New Mexico Institute
of Mining and Technology

Department of Electrical Engineering

Final Report

Small Scale Motion Table

Authors:
Kevin K. Ryan, Derrick K. Duran, Juan E. Lopez

Academic Adviser:
Dr. Kevin Wedeward

Sponsor:
Raytheon-Ktech

April 30, 2013

Executive Summary

The goal of this project was to design, build and test a motion simulation platform. This platform's purpose will be to serve as a method of emulation for the type of motion experienced by ships due to ocean waves. By simulating this motion, it is possible to calibrate and test maritime antennas that would otherwise need to be tested at sea. Having a controllable platform also allows for the user to produce a large variety of waves, in terms of periodicity and amplitude, that would not be possible to replicate in a real life scenario. The initial design for this project was based off a motion table used for a flight simulator. The Motion Platform Designer[1] software was used to formulate the basic design of the table. By adjusting different parameters such as platform height, motor arm lengths, motor spacing and degrees of freedom the program is able to create tables capable of vastly different motion. After determining table parameters that met our specifications, we then used the software to generate force and torque simulations. These simulations gave us a rough estimate of what sized motors would be required to move the table at the necessary speeds. Once we decided on a motor we attempted to find other compatible hardware from the same vendor as the motors. However, the components we were able to get were highly mismatched in terms of operating voltages. The table hardware including the rod ends and center joint were also ordered from the same vendor. The final table design was modeled in SolidWorks to verify that the table was able to reach the maximum rotation requirements. Once the table was fabricated, we drilled and tapped all the mounting holes. When the table was fully constructed we found that our center joint allowed for yaw motion that we did not want. To remedy this we had a new center joint fabricated that removed this unwanted motion. The accelerometer that was meant to be used for the feedback system was the wrong interface. This resulted in us only being able to test the platform maximum rotation and not the rotational velocity. The table meets the requirements of maximum rotation, but it is unable to rotate at the required angular velocity. This is largely due to the fact that the power supplies and motor drivers are not properly matched with the selected motors.

1 Introduction

This project has been completed with support from Raytheon-Ktech. The necessity for this project stems from Raytheon's need for a small scale motion table that can be used to calibrate and test their smaller antennas. The antennas that would be tested on this table are generally maritime antennas that are used aboard ships. Due to the unsteady nature of the ocean, these antennas are constantly moving with respect to the response of the ocean waves. This causes the antenna's radiation pattern to vary with the ship's motion which can lead to inconsistencies in measurements. This table would allow for testing of these antennas without the need to deploy them on ships first. Ocean waves generally are capable of a full six degrees of freedom. A full six degrees of freedom means that it is capable of full translational (heave, sway, and surge) and rotational (roll, yaw, and pitch) motion. For simplicity purposes our project was defined to have just two degrees of freedom, in this case, pitch and roll were deemed the most necessary by our customer. For the simulation of the waves, the goal was to implement what is known as "Sea States." This Department of Defense specification, MIL-STD 1399, describes in detail the characteristics of an ocean wave. Our customers already have software that is capable of producing this simulation. Our goal was to take their simulation and process it on our microcontroller in order to translate it to the necessary motor rotations. Table 1 below shows the full list of specifications for the project. This project consisted of two main aspects, hardware and software design. The hardware portion of the platform is what was focused the most on during the course of this project. The final design was modeled in SolidWorks and fabricated in-house by Raytheon-Ktech. The software portion of the project consisted of implementing a closed-loop feedback control system in order to complete the goal of Sea State implementation.

Size	
Platform Surface	24" x 24"
Motion	
Degrees of Freedom	2
Maximum Rotation	$\pm 30°$
Angular Velocity	$30°$/s
Maximum Sea State	5
Load	
Center of Mass	12"
Load Weight	50 Pounds
Controls	
Interface	Ethernet
Data Type	UDP
Cost	
Budget	$15,000

Table 1: Motion Table Specifications

2 Solution

The conceptual design for this project was created using Motion Platform Designer[1]. This software has a wide variety of parameters to control table behavior. Some of these parameters include:

- Degrees of Freedom
- Motor Spacing
- Motor Arm Length
- Platform Center Height
- Connecting Rod Length
- Payload Weight

Using this software it was possible to customize all of these parameters to fine tune the table to meet our specifications. Once the final specifications had been determined, we began running simulations to generate force and torque requirements. Using these estimates we then found a range of motor sizes that would be able meet these requirements. We found that we needed slightly larger than $\frac{1}{2}$ horsepower motors in order to drive the table properly. In order to get higher torque at the lower speeds that were necessary, we decided to use geared DC motors. Once the motors were selected we attempted to purchase compatible power supplies and drivers. However, the vendor that we were ordering from did not have adequate hardware, but we ordered the closest items to the desired specifications from the parts that were available. After all hardware had been selected the table was fully modeled in SolidWorks as shown in Figure 1.

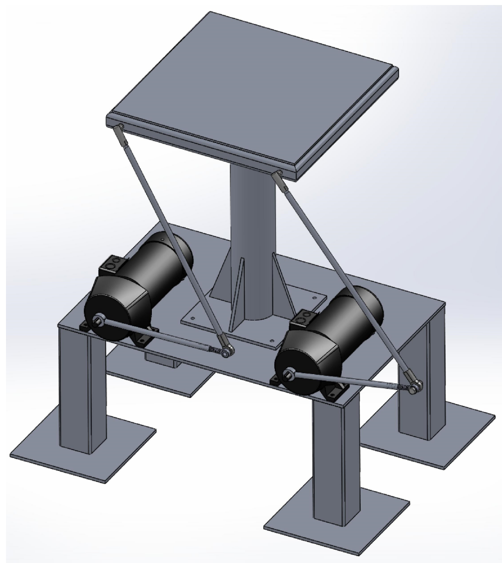

Figure 1: SolidWorks Model[2]

The software portion of this project included taking simulation data from a program given to us by our customers and transmitting it using UDP packets to our Arduino microcontroller using an Ethernet interface. Figure 2 shows the intended flow of the project.

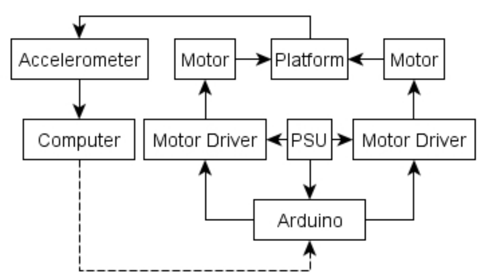

Figure 2: Feedback System Flowchart

The closed-loop feedback system was intended to be implemented by taking the control signal generated by the customers simulation and transmitting it over Ethernet via UDP packets. From there we could transform the data from the platform position into the necessary motor positions. We would then generate a control signal from the Arduino and send it to the motor drivers causing the motors to rotate. This motor rotation would then move the platform and the VectorNAV would report the table orientation, and depending on the accuracy of this reading compared to where we were expecting the platform to be, we would adjust the motors to be as accurate as possible.

3 Results

Project Specifications Accomplished:

- Platform Dimensions
- Degrees of Freedom
- Maximum Rotation
- Ethernet Communication

Project Specifications Not Finished:

- Angular Velocity
- Sea State Implementation
- Closed Loop Feedback

The center joint that we were initially using allowed for yaw motion. This resulted in motion characteristics that were unwanted and unaccounted for in the design. To fix this, we had a new center joint fabricated with the help of the machine shop here at NMT. This new joint has completely removed the yaw motion from the table.

3.1 Hardware

All of the following table components have been selected:

- Motors
- Power Supplies
- Drivers
- Rod Ends
- Center Joint

All of the individual table components have been tested and are working. However, the larger power supplies we have are too large for our motor drivers to handle and the smaller power supply does not deliver enough power to the motors. The total fabrication and assembly of the table surface, center pillar, and table base have also been completed. Total table functionality testing has been completed for the specifications that we are able to test. We have verified that the maximum rotation of the table meets the requirements. This has been tested manually without driving the motors. The reason for not testing with driving the motors is that if the motors pushed the table beyond the maximum possible rotation, it could cause structural damage to the table.

3.2 Software

The software portion of the project is largely unfinished. Part of this is due to our limited ability to implement a controlled closed-loop feedback system due to time constraints and an unexpectedly long lead time on parts. When we finally got our main feedback component, the VectorNAV orientation sensor, it was not the interface type that we had ordered. The version we received was not able to interface properly with our Arduino. As a result, the only feedback possible is manually through the computer. This is what has allowed us to verify the maximum table rotation still. The Ethernet communication is working with the Arduino and we have been able to establish basic communication with the computer. The program that our customers have written has not been interfaced with.

4 Future Work

In order for this table to work properly there are three major changes that need to be made. First, the torque requirements for the table most likely need to be lowered so that a non-geared DC motor can be used at a lower voltage. Second, new, reversible, motor drivers and corresponding power supplies need to be selected to match the new motors. Lastly, for the feedback system to work properly it would be necessary for a new VectorNAV unit to be purchased in order to interface with the Arduino microcontroller. Furthermore, for a tighter feedback system, stepper motors with encoders would allow for much more precise control of the table.

References

[1] Motion Platform Designer
http://www.fly.elise-ng.net/index.php/motionplatformdesigner

[2] Aaron S. Downie - SolidWorks Modeling and Table Fabrication
Raytheon-Ktech

Acknowledgments

Kevin K. Ryan	Date
Derrick Duran	Date
Juan Lopez	Date
Dr. Kevin Wedeward	Date
Michael T. Pace	Date