Design and development of computer controlled electro-mechanical mount for maneuvering an astronomical telescope

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Abstract **– It is essential requirement in area of astronomical research to develop a machine (known as alt-az mount) with which it will be helpful to track and view astronomical objects. This mount will be helpful in maneuvering a telescope and controlling it to point to the desired object in the sky. A computer software will send slew commands (for movement) to the mount which will in turn maneuver the telescope using electronic motors and mechanical assembly of the mount. The mount can be operated in 2 modes – Normal and Scanning. In Normal mode, the mount will simply move the telescope according to the arrow keys (up/down/left/right) selected on the software. In Scanning mode, the telescope will perform a line by line scan of the area of the sky selected in the software.**

Keywords – telescope, mount, alt-az, stepper motor, worm gears

I. INTRODUCTION

A. *Telescope*

A telescope is an instrument that gathers light and focuses that light into an image. In turn, this image can be magnified for viewing. A telescope is mounted in such a way that allows you to swing it freely from one object to another in the sky.

An astronomical telescope is used to observe celestial objects such as planets, stars, deep-sky-objects such as galaxies, nebulae, comets etc.

B. *Telescope Mounts*

Telescope mounts come in various types. The most two common types are equatorial mounts and alt-az (altitude-azimuth) mounts.

Equatorial mounts are more complex to design but are ideal for astronomical viewing as it allows movement aligned to the celestial objects i.e. about the polar axis.

Alt-az mounts are comparatively simpler to design and are primarily meant for terrestrial viewing. However these mounts are also used for astronomical viewing. The mount discussed in this paper is an alt-az mount.

C. *Need of an automated mount*

- An automatic mount facilitates fast navigation of the night sky when doing night sky observations.
- Compared to manual navigation of the telescope, an automatic mount requires less physical efforts as well, which can be very higher especially when using heavier telescope (larger than 8 inch scopes)
- In cold regions, staying out in the cold for an entire night doing observations can be a problem. In such cases, the observation can be done by sitting inside a room and controlling the scope using a computer.
- For long exposure photographic observations, a mount is used to avoid star trails which occur due to the rotation of the earth.
- Sky survey is done by many amateur astronomers around the world. In this, they scan an area of the sky looking for possibly new comets/meteors etc. This scanning can be done with minimum efforts when using a automated mount.

II. REQUIREMENT SPECIFICATIONS

- Load specifications: The mount must be able to maneuver a telescope which is maximum 1kg in weight and has maximum dimensions: length = 18 inches and diameter = 3 inches
- Performance specifications: The mount should have an angular resolution of 0.1°.
- Power specifications: The mount must be powered by 12v dc voltage either through a power supply or a battery.
- Dimensions: the mount (excluding the telescope) must fit in a box of 30cm x 30cm x 60cm.
- Communication specifications: It should communicate with an external device like PC/laptop over serial port. This communication will be used to carry the motion commands and information from PC to the mount and vice versa.

III. METHODOLOGY

The entire system will be as shown in the block diagram (Figure 1). The computer will be the master of the system and will issue commands to the electronic control board. This board will accordingly drive the stepper motors using the motor driver boards. The stepper motors will be connected to the gear boxes which will finally cause the motion of the 2 axes of the mount. The 2 axes will be vertical and horizontal,

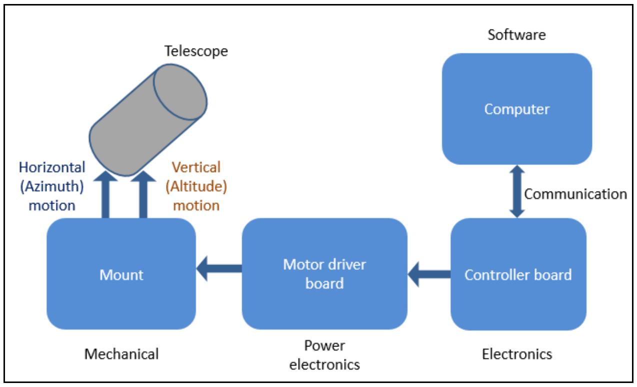

Figure 1- Block Diagram

known as altitude and azimuth axes respectively in astronomical terms. Hence the mount is also called an "alt-az" mount.

Each gear box contains 1 worm and worm-wheel gear set. The worm is driven by a stepper motor having step angle 0.9°. The worm-wheel is connected to the load. In case of azimuth motion, the load is the horizontal turn-table (red colour in Figure 3) along with the attached telescope. In case of altitude motion, the load is the telescope.

III. OPERATING MODES

The mount will be operated in 2 modes – Normal and Scanning. Overview of the same in shown in Figure 2.

A. Normal mode

In this mode, the telescope will be simply moved up/down/left/right using the arrows keys on the software. The resolution of the movement can also be controlled from the software. Lesser resolution will be used in moving the telescope from one point to another when the points are far away. This will help is faster movement. On the other hand, higher resolution will be used to perform very small changes in the telescope's position. This will result in slower but fine control when pin-pointing to objects in the field of view of the telescope.

B. Scanning mode

In this mode, the telescope will be used to scan a particular region of the sky. This kind of scanning activity, performed by amateur astronomers, is called "sky survey". Sky surveys result in observing and finding new celestial objects such as comets.

In this mode, the arrow keys will be used to position the scope to a desired start point in the sky. Then, the area to be scanned (e.g. 5° x 3°) will be entered along with the desired quadrant.

On pressing the "Zero" button, the mount will begin line-by-line scan of the selected quadrant and will cover the selected area of scan. The scan will be performed in a pattern where the scope will traverse the horizontal dimension first (i.e. 5°) and move up/down in a small vertical increment of 0.5° (fixed). It will again cover the horizontal distance followed by another vertical increment and keep on doing this till the vertical dimension (3°) is fully covered.

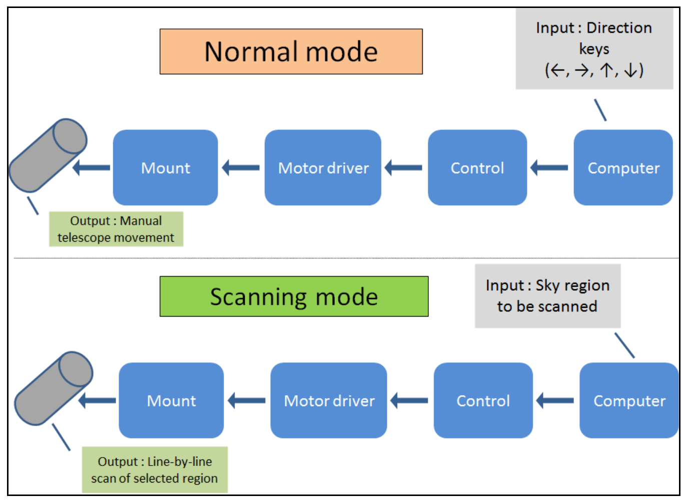

Figure 2 - Operating modes

The speed of scanning can also be selected from the software before beginning the scan.

IV. DESIGN

The design of the mount system is split into 3 parts each of which is given below.

A. Mechanical design

The mount is divided 2 sections according to the drive direction – Horizontal drive (blue) and vertical drive (red). The horizontal drive is enclosed in the base of the mount. It drives the turn-table on which the vertical dive assembly rests.

The vertical drive assembly consists of 2 pillars. One pillar houses the vertical drive whereas the other acts as a support to the telescope. Both these pillars have coinciding shafts which protrude out to connect to the telescope.

The 3D model of the mount is developed using CATIA V5 software.

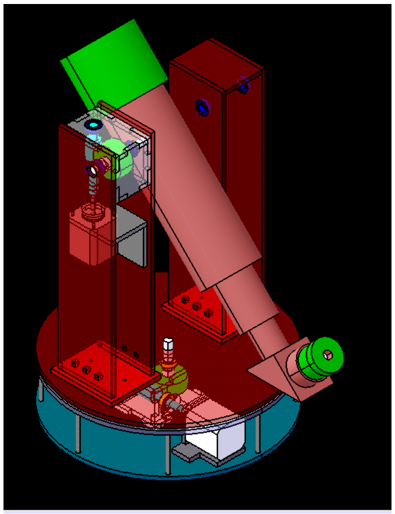

Figure 3 - Designed model of the alt-az mount with the telescope

Both the drives have similar construction. Each drive consists of – stepper motor, coupling, worm-wheel gears and bearings. The stepper motor shaft is connected to the worm shaft through an encoder coupling. The worm gear is made from EN-8 mild steel and the worm-wheel is made from Phosphor-Bronze material. The gears are assembled in a housing made of 6mm thick acrylic sheets. 10mm inner diameter ball bearings are used to support the gear shafts.

B. *Electronic design*

The electronics module consists of a control board and 2 motor driver boards.

The control board takes commands from the PC over the serial port and in turn gives drive signals to the driver boards. It also sends back to the PC status of the controller and other information. The control board uses an ATMega32 micro-controller.

Two driver boards are used, one for each drive. The driver board uses a L297 IC as the stepper motor controller. It receives the driving clock pulses and other control signals from the control board. Depending on this, it issues the winding sequences according to the selected step mode and direction. The winding sequence is given to the driver IC L298N which has a H-bridge driver within. The motor's four windings are connected to the four outputs of the L298N in a bipolar motor configuration.

A stepper motor with 0.9° step angle is used as a prime mover. It is used in full step mode to maximize the torque output. The motor is of a standard NEMA 17 size.

The control board also has a failsafe feature wherein it stops the mount operation in case of a communication failure, i.e. if there is no communication received from the PC for a timeout period of 2 seconds.

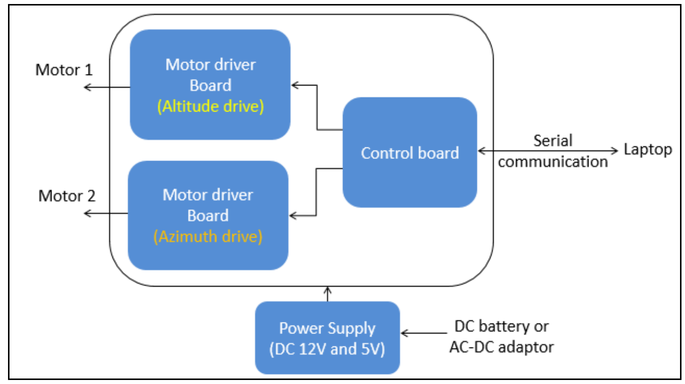

Figure 4 - Electronic design - block diagram

The schematic and board layout is designed using ExpressSCH and ExpressPCB software respectively.

The entire electronics is powered from a 12V DC power supply adapter.

C. *Software design*

The screenshot of the developed software is shown in Figure 5. This software application is used to control the telescope in both the operating modes.

To start, the COM port of the PC is selected from the drop down menu. The "Connect" button is used to connect to the selected COM port and then "Start" button is pressed. Default selected mode is "Normal". The arrow keys in the "Normal" frame can be used to the move the telescope in the respective directions.

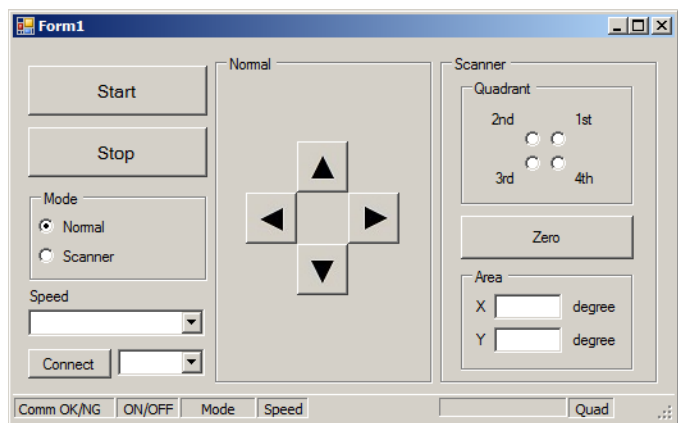

Figure 5 - Mount control software interface

By selecting "Scanner" button, the mount enters the scanning mode. Here it needs to be brought to an initial position using the four arrow keys. Once the initial position is set, the Quadrant and Area is set and scanning can be started by pressing the "Zero" button. Once scanning has started, the arrow keys cannot be used till the scanning is complete. If it is needed to stop scanning at anytime, the "Stop" button can be used to do the same.

The status strip at the bottom of the window gives various statuses received from the mount's electronic control board.

The software application has been developed in Microsoft Visual Studio using C# language.

V. CONCLUSION

An alt-az telescopic mount was successfully designed and developed from scratch. The developed mount was able to achieve the targeted system requirements such as 1Kg load and 0.1° angular resolution. It is working correctly as per the designed operating modes and their controls. The failsafe feature is also working as expected and stops the mount in case of communication failure.

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