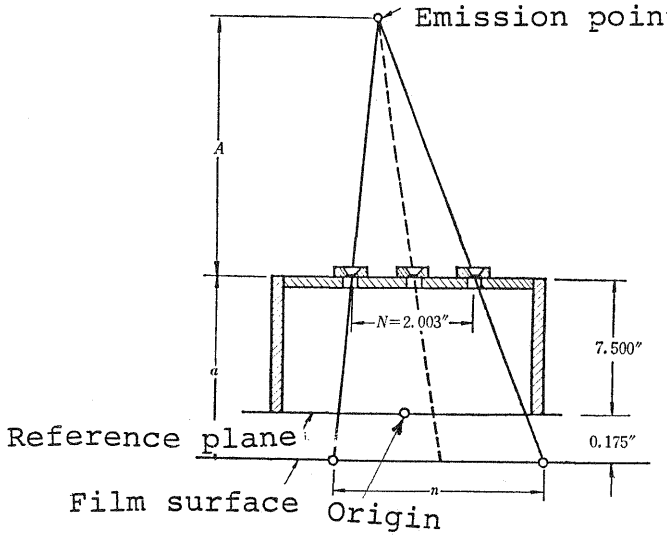


Fig. 7 Relation between cylinder and X-ray emission point for calibration

The cylinder is placed on the tilting table, with the Y axis of the cylinder coinciding with the tilting axis of the tilting table, with the X-axis kept perpendicular to it, and with the

central lead piece at the intersection of the X and Y axis.

Fig. 7 shows a state where three lead pirces form an image on the film surface. The distance between the X-ray tube and the film surface, i.e., A + a can be obtained from the following formula:

$$A + a = \frac{na}{n - N}$$

Where a = known value (measured value)
n = distance between two opposite lead pieces projected on film surface
N = actual distance between opposite lead pieces

As shown in Fig. 8, if the extreme end of the perpendicular given from the center of the cylinder to a plane including the X-ray emission source and parallel to the film is the origin, and coordinate axis X and Y are set in parallel to the x and y axis on the reference plane of the object, then the coordinates X and Y of the X-ray emission source on the plane can be expressed as follows:

$$X = -xA/a, \quad Y = -yA/a$$

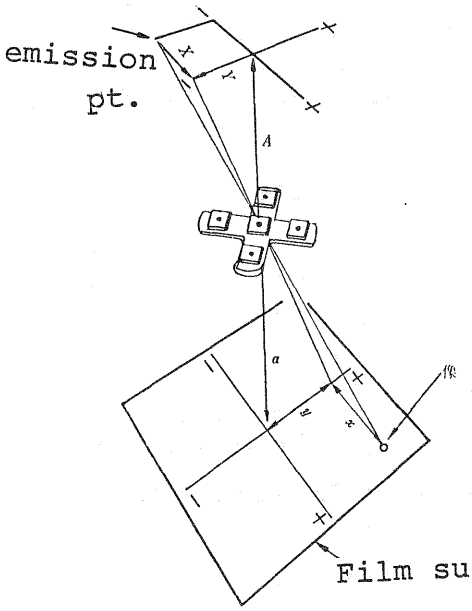


Fig. 8 Spatial position of image points on X-ray film surface

3-4. Decision of spatial coordinates

To decide the spatial position of an object by use of X-ray stereo-photos, a plotting instrument is usually used, but when no plotting instrument can be used, the position can be decided by simple calculation as described below. Fig. 9 shows a state where photographing is made using a tilting table.

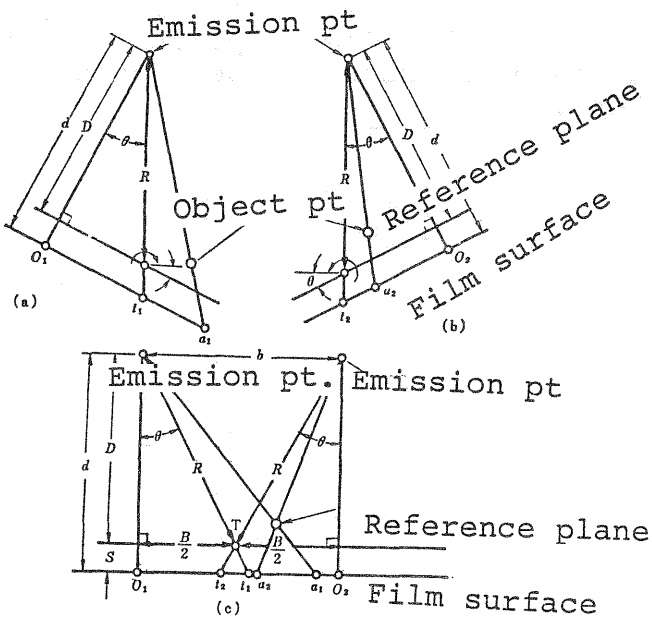


Fig. 9 Geometric relation of tilting table

A combined state is shown in (c). The coordinates of images at both points A and B on the film obtained like this are measured. Since the coordinates x_{a1}, x_{a2}, etc. are values from the extreme end of the perpendicular given from the X-ray source, length o_1t_1 or o_2t_2 in Fig. 9 must be added respectively.

Hence, To obtain the coordinates of point A,

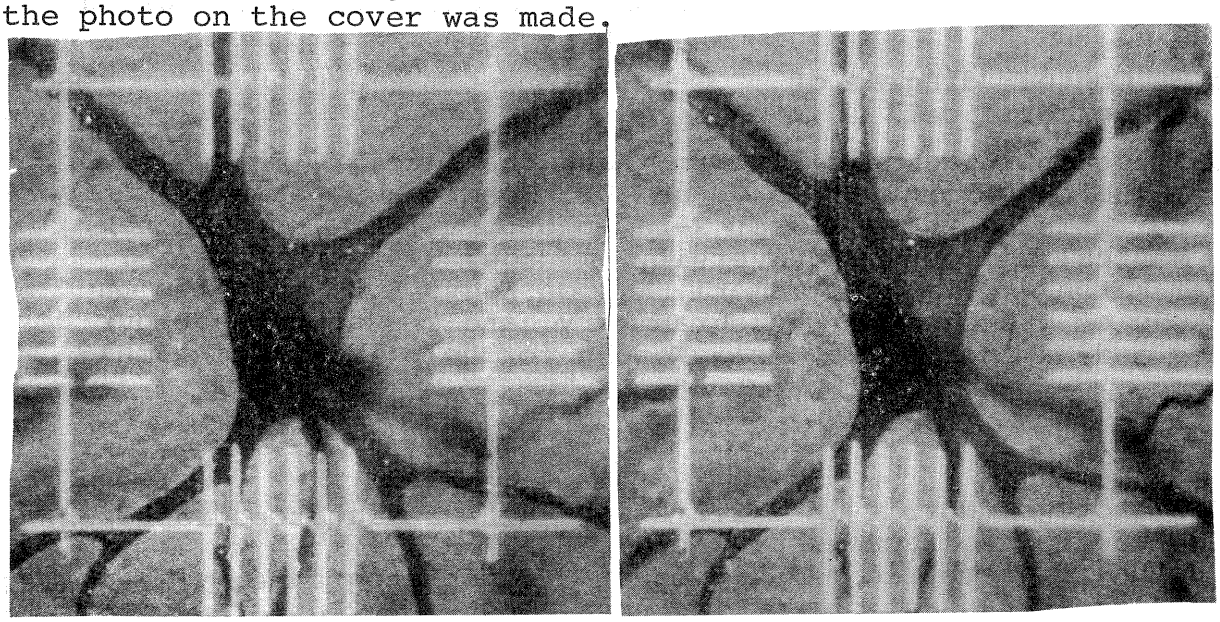
Coordinates of point B can also be obtained similarly.

4. Actual Examples of measurement

4-1. The specimens used for measurement were cerebral cells of a cat, and the specimen preparation and photographing were carried out by Prof. Mannen, Tokyo Medical and Dental University, and plotting and measurement were carried out by the authors.

For photographing, 25 X 25 cm contact film were used to make positives, and A7 Autograph was used for measurement. Each specimen was turned upside down to make the same operation, and this allowed the total surface area and volume of each cell to be obtained. The valued obtained by photogrammetry were compared with those obtained by conventional calculation, and all the values of the latter were found to be larger than those of the former. In addition, a feature could be clarified that while the conventional method gives greatly different values depending on the diameter selected, the values obtained by photogrammetry are similar and little different.

The calculation by Prof. Mannen suggests a new finding that the cells of the same kind in the same place of the brain are similar in size even though different in apparent form. On the average, the surface area was 80,000 μ^2, and the volume was 180,000 μ^3. If the specific gavity of cells is 1, the weight of a cell is appreximately one 5-millionth gram, that is, five million nerve cells weigh one gram. It is very signigicant that the application of photogrammetry to photomicrogaphs is going to develop a new field in cerebral science. Photos 4-a and 4-b were used to make a contour diagram shown in Photo 5. The contour intervals are 2.5 μ. From the diagram, a model of a cerebral cell as shown in the photo on the cover was made.



(a) (b)

Photo 4. Stereo-pair of cerebral cell

4-2. Example fo X-ray photos

In cooperation with tha late Dr. Ohtsu and Dr. Inoue, Dept.

of Pathology, Branch of Tokyo University Hospital, the change of renal blood vessels in form was measured. The conventional measurement by X-ray photos has been being applied to orthopaedic surgery and the approcimate measurement of location of intracorporeal foreign bodies. The application to the measurement of any internal organ may have been the first case. The specimens were renal blood vessels with a contrast medium injected, and it was attemped to quantitatively prove by photogrammetry that the phenomenon of arterial sclerosis appears ad change of blood cells in form. For photographing, a specimen was tilted on the tilting table. The measurement is limited in usable plotting instruments as mentioned before, and in this case, A7 Autograph was used.

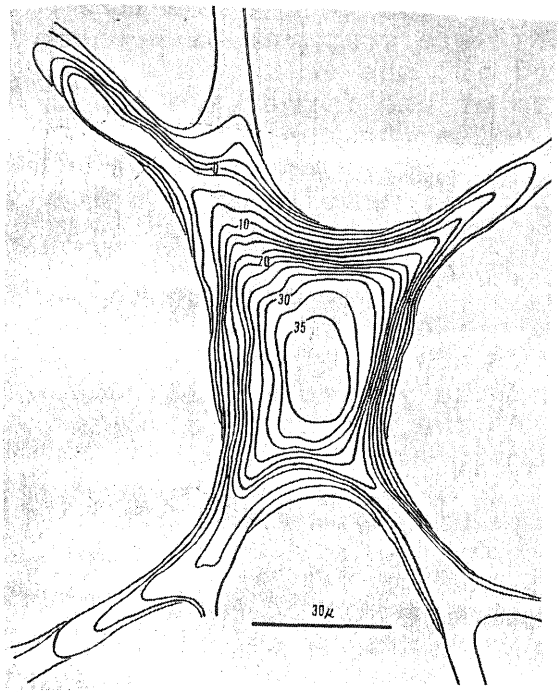


Photo 5. Contour diagram of cerebral cell

Photo 6 shows a state of blood cells in the ren used for the measurement, and Fig. 10 shows an example of measurement results. Each photo gave a silhouette, and did not allow the surface form to be measured. Therefore, the specimen was turnd around the central axis, to measure diameters each time for decision of sectional forms, though troublesome. However, if such a method can clearly quantify the change in the condition of a disease, it will provide valuable data for clinical medicine. The same method was applied also for the measurement of cardiac blood vessels. Thus,X-ray stereophotogrammetry promimises wide applicabiligy beyond the conventional application to surgery, to encourage our studies.

Acknowledgement: We would like to thank the late Dr. Ohtsu and Dr. Inoue, the University of Tokyo and Dr. Tokorozawa, Nagasaki University for help on the study of X-ray photogrammetry, Dr. Mannen, Tokyo Medical and dental University, Manager Ueno and Messers. Jinichi katoh and Takashi Tamori, Nippon Kogyo K.K. for help on the study of microscopic photogrammetry, and researchers in our offices and Manager Ohara, Asia Kosoku for help in Plotting measurement.

Reference :

1) Die Photogrammetrie in ihrer Anwendung auf nichttopographischen Gebieten; Otto Lacmann p178-p197
2) The basic geometric principles of X-ray photogrammetry:B. Hallert No. 123 (Transactions of the Royal Inst. of Technology,Stockholm)
3) Neuronal Stereophotogrammetry: Hajime Mannen p.96-p.102 (Medical andBiological Illustration, Vol. XVIII, No. 2, 1968
4) Microscopic Photogrammetry, T. Ohshima & T.Ueno p79-p83,1969 Photographic Indutry No.3
5) Roentgen Photogrammetry, Ohtsu, Inoue & T.Oshima p72-p76,1969 Photographic Industry No. 12

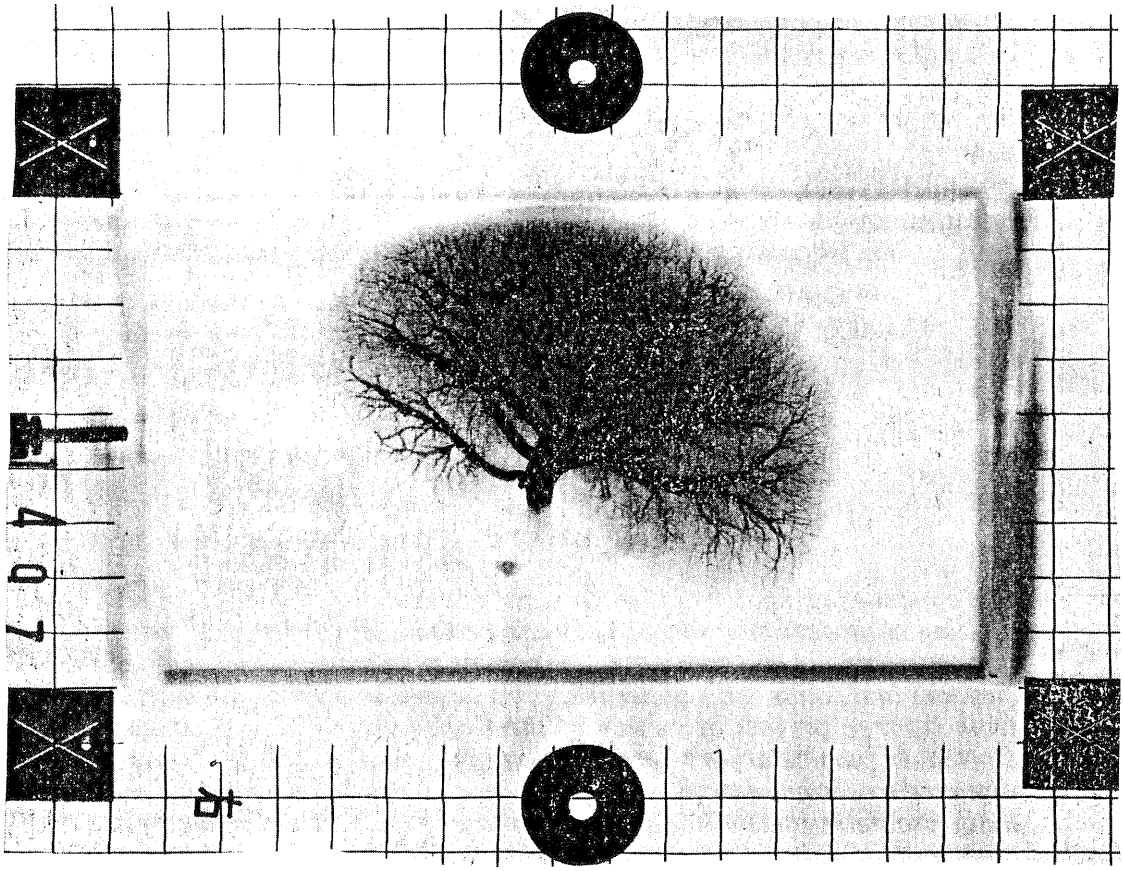


Photo 6. X-ray photo of renal blood vessels

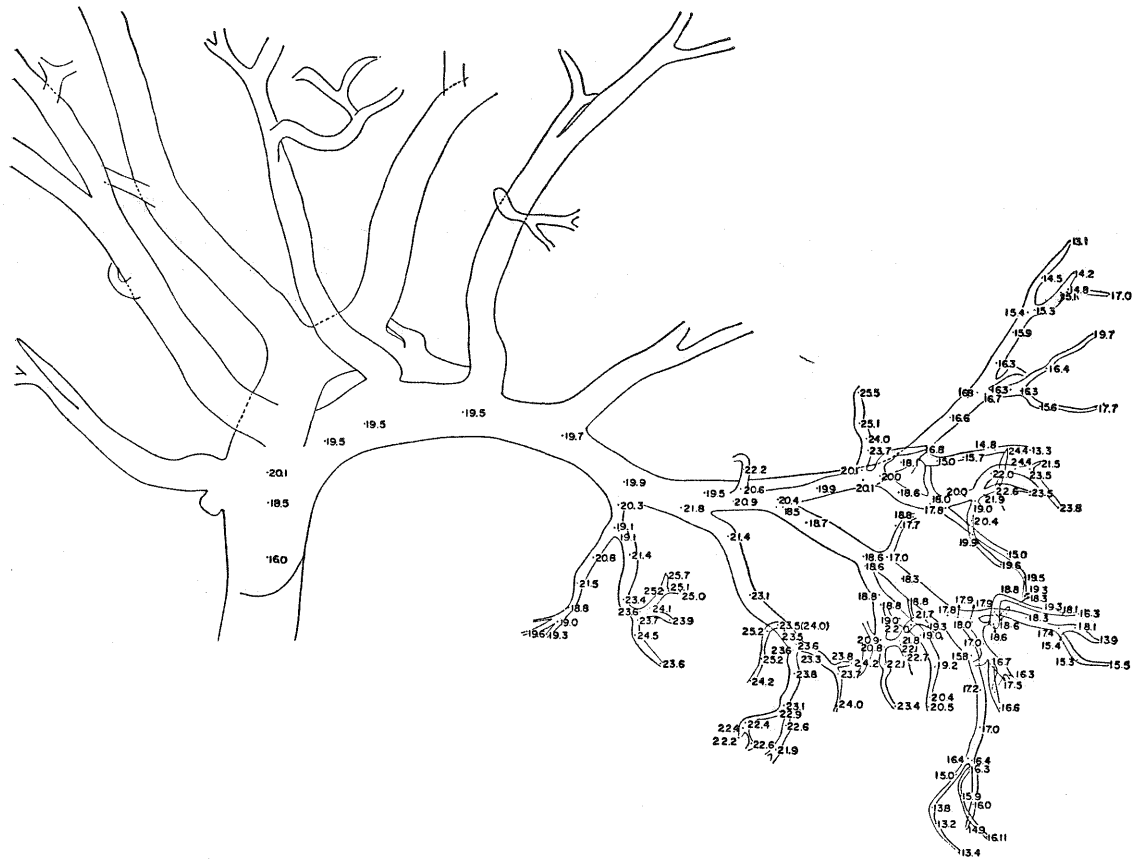


Fig. 10 . Example of blood vessel measurement (numerals show heights)