

## PROTOTYPE OF A METRIC PROJECTOR

Elena Baj

Department for Earth Science, Milan University  
7, via L. Cicognara  
20129 Milano (Italy)  
Commission n. V

### Abstract.

The Author, who has been studying the technique of raster-photogrammetry for some time has, until now, used existing projectors adapted to her needs, for its development. The results obtained and the interest created by the research have led the author to study a prototype of projector specifically designed for raster-takings. The funds were made available by the Ministry of Public Education ; the funds available allowed the author to obtain an instrument of a precision comparable to that of a metric camera but of low power.

The use of a metric projector has the following advantages:

a) only one picture needs to be taken; b) reading must be taken from one plate only; c) dynamic phenomena can be investigated without having to use two synchronized cameras.

So far experimental work has been carried out in doors.

### Introduction.

In many sectors of close-range photogrammetry the use of raster photogrammetry involving only one photograph is considered extremely interesting.

For such a technique, it is necessary to be provided, in addition to a metric camera, with a metric projector.

So far the author of this paper, who has been studying this technique for many years (1 4-5-7), had used the existing projectors adapted for that purpose. Because of the results she has obtained and the interest arisen from the research, she has decided to study and to create the prototype of a projector specifically made for raster takes involving only one photograph ; such a prototype is called "metric projector".

The funds were given by the Ministry of Public Education; the fund made it possible to obtain an instrument of limited power.

### Description of the Prototype

The metric projector consists of a high precision projector mounted on a theodolite; inside it is provided with a reticle, inserted into a reticle holding frame, placed perpendicular to the optical axis of the objective lens that projects it.

In figures (1) and (2) one can see the metric projector on the tripod.

In the "metric projector" the following data are known:

a) the position of the principal point P in the plane of the reticle, which is defined as the foot of the perpendicular dropped from the inner nodal point of the projection objective to the plane to be projected, namely the plane where the reticle is located;

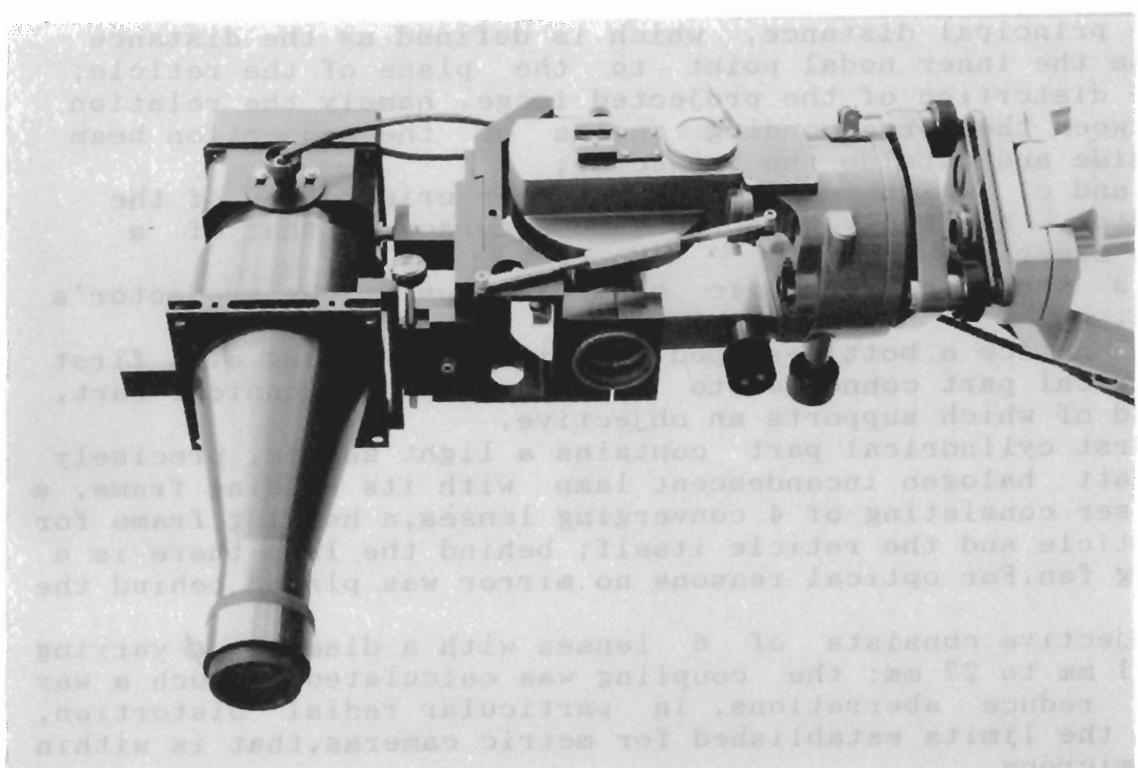


Fig. 2: Metric Projector

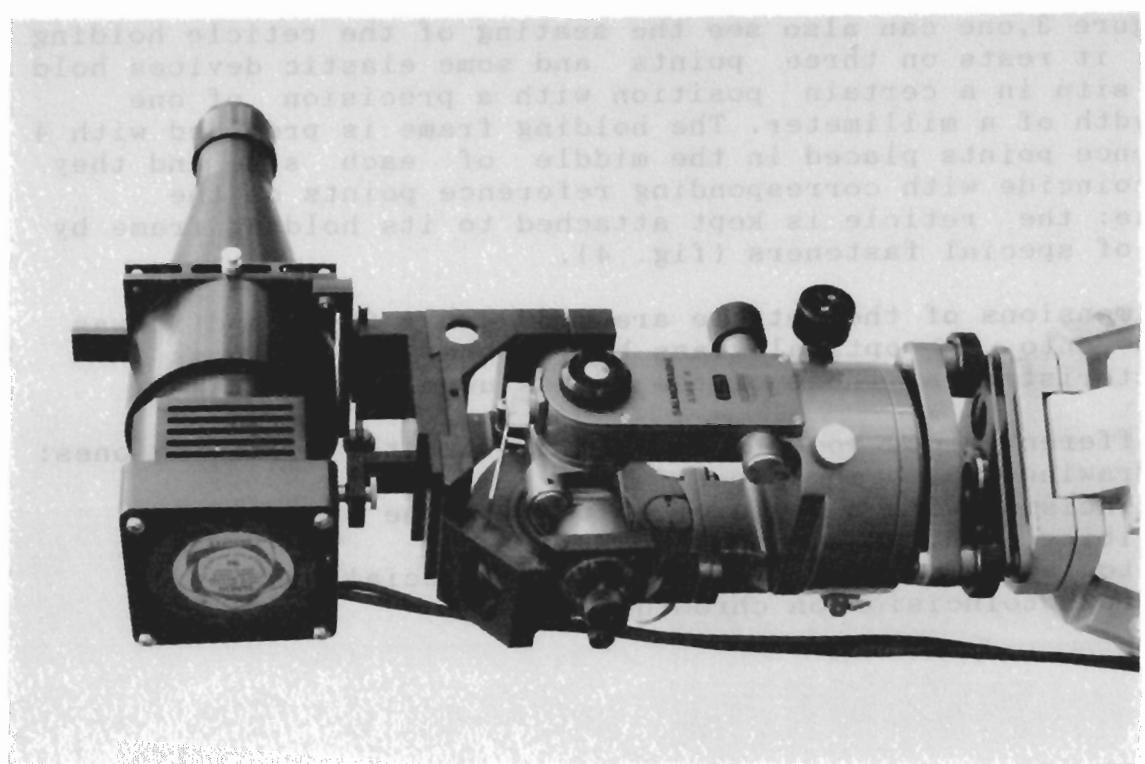


Fig. 1: Metric Projector

- b) the principal distance, which is defined as the distance from the inner nodal point to the plane of the reticle;
  - c) the distortion of the projected image, namely the relation between the corresponding angles of the projection beam inside and outside the projector;
- a) b) and c) which define the interior orientation of the projector, are known with the same accuracy as that of a metric camera.

Fig. 3 shows a schematic cross-section of the projector's optics.

You can notice a bottle-shaped housing, consisting of a first cylindrical part connected to another truncated conical part, the end of which supports an objective.

The first cylindrical part contains a light source, precisely a 50 Watt halogen incandescent lamp with its holding frame, a condenser consisting of 4 converging lenses, a holding frame for the reticle and the reticle itself; behind the lamp there is a cooling fan. For optical reasons no mirror was placed behind the lamp.

The objective consists of 6 lenses with a diameter  $\phi$  varying from 21 mm to 27 mm; the coupling was calculated in such a way as to reduce aberrations, in particular radial distortion, within the limits established for metric cameras, that is within a few microns.

The theoretical value of the principal distance is 161.47 mm and the focusing is calculated for a plane that is 8015.88 mm from the external nodal point.

The condenser, as I have previously mentioned, includes four converging lenses: these are supported by a framework in such a way as to allow the optical axes to coincide with one another and with the axis of the objective.

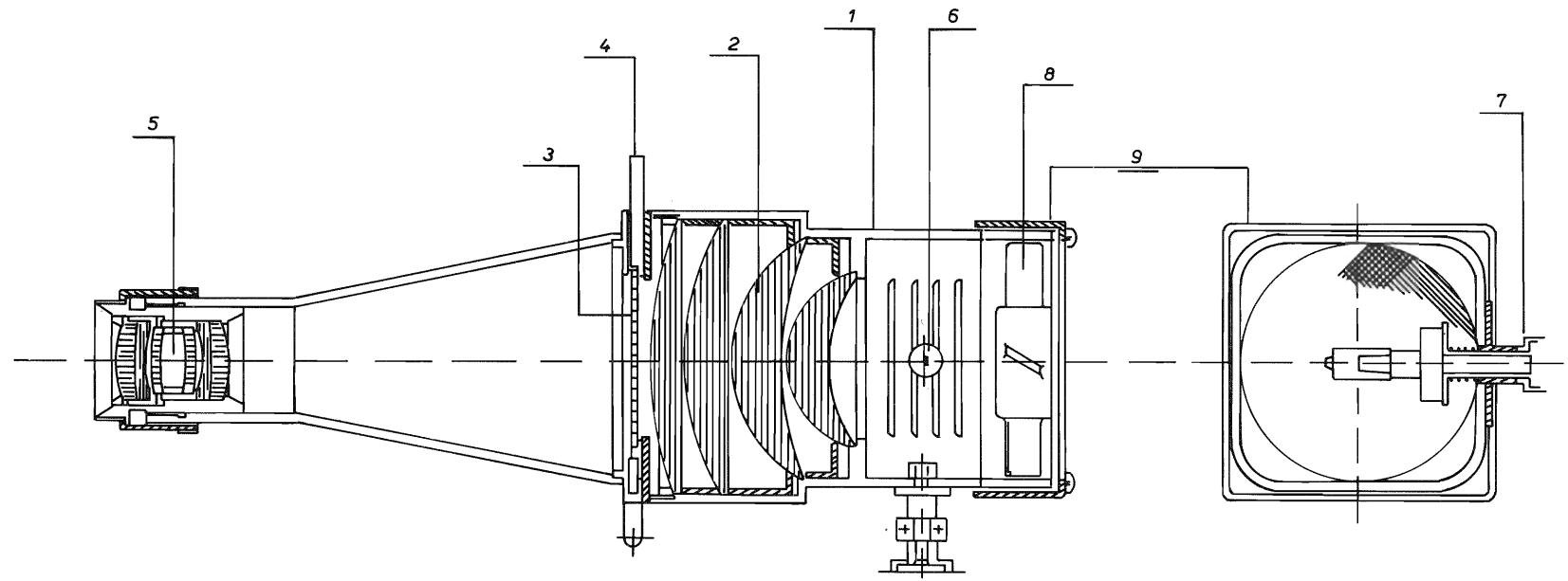
The first lens is 16 mm thick and its diameter  $\phi$  is 60 mm; the second lens is 16 mm thick and its diameter is exactly the same as that of the first lens and is in contact with it; the third and fourth lenses have a decreasing diameter and they are respectively 21 mm and 16 mm thick.

In figure 3, one can also see the seating of the reticle holding frame; it rests on three points and some elastic devices hold it in situ in a certain position with a precision of one hundredth of a millimeter. The holding frame is provided with 4 reference points placed in the middle of each side and they must coincide with corresponding reference points on the reticle: the reticle is kept attached to its holding frame by means of special fasteners (fig. 4).

The dimensions of the reticle are 60 mm x 60 mm<sup>2</sup> and it was coated onto an optical glass having the same flatness characteristics as those of the plates used for the takes.

The different steps to obtain a reticle are the following ones:

- 1) a drawing on tracing paper
- 2) an incision with a scale of 10 to 1 on the glass with scribing machines
- 3) photographic reduction of 1 to 10 on special plates
- 4) microphotoincision on chromium



- 1 SUPPORTING FRAMEWORK
- 2 CONDENSER
- 3 RETICLE
- 4 RETICLE HOLDING FRAME
- 5 OBJECTIVE
- 6 LAMP
- 7 LAMP CENTERING DEVICE
- 8 LAMP COOLING FAN
- 9 FAN LOCKING

Fig. 3: Schematic Cross - Section of the Projector's Optics

The pattern is made up of two series of parallel lines perpendicular one to the other and intersecting in points called nodes (fig. 4).

The width of the bright line is of 0.1 mm and the spacing is of 1 mm; the four reference points, mentioned above, determine the x and y axes of the reticle; their intersection marks the center which must coincide with the principal point P to one hundredth of a millimeter. The x and y axes coincide with two lines of the reticle.

It is important to remark that the width of the lines of the reticle and their spacing may vary from one reticle to another and they depend on different factors; for example, the width depends on the kind of instrument used for the reading of the plate coordinates and not on the distance of the object.

In fact, you must keep in mind that if you perform a normal take (where the axes of the camera and the projector are horizontal, parallel to each other and perpendicular to the base) of a flat object, with the camera and the projector having the same principal distance, the width and the spacing of the lines of the reticle in the photograms are the same as those of the original reticle.

Moreover, if the base is horizontal (and the conditions are the same as the ones described above) the width and the spacing of the images of the horizontal lines of the reticle on the photogram remain unchanged, independent of the shape of the object, as you can easily verify also analytically.

In this particular case, the projector was connected with the telescope of a theodolite by means of ties which one can see in figures 1 and 2: in this way it is possible to set up the instruments appropriate for the take; moreover, on the horizontal and vertical circles of the instrument, it is possible to read the corresponding horizontal and vertical angles with the precision of one hundredth of a sexagesimal degree.

The connection between the projector and the theodolite is such as to satisfy the following conditions:

- a) the optical axes of the telescope of the theodolite and the projector lie on the same vertical plane;
- b) the optical axes are parallel;
- c) the x (or y) axis and the reticle's lines parallel to it are horizontal.

In order to satisfy these conditions some adjustment devices are used: in fact, the projector, as you can see in fig. 1, or in fig. 2, can slide horizontally along a dovetail sliding block to perform the adjustment necessary to satisfy the a) condition; it can also rotate around a horizontal axis in order to satisfy the b) condition; other screws allow the adjustment necessary to satisfy the c) condition, namely the fastening screws of the ties.

The vertical rotations of the projector, therefore of telescope, can be obtained by means of a right and left jack and they are

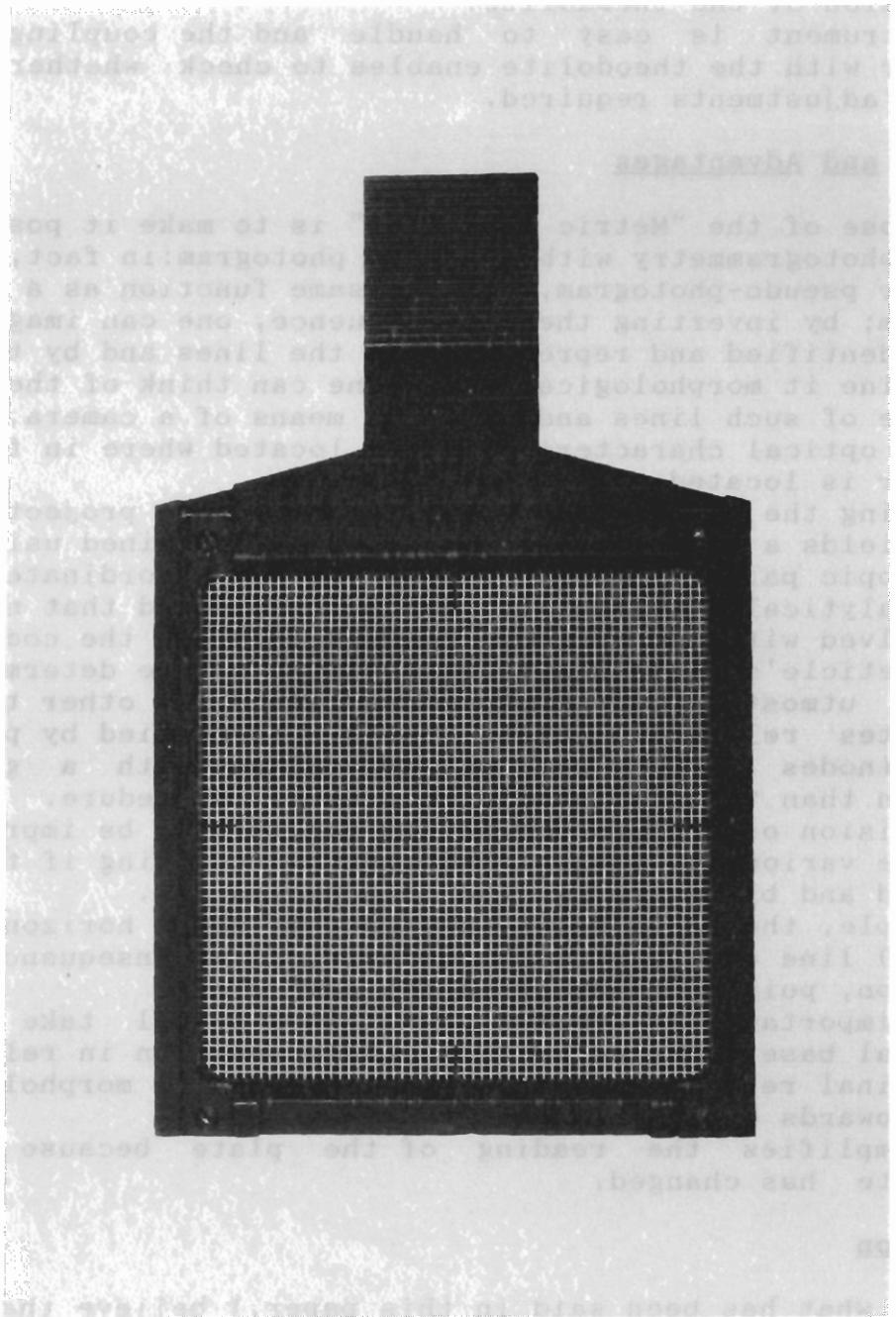


Fig. 4: Reticle and Reticle holding frame

limited to about  $10^{\circ}$ : the jack is necessary to ease the work of the friction of the theodolite.

The instrument is easy to handle and the coupling of the projector with the theodolite enables to check whether it has kept the adjustments required.

### Purposes and Advantages

The purpose of the "Metric Projector" is to make it possible to perform photogrammetry with a single photograph: in fact, the reticle, or pseudo-photogram, has the same function as a real photograph; by inverting the time sequence, one can imagine an object, identified and represented by the lines and by the nodes that define it morphologically, and one can think of the reticle as a take of such lines and nodes by means of a camera, having the same optical characteristics and located where in fact the projector is located.

In plotting the points onto which the nodes are projected, this method yields a higher precision than that obtained using the stereoscopic pair: in fact, out of the four coordinates taken in an analytical plotting, it can be considered that no error is involved with two of them because they are the coordinates of the reticle's nodes and therefore they can be determined with the utmost precision. Moreover, since the other two plate coordinates relate to points that are identified by projected targets (nodes), they can be determined with a greater precision than that obtainable in a normal procedure.

The precision of the plotted points can further be improved by using the various control procedures, by verifying if they are satisfied and by adjusting the obtained values.

For example, the nodes belonging to the same horizontal (or vertical) line of the reticle identify, as a consequence of the projection, points belonging to the same plane.

It is important to remark that in a normal take with a horizontal base, the nodes will change position in relation to the original reticle depending on the object's morphology; but always towards one direction.

This simplifies the reading of the plate because only one coordinate has changed.

### Conclusion

Based on what has been said in this paper, I believe that in the field of raster-photogrammetry the "metric projector" is very useful because it allows to do only one take, to achieve a greater accuracy and it makes automatic analytical plotting easier.

Another advantage of raster photogrammetry with a single photograph is the possibility of investigating dynamic phenomena without having to perform two synchronized takes; we can therefore foresee the development of cine-photogrammetry.

The mechanical part of the instrument was manufactured by Ditta Salvadori of Florence, while the optical part was manufactured by Ditta Silo s.n.c. of Florence.

## References.

- 1- BAJ E.: "Riprese fotogrammetriche con l'ausilio di un proiettore metrico". Bollettino SIFET, n. 3/4, 1980, pp.95-98.
- 2- FROBIN W., HUERHOLZER E. "Rasterstereography: a photogrammetric method for measurement of body surface". Photogrammetric engineering and remote sensing, Vol. 47, N. 12, 1981, pp.1717-1721.
- 3- HIERHOLZER E., FROBIN W.: "Automatic measurement of body surface using rasterstereography". Biostereometrics' 1982, S. Diego, California, Proceedings of SPIE Vol.361 pp 125-131.
- 4- AZZARELLI L., BAJ E., CHIMENTI M., SALVETTI O.: "Preprocessing procedures for automatic plotting in photogrammetry". International Archives of Photogrammetry, Vol. XXV, Part A2 Commission II, pp. 18-27.
- 5- BAJ E., CASALINI P.L., LOMBARDI S., TONAZZINI A.: "Automatic measurements of plate coordinates in order to obtain automatic plotting". International Archives of Photogrammetry, vol. XXV, Part A2 Commission II, pp. 28-37.
- 6- FROBIN W., HIERHOLZER E.; " Simplified Rasterstereography using a metric camera".Photogrammetric engineering and remote sensing, vol. LI, N. 10, Oct. 1985, pp.1605-1608
- 7- BAJ E., BOZZOLATO G.: "On line Restitution in Biostereometrics using one photogram and a metric projector" International Archives of Photogrammetry and Remote Sensing, vol. 26 part 5, June 1986, pp. 271-278.
- 8- BAJ E., BOZZOLATO G.: "Restituzione di Prese Raster". Bollettino SIFET, n. 3/4, 1987, pp. 177-184.