LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
-LIGO-
CALIFORNIA INSTITUTE OF TECHNOLOGY
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SURF Progress Report - July

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In essence, LIGO attempts to convert a gravitational wave (GW) into a detectable, meaningful signal. More specifically, an incoming GW would distort the lengths of two long interferometer arms in such a way that laser light traveling down the two paths would interfere and be detected as an electrical signal. Due to the sheer complexity of the project and the high cost of operation, computer simulation is a powerful tool for analyzing the instrument. My tasks consist of 1) simulating the exact process by which a GW from a particular source affects the interferometer and 2) integrating the code into LIGO's existing simulation software [3, 4].

Much of the relevant physics and mathematics is outlined in the appendix of [1]. However, the derivations are highly concise and without detailed explanation. A large portion of my work up to this point has been striving to acquire a deeper understanding of these underlying concepts. This knowledge will allow me to implement the actual physics in the time domain simulation program. Once that is complete, our research team will have a full working prototype simulation of LIGO.

In order to become sufficiently comfortable with the physics, I have begun rewriting the appendix of [1] in my own words, with intent to fill in the gaps and make the material more accessible to other researchers who require this knowledge. In working through the equations, I have made extensive use of the software package Mathematica. (In fact, virtually all of the non-literature resources I use are electronic.)

Soon I will become familiar with the simulation software; at that point I will be prepared to begin designing and coding the desired modules. In one module, the user will be able to describe a GW source in terms of its amplitude, polarization, and orientation relative to an earth coordinate system. This information will be fed into another module: here, several operations are performed, including transforming the GW to the earth coordinate system and calculating the distortion of the interferometer arms (which is measured by the differences in phase the laser acquires in each of the two arms). Once these data are known, it can be fed directly into the existing LIGO simulation. Then, we will be able to investigate how LIGO responds to a particular GW signal. One reason that this simulation is so important is that data analysis is much easier if one has some knowledge about the signal one hopes to extract from the noise.

The primary challenges up to this point have been in understanding the math and physics of LIGO. While I have not yet had to learn any entirely new subjects, I have pushed some of my prior knowledge and skills farther (especially relativity and using a computer to assist with analytical calculations). Once the next phase of my project starts, I expect to find the greatest challenges in debugging code and ultimately validating the work (i.e. showing the simulation produces results consistent with what we expect).

[1] D. Sigg, “Gravitational Waves” Proceedings of the Theoretical Advanced Study Institute in Elementary Particle Physics, 10/23/1998.

[2] A. Abramovici et.al., “Large Scale Measurements” Science 256, 325-333 (1992).

[3] H. Yamamoto et.al., “End to End Simulation program for gravitational-wave detectors” In Seiji Kawamura and Norikatsu Mio, editors, Gravitational Wave Detection II, Frontiers Science Series No.32, pages 331-336, (2000).

[4] B.Bhawal et al., “The LIGO End-to-End Simulation Program"”to be published in proceedings of the Moriond Conference on “Gravitational Waves and Experimental Gravity” (March, 2003).