Automated Speckle Interferometry of Double Stars

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Automation of astronomical observations provides a number of benefits, as pointed out by Boyd and Genet (1986). These include lower operating costs because observers are not required, and lower maintenance costs because the system is rarely disturbed by humans. Although human observers are required to handle unique, one-time observations, automated systems are usually more efficient than manual systems in repetitive, well-understood situations. As humans are rarely needed, telescopes can be sited almost anywhere without much concern for site access or human comfort.

Automation was first implemented on small telescopes making photometric observations of variable stars. In these pre-CCD-camera days, a "one-pixel" photomultiplier tube was used in an aperture photometry mode—with a real, physical aperture to block the light from all but the star under observation. The early days of automated astronomy have been described by Genet (2011, 2012). Full, continuous automation began at the Fairborn Observatory in 1983 (Genet & Boyd, 1984). The early automated telescopes are described in book-length detail in *Microcomputer Control of Telescopes* (Trueblood and Genet, 1985).

Borucki and Genet (1992) proposed using automatic photoelectric telescopes to detect transiting exoplanets. The first transit was detected by Henry (1999) with an automatic photoelectric telescope at the Fairborn Observatory, with a simultaneous detection by Charbonneau et al. (1999). Borucki went on to propose and successfully lead the Kepler space telescope which discovered well over a thousand exoplanets.

Speckle interferometry observation of close double stars is a repetitious, labor intensive, fast paced procedure. As most observatories are not equipped for high-speed speckle interferometry, we developed our own portable speckle camera (Genet 2013). This camera has been used with student operators at a number of observatories, including two week-long runs on the 2.1-meter telescope at Kitt Peak National Observatory.

Gathering and processing a terabyte of data during a speckle interferometry run in an orderly, reasonably error-free manner by human operators was difficult, as explained by Teiche (2014). Our thoughts turned to semi-automation for data processing, and soon thereafter to full automation.

First automated speckle interferometry was achieved on the 0.25-meter telescope at the Orion Observatory on the night of September 12, 2014. Custom software modules written by Teiche consisted of a Run Manager, Scheduler, Database, Andor EMCCD Camera Control, and Monitor/Logger. The custom software also included interfaces to a Sidereal Technology Controller, PlateSolve 3, MaxIm DL 6, and a stepper-based slider control system. Written, but not used on this first night of automatic operation, was software that controls a filter wheel and telescope focus.

The speckle camera, described by Genet (2014), consisted of a Van Slyke instrument slider that switched the optical path between a Canon T3i acquisition camera and an Andor Luca-R EMCCD science camera. For this test run, no Barlow magnification was employed, and the filter was set to clear. The acquisition and science cameras were mechanically configured to be parfocal.

For this initial run, a number of doubles were selected from Haas (2006). Separations were 1.0 arc seconds or greater, secondary magnitudes were brighter than 9.0, and differential magnitudes were less than 3.0. This list of double stars was loaded into the database ahead of time. The scheduler automatically selected targets from this list as it observed, taking into account the distance from the meridian, proximity to the moon, slew time to the next target from the current position, and the location of the local horizon. Single deconvolution stars near the target doubles were automatically selected from a list of 118,219 Hipparcos stars.

The exposure of the Andor camera was automatically set for each target by the custom control software. The exposure algorithm adjusted the integration time and EMCCD gain until the average well fill of the brightest N pixels was within a specified range. To avoid atmospheric smearing, EMCCD gain adjustments up to a gain setting of 300 were preferred over increasing integration times. The integration time was initialized at 10ms, and increased in increments of 10ms if the full EMCCD gain for a given integration time setting was insufficient. At each integration time, all gain settings between 0 and 300 in increments of 50 were attempted. On this first run, N was set to 26214 (10% of the pixels), and the average well fill goal was set to 50%. This algorithm was found to be unreliable at low magnifications. An adaptive algorithm is being developed to address this problem.

Figure 1. System performance can be monitored from the warm room at the Orion Observatory. Alex Teiche made corrections to the software from the warm room until the system finally ran entirely on its own.

The system starts by requesting a target from the scheduler, which returns either a double star or single reference star as appropriate. The sequences of events for the two cases are identical. The system concurrently slews the telescope and moves the slider to the acquisition camera. It then uses the acquisition camera to iteratively plate solve, using PlateSolve 3 developed by Rowe, and adjusts the pointing until the target is centered to within a specified value. The autoexposure routine is run, and a FITS data cube of 512x512 pixels and 1000 frames is collected if the target is detected in the science camera. The system logs this observation to the database, and requests a new target.

The software was written in Python 2.7, with the exception of the Andor EMCCD Camera Controller which was written in Microsoft Visual C++. SQLAlchemy was used to map MySQL database entries to Python objects for the target list, run log, and catalogs. PyEphem was used to calculate the moon and meridian distance. The software ran on an x64 Windows 7 machine.

The observational files and the "run log" that points to them were designed to work smoothly in conjunction with a semi-automated reduction program (Rowe & Genet 2014). Without this link, the reduction task would be overwhelming.

We are currently developing some additional GUI interfaces, working on user documentation, and refining some of the procedures. We are confident that automation of double star speckle interferometry will begin soon at other observatories, and that sizeable, productive research projects will be undertaken that would not have been attempted with manually operated systems.

Acknowledgments

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