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PHOTOGRAMMETRIC MEASUREMENT OF THE HUMAN FACE USING A PROJECTED GRID

Abstract

The dimensioning data required for the design of safe and comfortable safety glasses have been acquired with a special two-picture method, in which one of the pictures has been replaced by a grid projected on the face. In connection with the photography, the projector was calibrated using a metric camera for photographing the grid projected on a plane.

Due to the solution adopted, the number of pictures required is reduced to nearly one half, the targeting of the points to be measured demands no extra work, and time is saved because the measurement can be performed using a mono comparator.

0. Introduction

For the acquisition of the three-dimensional dimensioning data necessary for the designing of safe and comfortable safety glasses, a measurement of the faces of some 200 persons was performed at the Laboratory of Photogrammetry of the Helsinki University of Technology

The special characteristics and requirements of the measurement

- approximately the same points have to be measured on all faces
- the surface of the skin is poorly visible in the photographs
- the number of photographs and measurements is great
- the result is taken up for further numerical processing
- the photographs have to be suited for later anthropological measurements

led to a solution different from the conventional two-picture method; in it the number of photographs to be taken is reduced by almost 50 %. Also earlier experiences of use of projected grids gave encouragement to adopt the solution reported upon in the following chapter / 1 /. A report on a different solution has been given by J. Söderlund, among others; the object of his research was the design of children's spectacles / 2 /.

1. The principle of the method

The method used is basically a two-picture method, in which one of the bundles of rays remains the same in all pairs of pictures. This is accomplished by replacing one of the cameras with a projector, by the help of which a grid of the needeed shape is projected on the surface of the object to be measured. From here it is photographed with a metric camera. The projected grid and the photograph are measured with a comparator, and, after numerical processing, the final result obtained consists of object coordinates.

Because the control points required for the absolute orientation of a model are visible only on the photograph, the scale has to be determined in some other way. In fact, there are several possible ways to do this. In case at hand, part of the projected rays hit the plate that was in the same plane with the control points. Here, in computation, the condition that the said points are on this plane must be fullfilled; and, if the plane is parallel to the plane determined by coordinate axes, the situation is the simplest.

The calibration of the projector forms part of the method. This is done by projecting a grid on to a plane and by photographing it with a metric camera. However, for the determination of the focal length of the projector and the coordinates of its principal point, other observations or constraints are required, in addition to the picture coordinates. In this case, the distances from the control points to the projection center of the projector have been measured.

2. Instrumentation

2.1 The control point plates

Separate control point nets were needeed for the calibration of the projector and for the measurement proper. The points were marked with a black felt pen on white chip boards 18 mm thick, with a mat surface, and of the size 60 cm x 50 cm; they formed sets of 2 x 3 points (Figures 2 and 3); and their plane coordinates were measured on the tracing table of a Wild A8. At the time of photography, the boards were fastened firmly on to an adjustable table using a metal frame. In the middle of the board used in the measurement proper, there was an opening of the size 31 cm x 22 cm for the face; it is here that the supports for the chin and forehead were fastened.

2.2 The projector

The projector used was a very small-sized slide projector of Leitz that was fastened with a screw on to an adjustable camera tripod. The lens of the projector was Elmar 1:2.8/50 mm.

To avoid a change in the interior orientation of the projector in the course of photography, special locking devices were made for the lens tube and the picture holder.

2.3 The grid

The grid to be projected (Figure 2) was prepared out of a regular Letratone set of squares, on to which additional markings were made to facilitate the identification of points. A 35 mm camera was used to photograph the pattern on film, which, in turn, was used to produce the final positive grid in the form of a contact print. The size of the squares was so choosen that the

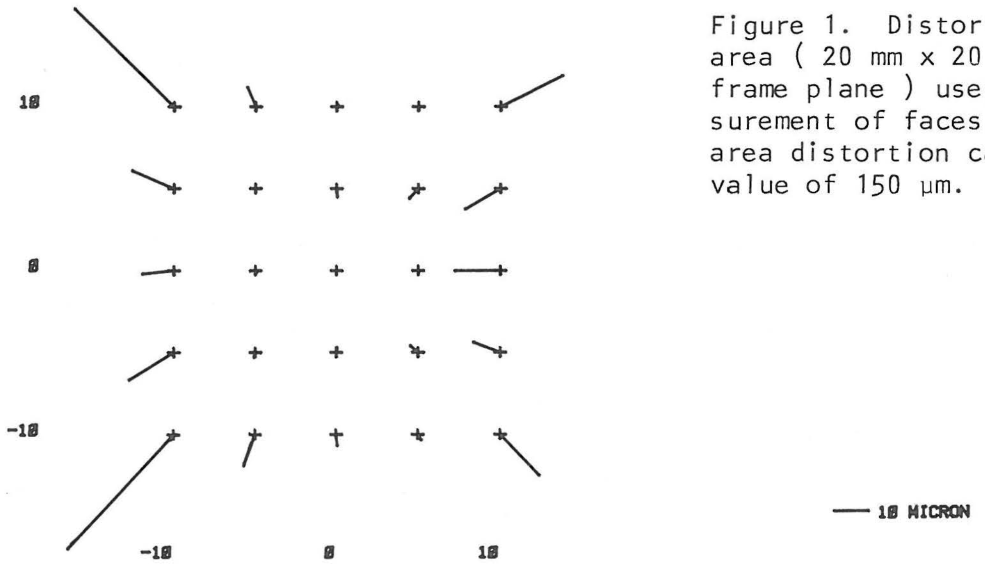

Figure 1. Distortion on the area (20 mm x 20 mm on the frame plane) used for the measurement of faces. Outside this area distortion can reach the value of 150 µm.

perpendiculary to this plane and intersected the face at about 3 cm from the middle line of the head, so as to show one side of the nose well on the photograph. The projector was placed at the same distance from the control point plane so that the base was about 25 cm. A grid was projected on the right side of the face; it was oriented by means of the leveling screws of the tripod in a way that a certain grid line passed throug the pupils. The position of the ear is of great importance for the designing of glasses, and it could not be measured in the normal way. Therefore it was targeted by means of a small plate, the distance of which from the control point plane was read at the time of photography.

The time of exposure was 1 sec. The photographs were developed using a sensitizing developing agent, Acufine.

The photographs were measured in a monocomparator. In addition to the fiducial marks and six control points, measurements were made of the pupils, of the targeted point on the right ear, of 30 - 35 grid points on the face, and of 4 points projected on to the control point plane. Following this procedure, the measurement of one photograph took about 20 min.

The final computation was performed using the general block adjustment program mentioned above. For the determination of the pupils, it was set down as a condition that the point closest to the pupil (< 1 mm) and the pupil are at the same distance from the control point plane. All points werw included in this computation so as to reduce to a minimum the influence of the somewhat disadvantageous geometry. Furthermore, the use of a separate intersection program would demand an extra effort.

The standard error of unit weight i.e., that of one coordinate observation, as derived from the computation varied between 5.0 µm and 10.0 µm.

The lists of the coordinates thus obtained were delivered to the orderer of this research. By means of the coordinates of the pupils and of one ear, the results are transformed into the same system; this makes possible the determination of the dimensions needeed by the designers.

distance between the points on the face was about 3 mm during photography.

Of the grid, a set of 5 x 7 points, used for the calibration of the projector, was measured in a monocomparator, PK1 of Zeiss/Oberkochen; futhermore, about 70 such points were measured that would be actualized in the measurement of faces.

2.4 The camera

The camera uded in photography was the TMK of Zeiss/Oberkochen (c = 60 mm). The camera was equipped with a Zeiss front lens, Nr. 2, thus giving a depth of focus of 62 cm ± 6 cm.

3. Calibration of the projector

The projector was calibrated at the beginning and end of each period of photography of about 2 hours. This was done by projecting the grid from a distance of 65 cm perpendicular on to the control point plate and by photographing it with the TMK located as close as possible to the projector. In addition, a measuring was used to measure the distances from the projection center of the projector to the control points. For this purpose, the position of the projection center in the lens tube had been determined beforehand. From the photograph, the control points and 35 grid points used for calibration were measured in a monocomparator.

In the computation that followed, the exterior orientation of the metric camera was determined; also the object coordinates of the grid points were determined, assuming that they all were in the same plane. After this, the exterior and interior orientations of the projector were computed. In this computation, the object coordinates of the projected grid points, obtained in the preceding phase, were used as control point coordinates, and the observations of distances to the projection center, mentioned above, served as additional observations. The standard errors obtained for the coordinates of the projection center, determined by means of the distance observations, were ± 1.5 mm in the plane parallel to the picture plane and ± 0.5 mm in the direction of photography. The division of the computation into two phases was due to the general block adjustment program used, which treats the interior orientation of all photographs in the same computation in an identical manner.

Also radial and tangential distortion parameters could be included in the determination of interior orientation; this gave the distortion of the projection lens seen in Figure 2. However, because the distortion values were relatively low in the area to be measured, distortion parameters were not determined in the final computations. The influence of this on the final result was on an average ± 0.1 mm. The computation of the calibration photographs showed also that interior orientation had been well preserved during all periods of photography; consequently, the interior orientation obtained by calibration performed at the beginning of each period was used for all cases within the period in question.

4. The measurement of faces

When photographing the faces, the metric camera was placed at a distance of 67 cm from the control point plane in a way that the photographing axis ran

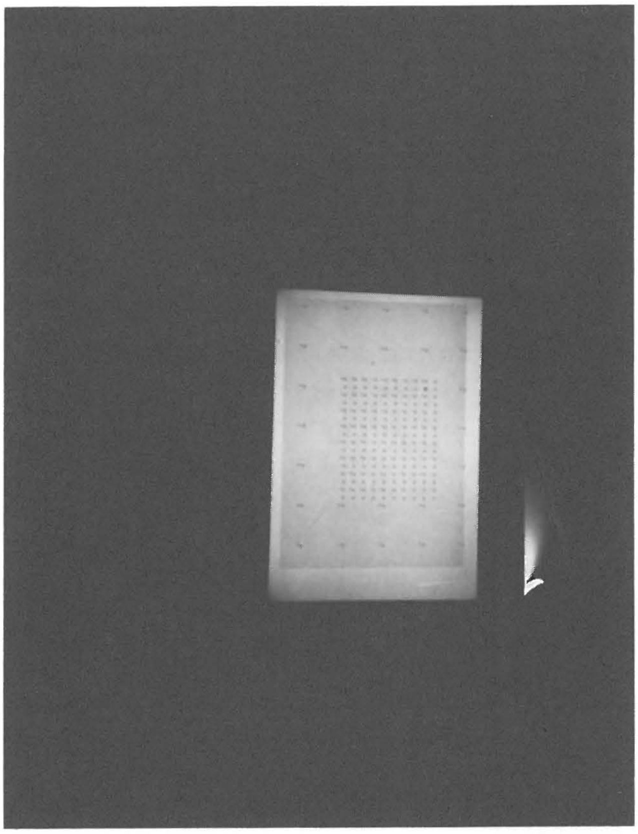

Figure 2. A contact print of a TMK photograph for the calibration of the projector.

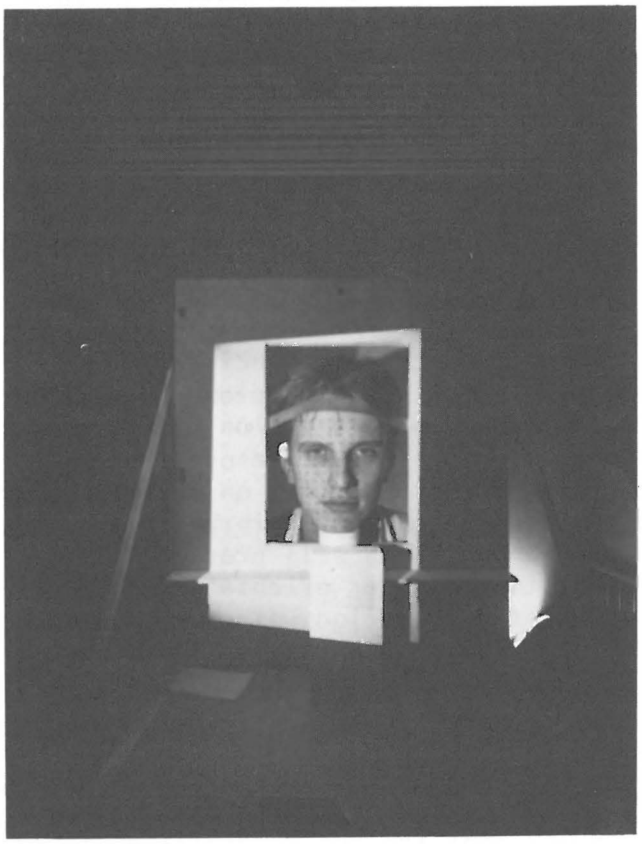

Figure 3. A contact print of a TMK photograph for the measurement of faces.

Figure 4. Set-up for photography.

5. Conclusion

The method used proved to be very well suited for the application in question, and the objectives set were attained. The method is rapid in the photographing and measuring phases, but fluent computation would demand a computer program better suited for this kind of a purpose.

In the case at hand, the accuracy requirements were not particularly high, but the use of projected grid makes possible an increase in accuracy. This can be achieved by carefully calibrating the bundle to be projected, which can be done rather easily, at least in some cases. Futhermore, if the photographing set up is so arranged that, in the determination of the most critical coordinate, theinfluence of projection bundle is the greatest, the accuracy of the final result is improved.

References

/ 1 / Jaakkola J.: A Method for Measuring the Thickness of Water Films Disturbed by Raining in Model Experiments. Presented Paper of the XIII ISP Congress Helsinki 1976.

/ 2 / Söderlund J.: Children's Spectacles. Presented Paper of the XIII ISP Congress Helsinki 1976.