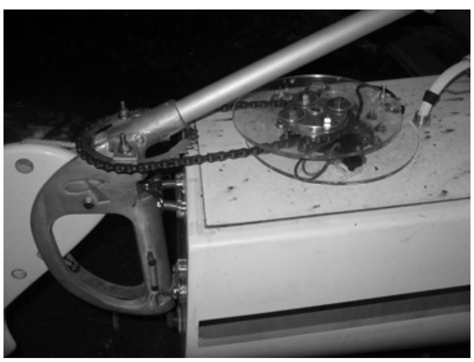
Rudder Control for an Autonomous Sailing Catamaran

by Jose Madrigal &
Ricardo Chavez

Introduction

The Atlantis is an autonomous catamaran developed by Gabriel Elkaim. The project was for his doctorial thesis from Stanford University in 2001. Currently the project is being improved by Rob Kelbley a graduate student attending UC Santa Cruz. One of the main improvements on the catamaran was on the rudder control system. The original steering was preformed by a single linear actuator which through a linkage moved both rudders. The improvement removed the linkage and added a motor to drive each rudder independently. The following paper will discuss the new rudder system and how it is integrated with the boat's main computer.



(a)

(b)

Fig 1 *Pictures (a) and (b) show new rudder system on starboard pontoon*

System Overview

The redesigned rudder system uses a 240:1 geared motor. The motor is controlled by a Gekodrive G320 motor controller. The position of the motor is read from the AS5035 magnetic encoder which updates the motor controller and the microcontroller. The HC12 microcontroller is the brain for the system and brings each component together. The microcontroller communicates to the boats main computer over the Controller Area Network (CAN) bus. The block diagram in Fig 2 outlines this process.

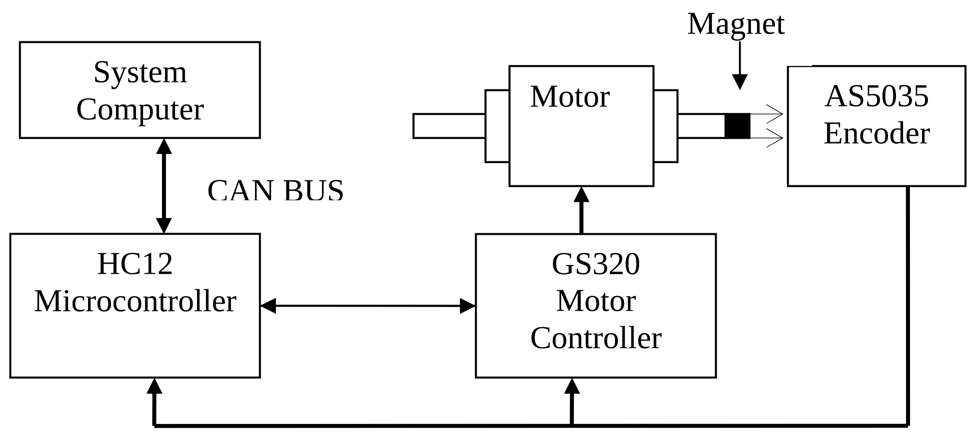


Fig 2 *Block diagram of rudder control system*

Construction of Circuit

The circuit which controls the rudders was first built on a bread board. A schematic was generated in Logic Works and is attached. The circuit was tested by using a joy stick to send commands through the CAN. Once the circuit was working correctly a permanent circuit was created by soldering the components together. The circuit contains a 5V voltage regulator to provide power to the integrated chips. A MCP2551 CAN transceiver chip is used to translate the digital output from the microcontroller to the CAN bus. The encoder was placed on a separate board which could be mounted over the back of the motor. The back of the motor contains a small magnet on a shaft which the encoder uses to sense rotation in the motor. The next step in the process was testing the completed rudder controller in the boat.

Troubleshooting and Solutions

The rudder system was installed in the boat testing showed unreliable performance. Troubleshooting reviled noise issues in two locations. The motor controller continually sent error signals to the microcontroller causing the motor to stop. The oscilloscope showed noise on the error line which caused the motor controller to fault. This problem was fixed by installing an optical isolator chip in the error line. The isolator filters the noise from the line by converting the signal to light. The light is then converted back to an electrical signal. The isolator circuit can be seen in the included schematic. Noise issues also caused problems with the performance of the center switch. The center switch resets the counter when the rudder is positioned parallel with the pontoons. This allows the ability to tell when the rudder is centered. Noise due to the motor running caused the HC12 to reset the encoder count in random positions. This problem was fixed by replacing the switch wiring with shielded cable. After further testing of the circuit, reliable performance was obtained.

Programming
The main aspects for the rudder control programming include: receiving message from CAN, determining the type of message, implementing the control associated with the message, and sending status updates via CAN. Initially the HC12 will receive a message over the CAN. The message has an identification number associated with it so that it will only affect the desired rudder. The ID number also determines what control will be performed when it is received by the HC12. Upon receiving the message the HC12 compares the ID with a series of defined ID numbers until a match is found. When a match is found the proceeding control process is performed. The HC12 is also sending out periodic status updates called heartbeats. For this system the frequency of the heartbeats is at 100Hz. The heartbeat also has its own ID so that when the main computer receives the message it can be displayed correctly on the Graphical User Interface.

Calibration

Two types of calibration were performed on the rudder controllers for proper alignment.

Limit and Center Switch Calibration
The rudders were put through a software routine that rotates the rudders through their full range of motion. While rotating the center and limit switches are tripped. The encoder counts are read when each of the limit switches are pressed so that the HC12 can determine it's upper and lower bounds. These bounds are set to protect the rudders from over rotation and damage.

Encoder Count to Degree Calibration
To calibrate the rudder we devised a method that would relate angles of rotation to the number of encoder counts. A laser was mounted to the rudder and focused on a scale of angle measurements. The rudder was then run through its range of travel while the encoder counts and their corresponding angles were recorded in excel. From the excel file we obtained a degree to encoder count relationship which would ultimately be used in programming. The code was changed so that an encoder count could be input and the rudders would rotate to the corresponding angle.

Comments
The rudder control system has been developed to its final stage for this phase of the Atlantis project. There were several troubleshooting that were resolved in order to achieve this. It is now an integral part of the overall redesign and control of the Atlantis. Further testing will be needed to asses the rudder control's true ability to successfully navigate the Atlantis. This testing may produce issues that were not taken into account prior. At that time more troubleshooting and redesign will undoubtedly be necessary.