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TWO-MATRIX PHOTOMETER CONTROL SYSTEM

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ABSTRACT. In this paper astronomical two-matrix photometer is described. It differs from common one CCD camera photometers by using the second CCD camera. It enables simultaneously to carry out the studied star and standard star light inputs measurements. The second camera application enables significantly to increase measurements accuracy and at least twice time decrease of one star observation. The significant increase of measurements accuracy is reached by carrying out simultaneous observations, and errors caused by the Earth atmosphere fluctuation are the same as for studied star so for standard star. Time decrease is reached by carrying out both stars simultaneous observations.

In the paper photometer's optical mechanics scheme is given. The motion mechanism of receiving and recording block with micrometer screw rotated by stepping motor is described. It is demonstrated that exact coordinates of matrix position attached to clutch on micrometer screw are shoot by absolute magnetic encoder.

The applied two-matrix photometer control system electronic equipment is described. The photometer operation control algorithm installed on Tien-Shan astronomical observatory 1-meter telescope is presented.

Key words: star, telescope, photometer, CCD-matrix, optical mechanics scheme, control system.

1. Introduction

In conducting astrophotometrical observations it's important to carry out measurements of the studied star and standard star simultaneously. But practically standard star is always located in some distance from the studied star so even in using CCD camera with maximum sizes (50x50 mm), it doesn't arrive at the emission receiver (matrix). All known photometers (for example, Liutyi et al. 2009) apply one matrix. Therefore observations are carried out separately (in order). Firstly, separate measurement worsens measurements accuracy due to different fluctuations over time in the Earth atmosphere, secondly, increases observational time on photometry of each studied object separately. This disadvantage can be eliminated only in simultaneous measurement of the studied star and standard star then atmosphere fluctuations effect will be the same on two stars.

Apart from in astrophysics there is a number of important tasks which can't be solved or difficult to solve with existing photometers. For example, in astroseismic observations of faint objects, searching exoplanets and a number of other tasks where the studied star variations in brightness are small and fluctuations in the Earth atmosphere don't enable to conduct measurements or strongly distort them. In order to reveal such variations in light long-term observations applying complex mathematical analysis (e.g. Fourier analysis) are carried out. However, many such kind of tasks can't be solved by using one-matrix photometers and they aren't simply solved. In one-matrix photometers these variations in brightness "sink" in atmospheric fluctuations noises.

Thus, development of two-matrix photometer and putting it into the process of astronomical observations enable:

1. significantly to increase photometrical measurements accuracy due to conducting the studied star and standard star simultaneous observations;
2. to decrease twice the time of observations and, hence, more than twice improve observational time effectiveness on telescope;
3. to solve a number of tasks which are impossible to do with one-matrix photometer and extend the range of studied objects.

2. Equipment structure and algorithm of control

Development, manufacturing and adjustment of photometer optical-mechanical connection joint, electronic control schemes and software were required for creating astronomical two-matrix photometer.

Two one-meter telescopes of Tien-Shan astronomical observatories (TSAO) have Ritchey-Chrétien system which enables to create a big undistorted field in the telescope focus that gives additional advantages for two-matrix photometer operation.

One of CCD-matrix (main) is installed on telescope main optical axis from which the studied star measurements are carried out. The light flow from standard star with the help of diagonal mirror "placed out" onto photometer side surface with turn at 90° (degrees). Connection joint consisting of diagonal mirror, filters and CCD-matrixes is gathered into one optical block and has the possibility to move telescope focal plane on one of coordinates. Moving on the second coordinate is provided by photometer turn on telescope turning circle. This responds to that standard stars can locate towards the studied star at different distances and in various positioned angles. Moving the second CCD-matrix in two directions, it's practically always possible to direct with coordinates onto standard star.

Optical scheme of photometer main channel (for the studied star observations) with Apogee U10 CCD-camera is presented in Fig. 1.

In the second channel simple matrix without cooling can be used. As standard star brightness is always higher so less sensitive CCD-receivers can be applied which have small sizes and weight. Small sizes and weight are essential, as optical block with matrix must move inside (relatively) photometer. The second channel mechanism of matrix moving operation principle is the following: with micro screw which has worm gear and is rotated with (SE) moves optical block with diagonal mirror, filters and CCD-matrix in one direction up to 14 cm with the possibility of crossing telescope main optical axis (MOA). In crossing telescope MOA there is appeared the possibility of both matrix testing and to determine instrumental recovery. Accurate coordinates of optical corrections block position is determined with absolute magnetic encoder which is hardly connected with micro screw (connected with micro screw from opposite side of SM).

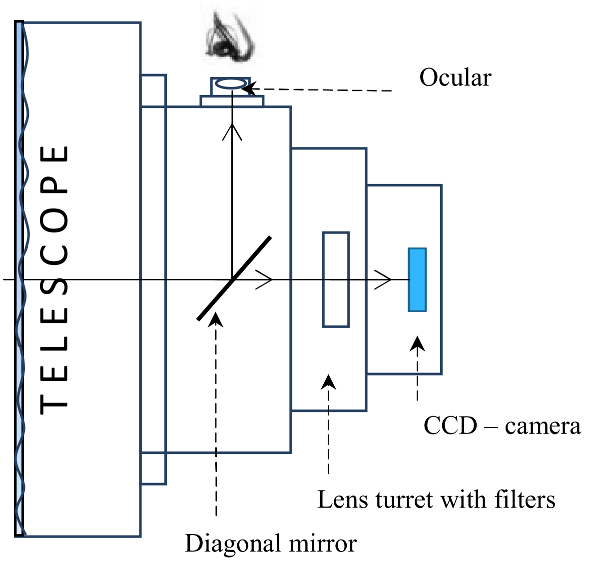

Figure 1: Optical scheme of photometer main channel

3. Electronic apparatus of two-matrix photometer control system (TMPCS)

In Fig. 3 TMPCS structural scheme is given.

Two-matrix photometer hardware structure includes the following components:

1. Micro controller platform of ARDUINO UNO (Petin 2015) type which is simply called microcontroller (MC) serves as the central control link. In fact, Arduino Uno model is the device on the basis of ATmega328 microcontroller. ATmega16U2 microcontroller provides the connection of receiver-transmitter with computer USB-port and in switching on to PC it enables Arduino to be defined as virtual COM-port. 16U2 micro scheme weaving uses standard USB-COM driver therefore external drivers installation isn't required. At Windows platform only appropriate .inf-file is needed.

2. Electromechanical node (EMN) consists of 25 cm long micro screw which moves optical block consisting of diagonal mirror, turrets with filters and CCD-2 matrix. Moving is carried out with step engine (SE) which rotating micro screw moves optical block from the second matrix with installation accuracy up to 0.05 мкм. SE control (Kenio 1987) is carried out with A3967 EasyDriver V4.4. Driver control is carried out from Arduino controller with special programs.

3. As all telescope electronic nodes are connected with distributed net and are in significant distance then all nodes are connected with RS-485 [*www.radiomedtech.ucoz.ru//RS-485.pdf*] converters. RS-485 is chosen by us as it can lead up to 32 receivers with communication speed by specification up to 10 Mbd/sec at distance up to 1200 m.

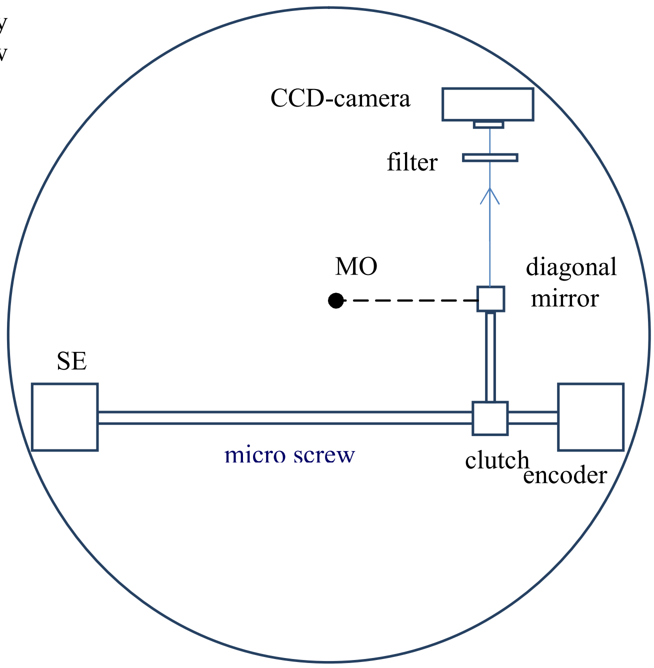

Figure 2: Optical-mechanical scheme of photometer second channel

4. Micro screw angle turn sensor (encoder) is used for carrying out the right system positioning and conducting the control at optical block moving from the second matrix in TMPCS. Baumer Electric CH-8501 absolute magnetic encoder which peculiarity is in saving angle turn data in voltage falling or disappearing, or in computer reboot is used as angle turn sensor. If in de-energized state the encoder shaft was turned onto definite angle or some number of turns so in voltage appearing encoder immediately gives shaft new actual angle position and factual number of turn. Thanks to this it isn't required after every switching on the system to produce moving of machine mechanical parts onto start-up position that is absolute encoders inarguable advantage.

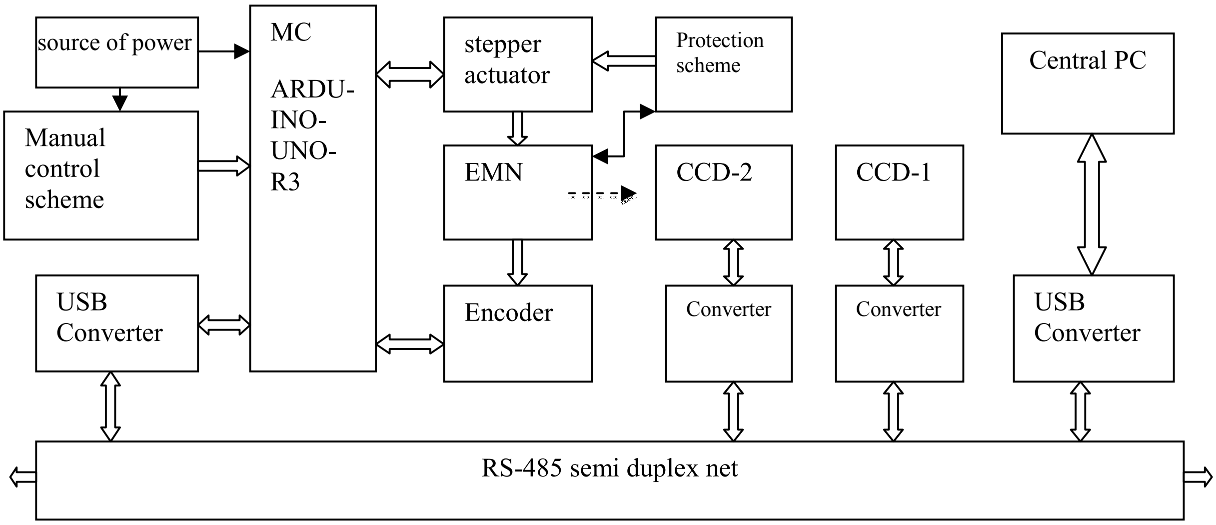

Figure 3: Structure of two-matrix photometer control system structure

5. Protection scheme includes mechanism of final switchers on both boundaries of optical block acceptable to move on micro screw which prevents mechanical breakdown and gives MC signal about reaching moving boundaries.

6. Manual control scheme enables to carry out button reset into initial position, gives commands on moving and movement direction option in testing mode.

4. Algorithm of diagonal mirror moving control from MC

Software development is based on using Arduino (Sommer, 2015) development medium and contains the following main elements: text editor for writing a code, area for messages output, text console, toolbar with traditional buttons and main menu. This soft enables computer to interact with Arduino as for data transmission so for weaving the code into the controller.

In figure 4 algorithm flowchart of diagonal mirror moving control from MC is shown. In this algorithm of encoder code and final switcher values are used for reverse, the second matrix optical block moving is carried out with discrete steps which are alternated with periods of long home stations during which photometrical information about stellar objects picking up takes place. Movement control depends on triggers value “**Movement**” and “**Direction**” (moreover, MC definite output port bits are implied as these triggers), and discrete micro steps a number of which is given by programming subtracting counter and is defined by necessary moving accuracy.

5. Conclusion

The developed two-matrix photometer is the astronomical measuring engine used in photometrical observations. Measuring engine distinctive feature lies in possibility to carry out simultaneous measurements of light flow from the studied star and standard star with increasing measurements accuracy and within less time.

Astronomy is the field of two-matrix photometer advantageous application: for researches of natural and artificial celestial objects.

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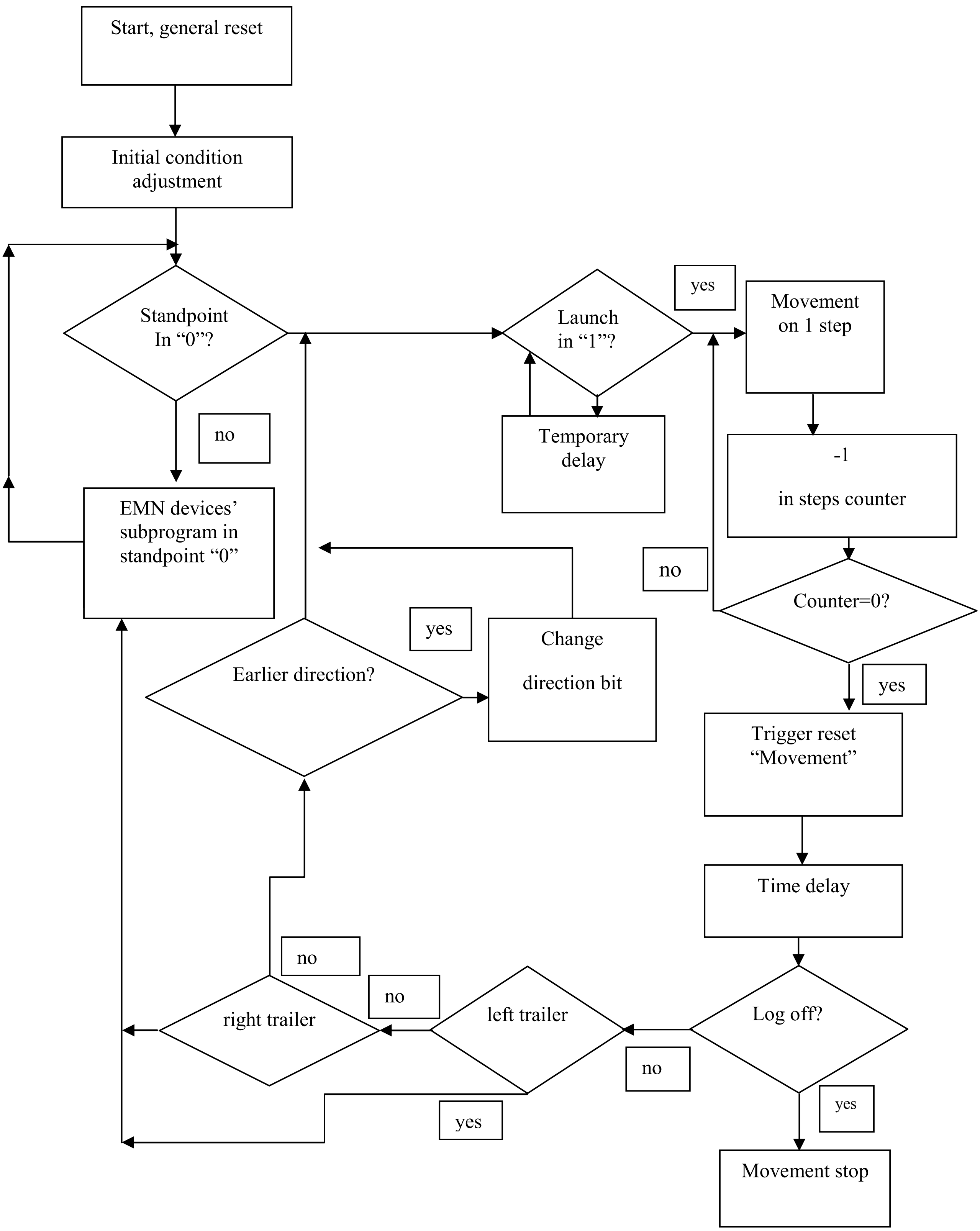

Figure 4: Algorithm of diagonal mirror moving control from MC