The Alan Cousins Telescope - A Robotic Multi-Purpose Telescope for Sutherland

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Abstract. Much work has been done on the Alan Cousins Telescope over the last few years in terms of testing and commissioning the telescope system and to prepare it for regular operation. Many problems were encountered and overcome in the process. The result is a system that is essentially ready for use by remote observers and that will soon be ready for regular, automatic operation.

1. Introduction

The Alan Cousins Telescope is a $0.75 - \text{m}$ multi-purpose, robotic and remote access telescope at the Sutherland site of the South African Astronomical Observatory. It has a modular photoelectric photometer, currently with a Johnson-Cousins UBVRI filter set. Unlike the other telescopes in Sutherland of a similar size, the ACT was designed and built to be controlled by a computer, thus eliminating the need for an observer to be present.

Efforts to bring the telescope system to a point where it can be used regularly either under automatic control of the computer or under manual control of a remote observer started in 2010 with the development of the first version of the ACT control software suite. In 2011 the control software suite was installed on the control computer in the dome along with a new Programmable Logic Converter (PLC) to remove many of the lower-level operational burdens from the computer - in particular communicating with and managing the various devices that form part of the telescope system (e.g. filter and aperture wheels, telescope focus, dome rotation, dome shutter).

During the testing and commissioning process, many hardware and software related issues were encountered - all of which (except for the most recent issues) have been solved, resulting in a system that is essentially ready for operation with a remote user, albeit with limited efficiency. Although a detailed discussion of all of these problems and their solutions fall beyond the scope of this document, a brief overview of the more recent hurdles and their solutions are given here.

2. Flopping Acqusition Mirror

As with most telescope systems, the ACT has a folding mirror (acquisition mirror) with a circular cut out in one half of the mirror in order to be able to direct the light within the telescope's field of view (or part thereof) to either the science instrument or to a camera used to acquire the target (depending on the position of the mirror).

Some large offsets were occasionally enountered while moving the telescope to a star and centering it on the field of view. After some investigation it was noted that moving the acquisition mirror in and out of the beam caused the star field to shift by tens of arcseconds - much too large to be able to use the telescope efficiently and collect meaningful photometry.

This "flopping" effect was caused by the motorised screw mechanism used to move the acquisition mirror back and forth and the two rails on which the mirror moved not being sufficiently rigid. This issue was solved by tightening the screws holding the rails to the casing, introducing a third rail to reduce the torsion on the existing two rails and connecting the rails together at the free end.

3. Spurious Photons on PMT

While performing the first commissioning tests of the science instrument on the ACT (a photomultiplier tube), some sharp spikes were occcasionally recorded in the photon counts detected by the system. The peaks were so strong, in fact, that the photon count rate reported by the PMT were very nearly at or greater than the maximum allowed by the control software, which causes the control software to close the science instrument shutter and move the acquisition mirror into the beam in an effort to protect the PMT from overillumination and eventual temporary or permanent damage.

At the time, the spikes in the count rate reported by the PMT was thought to be noise originating from the cables connecting the various devices that form part of the telescope, instrument and dome to the PLC that controls them. PMTs are typically quite susceptible to electronic noise from devices in the area. The spikes seemed to occur most frequently while moving the acquisition mirror. It was noted that unplugging the cable for the acquisition mirror from the PLC made the spikes disappear, however the system would not be usable if the acquisition mirror could not be articulated.

Many attempts were made by the SAAO electronic technicians to remove (or at least reduce) the noise, to the point where the cable was replaced completely. These attempts were unsuccessful, but further investigation revealed that the spikes were in fact not electronic noise, but real light eminating from the acquisition mirror. Opto-isolator switches are used on the rails of the acquisition camera to sense when the acquisition mirror is at the limit of the rails.

The opto-isolator switches on the acquisition mirror rails were replaced with Hall-effect sensors, which eliminated the noise problem.

4. Simplified Scheduler Programme

The scheduler programme is a component of the ACT control software suite which determines what observations in the queue to observe whenever a block of observations are completed. For the first version of the scheduler programme, it was decided to allow the user to schedule observing blocks on-the-fly. This caused many problems, as it meant that the scheduler programme needed to effectively multiplex between observing blocks in the queue and those scheduled by the user. It also required that the other components of the software suite be informed of whether or not an intelligent observer is present when the system is effectively performing an observation automatically - this is because different safety and sanity checks are performed by all software in the suite depending on whether or not an intelligent observer is present, which is determined based on whether a command is received from the scheduler programme or whether commands are given directly to the software components by the user.

This issue was resolved by significantly stripping down the scheduler programme, to the point where it was simply a programme that reads the details of observing blocks from a database and issues the necessary commands to complete the observations. In other words, the user can no longer issue any commands to the scheduler programme, except to cancel the block of observations currently being completed or to modify the observing queue in the database, which is done with an external programme that is not connected to the control software suite.

5. Pointing and Tracking Errors

Pointing errors are caused by misalignments and manufacturing flaws in the mount. For telescopes with an equatorial mount (such as the ACT) it is quite common for the polar axis to be offset from the Earth's rotation axis. Another fairly common source of pointing errors is a non-perpendicularity between the right ascension and declination axes. Such errors make it difficult to find targets and so most telescope systems have a numerical model in the software that corrects for them. Depending on the regularity and size of the errors, between a handful and several dozen terms may be required in a pointing model that corrects for these pointing errors and anything between tens to thousands of data points may be required in order to construct a reliable model.

In the ACT's case, the errors are quite large (up to ca. $10'$), but fairly regular and stable - see figure 1. This means that a fairly simple pointing model should be able to correct for the pointing errors. However, given the size of the errors, misidentification of stars is not uncommon, which greatly impedes progress in this regard.

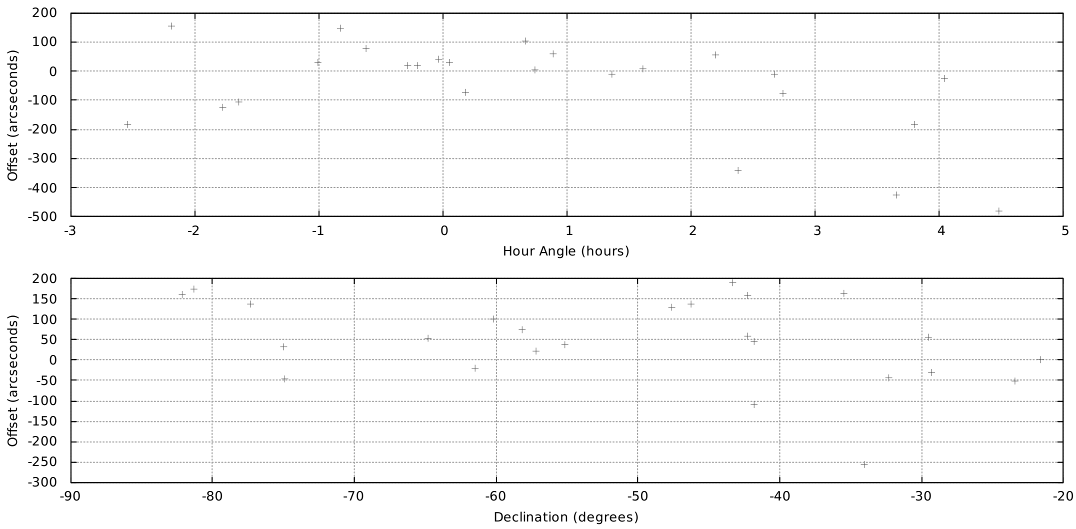

Figure 1. Hour angle and declination pointing errors. Note the parabolic profile in the hour angle offsets, which is indicative of a misalignment in the polar axis. The declination errors are more complex, but a major contributing factor is the non-circularity of the declination axis running surface.

In addition to the pointing model, the ACT control software has an advanced pattern matching system that can match the star pattern in the camera's field of view with that of a recorded template field. Offline tests of the pattern matching algorithm has shown that it can effectively correct for initial pointing offsets of up to $4-5'$. It should not be difficult to establish a pointing model that can reduce the pointing errors to this level, however a moderate number of reliable pointing offset measurements (on the order of 50) is required to in order to establish a sufficiently accureate pointing model.

Due to the large pointing errors, the telescope is also not able to track a star and keep it in the aperture of the science instrument for more than a few minutes at a time. This problem will also be solved by establishing an effective pointing model. Additionally, there are some small-scale tracking errors (minor shifts in hour angle while the telescope is tracking a star) which cannot be effectively removed with a good pointing model. However, these errors are small enough (a handful of arcseconds at most) to still allow the telescope system to collect photometry. The small-scale tracking errors are also highly regular, with frequencies that can be easily identified from a few hours of tracking offset data.

6. Conclusion

In summary, the ACT has enjoyed much attention since 2010, with several thousands of hours being spent testing the system, troubleshooting any identified problems and finding appropriate solutions. Although many problems have been encountered, the system is now reaching a level of stability and reliability that will enable it to operate automatically and without human supervision in the near future.

The large pointing errors is the only issue at the moment that is preventing the telescope from being operated automatically on a regular basis. However, it is at the moment possible for a human observer to use the telescope system (albeit remotely) and collect photometry with it. The observer will need to scout for the target star and the telescope will need to be re-centred on the star every few minutes, but it is strictly speaking possible.

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