A MICROPROCESSOR-CONTROLLED ORTHOPHOTOPROJECTOR SYSTEM MADE IN CHINA

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ABSTRACT

The first orthophotoprojector designed by China has been successfully turned out recently. The paper describes in the first place its principle, construction, error analysis, computer control, operational experience and test results, and in the second place a simple analytical plotter called "DEM Producer", which has been designed by combining Intel 8086 single board computer with stereocomparator to provide, mainly, DEM data for the projector.

1 ORTHOPHOTOPROJECTOR

In order to satisfy the needs of the people for orthophoto maps an orthophotoprojector has been developed. This projector is based on the differential rectification through optical slit projection and is controlled by a 16-bit single board processor. The principle of the optic-mechanical instrument is shown in Figure 1.

The movement range of the image carriers 240mm both in x and y.
The magnification m changable within 1.7^x-12^x.
The image rotation α 360^o.
The movement of the drum in object space 700mm by 700mm both in x and y.

The most delicate part of optics is the ZOOM system, and the rotation of the drum is very important for the mechanism. The important task the optics does is to assume a high resolution, because the resolution can not be controlled by a programmer.

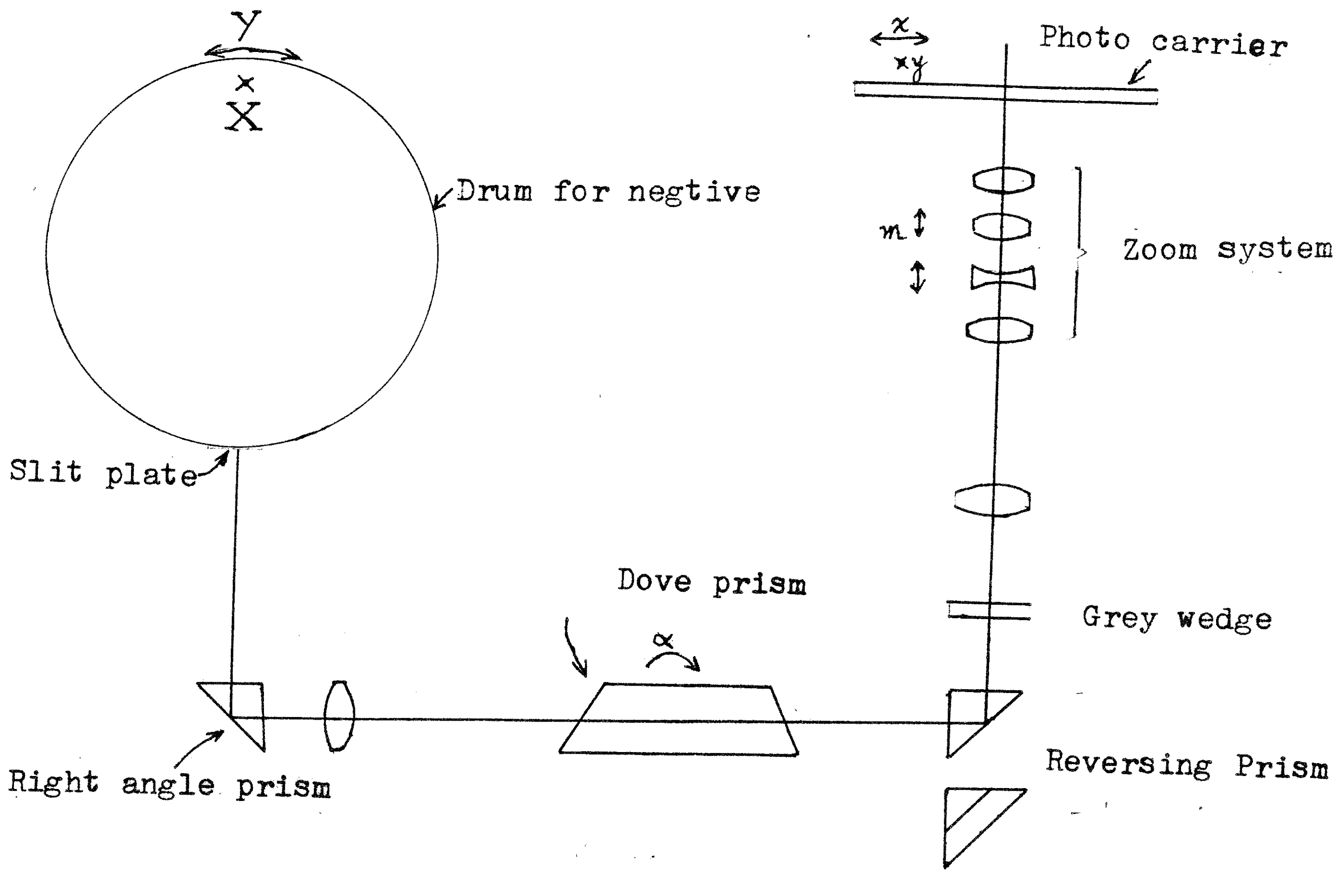

Figure 1.

(1) The Principle of Electronic Components

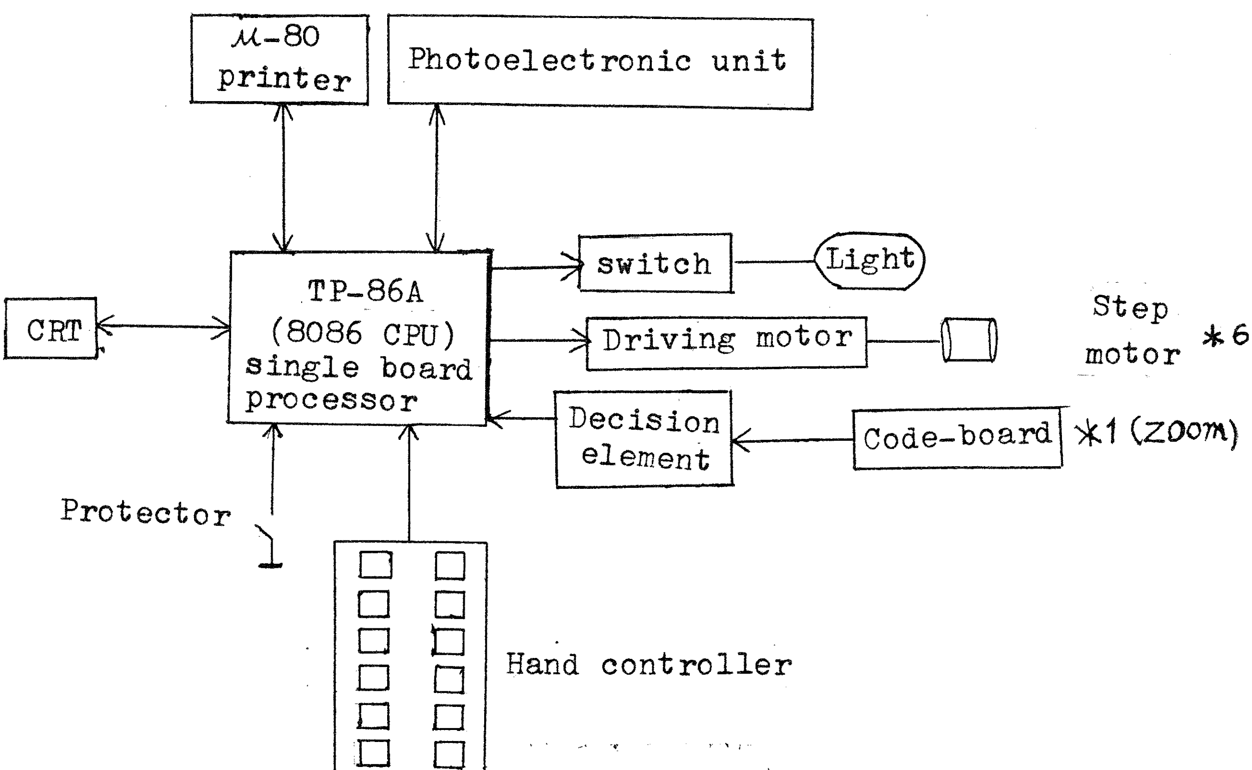

Figure 2.

It is of great importance for the hardware to be as standardized as possible so that maintainance and service can be easily carried out. Using to the maximum the large scale integrate circuit (LSI) can greatly reduce the nember of connections and thus increase the reliability to a great deal.

The CRT and μ-80 printer shown in Figure 2 can be excluded from the system when the development comes to a perfect halt, which means the cost of the orthophotoprojector system will get even lower.

This instrument looks as if it were based on rectification by linear elements, but in reality, it is based on that by area ele.. The reason for this is that the registration interval (DEM'S) in y direction is exactly the same as that in x direction, which takes a form of a square. There is no need to favor y direction than x, since registrations along y direction are much thicker.

(2) Main Factor for Determining the Slit Width -- Second Elevation Difference.

Projection from a photograph onto a tilted ground surface means perspective transformation P_1 and due to the relief P_1 is not a constant matrix. The projection from the ground surface onto the horizontal plane (map) is an affine transformation A. The principles of geometry tell us that to project directly from a photograph onto a map the new perspective transformation formula $P_2 = A \cdot P_1$ should be used; but we approximate P_2 by a similarity transformation (near axial beam) only, of course this approximation is limited, what is remarkable was the error which would result from the second elevation difference in the slit. To show this the Figure 3 is provided.

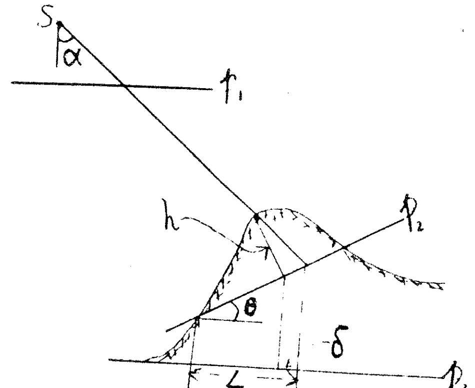

Figure 3.

$p_2 = P_1 \cdot p_1$, $\quad p_3 = A \cdot p_2 = A \cdot P_1 \cdot p_1 = P_2 \cdot p_1$.

The displacement caused by the second elevation difference would be:

$\delta = h \cdot tg(\alpha - \theta) \cdot \cos$

α is the tilt of projecting beam.

θ represents the tilt of the ground feature.

L stands for the width of the slit.

h is for the second elevation difference.

Note: any ground surface, tilted in the direction against the projection center has a negtive .

Such is the practical formula for the determination of the slit width.

(3) How Much Information on Earth Needed for the Production of an Orthophoto map.

When a ground surface lies in a horizontal, and parrallel to the photograph plane, it takes only about less than 20 bits of information to produce an orthophoto. When the plane is equally tilted, it needs several dozen of bits. To produce a 500x600mm photo map with the 8mm-wide slit, it takes 16K bytes of information, among which however there are great amount of redundancy and 2/3 or 3/4 of which could be dismissed by a simple reduction. It results a doubt in the necessity of using half-inch magnetic tapes in this case.

(4) Integration Algorithm of "Differential Rectification"

An orthophoto making process is similar to plotting "random curves" in a five-dimentional space. A fine image can be achieved by smooth and accurate plotting of these "random curves". (see Figure 4).

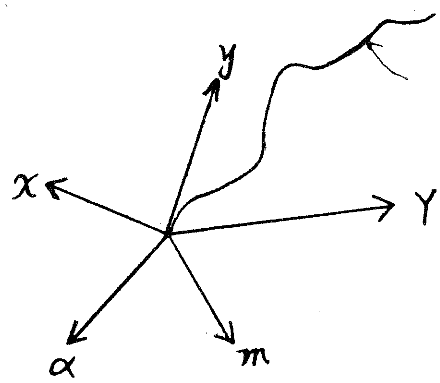

Figure 4.

A random curve is divided into numerous pieces and every piece can be represented by a straight line. For each piece of the line the slops are to be computed, namely: dx/dt, dy/dt, dY/dt, dX/dt and dm/dt, in which only dY/dt is a constant. When dY/dt=1, it is treated as an undivided frequency; when dY/dt=$^1/2$, it is regarded as half frequency. Frequency division is aimed at uniforming the pulses; and the orthophoto process is more or less like running integrator.

$$x = \int \frac{dx}{dt}\, dt \ , \qquad y = \int \frac{dy}{dt}\, dt \ \dots \ \dots$$

A pulse would be transmitted to a degree of freedom, whenever an integrated value exceeds an integral. In this way, a five-dimentional curve can be "plotted" out.

(5) Correction of Optic-Mechanical Errors by a Program.

The manufacture accuracy is limited, but the computation accuracy becomes more and more precise with the expanding of the word length. Using program to correct optic-mechanical errors caused by manufacturing is the common practice and charicteristics in modern instruments.

In modern precise photogrammetric instrument, software plays a leading role, and this is the cause for the lower requirement imposed on the manufacture of the optic-mechanical instrument. Now, the conception of "instrument" has given place to "system" and the user would also poke his nose into the development. Therefore, the monopolizing positions of the traditional instrument manufacturers have been shocked.

For this othophotoprojector the precise programs are introduced to ensure the corrections to the orthogonality of the picture carriers, the nonlinearity of the ZOOM system, the eccentricity and the turning of the drum and etc. The corrections can be carried out in two ways: functions and tables. The table would be adopted whenever an error pattern was difficult to be functionized.

(6) System Configuration

The grids, profiles, discrete points and digitized contours all could be used as inputs for the orthophoto production. The various formates of imputs made the orthophoto system larger and larger (shown in Figure 5).

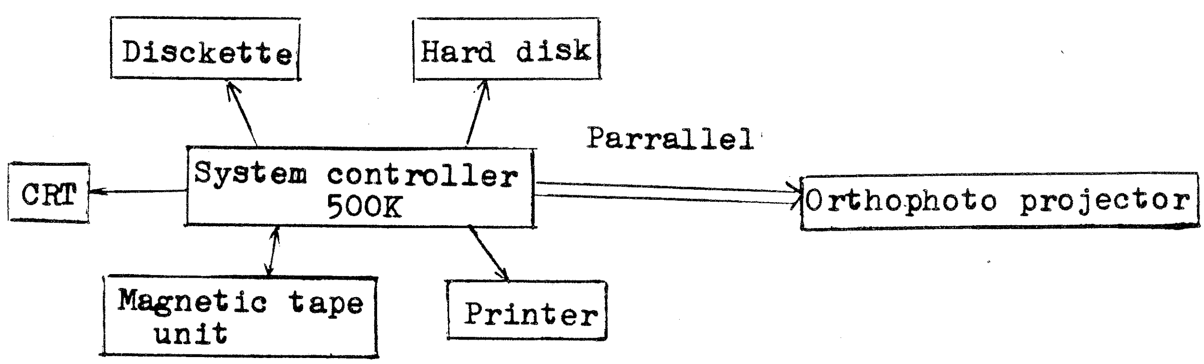

Figure 5.

Here, the system controller interferes directly in every step of the projector. This configuration costed more money, unreasonable and not neccessary. From the trend that modern computer technology experiences from the centralised to the distributed, this system should be configurated in the way shown in Figure 6.

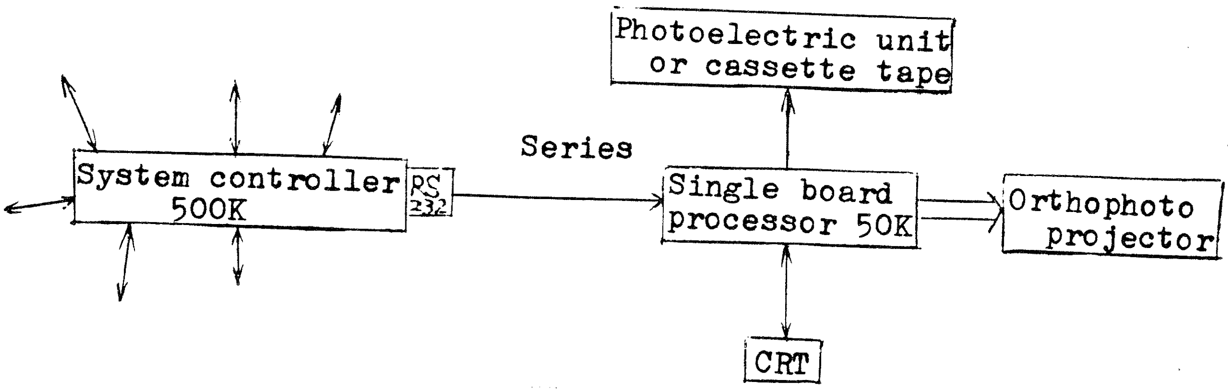

Figure 6.

Such a configuration will allow off-line as well as on-line operation. When the orthophoto data needs to be reprocessed, it can go to the system controller first. Having been processed into the controller data by the system controller, it can then be fed into the secondary unit which controlls the projector.

2 DATA ACQUISITION

To acquire data we have developed a DEM collector called DEMER. It is quite difficult for a human as a living correlator to make a "correlation calculation" with a moving "target window area", and that is the most severe problem of stereoscopic observation from objective space instruments. The stereoscopic observation in object space is not only difficult to perform but also poor in accuracy. However with an image space instrument, we succeeded in the high speed and accuracy of DEM data acquisition. As the data thus obtained could not be used directly in the orthophotomap production without a transformation, we developed a program which can scan the object space for the image space instrument. With this program the instrument can directly produce regular grid of elevations in objective space. Thus, an attention should be paid to the density of DEM required by the orthophoto production, which is far more lower than that required by contouring.

(1)Ciculative procedurefor the Iterative Solution of Implicit Functions through the Joint Efforts of Operator and Machine.

Provided the 4 degree of freedom x, y, P_x, P_y with motors and then connected to a TP-86A computer, any common comparater can be turned into what we called DEMER. In the image space, when relative and absolute orientation of the model is completed, the only problem left is how to realise the circulative procedure.

Traditionally we have: $(x, y, P_x) = f_1(x, y, z)$ but we need: $(x, y, z) = f_2(x, y, P_x)$.

As the explicit function f_2 is hard to get, the only thing we can do is to make iterative solution of the function f_1 (see Figure 7).

With the circulation; The correlation, the resposive solution of the implicit function and the collinearity equations etc. are converged at the time, which of course needs highly frequent interaction.

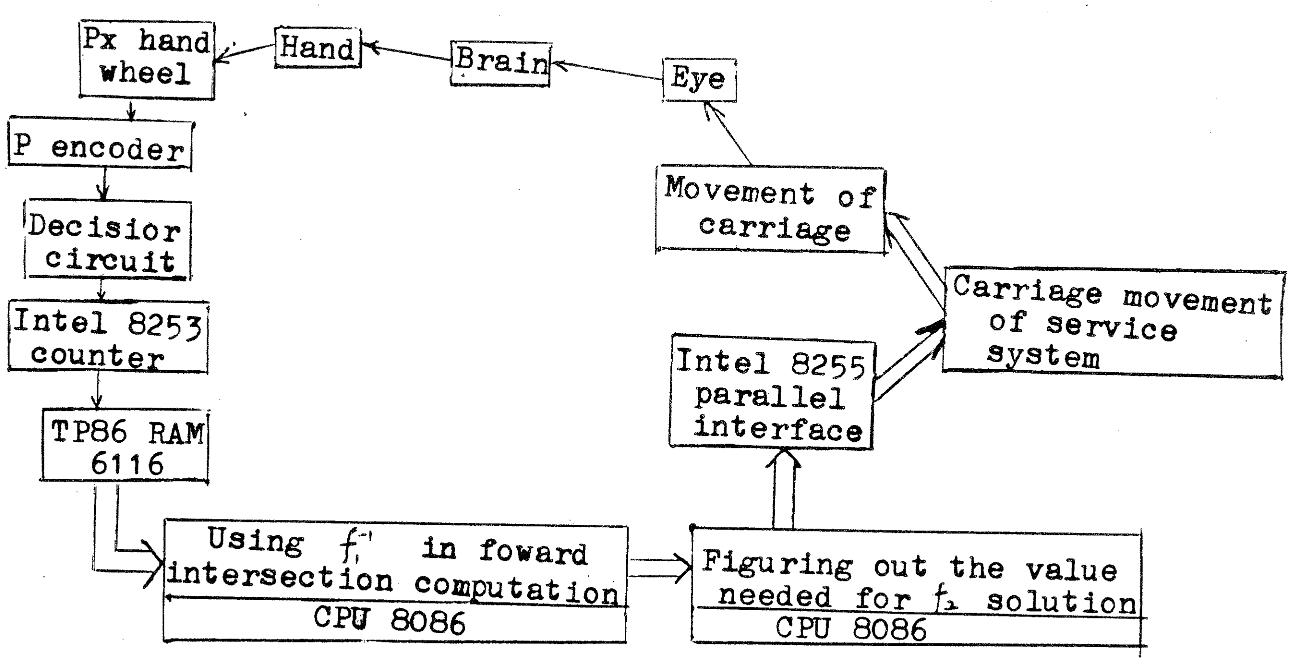

Figure 7.

(2) Microprocessorized servo System

For the wide use of LSI, every degree of freedom is manipulated with one 8-bit processor. Realisation: LSI+triode=servo -system.

For the position feed-back, speed control and acceleration the programms have been developed. The step motors are used; thus the programms for differentiating circuit, speed acceleration and deceleration, position feedback etc., are all firmed into the ROM, that is in the chip 2732 (see Figure 8).

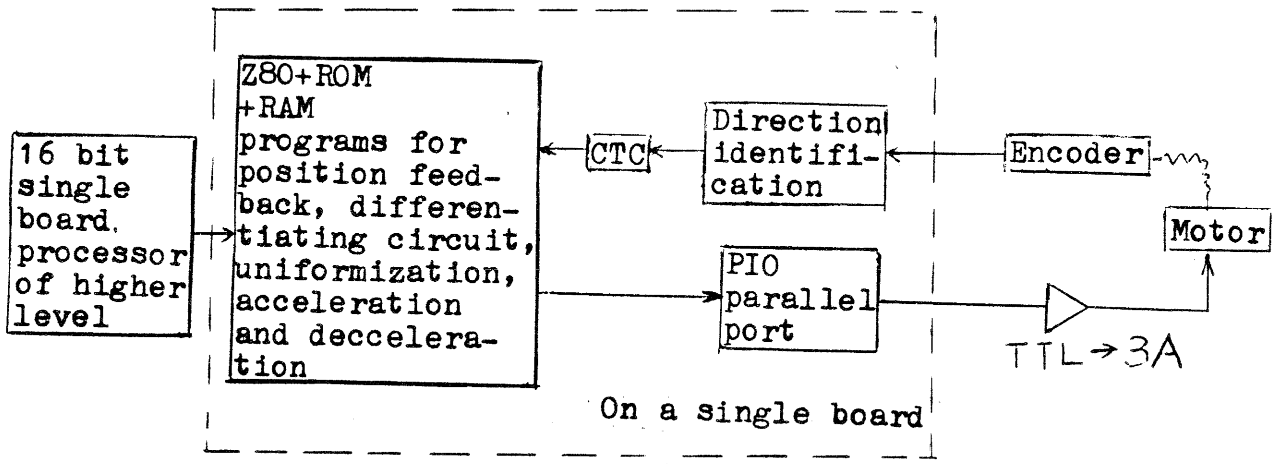

Figure 8.

(3) Elementary Artificial Intelligence

A modern instrument can be used both for routine production and for trainning of operators. This means that in the computer not only stored the program-natured codes but also the non-programme-natured codes which lead the trainee through his practice in the way chosen. A cheap lettering terminal can possibly be used to display the approximate position of a point. It will be helpful for finding control points and kowing the density of the points. The gross errors elemination, part repeatition and the automatic pointing to the certain standard points, all of these give much help to the operator at the orientation stage. The automatic scanning density control system possibly has some value, but it seems more practical using the "fore-sighted observation" to forcast the next point from measured points, and automatically set it on the hand wheels. As long as the operator is pointing, the machine will not go automaticly to the next point. This point by point observation form has proved to be high in both accuracy and speed.

3 EXPERIMENTS

The experiments on the production of orthophotos were carried out not only with the wide-angle photograph but also with wuper-wide angle photographs.

Experiment A:

Photographic Area: Guang Dong, China
Photograph: Super-wide angle, scale - 1:36000
Product: Map scale - 1:10000; Contour well registered.

Experiment B:

Area: Switzerland
Photograph: Wide angle, scale - 1:5000, MSE of point position -- 0.4mm.

ZS-1 orthophotoprojector

Experiment A

Experiment B