Software for the computer-controlled Rectimat C rectifier

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In photogrammetric instrumentation digital techniques become more and more important. Their applications range from tasks of data acquisition to the control and realization of internal instrument functions. This also applies to the field of rectifiers.

The Rectimat C precision rectifier is an equipment of the new generation featuring a very high optical efficiency, a precise mechanical construction as a prerequisite for high accuracy and an efficient electronic system including microcomputer with the appertaining software. The programs which in their entirety are termed software have to ensure the operation of the equipment and to control the functional processes.

The software consists of the computer, control and operating software.

The computer software includes

- the counter programs which ensure the taking over of the count values and the counting of the setting values for the supplementation of the 8-bit hardware counters as well as the availability of the current values of the setting elements;
- the model calculation programs for the mathematical model, which realize the formulas of the Scheimpflug and Newton conditions and in which simultaneously correction calculations are carried out for the individual setting elements (correction of residual errors of the axial system and the like).

This software also includes an arithmetic fixed-point program package.

The control software comprises programs for

- the positioning of the setting elements in the zero position,
- the motion of the independent setting elements a', φ', ω', e_x, e_y,
- the regulation of the motor speed (start-up, braking),
- the positioning of the setting elements to preselected values.

The operating software includes

- button identification programs,
- processing of button information (multiply used buttons, different phases of operation etc.),
- control of lamps allocated to the buttons,
- setting of the filter and diaphragm system as well as of the projection lamp (position blue, green, red) and the tilt compensation filter,
- operation of the shutter,
- display programs for the various equipment states (including converting programs) and darkening of the display,
- error recognition routines and error signalization.

The performance parameters and working possibilities of Rectimat C [1, 2] are implemented only by the interworking of the mechanical-optical and electrical units with the programs and program parts of the software package. Part of the electrical equipment section [3] is a microcomputer with a U 880 central processor unit (CPU). Its memories include 1 K RAM and 15 K PROM. For controlling the servo-motor amplifiers and the display and for taking over the values from the incremental encoders (IGR) and from the keyboards, peripheral PC boards with I/O units and time counting units as well as the PC boards "counter" for 8 setting elements are connected via a bus system with the CPU.

Two different operating modes may be distinguished in Rectimat C. During the fitting of points to control templates it is necessary to continuously guide the setting elements and to maintain sharp focus (rectification by control points), whereas with given magnification and known tilts only the final state is of interest (rectification by setting values) without it being necessary that during the setting procedure the model conditions have to be fulfilled. The former means that the programs must run as real-time programs with time conditions.

The programs can be subdivided according to different aspects:

- working regime of the equipment,
- functional groups of the machine,
- special requirements of the functional groups and hardware interfaces.

The objective of this article is neither a systematic representation nor a complete explanation of all program functions, but a description only of essential features of the software package.

It must not be left unmentioned that the use of a microcomputer and the associated software package for the control of the equipment involves changes in operation. The more the software becomes a central part of a machine and is not only an aid for individual partial processes, the more these differences become noticeable in the operation of a machine. Especially by the combination possibilities of buttons and their sequence of operation manifold processes can be realized. Furthermore, the computer allows to add quite a series of safety elements, button interlocks and failure displays, which in traditional equipments have to be dispensed with because of the too high constructional outlay.

The above viewpoints of subdivision also show that all functions and processes of the Rectimat C rectifier are associated with software programs or are controlled by programs.

Operating controls of the equipment are:

- main switch of the equipment,
- input (or operating) keyboard (stationary operating panel),
- keyboard for machine motions (portable operating keyboard).

The following functions are realized by the microcomputer:

- positioning of the setting elements,
- diaphragm setting,
- filter setting,
- positioning of the projection lamp,
- setting of the tilt compensation filter,

- run of exposure time,
- control of the shutter,
- digital display on the stationary panel,
- lamp displays on the stationary panel.

Input information for the microcomputer includes:

- coarse counting pulses of the 8 setting elements,
- interrogation of the filter-diaphragm positions,
- information of the tilt compensation filter,
- clock frequency for time counts.

Output information from the microcomputer comprises:

- motion steps (motor speeds) for the driving motors of the setting elements,
- locking pulses for the motor amplifiers,
- motion pulses for filter-diaphragm turret or lamp and compensation filter,
- display information for equipment values and operating states.

Switching on

When the equipment is switched on, the computer program is started, it allocates the "basic state" in the memory and at the output channels, and waits for inputs. At this time the latter only involve the input and display of values, the choice of filter and diaphragm, the choice of the programs "ZERO", "exposure B/W" (EXP 1), "exposure-colour" (EXP 2) and their execution. Other inputs are rejected.

Program ZERO

In the program ZERO the zero pulses as available on the hardware side and the appertaining limit switch signals (positive or negative side) of each setting element are used to move stage and image plane into the horizontal position and to set the necessary projection distances on the image and projection sides. Essential points of the algorithm are the incremental change of the motor speed by means of the program and the exceeding of the zero position with immediate start of the count and moving back to the true zero point. Worth mentioning is also the possibility of achieving a highly precise adjustment by means of stored correction constants or zero point values despite deviations of the focal lengths of the lenses being due to manufacturing tolerances.

The program ZERO (same as all programs) is executed after pressing the start button. Additional entries of values are not necessary.

Exposure programs (EXP 1, EXP 2)

Any settings reached within the rectification process are mechanically and optically maintained when the equipment is switched off and, after renewed switching on with immediate choice of EXP 1 or EXP 2, can be used for further exposures with the possibility being provided of altering the exposure time, diaphragm and filter by entering other values.

The exposure time is counted by the microcomputer and only the STOP button is simultaneously accepted. The STOP button interrupts the current exposure. The exposure programs automatically insert

the appertaining filters in the preselected sequence and open the shutter for the preselected times. By means of exposure times of 0.0 seconds it is also possible to make a selection from the sequence blue filter, green filter, red filter. For exposure a tilt compensation filter has been provided for correcting the non-uniform distribution of illumination on the tilted easel. In selecting an exposure program the angle of the tilt gradient of the easel is calculated for the compensation filter and the tilt compensation filter is turned into this position.

Several filters have been provided for optimally compensating the decrease in illumination by the tilt of the easel. The filter to be chosen in dependence on focal length, magnification and tilt of the axes is calculated as filter number and this can be called up, so that the proper tilt filter is used.

Counters

After the program ZERO the counters are activated and continuously take over the values of the setting elements as far as they change. The counter programs guarantee the short-term acquisition of all signals coming from the incremental encoders for the 8 coordinates, since they are reached by means of interrupt and are minimized with regard to the number of instructions to be executed.

Rectification by control points (MAN)

After the execution of the program ZERO an automatic change is made to the operating mode "rectification by control points". The program permanently calculates the corrected actual values of the independent setting elements and the nominal values of the guided setting elements of the photo carrier. These nominal values are regulated. The calculations for the mathematical model include the equations for the Scheimpflug condition and the Newton condition as well as the correction factors, which take into consideration the residual errors of the adjustment of the setting elements. The tilts are calculated as tangent values and are also indicated as such. The internal accuracy is given with 24 bit or 3 byte words and associated arithmetic operations. The arithmetic programs have been designed for fixed-point calculations in order to reach the necessary interrogation and control frequency in the regulation of the guided setting elements. Especially for division the necessary accuracy and the required computing time have been harmonized. The input and display values for the tangent values of the tilts are used with 5 decimal places. Magnification is limited to 4 decimal places. The projection distance a and a' between image plane and lens or easel and lens have 2 decimal places corresponding to an accuracy of one hundredth of a millimeter.

The input of values (tilts, magnifications, easel height correction, exposure times etc.) is always made with a standardized number of places for the individual quantities, which are supplemented by the computer itself. It is ensured by this that only those input buttons must be actuated which are absolutely necessary and that the always standardized display still provides a good check of the values. Missing places and a missing decimal point are, as far as the values are admissible, automatically supplemented. Illegal values which are, for example, too large, are rejected with an error display. Redundant supernumerary decimal places are erased.

The motion of the independently variable setting elements (ω', φ', a', e_x, e_y) interferes with this basic program for the calculation of the formulas, the updating of the display and the measurement of the setting values in such a way that the aforementioned values are changed by means of the buttons of the portable keyboard. For this (same as for the input and program buttons) it is necessary to use the interrupt program and the button identification program.

The independent setting elements are running as long as the appertaining button is pressed. The program controls the start-up and braking of the motor. In this process a start-up curve with motor control values is allocated to a temporal gradation with steps of 0.1 second and in braking the speed is switched down step by step. Two each of the three setting elements $\nu(a')$, ω', φ' or the two photo shifts e_x, e_y can simultaneously be actuated.

The guiding of the associated dependent setting elements is accomplished with a minimum clock time of less than 0.03 seconds. According to the residual path still left for the individual setting element use is made of a special table for determining the motion speed. This allows a very sensitive and vibration-free motion of the setting elements into position. The positioning of the setting elements controlled by computer programs is monitored by program also when the nominal position has been reached.

Rectification by setting values (AUT)

When the exact setting values for a photograph to be rectified are available, they can be entered as nominal values by preselecting the program AUT. With START (of the automatic setting motion AUT) these are then set with high accuracy. The individual values of the setting elements are calculated in their dependence on each other, but individually set one after the other.

The condition is duly considered that tilt changes and the changes of the image planes and easel position relative to the lens must not lead to mutual disturbances. Therefore, the sequence of the setting elements is determined and run in dependence on the momentary position and on the nominal values to be reached. If the input values are by mistake too large, the automatic process of moving into position is stopped by program, when the limitation is reached (acoustic signal) and the operating mode "manual motion" is initiated. This may be followed by a correction of the individual setting elements by means of the portable keyboard or the correction of the nominal values and the release of a new process "automatic fitting".

This automatic motion into a particular equipment position is in connection with a further program important for the entire operation.

Storage of the actual position (MEM)

The MEMORY program takes over all necessary values of the momentary equipment position and stores them as values for automatic fitting (AUT). This is of considerable help for necessary changes, e. g. of the position of the photo carriage for the exchange of the photographs or the tilt compensation filter, to mention but two examples. By automatically setting the stored values the previous rectification position is restored by pressing a button.

As a whole the aim was reached that

- not errors due to faulty operation (approach to limit stops, wrong inputs) go undetected,
- in such an equipment position it is possible to continue work in a reasonable way.

Program modules can be checked for their contents by means of several buttons. For this purpose the four-digit hexadecimal test sums of the contents of the memory chips are checked and errors of these contents are detected with high reliability.

The above-mentioned aspects of the software package show the variability of the program control and the possibility with equal mechanical prerequisites to achieve a higher accuracy by means of the digital technique. An adequately developed software permits of less complex constructive solutions in mechanical and electrical respects.

A crucial point was to design the software of the Rectimat C so that

- the possibilities of the equipment as they were intended by construction, physical prerequisites and the purpose of application are fully utilized,
- a convenient and rational mode of operation (logical sequence) is possible,
- incorrect operations and wrong inputs of parameters are surely recognized.

So the efficient software forms the link between the given constructive design and the working and operating processes as well as accuracy requirements and hence is an essential constituent of the equipment.

Only the combined action of mechanics, electronics and software ensures that a modern and efficient equipment can be made available to users.

References

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Summary

The software of the Rectimat C rectifier is a central constituent of this newly developed system. It has an essential part in making the Rectimat C a very efficient rectifier with high accuracy, versatile applicability and high operational comfort. The individual programs and principles of their design are described.