FRONTISPIECE. Prototype of a videoplotter.

Microcomputers and Photogrammetry A New Tool: The Videoplotter

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ABSTRACT: Up to now, photogrammetry has generally kept to its classical approach, i.e., measurements on film, even in the case when the stereo-images had originally been produced as digital data. However, interesting new possibilities have developed in the present technological environment, with its improved image digitizers, monitors, and microcomputers. Thus, it does not seem unreasonable to believe that the standard stereoplotter - analog or analytical - will eventually be replaced by a new type of instrument, which could be called videoplotter and which would simply consist of a powerful microcomputer with a high-resolution monitor, driven by appropriate software. This paper describes the prototype of such a plotter. It shows how stereo-images are stored in a digital form and displayed on a screen on which three-dimensional measurements and plotting can be achieved, using a stereoscope, digital mapping techniques, and a measuring mark that has the advantage of being part of the image matrix. An example of interior orientation and plotting is given, using the simple case of a model taken by stereometric cameras. On-going developments, directed at universal plotting, are also presented, along with the main advantages of the new and inexpensive technique.

INTRODUCTION

THE ADVENT OF THE MICROCOMPUTER has come at a time when other technological advances have been numerous and when, in particular, stereo-images obtained from digital data have come to be part of the photogrammetric environment (for example, digital data coming from satellites, from tomographic scanning, from electronic microscope scanning, etc.). Whereas, in general, the remote sensing approach has been to deal directly with digital data when it was available in this form, the conventional photogrammetric approach has implied, as a first step, digital to analog conversion, so that the information, duly registered on film as an image, could be processed using standard stereoplotters, either analog or analytical.

As a consequence, many developments and improvements in remote sensing techniques and potential have been directly related to the outstanding advances in microcomputers, graphics boards, and high-resolution monitor technology. In these techniques, however, stereoscopy plays a rather unimportant part. On the other hand, while photogrammetry, in the same period of time, has shown a rate of development hardly comparable, its contribution and importance continue to be major, because of the importance of the three-dimensional information that it provides. As a consequence also, as both disciplines remain so closely related, both dealing with imagery and deriving spatial information from it, it seems only normal that ways should be found to close the gap between them and to put together the specific advantages or strengths of each discipline.

And this leads directly to the concept of what could be called a videoplotter, a system that shows the potential of gradually replacing the stereoplotter and in which, basically, the stereo-images, in digital form, are directly fed into and processed by a microcomputer, the output being three-dimensional information, which can be displayed on the screen, stored, or plotted. With the existing hardware, materialization of this concept,

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which was unthinkable only a few years ago, is now quite possible and at very reasonable costs.

DESCRIPTION AND USE OF THE VIDEOPLOTTER

HARDWARE

The prototype of a videoplotter is shown on the Frontis piece. It consists of

- an IBM-PC XT with two floppy disk units,
- a Sysdyne color monitor (resolution of 320 by 200), and
- a mirror stereoscope mounted in front of the monitor to facilitate stereoscopic vision.

As shown on the figure, the two stereo-images are displayed on the screen. A superimposed measuring mark, driven by a mouse, is brought into contact with corresponding image points, which are observed in three dimensions by the operator sitting in front of the stereoscope. Stereoscopic pointing to any point is made possible by displacements of the two half-marks in X, Y, and p-X. The computer transforms these movements into X, Y, and Z values. The mouse has three buttons. Positive increments of X-parallax are obtained by depressing one button and negative increments by depressing another one. The third one serves to register and store, when needed, the screen coordinates of the two half-marks, once a three-dimensional pointing has been performed. Increments of X-parallaxes go by one-pixel steps, at a speed that the operator can modify by depressing a specific character on the key board. It has to be noted that screen deformations have no effect on the measurements and results, because these deformations affect the half-marks in exactly the same way as they affect the displayed images.

SOFTWARE

Experiments with the system shown in the Frontispiece were first carried out with the most simple case met in photogrammetry, the case of a stereomodel formed with photographs taken with stereometric cameras, which means that ground coordinates can be derived without having to go through the general procedures of relative orientation, scaling, and leveling of the model. Of course, the same simple system can be used for the general photogrammetric situation, provided that appropriate software performs the necessary processing, relative and absolute orientation being computed from screen-coordinate measurements.

Once the observation is made on the two corresponding submatrices of pixels displayed on the screen, a position is fixed by storing, for each of the corresponding points, the line and column number, as defined in the original matrix of the digital or digitized photograph. The positions of the fiducial marks have been previously measured and stored, from which the positions of the principal points and the possible κ-rotations are computed, along with the pixel/millimetre ratio for each axis. From this and from the screen positions corresponding to each point, the program determines the photograph coordinates x', y', x'', and y''. With this information, it then computes the X, Y, and Z coordinates of the points, using data that have been previously entered: the base, the focal length, and the X, Y, and Z coordinates of the left perspective center.

FIG. 1. The right photograph of the digitized model.

EXPERIMENTS

Development and testing of the system was carried out by means of the following experiments. First, paper diapositives of a model were produced by a two-times enlargement of glass negatives obtained with a Wild C40 stereometric camera. The positives were digitized with a Hewlett-Packard Scan-Jet Digitizer, at a resolution of 75 pixels/inch, in 64 shades of grey. The object chosen, as shown on Figure 1, was a 30-cm high reproduction of the familiar RCA trademark, the Nipper dog.

Figure 1 shows that, in order to make easier stereoscopic pointing, a rectangular grid was projected on the object. In addition to well-defined points, such as table corners, targets in the form of black circles also were placed at different spots on the object. The Wild BC-1 analytical plotter was used to determine the ground coordinates of these targets, the well-defined points serving as control points. Comparison of BC-1 ground values with videoplotter-derived ground values gives a good idea of the order of accuracy that can be obtained with the very unsophisticated system that has been used as a first-generation experimental prototype.

A priori considerations regarding the accuracy of the output have to take into account the resolution of the system. One pixel on the screen measures 0.17 mm on the original negative, which is at a scale of 1/12. Thus, one-pixel resolution of screen observations means 2 mm at ground scale, in X and Y. This leads to an expected accuracy on the order of 1 mm, as it can be assumed that the floating mark can be centered to the closest one-half pixel. Another source of error, in our experiments, came from the fact that the 64 shades of grey produced by the scanner had to be converted to a display of eight shades, due to the specific configuration of the Techmar's "Graphics Master" adaptor used. Displacements of the centers of some targets had to be expected as a consequence of this generalization process, which causes the display on the screen of only the more contrasted part of the black spot. Comparison of Figure 1 with Figure 2 makes this very evident.

RESULTS

Comparison of videoplotter-determined ground coordinates of the control points with the corresponding values obtained with the BC-1 has given the results presented on Table 1. These results fall well within the 1-mm expected order of accuracy, in X and Y, and the ΔZ values are coherent with the ΔX, as the model had a depth-to-base ratio of 2. This means that our preliminary expectations had not been unduly optimistic. Of course, final figures on the actual accuracy of the system would require a detailed analysis of not only one but of several tests. However, this was not needed in this case because the system, being in its very early stages of development, is expected to evolve very rapidly, with its accuracy changing accordingly. Thus, what was needed was a general indication of the quality potential of the output produced with the prototype.

CONCLUSION

The indication seems clear: The potential is there and we now have the tools to address photogrammetric problems in a way

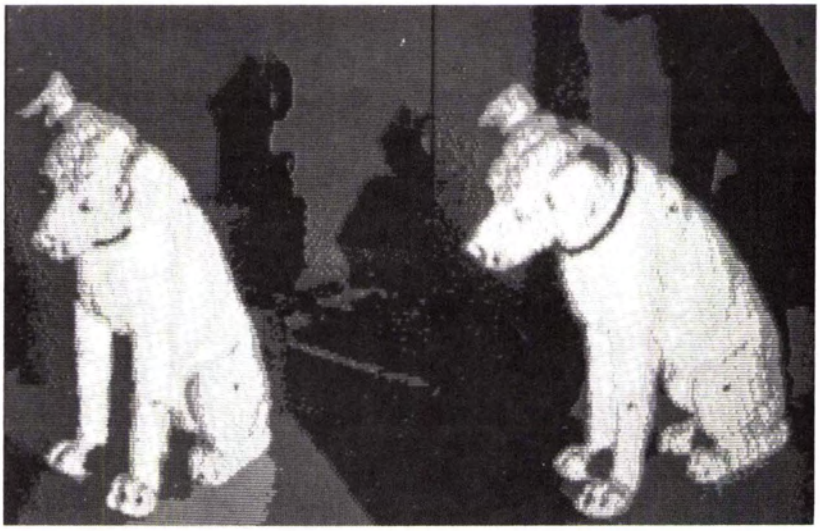

FIG. 2. The quality of the observed video-images.

TABLE 1. DIFFERENCES BETWEEN BC-1 AND VIDEOPLOTTER COORDINATES.

Point number	ΔX (mm)	ΔY (mm)	ΔZ (mm)
1	−0.22	−0.42	0.45
2	−0.95	0.02	0.99
3	0.02	0.37	−0.37
4	1.25	−0.89	−1.52
5	0.55	0.20	1.68
6	−0.26	0.05	−0.94
7	−0.43	−0.02	−1.29
8	0.04	0.70	0.99
RMS	0.62	0.45	1.12

that has proven so beneficial to the development and expansion of remote sensing. These tools, however, still have to be refined and the refining has to be achieved at reasonable costs. This, it can be assumed, will be the case, because the tools are part of the world of computer technology, which has been marked by a sharp rate of development and decline of prices. For the videoplotter, improvements, at this stage, imply

- more sophisticated software, capable of solving more diversified photogrammetric problems, in a user-friendly and efficient way;
- higher resolution and speed of digital cameras or image digitizers;
- higher speed and capacity of microcomputers; and
- higher resolution of color monitors.

Software developments are already under way and existing pieces of hardware can already be combined to make up a videoplotter that could address successfully photogrammetric problems at a cost many times lower than the conventional approach would permit. And, finally, it can already be seen that videoplotters, for reasons of costs, ease of operations, and flexibility, have the potential to make photogrammetry directly accessible to a lot of new users, in forestry, agronomy, architecture, archeology, police investigations, etc.

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