The S-90 Go-Kart

By

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Executive Summary

This project is to design and build a go-kart for a client with severe cerebral palsy. The client has almost no reliable motor control of his body or limbs, ruling out the possibility of him driving traditionally designed go-karts. The idea behind this project is to take the control that he does have and give him the experience of a real go-kart. To do this a go-kart will be built from the ground up to meet his specifications. It will have three different modes of control: remote control, joystick control, and steering wheel with pedals control. This will allow the client to use the vehicle on day one, and progress to having more and more control of the go-kart with practice.

The go-kart will be extremely safe, with software and hardware systems that shut down and stop the vehicle, at the push of a head switch, or if something goes wrong. The vehicle is designed with the client’s condition in mind and will ensure that his body is positioned correctly for maximum motor control. Since this would be an awkward position for a normal driver the vehicle will also be adjustable to allow for a wide range of people to be able to drive it. This go-kart will be built from the ground up to meet the client’s needs, and it will be safer, more versatile and more fun than anything else on the market.

1. Introduction

1.1 Background

This project is intended to design and create a go-kart for a child with severe cerebral palsy. The client is a ten year old male who is very smart and enjoys all things related to motor vehicles and driving. His condition makes it nearly impossible for him to operate a typical go-kart, however. The client has no reliable use of his arms or legs at this time. He has been working to develop enough motor control in his arms to allow him to use a power wheelchair with joystick control. The client can use a head switch with great reliability and this is an important factor in the design of this go-kart.

In addition to a lack of reliable motor control the client also needs to be positioned correctly both for comfort, and to optimize the motor control he does possess. He needs to be secured tightly in his seat at the waist. This is to ensure that his waist is constantly at a 90° angle, which helps his movement. The controls must also be setup in such a way that the client’s thumbs are pointing upwards. This is both to help train his muscles to maintain that position and for comfort.

1.2 Purpose of the Project
The overall purpose of this project is to provide the client with a go-kart that will allow him to experience the thrill of driving just like a person without cerebral palsy can. This go-kart is intended to be a much needed outlet for fun and stress relief in the life of the client. The client’s condition does not allow him to control a go-kart in the tradition sense, so other methods of control must be developed. To allow for the client’s continued development of motor functionality three progressive methods of control will be implemented. The go-kart will also meet all of the positioning and restraint requirements to allow the client the most safe and comfortable ride possible. The most important part of this go-kart is to maximize the client’s safety and fun while using it.

1.3 Previous Work Done by Others

1.3.1 Products

There are examples of other projects and products that have attempted to accomplish similar goals to this project. There have been two teams at the University of Connecticut who have developed go-karts for clients with cerebral palsy. In both cases, 2001 and 2008, the project was designated the title E-Racer. In both cases the client had limited mobility, but the relatively efficient use of one hand. The 2001 team modified a go-kart to allow it to be driven with a joystick control. The 2008 team designed their go-kart so it could still be driven with a joystick as well. Both projects created a product costing roughly $2500.

An NSF project in 1994 called the Recreational Electra-Scooter was completed at the State University of New York-Buffalo. This device essentially consisted of a platform on wheels that a wheelchair could be secured to. The platform could be programmed to move in either a straight line or in a preset circle. This left the driver with very little responsibility for actual driving, and allowed them to just enjoy the ride. The wheelchair was secured to the platform of the Electra-Scooter in a similar manner to how wheelchairs are secured on public buses. The cost of materials for the Electra-Scooter was $870.

A number of other colleges and universities have attempted projects similar to the E-Racer projects done by University of Connecticut senior design teams. In most cases the go-karts were controlled using a joystick system, and most were electric. These products rely on embedded software to interpret input from electrical control systems to drive and steer the go-karts. These projects typically range in price from $1000-$3000.

A number of commercially available go-karts are manufactured by Mobility4Kids, which are designed to allow people with disabilities to drive. The controls for these go-karts allow people with loss of lower extremity control and other severe disabilities to control them by the use of a joystick or switch controls. The go-karts are electric powered with electric brakes and are mostly intended for on road or light off road use. The maximum speed of these products is 7 mph. The go-karts are also available equipped with a steering wheel. Mobility4Kids markets go-karts for a variety of different applications, and they range in price from $5300-$6900.
1.3.2 Patent Search Results

One patent applies to the control systems of a go-kart for people with disabilities. A device called the Handi-Driver was designed by Keith Alan Roberts in 2002. It incorporates the three essential controls of driving; throttle, brake, and steering, into a single steering column. The purpose of this design is to allow people with the use of only one hand to drive a vehicle. The Handi-Driver uses a motorcycle-style grip throttle along with steering and braking levers for control on the steering column. It also incorporates a kill switch so the user can shut down the vehicle if control is lost for any reason.

2. Project Description

2.1 Objective

The following must be incorporated into the design:

1. There should be 3 methods of control that can be easily switched by someone helping the client.
   a. Remote control
   b. Joystick control
   c. Steering wheel and pedals
2. There should be a head switch operated kill switch to allow the client to shut down the go-kart at any time he feels the need.
3. The seat and restraints should keep the client’s waist at a 90⁰ angle at all times during the driving of the vehicle.
4. The design of the controls should ensure that the client’s thumbs are pointed up during vehicle operation.
5. The vehicle must fail safely in the event of a malfunction on loss of the main power supply.
   a. A dedicated circuit connected to a secondary power supply must apply the brakes if main power is lost.
b. The engine must be shut down if the main power supply, or control communication is lost.

6. The vehicle must be capable of reasonable driving performance. The vehicle must be capable of reasonable driving performance.
   a. The vehicle must have a gas engine.
   b. The vehicle must have independent front, and semi-independent rear suspension.

7. The vehicle must be adjustable for the client to grow, and for others to drive the vehicle.

8. The vehicle must be blue.

In order to effectively implement these requirements the following designs need to be created:

1. A selector switch must be created to allow the operator to choose which method of control is to be used. This switch will govern the control system hierarchy in the software.

2. A system of RF communication that can control throttle, brakes, and steering must be implemented. This system must integrate into the software that controls speed and steering.

3. A joystick that can control throttle, brakes, and steering must be created and interfaced with control software.

4. A steering wheel must be created that interfaces with the software control system instead of being physically connected steering mechanism.

5. Pedals that interface with the software control system must be created.

6. A high torque gear motor must be mechanically interfaced with a rack and pinion and electrically interfaced with the control software to provide power steering.

7. Motors will control the throttle, forward reverse shift, and the brake, and will interface to their respective mechanical components as well as the control software.

8. Mechanical and Electrical safety measures must be created.
   a. A head switch operating as a kill switch must be added.
   b. A remote kill switch for the parents must be created with the remote control implementation.
c. The essential electrical components must be designed with feedback to the software, and the software will be designed to kill the engine and apply the brake if a component fails.

d. A dedicated circuit on a separate power supply that applies the brake if the main power supply is lost must be created.

e. The software must be designed to govern the speed of the vehicle to a reasonable level.

f. The seat must be designed to incorporate a safety harness system that will not allow the operator to fall out of the vehicle.

g. A roll cage must be created to keep the operator safe in the event that the vehicle flips.

9. An engine and transmission must be designed to provide reasonable speed and acceleration performance for the vehicle.

10. A suspension system must be designed that gives the operator a comfortable ride.

11. A seat mount that allows for both the client’s seat custom seat and a traditional seat to be mounted must be designed and created.

   a. The seat mount position on the chassis must be adjustable to accommodate client’s growth and other operators.

   b. The seat mount must be low on the vehicle for stability.

12. A chassis with space for all necessary components and ample room for the operator must be designed and created.

The innovations and novel design ideas associated with this project make it truly unique among other projects with similar goals. The three methods of control, which allows it to be used by operators of any motor ability level, are not seen on any other similar device. There is also a major focus on client safety for this device. The various fail safes and component feedbacks are an essential part of improving the overall driving experience for the client. One of the most innovative things about this design is the ability for it to be operated by anyone, not just the physically disabled. The ability to easily switch seats, along with the three control methods makes this design easy for anyone to comfortably drive. Above all, the go-kart is designed with the particular needs of the client in mind, and the design will allow him to safely have the most fun possible.
2.2 Methods

A go-kart will be built from scratch for this project. There are extensive modifications to a traditional go-kart design that must be made to accommodate the client, and instead of trying to fit everything into an existing design it was decided that it would be better to design from the ground up. This project can be split into three major components: mechanical, electrical, and software. In general terms all control systems will be processed by the software and transformed into mechanical adjustments through the electronic interface systems. Splitting up the different systems of the project allows work to be intelligently split up as well. The following sections will describe the design of each of the three systems mentioned above.

**Mechanical**

The mechanical heading encompasses a broad range of topics. Included in this section are: the chassis, the drive train, the suspension, the roll cage, the steering system, and the seat. Since the project will be built from scratch, this allows for a unique opportunity to integrate the various electrical components into the structure of the go-kart. No go-karts on the market currently have power steering, throttle, shifting, seats, and brakes, so all of the linkage and transmissions for the various electric motors need to be designed creatively and efficiently without any model to work from.

**Chassis**

The chassis of the vehicle will be made up of two separate components. The rear component will house the drive train, including the engine, gear box, automatic transmission, axle assembly, brake system, and chain tensioner mechanism. The rear chassis will have pivot mounts for the rear suspension, as well as heavy duty brackets for mounting to the front chassis. The front and rear chassis will be connected by a 30”x3/4” steel pin. The front chassis will house the linear actuator for the seat, the front suspension arm mounts, mounts for the rear suspension built into the roll cage/roll bar, the seat mount, and the steering mechanism. A large front guard will be mounted to the front chassis to protect the steering linkage and front suspension arms. Chain, sprocket and brake guards will be mounted to the rear chassis. The front and rear chassis will be designed to be extremely rigid in the X, Y plane and will be able to handle a small amount of flexion/torsion in the X/Z plane.

**Drive Train**
The drive train for the go-kart will allow for a maximum amount of torque to be delivered by the engine. The proposed engine has 13.5 ft-lbs of torque. Since the drive train utilizes an automatic transmission with a 2000rpm engagement speed, the torque of the motor will be high on the engine’s power curve when the transmission engages. This automatic transmission allows the use of a secondary gear reduction that will allow for a total reduction ratio of over 7.5:1, which in turn means that the 8hp engine will be able to deliver over 100ft-lbs of torque at the axle. The gear box that is being used as the jack shaft of the go-kart has a 2.7:1 reduction ratio for reverse and a 1:1 ratio for forward. This will make it easier for the client to go in reverse since the go-kart will be moving at almost 1/3 of its normal speed. At peak hp and rpm, the go-kart will be able to travel just over 40mph, with a 20% mechanical reduction taken into consideration for drive train inefficiency. The speed of the go-kart will not be monitored by engine rpm, but rather by axle rpm so that the client will be able to rev the engine and accelerate at the highest rate possible.

**Suspension**

The go-kart will have independent front suspension and semi-independent rear suspension. The front will have two parallelogram shaped suspension arms, each equipped with a 500+lb max weight shock absorber. The semi independent rear suspension will work about three pivot points: one where the front and rear chassis meet, one mounted to the roll bar on the front chassis, and one mounted to a re-enforced cross member on the back end of the rear chassis. The rear suspension will have two 14” coil over springs rated at 150lbs/in.

**Roll Cage/bar**

The roll cage/bar for the go-kart needs to be strong enough to withstand high impact forces as well as the weight of the fully loaded go-kart with a suitable safety factor. The roll cage/bar needs to be taller and wider than the client, and needs to be strong enough to withstand the forces from the rear suspension mount. The roll cage/bar will either be made from a single piece of bent low gauge steel tubing or from re-enforced welded steel sections.

**Steering**

The steering system will need to be calibrated to the size and geometry of the parallelogram suspension arms. The steering will come from a high torque gear motor that will turn a rack and pinion. This in turn will push tie-rods that are attached to the lever arms coming off of the front wheel spindles. The length of the tie rods and angle they make with the rack and pinion/spindles needs to correspond to the suspension arms or the wheels will turn as they move up and down. The leverage and amount of clearance that the front spindles will need will be governed by the stroke of the rack and pinion. This in turn will be governed by the gearmotor used to turn the rack and pinion. There will be a gear box that
will increase the speed of the gearmotor shaft so that turning from completely left to completely right will only take about 1 second. This is done to increase the performance of the steering system at the cost of high stresses, high electric currents, and robust linkage.

Seat

Since our client has special requirements for his seat, the go-kart design will implement a mounting bracket for his existing car seat with an optional bucket seat attachment. This way the client is guaranteed to have the proper support that he needs for his condition. Also, by including a bucket seat, if other people want to ride in the go-kart such as family of the client or test pilots in the testing phase of the project, they will be accommodated, too. The seat will implement a linear actuator for the adjustment of the seat. This way, the optional pedals and steering wheel will be able to be fixed in place and the seat will not be able to ever come loose since the linear actuator holds its position. The seat mounting plate will ride along two steel rails that will keep it centered and attached to the main front chassis. The steel rails will allow for some play in the seat mounting which will make fabrication of the assembly easy.

Electrical

A number of components of the design fall under the electrical heading. The control mechanisms are included in this section. These are: the remote control system, the joystick, and the steering wheel and pedals. Also included are the controlled components. This encompasses the steering motor and its non-software controls, the motor for controlling the throttle, the motor for switching between forward and reverse, and the motor for applying the brake. In addition the power supplies and various buttons are also electrical components for this vehicle.

Remote Control System

The remote control system works using commercially available products. The actual remote controller interfaces with a receiver on the go-kart and takes in signals that detail the position of the physical controls. These signals are then converted into pulse width modulation (PWM) signals and are output to the microcontroller.

In addition to this control system, which is for the throttle, brakes, and steering, a separate controller will act as a kill switch. A RF transmitter will work in a similar way as above to transmit a stop signal to a receiver on the go-kart. When this signal is received it is passed to the microcontroller for action.

Joystick Control
The joystick that has been selected for use with this project has a dual axis potentiometer control system. It takes a supply voltage and runs it through a potentiometer that corresponds to each axis, and then outputs two separate signals. As the joystick is moved it changes the resistance of the potentiometer that corresponds to the axis of movement. This in turn changes the output voltage of the lead. By comparing the output voltage to the input reference voltage the analog to digital converter on the microcontroller can interpret the position of each axis.

The X axis of the joystick will provide control feedback correspond to the position of the wheels. The Y axis of the joystick will be split between controlling the throttle and controlling the brake. Pushing the joystick forward will open the throttle, and allowing the joystick to come to rest in the center will take the engine out of gear. Pulling back on the joystick will engage braking power relative to the position of the joystick.

**Steering Wheel and Pedals**

The steering wheel and pedals will work off of the same principle as the joystick. The steering wheel will be connected to a rotary potentiometer that is supplied with an input reference voltage. The output will be that voltage scaled based on the position of the potentiometer. This signal will then be input to the A/D converter on the microcontroller. Likewise, the pedals will be mechanically attached to their own potentiometers and the signal will go to the microcontroller.

**Steering and Braking Motors**

The power steering will come from a 12V gear motor controlled either by a custom H-bridge or a commercially available speed controller. The output shaft of the gear motor will be attached to the mechanical rack and pinion to move the wheels. The gear motor will be made to move forward to turn the vehicle one way, and made to run in reverse to turn the vehicle the other way. This is accomplished using a signal from the microcontroller to switch the direction the control circuit allows current to flow into the gear motor.

The gear motor has no mechanism to track its own movement, so to keep track of which way the wheels are pointed a linear position encoder will be used. This position encoder will be attached to the rack and pinion and will move as it moves. The encoder outputs a signal denoting its extension, which will be used as an input to the microcontroller.

The power braking system will work in a very similar way to the power steering. A gear motor will be used to open and close the brake calipers. An H-bridge taking signals from the microcontroller will control the forward or reverse movement of the gear motor. The forward and reverse movement of
the gear motor corresponds to the opening and closing of the brake. The brake position will also be tracked by a smaller linear encoder.

**Throttle Servo**

The opening and closing of the throttle will be controlled by a servo motor. Servo motors take a PWM input from a source, in this case the microcontroller, and based on the PWM signal maintain a certain position. Servo control for this application is ideal, because of the relatively low torque requirements and the precision movement. Servos use their own encoders and do not need to send feedback to the microcontroller in order for the correct position to be maintained.

Shifting between forward and reverse for the transmission is also a matter of simply turning a selector. This will use a servo as in the same way as well.

**Buttons and Selectors**

Various buttons and selector switches will be necessary for the setup and operation of this go-kart. Most of the buttons will be simple push buttons that do not actually change physical state after being pushed. This is to ensure that the client can always push them without resetting. These buttons transmit a brief closed state to the microcontroller which then further processes the signal.

Two main selector switches will be used for this design. One will designate which method of control is to be used, and the other will designate forward and reverse. These selector switches have different states, and will continuously output that state to the microcontroller.

**Software Control**

The main software control will come from a Microchip PIC microcontroller that is programmed using embedded C code. The software is responsible for taking the various input signals from the selected method of control, processing the data, and outputting the proper signals based on those inputs.

Two main loops will be present in the software code at all times. The first main loop is the primary main loop which controls inputs and outputs during normal circumstances. The other main loop is the emergency main loop which is engaged by the activation of a kill switch. Each main loop will contain other loops and functions required to carry out all of the necessary tasks for operation of the go-kart.
In addition to the main software control a secondary dedicated circuit will run off of a secondary power supply. This circuit will have its own microcontroller with software that checks the status of the other microcontroller and can apply the brakes if the other fails.

**Primary Main Loop**

The primary main loop is responsible for controlling almost everything on the go-kart during normal operation. It comes after the initialization of the program and runs until a kill switch is activated or the system is shut down. The primary main loop checks to see which method of control is selected each time it runs through. Upon knowing a control method it runs in the appropriate secondary loop. Each secondary loop takes inputs from its designated control system as well as the control systems that are common to all control methods. These include encoder feedback and failsafe signals.

Each incoming signal is collected by the software and then run through its own function for analysis. Each function is designed to interpret what the incoming signal means. At the end of the function an action is designated. The action can either tell the software to make a change, or do nothing. Whatever the function decides based on the input signal is the changed at the output pins on the microcontroller.

This is done sequentially with each input modifying their designated output(s) based on their status. After each control system is taken care of the loop resets and repeats the entire process over again. In this way the software is constantly updating the condition of the go-kart based on what is happening and what should be happening.

**Emergency Main Loop**

The emergency main loop works a lot like the primary main loop, but is more set in what it does. The emergency main loop is activated by either the head switch or the remote kill switch, and cannot be left until the entire system is reset. The emergency main loop can also be entered if one of the other failsafe inputs is activated. The only goal of the emergency main loop is to safely stop the vehicle.

Upon activation of the emergency main loop almost all of the normal inputs stop being checked. The only inputs that continue to be checked are the wheel position, the speed and the brake position. Regardless of other inputs the emergency main loop begins a routine to stop the go kart. The throttle is closed and the brakes are applied. When the speed is at a reasonable level the wheels are straightened. The emergency main loop shuts down the engine and maintains full braking power until the system is reset.

**Dedicated Failsafe**
The dedicated failsafe software architecture is very similar to the emergency main loop in that it runs on a predetermined program and then maintains its final position until it is reset. It takes inputs from the throttle and the brake, as well as status inputs from the other microcontroller. If it loses contact with the main microcontroller it cuts power to the engine and applies the brakes. Once the vehicle is stopped it maintains that configuration until reset.

3. **Budget**

The preliminary budget for the go-kart is listed in the figure below. This budget is likely to change significantly before the project is complete, and these numbers are rough estimates. The actual cost of building this project is significantly less than it could be, because much of what is being used has been donated, or found in the senior design lab. The estimated cost of the free parts is included for the production cost estimates. The overall budget for this go-kart is right around the $2000 mark, not including prices for the free components. If the production price is generally set a 35% of the prototype production cost then this product would likely sell for $$$. This would be significantly less than other go-karts that are on the market for people with disabilities.
### Team 1: The S90 Go-Kart

#### Budget breakdown

**Free Parts**

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**Free Parts Total Value:** 4692.49

**Total Cost:** 2205.36

**Total Project Value:** 6897.85
4. Conclusion

In conclusion this product will provide the client with the enjoyment he is looking for all in a safe and versatile package. The ability to switch between three methods of control, including remote control, ensures the client’s ability to make use of this vehicle no matter what. The vehicle will have the power and control to make driving it a great experience. The vehicle is designed in such a way that it can grow with the client and provide years of entertainment and fun. It is so versatile in this manner that even fully grown adults with no disabilities can use it comfortably and without learning any new control systems.

Most importantly this is a safe product. It has a number of different ways that a full shut down can be implemented in the case of lost control. In addition the client is protected by a harness and a roll cage. The design of this go-kart puts the client’s needs and wants first, and everything else is designed around those important specifications. This product will be as good, or better, than anything already on the market. The goal is for the client to be able to have the maximum fun in the safest way possible and this go-kart design accomplishes just that.

5. References


