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GEOMETRIC INFORMATION FOR DOCTORS

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Abstract

Our paper is an attempt on assortment of the images used in medical practice and also image-like goods producing instruments. In our opinion the two most significant points of view of the assortation are the applied physical principle and the geometry of the projection. The geometry of the projection is extraordinarily important for the iconometry because it has a role only when, from image-projected information and from some other points of view, the geometrical ones seem to become important. The second part of the paper presents two experiences in which concerning the size, the shape and the situation of the object we gained information from endoscope photos and from nonmetric images.

Keywords: biophotogrammetry, close-range photogrammetry.

1. Images and Information

Images are two-dimensional projections of certain space sections of the real three-dimensional world. By the use of the method they are based upon physical phenomena. The information of the images — quite apart from the physical phenomena — can be divided into three groups: radiometric, semantic and geometric information.

Radiometric information contains the effect of the photographed space-section radiation on projection system. Semantic information describes the characteristic of the object — e.g. a wood — while geometric data refer to geometric relations which can be used for the characterization of the space-section (DETREKŐI, 1988).

'Photogrammetry is a discipline which deals with the determination of the relationship of the object and the phenomena and it is based on a photo of the object or of the phenomenon.' (HOMORÓDI, 1973) — as the classical definition says. As the result of semantic changes nowadays the definition itself has changed. The general expression of remote sensing is the mostly used, but the expression iconometry also seems to come into general use. The latter is an expression borrowed from the lingo of the history of art and it takes under close examination the semantic and thematic message of works of art. The motive of gaining ground of the new expressions is that as long as the expression photogrammetry is connected with photos (as the central projection of the optically processed object) we can meet more and more frequently with projections which differ from central ones respectively photos stored up nonphotographic support. The general custom among medical practitioners is that the doctors have to meet some kinds of images or picture-like products. This is a real challenge not only for the doctors but also for the technically trained engineers. A photogrammeter (correctly: iconometer) can only help the doctor, when for a correct diagnosis or for other reasons, he needs to become acquainted with a geometric information from a picture-like product. This paper has the intention of making an attempt at iconometry-eyed division of the generally used production instruments and afterwards we should like to present two experiments where for a better diagnosis and respectively for the reason of the qualification of an operation there were needed geometric information from images.

2. The Generally Used Projectional Systems in Medical Practice

The projectional systems used in medical practice can be divided into groups from many points of view. From the point of view of iconometry the basic question is whether during photo taking the principle of central projection was put into practice or not. The other main possibility of classification depends on whether the base of the image is a photographic one or not. Another possibility of classification is whether the image processing system is developed positively for medical purpose or it is only an instrument evolved for other purposes adapted for doctors. Naturally, the applied physical method of working is the key question of the classification. Systems may be active or passive depending on whether the instruments have their own radiation or they can register the radiation of the object or only the radiation reflected.

Here are some projectional systems divided into groups by us and some examples of their medical usage:

Metric photogrammetrical cameras (e.g.: orthopaedies).
Nonmetric cameras (e.g.: dentistry).
X-ray (e.g.: surgery).
Endoscopes (e.g.: dental surgery).
Digital cameras (in each case where metric or nonmetric cameras can be used).
Thermograph (e.g.: focus research).

Electron microscope or EM (e.g.: virus research)
Hologram (e.g.: dental surgery).
Moiré processing (e.g.: relief changes on body trunk surface).
Video (e.g.: research of living human body).
Computer tomograph or CT (e.g.: various tumours).
MR (e.g.: tumours of the encephalon).
Ultrasound (e.g.: tract research).

Adhering to the used physical process the chemical and electrical reaction produced by light has the geometrically most elaborated accomplishment, i.e. the photographical solving and its improved modifications. Among the instruments used in medical practice we can include metric cameras, nonmetric cameras, various endoscopes and also the instruments of video and that of digital photographing. Geometric information can be gained by comparatively elaborated mathematical apparatus for they are in possession of a projection system — like the instruments above — following mostly the principle of the central projection.

Moiré symptom is a peculiar case in which by the use of an equispaced transparent plane grating shadow effects can be gained and by observing these effects through a small hole from a point which is not similar to the convex surface under test we can obtain a practically parallel projection (ATKINSON, 1980). If we place a camera in the observing point we can take a photo of the object with its contour line drawings.

Hologram technique may be treated like an extreme case. Here i.e. being at variance with the generally used projectional optic they do not use incoherent optic but coherent ones. In coherent optical systems the source of light is mostly a laser which produces a monochromatic light and it is coherent in time and space. Applying the peculiar characteristics of the coherent optic systems one can produce interference images, i.e. holograms. In close-range photogrammetry the holograms made directly of three-dimensional objects are an alternative to photogrammetrical models since the object and its image are generally of the same size (KARARA, 1978).

Another group of the instruments applies — within electromagnetic spectrum — the other sections differing from the domain of the visible light. From the point of view of appliance the most important question is the interference of the electromagnetic radiation with the infiltrated material since this determines its influence on any kinds of detectors. The various effects of the various domains of electromagnetic waves can be explained by the difference of their energies, but most of them can be understood on basis of all kinds of resonance. A particular system is sensitive only to certain frequencies of electromagnetic waves but the irregular ones will not influence it (KASTLER – PATAY, 1993).

The radiation of X-rays used in medical practice is situated in the $10^{-8} - 10^{-11}$ m wavelength domain of the electromagnetic spectrum. This radiation is imperceptible to human eye and for this reason it can be made visible only by an image-forming system. An old accomplishment of the theme is the photo-sensitive layer, the X-ray film. For the reason of a better quantum yield a combination of a screen film is applied and by means of an amplifier screen the X-rays can be transformed into a beam of light. Another instrument of making fluoroscopic pictures is the X-ray screen. The radiograph appears on a fluoroscopic screen and it will be examined by the doctor without fixing it. The mode of operation of fixing the pictures is radiography and with a suitable camera we can take a photo of the fluoroscopic picture. It can be stored up also with a video camera. The transformation of an analog monitor picture into a digital one makes possible the adoption of all the methods of picture manipulation (CSÁKÁNY – FORRAI, 1984).

X-rays are applied also in CT. The principle of the method is as follows: the line integral reduction of the narrow beam of rays which infiltrates through the cross-cut of the human body is measured point by point. This reduction is produced first of all because of the absorption factor and its degree depends on the material the X-ray infiltrates through (HORVÁTH, 1994).

Thermography deals with the detection of the radiation in the infrared domain of electromagnetic spectrum. It has two main methods: telethermography and contact thermography. The well-known instrument of telethermography is the thermovision installation which gives an emission image in the course of image-processing (WINKLER, 1991). This means that from the solid angle under test it measures the difference between amplitudes irrespective of the temperature and of the emitting area. There is nothing to worry about in case of a human body for the human skin is a homogeneous surface and the emission differences can be interpreted as temperature differences.

In the course of ultrasonic testing (sonography, echography) the difference in capability of repercussion of the tissues of the human body is used for photo-forming. The arrival time of the repercussion of the wave is proportional to the distance and to the amplitude of the echoing sound and it depends on histological relations and they make photo-forming possible.

MR image expresses distribution of the water in a human body and its combined slate is based on the magnetic character of the hydrogen nucleus (proton).

The capacity of the light microscope is limited by the light itself, i.e. its resolving power is only the half of the wavelength (BERNOLÁK – SZABÓ – SZILAS, 1979). Applying the shortest visible light, the wavelength of which is 400 nm, it is 200 nm. Using electron ray instead of light beam the resolving power can be increased by thousand times since the wavelength belonging to electronic ray is much shorter. The electrons coming out of the electron gun can be focused with magnetic lens like the light itself. The difference is that the electrons are moving round a helical course. A comparison can be drawn between the photo-forming of the electron microscope and that of the projective light microscope and the only difference between them is that in the first case the image appears on the fluoroscopic screen and in the second case on a frosted glass.

The principle of grouping the instruments into two main parts (i.e. instruments developed positively for medical purpose or an instrument borrowed from other fields) is important only from the point of view of the history of science. Thermography is a good example for the second group; it was one of the devices of the military reconnaissance and CT illustrates the first group.

The other possible classification concerning the medium of instruments limits the potential instruments of processing. In case of need these borders can be passed across.

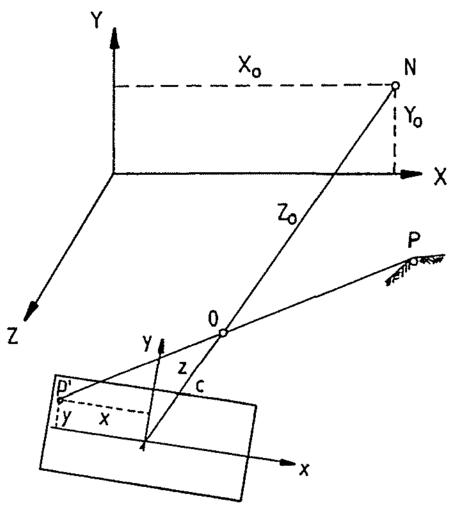

Fig. 1. The relationship between image point and object point in central projection

The most important difference between applied systems for us is the geometry of projection. Photo-taking apparatus, nonmetric cameras (*Fig. 1*), all kinds of endoscopes, X-ray installations (HALLERT, 1958), videos (MELEN – BALCHEN, 1994) and various kinds of digital cameras (TSURUOKA – SHIBASAKI – BOX – MURAI, 1994), (MITCHELL, 1994) are all based on the principle of the central projection or on a principle which can be traced to it. If we have an object with its coordinates (they are X, Y, Z) and all the image coordinates are in the coordinate system of the image the relationship between them can be represented by this equation:

$$\begin{aligned} x &= f(X, Y, Z, X\ , Y\ , Z\ , \varphi, \omega, \kappa, c, w)\,, \\ y &= g(X, Y, Z, X\ , Y\ , Z\ , \varphi, \omega, \kappa, c, w)\,. \end{aligned} \tag{1}$$

In this relationship (1) X, Y, Z and φ, ω, κ values are the parameters of spatial transformation, c and w values are the features of the receiving optic. This equation can be applied for photogrammetric images, for X-ray images and also for a group of digital images. In the case of the other group of nonmetric, endoscope and digital images is (1) (because of the insufficiency of the system of referenceit) is necessary to complete the part in brackets with three more members of the image:

$$\begin{aligned} x &= f(X, Y, Z, X\ , Y\ , Z\ , \varphi, \omega, \kappa, c, w, \xi, \eta, \beta)\,, \\ y &= g(X, Y, Z, X\ , Y\ , Z\ , \varphi, \omega, \kappa, c, w, \xi, \eta, \beta)\,. \end{aligned} \tag{2}$$

Thermographs — the receivers of the thermography — can be included here under certain conditions. We can discover the usual optic system here with only one difference: the lens are made not from glass but from germanium. An optical or mirror system resolves the image within the receiver and transmits it to the detector (*Fig. 2*) (WINKLER, 1991). From these facts it emerges that if we should like to project a 'still' with these receivers the aberration from central perspective is only loaded by the defects of the image resolution. In the case of an 'immotional' object the situation is much complicated, i.e. the various image points belong to object points which came into being in various moments of the time like in the case of scanners. So the not too good scanning makes generally possible the application of equation of central projection.

The image-forming of the EM is also based on central perspective. The small field angle and the extremely large magnification produces a projection which will contain parallel elements (*Fig. 3*) (KARARA, 1978). The parallel-projective *Eq.* (2) can be represented in a manner that regarding y it is completed with element k expressing scale differences

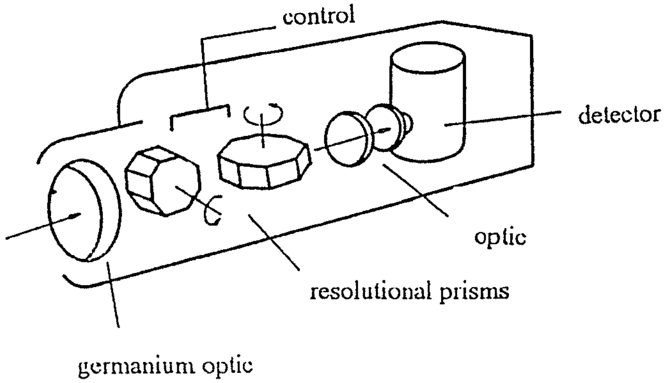

Fig. 2. The principle of thermograph construction (WINKLER, 1991)

(LEEMANN – MARGADANT – WALT – JENTSCH – HALLER – ANLIKER, 1994):

$$x = f(X, Y, Z, X\ , Y\ , Z\ , \varphi, \omega, \kappa, c, w, \xi, \eta, \beta)\,,$$
$$y = g(X, Y, Z, X\ , Y\ , Z\ , \varphi, \omega, \kappa, c, w, \xi, \eta, \beta, k)\,. \tag{3}$$

The image obtained by moiré technique can be perceived like a photo completed with contour lines so that the possible moods of obtaining geometric data are in accordance with it (TERADA – KANAZAWA, 1974).

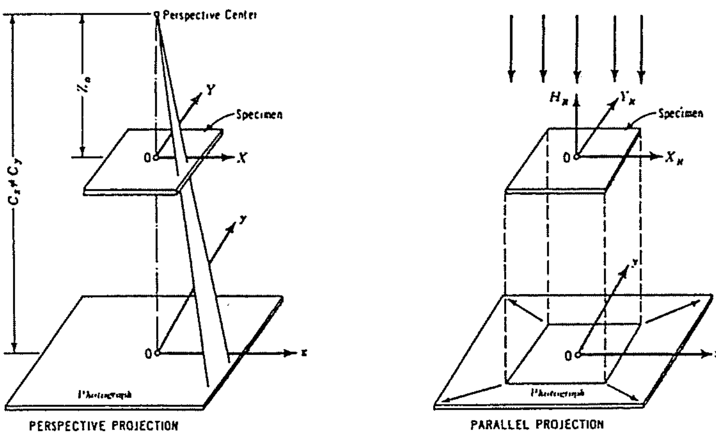

Fig. 3. Perspective and parallel projections in electron microscope (KARARA, 1978)

Holograms should be regarded as geometrically correct interference images. One cannot see anything on a hologram it looks like a faded image. But if we transilluminate it in a right way the human eye can see a geometrically correct virtual image in the original place of the object (*Fig. 4*). The measurement of the virtual image was solved in many places and it gained adequate precise result and this result was fed back into photogrammetrical interpretation (KARARA, 1978), (YOSHINO – TSUKIJI – TASAKAI, 1976).

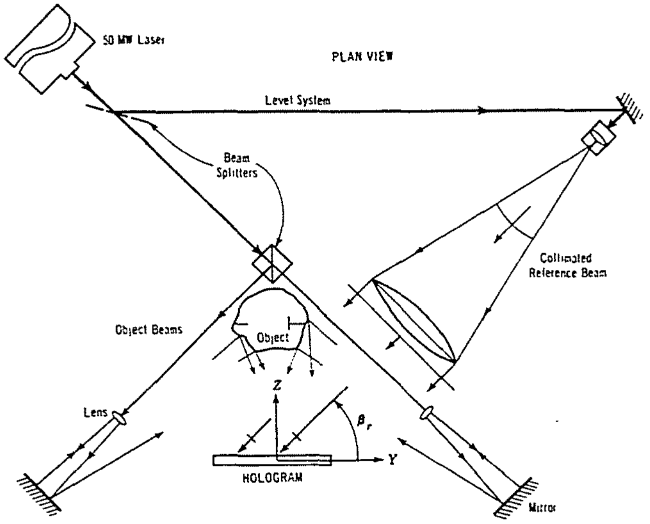

Fig. 4. Hologram recording with multiple object beams (KARARA, 1978)

CT projects each of the cross-cuts of the person under test and these are put together — if needed — into an image in space. The principle of operation of CT uniformly is the following: the ray tube and the beam of rays coming out of it by means of an adapted detector are made to be equivalent to each other (*Fig. 5*) (HORVÁTH, 1994). The beam of rays is sweeping the person under test and the detector is making an absorption profile from the detected radiation. Gray values, i.e. (colour) values belonging to various kinds of image pixels are projected by using various profiles from various directions. 'Consequently CT is a method of transversal X-ray slice recording technique which presents the values of ray absorption of a given cross-cut in accordance with their distribution in space and it is presented in the form of a matrix image in a network which depends on the resolving power.' (BÁNKI, 1994).

The quick motion of protons and neutrons round the axis originates the spin. In the nuclei in which the element having a spin is uneven the

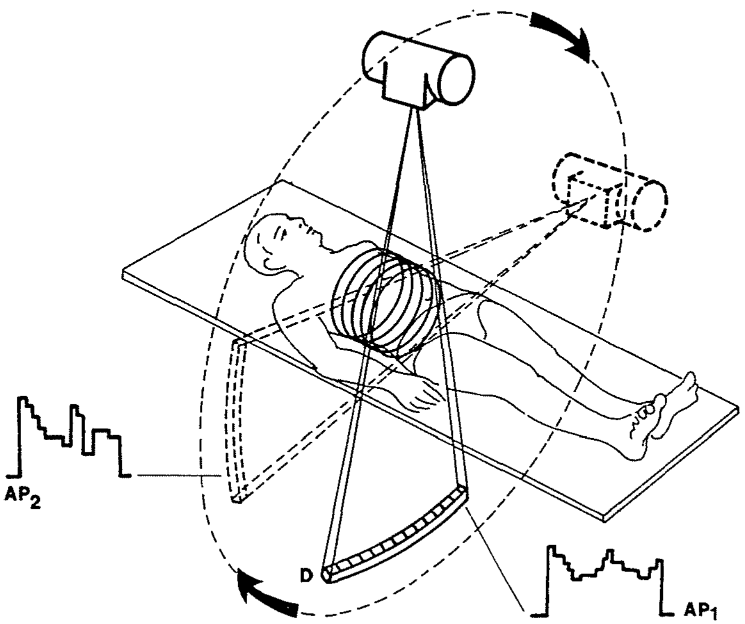

Fig. 5. The solution of CT-visualization technique (HORVÁTH, 1994)

nucleus itself will also have a spin. If this spun nucleus will arrive at an external magnetic field it will stand in with its axis of rotation in the direction of the lines of force. Among the main constituent elements of living body only H nucleus, the proton, has got a spin. It can be put into a resonant condition by an adequate high-frequency current. When the external effect ends the original condition will be restored slowly, but during this time a measurable electricity based on the principle of the dynamo will be produced and its tension is in direct proportion to the number of H nuclei while its course in time is proportional to their defined condition. The image-forming of this kind of principle is possible due to the fact that inductive high-frequency power-wave puts each slice of the human body into resonant condition separately. It is possible the detect to different slices of the body by changing the frequency. Applying additional gradiensters the time of the running off can be measured in the point of intersection and it depends on the water content of the tissues belonging to the different pixels. At the end of the measuring process an MR image of the whole human body will be gained (KASTLER – PATAY, 1993).

In the ultrasound apparatus the electric pulse has an effect on a piezoelectric featured material which performs a mechanical vibration. Energy transformation may take place also in the opposite direction — reversely — so as the mechanical vibration may originate electric tension. The interval of the ultrasound pulse produced in the ultrasound apparatus is only of some micros, therefore the interval between two pulses is enough for the wave to make its way into the human body and to be reflected into the apparatus. The well-known methods of the projection are A-mode (Amplitude mode) and B-mode (Brightness mode) (CSÁKÁNY – FORRAI, 1984). Using A-mode echo adequate signs appear vertically on the screen of the oscilloscope while electron beam rays move on the screen. The size of the amplitude is proportional to the intensity of the reflection and its place on the horizontal baseline is proportional to the distance of the surface. It emerges from these facts that we can make a linear ultrasound survey by A-mode. When using B-mode the echo adequate signs appear also in form of bright points. The apparatus reconstructs the screened cross-cut in form of a two-dimensional image from the recorded echo under different bundle conditions.

3. Two Experiences

This part of our paper presents two experiences in which the medical practitioner or the surveying doctor need geometric information from images for a better diagnosis, i.e. for the qualification of the operation. Both of the experiences have a common element, namely the semantic information were given by physicians and the geometrical ones by the research workers of the Photogrammetric Department of the Technical University Budapest (DETREKŐI – FEKETE – WINKLER, 1994).

3.1 The Determination of the Internal Surface Points of the Antrum of Highmore

When taking under close examination the human antrum of Highmore the research workers of the Department of Dental Surgery of Semmelweis University of Medicine Budapest came to the conclusion that it would be of great advantage to have precise information about the inner dimension and shape of the antrum of Highmore. They could use these pieces of information in their everyday therapeutical and prophylactic activity. We (the members of the Department of Photogrammetry) had to measure living persons, so we could give only photogrammetric solving of the task. Instead of doing the measurement by direct means, we have chosen the only obvious solution, that of measuring the photographs made of the object.

For that special purpose we applied an apparatus based on the principle of an endoscope.

The opportunity was given by a 35 mm OLYMPUS optic, it was the property of the clinics (*Fig. 6*).

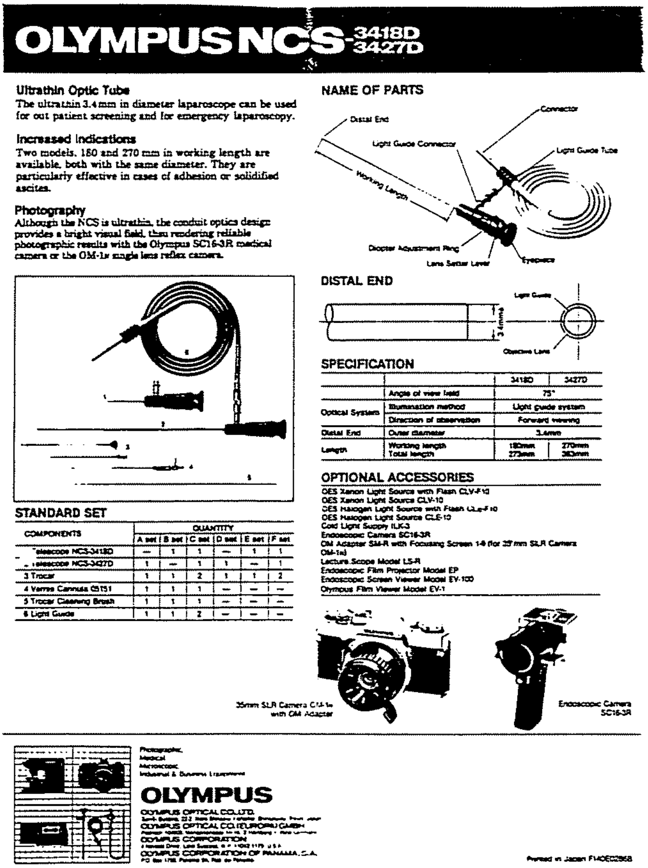

Fig. 6. The OLYMPUS optic

This apparatus completed by an adapter is able to receive the light coming out of the endoscope.

Our receiving apparatus consisted of a camera and a set of endoscopes which provided an opportunity for us to do three different angular offset photos (30, 70, 120 degres); we speak about the angular offset of the spindle of the camera in comparison with the rigid spindle of the endoscope.

After breaking the cheek-bones a foramen of the antrum of Highmore the endoscope penetrates through of 4 mm in diameter, so by setting it in motion along the spindle of penetration forward and backward and by rotating the different angular offset optics it is possible to solve the covering up the entire inner surface of the antrum of Highmore by pairs of photos.

Accordingly the problem to solve was a photogrammetric triangulation from optional direction using nonmetric photographs made by different optics without any control points. Our problem can be solved only if the interior orientation data of the optics are known, and we consider our network as a quasi free network.

What quasi free network means for us: Our despair of doing the determination of the direction in space of the antrum of Highmore is in absolute sense because it has not got a medical importance for the moment. It involves such difficulties as they can only be solved by adapting some methods borrowed from mining engineering.

The size of the antrum of Highmore can be determined afterwards from the external orientation data measured separately, they were measured by means of simple devices worked up for the taking of the photographs. In order to determine the orientation of data a test field was made. This field is in compliance with the geometric arrangement of the endoscope photographs. The determination has been solved by the appraisal of the photographs taken of the test field and by using the KERN DSR analytical plotter with CRISP programme. The exterior orientation data were interpreted like the motion and the rotation of the spindle of penetration.

The interpretation and determination of the object space control coordinates were made by the CRISP and MAP 200 user programmes on a KERN DSR analytical plotter.

Summing up and interpreting the results one can set down the fact that the given problem can be solved by an elaborate operation and by a necessary precision. This fact can be proved by the results obtained in the course of the processing the photographs. The photographs were made about a cranium. The greatest difficulty for us when we were processing the antrum of Highmore of a living man was caused by the problems of identification. For this reason our team made the proposal of an addition of the used optics. By the means of these optics the surveying field might be supplied by some points of identification. This process might function by the help of a light up fiber optic. We also proposed instead of the usual camera the appliance of CCD cameras.

The survey proved the suitability of the endoscope for the determination of the geometric data. It is true that the use of this complicated apparatus and software will not make easier the general use of this method in hospitals and clinics.

3.2. The Photogrammetric Investigation of the Closing of the Edges of Golden Fitting Strips, Heliomolar and Isosit Fitting Strips

According to the judgement of the physicians from the Department of Preservative Stomatology at SOTE the fundamental question when estimating the filling materials is the problem of the transition from the filling to dental enamel, namely the perfection of the closing of the edges of filling; the evaluation of the secondary caries can only be prevented by the perfect closing of the edges. So the task of the photogrammeter was to work out a method which is suitable for both the control of the dentists' work and the estimation of the filling materials. He has to estimate the utility of the different methods. We have to guarantee the reproduction of the survey and also the representation of the results; we have to extend our survey over the golden fitting strip, the heliomar fitting and the isosit fitting strip (*Figs. 7, 8, 9*).



Figs. 7-9. The golden, the heliomolar and isosit fitting strips

The accessibility and the circumstances of taking photographs are very special: we have to take photographs of a person sitting on a chair at the dentist's and they must be suitable for photogrammetric elaboration. That is the reason why we suggested the use of a nonmetric camera. The

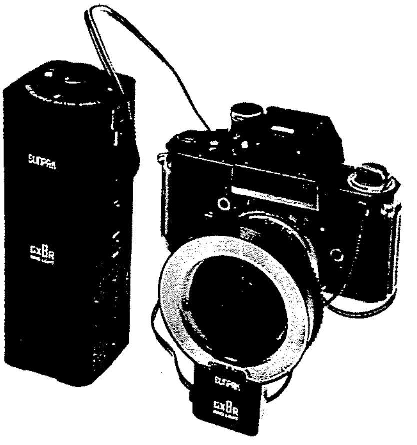

Fig. 10. Practica LRC camera

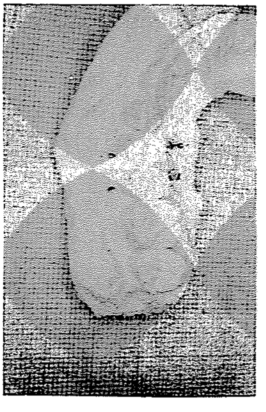

Fig. 11. The plastercast on mm-paper

Practica LRC camera owned by the clinic was of great help. It became a suitable instrument (*Fig. 10*) when it was completed by an anchor ring and a GX8R ring light. So we had to do the appraisal from a pair of nonmetric photographs which were of optional sorting; we had to do it without using control points and without knowing the interior and exterior orientation data of the photos. We solved the task by appraising a subsidiary pair of photographs. An impression was made as usual in dental surgery. We used Modelit hard gypsum (*Fig. 11*) for making the plastercast. After recovering we put the cast on a red mm-paper and repeated the photographing. By the elaboration of this pair of photos one can calculate the inner orientation data and, some well identifiable points can be intersected; these points can be used like control points during the appraisal of the original pair of photos. Our task has been traced back to a case which is easy to solve and which occurs often in practical experience. The appraisal of the photos was done by the help of a user programme developed at the Department of Photogrammetry partly on a DSR analytic plotter using CRISP and MAP200 user programmes partly on a Stecometer C instrument as monocomparator.

Our aim was also the examination of the suitability of the photogrammetric method and the comparison of the 3 dental conservation techniques taking one representative from each of them. We made this with the reservation of having a great many samples. Naturally we cannot reach a conclusion otherwise. The photographs were made by nonmetric cameras not only of the sets of teeth but also of the plaster cast of teeth. The results obtained according to our former expectations proved the suitability of the photogrammetry in medical practice. The result and the comfort of elaboration can be improved by the new techniques (for example: digital cameras, CCD) and by better instruments (optics supplied with reseau).

4. Summary

After the presentation of the information gained from images this paper is trying to make a classification of the ea. images and instrument producing image-like devices in medical research and practice. Our two main points of view were the physical principle and the solution of the possible projections of geometric information. Our list is incomplete, the recently developed instruments like PET, EEG image or EKG image are not included. The motive of this absence is that the image-forming devices are merely new from the point of view of the iconometry and the profession is owing us the most important researches yet. This fact — naturally — does not mean that our knowledge concerning the other systems is sufficient.

The experiences presented above, in which there were shown well-known instruments used long time ago, illustrate that we need the appliance of other methods an processes than the usual ones and last but not least we need the unusual combination of possibilities of solution. In our opinion the variety of medical-photogrammetrical tasks make this field of science really interesting and exciting.

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