Developing Software for the TURBO Telescope Prototype

Meredith Wieber

University of Minnesota, Twin Cities - College of Science and Engineering

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Abstract

This project set out to develop a Python software which would remotely control the TURBO (Total-Coverage Ultra-Fast Response to Binary-Mergers Observatory) telescope prototype. TURBO's mission is to have the unique ability to image the Laser Interferometer Gravitational-Wave Observatory (LIGO) localization region within just several seconds. This time-frame is predicted to fall within the *in-spiral* of two black holes, which lasts in the tens of seconds. Creating the software included the operation and sensitive control of six Talon SRX motors. One method explored for accomplishing this was to use the roboRio instrument, developed by National Instruments for use by First Robotics teams. The roboRio was chosen as it included documentation for operating motors written in the Python language. Over the course of the semester, a preliminary software was written which has the capability to control at least one motor and its corresponding limit switches. In the future, the software will need to be optimized for the specific conditions of TURBO's environment. This may include eliminating the roboRio instrument by simply using the Talon SRX controller.

Introduction

When LIGO detects a GW event, it is only able to localize the region of the source approximately. This localized region, according to a joint projection by LIGO (Abbott et al., 2016), Virgo (Collaboration, 2009), and KAGRA (Somiya et al., 2012) collaborations can be approximately 110-180 square degrees with current technology (see Figure 1). Previously, in the 2017 GW merger of neutron stars, a team of observers and telescopes around the world spent *eleven hours* to locate the electromagnetic counterpart of GW170817. This search was conducted using many small telescopes which imaged galaxies in the localized region one-by-time. Out of LIGO's ten observed cases of the merger of a binary black hole system, only one event has a secure EM counterpart (Connaughton et al., 2016). This is where TURBO will be able to introduce new technology and image the region in a much shorter time-period.

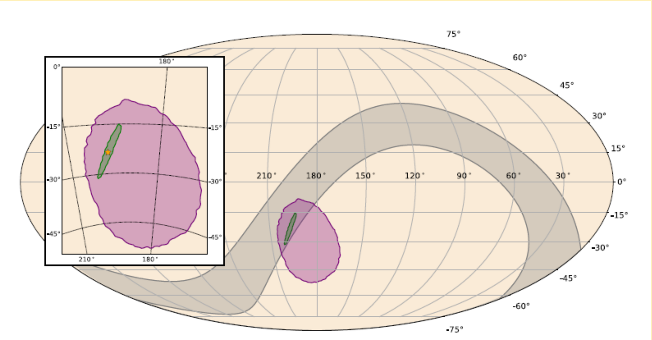


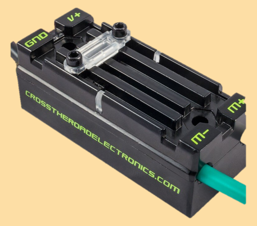
Fig 1: *An example of a LIGO localization region from the source which produced GW170817 and GW170817A. [1]*

Through the use of a new method and telescope for the search, it may be possible to identify any EM counterpart while the merger of two black holes is *still occurring.* TURBO, will have the unique ability to image the LIGO localization region within just several seconds. In recent years, the observations of gravitational wave (GW) sources have allowed a new understanding of our universe. Locating the electromagnetic (EM) counterparts of observed events, such as black hole mergers and neutron star mergers, enables measurements of the redshift of the merger, leading to other significant measurements.

Methodology

Interfacing with the roboRio

- Usage of the RobotPy online documentation
- Determining how to use the Talon SRX motor controller from CTR Electronics
- ✓ Gained control of the motor through the use of RobotPy
- ✓ Tested speed capabilities and encoder abilities with the help of an Xbox controller



Talon SRX Motor Controller (CTRE)

roboRio from National Instruments

VexPro775 from Vex Robotics

Limit Switches

- Determining where to control the limit switches from
- Ensure the motor stopped upon triggering the switch
- ✓ Found it possible to control the switches through the motor's encoder
- ✓ This method is much more efficient than the alternative

The VersaPlanetary encoder which is attached to the motor. The gold strips are the connections for a forward- and reverse-limit switch.

Translating Coordinates

- Gathered the LIGO coordinates from the PyGCN reporting system and filled them into the motor code
- PyGCN reports coordinates in right ascension/declination, while the motors will move the telescope with an altitude/azimuth system (see Figure 2).
- ✓ an existing library in Python, called astropy is meant for converting astronomical coordinates
- ✓ I constructed a coordinate conversion function.
- ✓ the alt/az coordinates needed to be converted to "ticks" in order to be understood by the motor encoders
- ✓ There are 4096 ticks in one revolution. In order to convert alt/az position to motor ticks, I divided 4096 by 360 degrees. This became the conversion factor and could be used to transform the alt/az coordinates into motor ticks

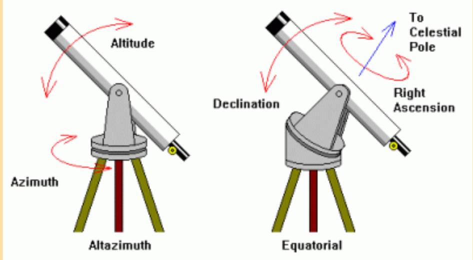


Fig 2: *A visualization of the difference in coordinate systems.*

Results

I am confident in the ability of the code to control the various motors on the initially-proposed mounting system. The organization and finer details of the code need to be re-visited when the new mounting system is designed. Once this is done, the first steps might be to find a way to optimize the method for arranging the astrographs such that they will cover the entire LIGO localization region. The regions are not constant in size or shape so this will be an interesting problem to solve.

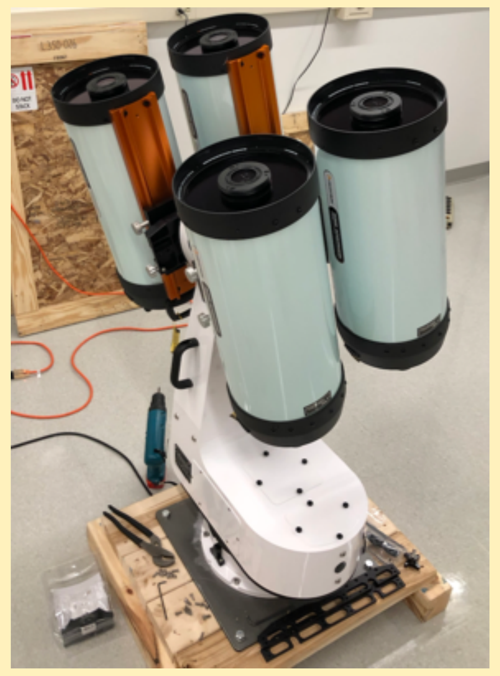


Fig 3: *The current TURBO prototype which has been installed in the test site on the UMN St. Paul campus.*

Conclusion

The TURBO telescope Python software is in its first stages of development. The project is ready to be re-imagined with the new mounting system. During my UROP project I found how to control the motors using the roboRio instrument, how to incorporate limit switches into the encoder of the motors, and the problem of converting coordinates throughout the process of receiving LIGO event locations into ticks of the motor revolution.

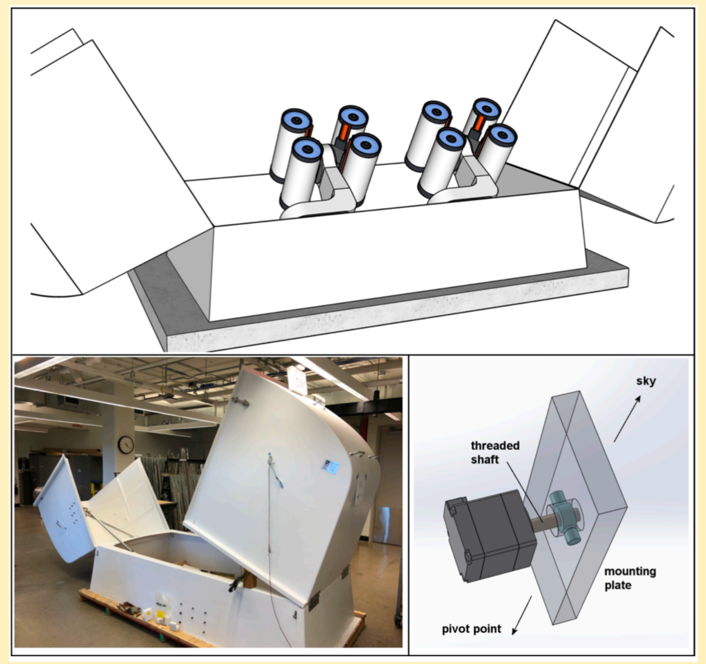


Fig 4: *The proposed end-product for TURBO. The fiberglass "clam shell" enclosure is currently installed on the UMN St. Paul campus in the research fields. There would also be twice the current prototype, as shown above, in the final version.*

Acknowledgements

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I'd also like to acknowledge the other undergrad members of this team, especially Matthew Tran and Adam Imdieke.

[1] LIGO Scientific Collaboration, https://www.ligo.org/science/Publication-GW170817GRB/index.php