CS486C – Senior Capstone Design in Computer Science

Project Description

Project Title: NPOI Camera Centering Software	
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Project Overview:

The central goal of all astronomical observation is to better understand our universe and how it works. Earth and our solar system are just one possible astrophysical arrangement, so what we can learn by looking around our own neighborhood is limited. By observing the billions of other systems out there, we can develop a better understanding of what other arrangements are possible, how they might have formed, and what the implications are for potential future off-earth explorations.

Just as when you view the world with just one eye, there are limitations to viewing celestial phenomena from a single point, i.e., a traditional telescope. Observation of many 2D features benefit from combining multiple views of the target from points that are spread out spatially, a technique called interferometry. For example, the centroid of binary systems changes as one star orbits its partner, and it is the centroid of the binary system that a single telescope measures to generate a catalog of stellar positions; other applications include star-spots (which have yet to be seen!), accretion discs (as the stars spin and toss out matter of different temperature and mass), star rotations (what is the spin rate and orientation of polar axis?) and other interesting science that single telescopes simply cannot measure; we may eventually be able to use nulling interferometry for exoplanet detection.

The Navy Precision Optical Interferometer (NPOI), an astronomical long-baseline optical interferometer, has been in operation on Anderson Mesa, just outside Flagstaff, Arizona, since 1994. An aerial view of the site, shown in Fig. 1, illustrates the general shape and layout of the 2.2 m to 437 m baseline array. The NPOI has a unique capacity for detecting and determining motions and orbits of binary systems. Many regional partners collaborate with NPOI to take advantage of its unique capabilities, including Lowell Observatory, Northern Arizona University, New Mexico Tech, Seabrook Engineering, and Tennessee State University.

The NPOI collects and combines light from up to six apertures simultaneously to form a high spatial resolution synthetic aperture. The wavelength range of operation is currently in the visible spectrum, 400 nm to 800 nm, and will soon include infrared wavelengths. Reconfigurability of the array generates baselines from 2.2 m to 437 m, and the light collected at each station is transported as a 12.7 cm beam through evacuated pipes to a beam combiner. Reconfiguration of the array is analogous to a zoom lens on a DSLR camera. Software automates micro-adjustments to mirrors along the optical path length to ensure extremely accurate tracking of stellar objects.

Fig. 1 NPOI site, Flagstaff, AZ (Photo courtesy of Michael Collier)

Periodically, for optimal performance, the optical mirrors across the array have to be realigned. The optical feed system is mainly in vacuum, therefore small motors are used to tip or tilt the mirrors into alignment. An alignment telescope is used to bring small LED targets into focus, while an engineer tips and tilts the mirrors to move the LED targets into the center of the alignment telescope. To date, different people have taken part in the alignment process, which creates differences in the alignments. NPOI is in the process of expanding their capabilities, and a more robust alignment system will allow them to be more accurate and achieve more reliable data.

The Problem:
As the alignments extend further out to the outer arms of the array, the LED targets showing through the alignment telescope get smaller. The internal crosshairs of the alignment telescope covers the LED target, making it so the LED target may not be truly in the center of the telescope. Currently, the alignment is done manually by looking through the eyepiece of the alignment telescope. Due to parallax, different people can align the mirrors differently due to differences in their vision. NPOI has a target to align the system consistently and effectively to within .25mm from the center of each 3mm LED target.

The Envisioned Solution:
The goal for this project is to find the geometric center of the LED target in an image when the telescope is intentionally out of focus, so the spot can be seen around the crosshairs of the alignment telescope. This would be done through a client determined camera.

Level 0 - Minimal viable product:
- Record an image from a CCD camera attached to the alignment telescope and find the geometric center of the LED target.
- A GUI to show engineers the relation between where the system is pointing versus the geometric center of the LED both quantitatively and through an image.
- Display in real time the center of the LED as it is being aligned.

Level 1 - Some nice additional features:
- Ability to take timelapse photos for later analysis and usage, like showing long-term drift.

Level 2 - Stretch Goals:
- Give an algorithm to programmatically align the feed system.

Significance:
NPOI has the longest baselines of any optical interferometer in the world, which means during operation its instruments can also achieve the highest angular resolution among its peers. This unique capability means data collected by the instrument has immense research potential, assisting in the path of discovery for decades to come. NPOI's status as a collaborative partnership between the Naval Research Laboratory, the US Naval Observatory and Lowell Observatory, means that a successful product will provide each of these agencies a new capability to assess the quality of data being collected and monitor the performance of observational systems. Additionally, engineering and observation crews will more easily be able to identify and track down issues across the array, lowering down time and increasing observational potential. Even though this project is a small piece of a much larger system, the alignment of the system is critical for its proper function.

Knowledge, skills, and expertise required for this project:
- Experience in C/C++ and Python
- Familiarity with GNU/Linux
- Knowledge of working with embedded systems
- Strong mathematics background

Equipment Requirements:
- No special external equipment or software should be required, other than a basic computer and freely available software/tools.
- Any additional equipment will be provided.

Software and other Deliverables:
- A report detailing the design and implementation of the product in a complete, clear and professional manner. This document should exactly detail the development process such that any new developers wanting to work on the solution can easily and quickly understand the system.

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- A software package that finds the geometric center of a LED in an image and displays the information to an engineer in a graphical format.
- Professionally documented source code, delivered to both NPOI’s internal wiki and central computer.