Anonymous Go-Kart: Specification Report

May 8, 2011

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Abstract

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1 Project Overview

The aim of this project is to convert an existing electrically powered go-kart into an autonomous vehicle with the ultimate goal of circumnavigating a campus building without human interaction.

Autonomous vehicles and more specifically driverless cars are part of a field of research that has seen a large amount of development in the last few years. This research comes as the increasing power of computers makes the processing of sensors and the decision making required by these vehicles able to happen in real time even when the vehicle is travelling at high speeds.

There are many advantages to this automation. These include improved safety (annual road deaths currently stand at 1.3 million[5] by preventing road accidents caused by human error, the transportation of loads in dangerous areas such as disaster zones and improving traffic flow. For these advantages to be realized however robust programs must be developed that will allow the vehicle to adapt to operate in a varied and continually changing environment with many unknown variables to compensate for.

Recent projects in this area can be divided into two main areas. Vehicles for surfaced roads and free ranging vehicles. On surfaced roads the major current project is the Google driverless car [6]. This system combines information gathered by Google street view with information from its on board sensor array to drive on highways with no human interaction. To date these vehicles have driven over 200,000 km without any incidents. A second major driverless vehicle project was the VisLab Intercontinental Autonomous Challenge which ran in 2010. In this challenge 4 autonomous vehicles were driven on a 15,000 km trip from Parma, Italy to Shanghai, China with almost no human interaction [1].

In free ranging vehicles the DARPA grand challenge run by the US military offered contestants a $2 million prize for the autonomous vehicle that could complete their off road coarse in the shortest time. The winner of this race vehicle in 2007 completed the 96km course in 4 hours 10 minutes averaging 23 km/h over rough terrain [3].

All recent large projects into autonomous vehicles have made extensive use of LIDAR (light detection and ranging) sensor that rapidly scans a laser over the environment measuring distances to create a map of the surroundings. These maps can then be used to allow the program to make decisions about its operation based on a very accurate picture of the world. The only disadvantage with the LIDAR is its large price tag when compared to any other form of sensors. A low cost LIDAR that can operate in direct sunlight costs in excess of $5000.

2 Requirements

The project is split into two separate elements, each with their own set of requirements.

2.1 Drive-By-Wire

2.2 Sensing and Behavioural Control

3 Approach and Preliminary Design

3.1 Brake

The go-kart's brakes will be controlled via a linear actuator. This will be connected by removing the brake pedal and connecting the actuator directly to the input of the hydraulic brake systems. It was decided to use the existing hydraulic system rather than attach a controlled actuator directly to the brake disk. This was done as it allowed the system to be attached and operated with minimal modifications to the existing kart. Another reason this decision was made is that actuators with relatively low force and large travel were much more readily available and cheaper then those with small movement and high force and the existing hydraulic system already converted this large movement into the high force required resulting in a cheaper system. Through rough testing it was determined that a human could apply approximately 300 N to the brake pedal. The leverage in the brake pedal was estimated at be roughly a 2 to 1 system. This meant the ideal actuator had to provide 600 N of force to operate the brakes. To go from full off to fully on the actuator required 30 mm of travel.

The actuator selected to power the brake was a 24V Warner linear m-track1. Its specifications deviated from our requirements slightly. The actuator had 100mm of travel more then three times the required making it longer then necessary. However space was not an issue so this was not seen as a problem. The actuator could only produce 450 N of force, it has yet to be seen how fast a deceleration this will allow however as 600N is the maximum a human could reasonably apply we are confident 450N will be sufficient. In the unlikely event this force proves too small in testing the large travel of the actuator means it can instead be mounted to the brake pedal using the leverage to give the required force. The actuator moves at 15mm per second under load. This means that from off to full lock takes 2 seconds. This speed is a lot slower then desired however the brake pads do not actually touch the brake during the first half of the travel. This dead zone is there to prevent drivers accidentally applying the brakes and to accommodate different thickness brake pads as they wear. If the servo is recalibrated on a regular bases this dead zone can be all but removed allowing full brake control in a second. The main driving decision in the purchase of the actuator was price. The actuator was an end of line product that had been heavily discounted to sell this meant that it only cost $110 NZD including shipping to New Zealand from America. An actuator of similar specification could not be located for less then $220 in the US or within New Zealand for less then $300.

3.2 Steering

The steering on the go-kart operates on a rack and pinion system. The steering wheel rotates from lock to lock in 270 degrees. At rest on concrete the wheel requires 7 Nm to turn, this value represents a worst case scenario with significantly less force required when the kart is moving or on grass. Initially a servo was going to be used to drive the steering wheel however servos with the ability to produce 7Nm of continuous torque at a reasonable speed were found to be both difficult to locate and prohibitively expensive ($500+). Instead a system of a DC motor, gearbox and encoder is to be used. For the motor to be attached the steering column needs to be removed and the output of the gearbox will drive the pinion directly with the motor bolted in the space left by the removed column.

The motor system selected for use in the go-kart is the IG52-04 52mm gear motor. It comes with a 1:353 gearbox and a Hall Effect encoder attached to a second rear output shaft on the motor. This motor produces 10 Nm of continuous torque which will allow it to easily turn the wheel. Its gearbox output rotates at 10 RPM allowing it to travel from lock to lock in 4.5 seconds. A concern with using this motor is that it has the ability when stalled to produce a peak torque of up to 100 Nm. This high torque has the potential to damage the steering system or the gearbox which is only rated for peak torques of 30 Nm. Because of this it must be ensured that the wheel is never driven right up till the end of its travel to prevent the motor stalling against the end and generating these forces. The encoder must be calibrated upon each setup of the system. This is because the encoder only outputs change in rotation and the rack may be in any position when the system is initialised. Because of this limit switches will be placed on small plates attached to the rack shaft to indicate when it has reached the end of its travel. On start up the motor will locate both limit switches to calibrate its location. These limit switches will also act as kill switches during operation to prevent the motor reaching the end of its travel.

3.3 Controlling the motor and actuator

Both systems operate on 24V. This was done as the go-kart already had a 24V rail for driving the main motor. Using the same voltage saves money and simplifies the design as it precludes the need for converters that would have to be capable of the 5A peak currents produced by the system. Both systems are controlled through an H-Bridge interfaced with a SAM7 processor connected to a can bus. These SAM7s take care of all the low level control required to operate the drives allowing the main control computer to operate them at a high level with instructions that corresponds to desired behaviour rather low level drive operation.

The SAM7 responsible for steering will take the desired wheel angle as an input from the can bus. It will also track the encoder's output to calculate the turning angle. Running a PID controller between the setpoint and current value it will send the PID loops output as a PWM signal to the H-bridge.

The design of the linear actuator is similar. The SAM7 will be passed the current and desired speeds of the go-kart. From this and the voltage output by the potentiometer built into the linear actuator the error in the actuator's location will be found. Again a PID controller will drive a PWM signal to the H-bridge controlling the actuator.

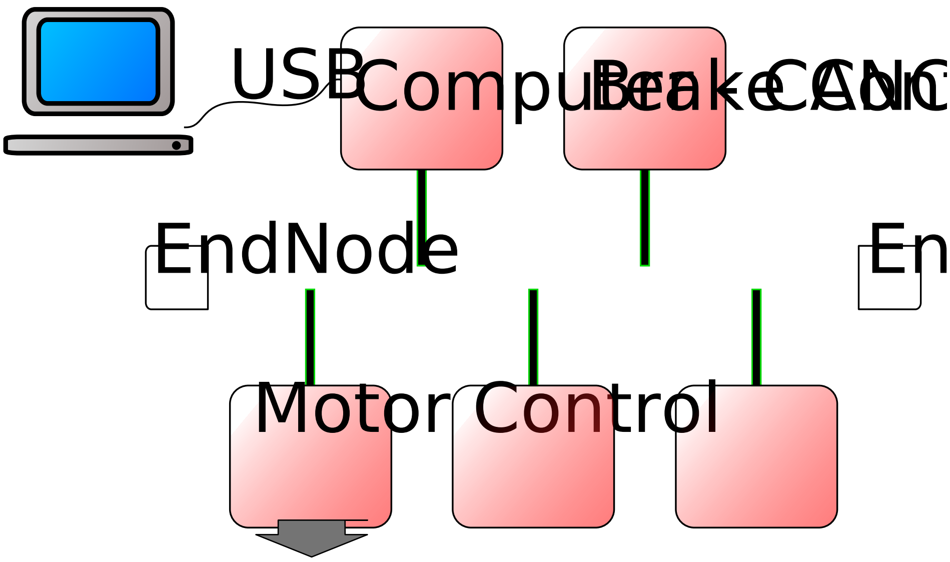

Figure 3.1: Basic go-kart control system overview.

3.4 High-level logic and control

For high level control it was decided to design a system where the go-kart can be fully controlled by a laptop using a simple USB interface. There are a few reasons behind this decision, the biggest one would have to be the much nicer programming environment presented on a standard PC. A large availability of higher level languages and better libraries for any low level stuff that may be required means that it will be easier to design and build the control system.

This also makes it much simpler to interface to a set of more complex sensors, doing any sort of computer vision system on an embedded system would require a lot more effort to design, build and test than doing the same on a standard PC.

To support this simple USB interface a modular design will be employed, a general overview of the approach can be seen in Fig. 3.1.

3.4.1 SAM7X

3.4.2 CAN bus

4 Budget and Timeline Summary

5 Project Risks and Conclusions

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