Experiment M10
RC Retrieval Vehicle
Procedure

Deliverables: Checked lab notebook, demonstration of working vehicle

Overview

Background

In this lab exercise, you will design, build, and test a remote control (RC) vehicle with a robotic arm that can pick up an empty can and drop it in a 4" tall basket. You will use many of things you have seen in the previous lab exercises: DC motors, motor driver boards, remote controls, driven wheels, and 4-bar linkages. Shown below in Fig. 1, there are a wide variety of vehicle design configurations for this lab.

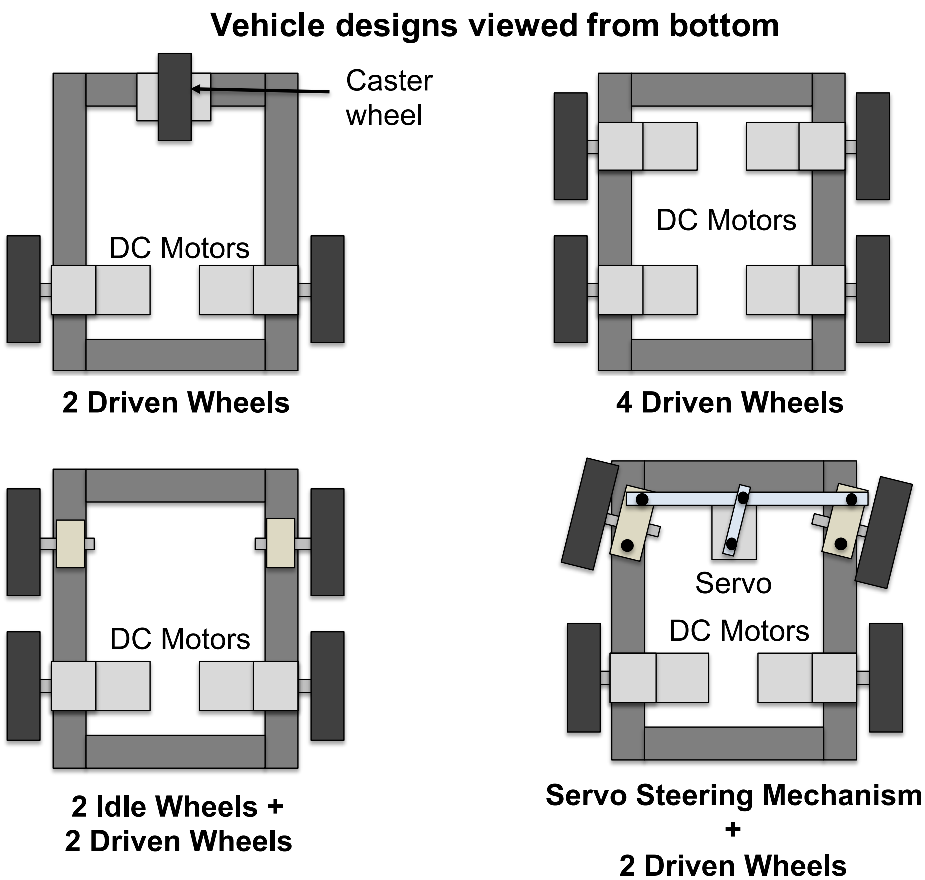

Figure 1 – Four possible vehicle designs include (top left) 2 driven wheels with a single idle caster wheel, (bottom left) 2 driven wheels with two idle wheels, (top right) 4 driven wheels, and (bottom left) two driven wheels with two idle wheels connected to a 4-bar steering mechanism.

Design Decisions

A wide variety of components will be provided in lab for constructing your vehicle, and you will need to make several design decisions.

- Chassis size and wheel-base – Various lengths of 2020 slotted rail
- Motor gear box – No-load speeds of 100, 200, and 550 RPM
- Wheel diameter – D = 2”, 2.875”, 3.875”, and 4.875”
- Overall vehicle design configuration – See Figure 1
- Remote control configuration – Human-machine interface (HMI)

Lithium Battery Safety – Standard Operating Procedures

1. Wear safety glasses whenever working with lithium batteries.
2. Inspect all batteries for damage before use. Do not use the battery if:
   a. The case appears cracked or swollen.
   b. The external cable insulation is damaged with the inner conducting metal exposed.
3. Charge all LiPo batteries with a proper charger-balancer.
4. Connect the battery to the charger-balancer and verify that all cells have sufficient charge before use.
5. An in-line fuse must be incorporated in any custom circuit that will be connected to a battery. The fuse should be immediately after the battery connector.
6. Do NOT remove the connector from the battery cables. This special connector ensures the battery cannot be accidentally short circuited or connected backward.
7. Lithium batteries should be stored and charged inside a special flame-retardant bag or case.

Subsystem A: Electric Powertrain

You will begin by creating the electrical powertrain—the system that distributes electrical power from the battery to the motors.

CAUTION: Lithium batteries pose a serious fire risk. Follow all instructions carefully when building your circuit. Do NOT intentionally modify or damage the battery in any way.

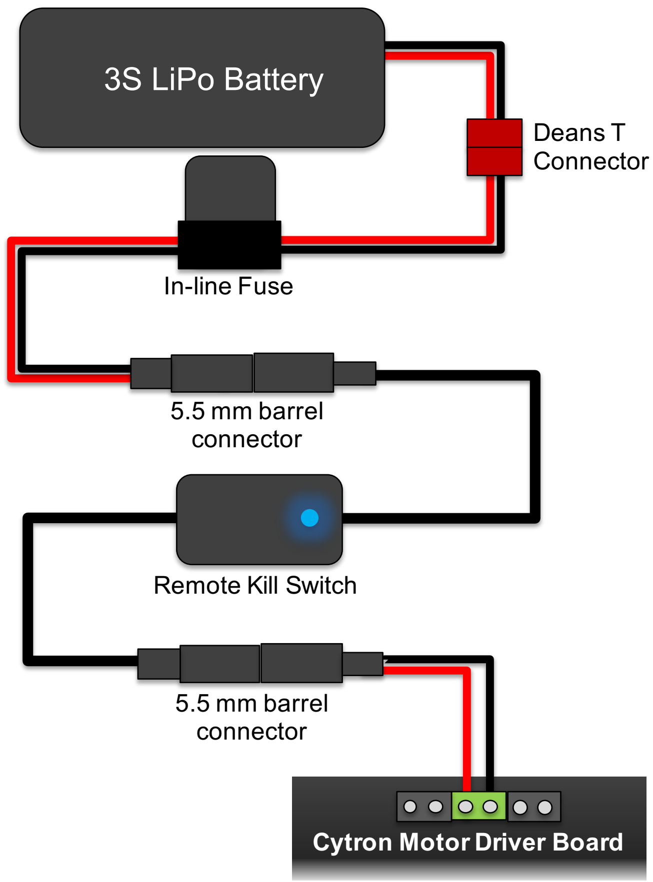

Figure 2 – A 3S LiPo battery is connected to a Cytron dual motor driver board. Between them are a series of safety features that regulate the flow of power.

Safety First: You must wear safety glasses when working with lithium batteries.

Procedure

1. Sketch the system shown in Fig. 2 in your lab notebook.
2. Connect a female 5.5 mm barrel connector to the green screw terminals on the Cytron motor driver board. The red wire goes to the + terminal, and the black wire goes to the – terminal.
3. Locate the 3S LiPo battery. Take it over to the counter top and plug the connector with the four small wires into the battery charger and balancer. You should see all three LEDs light up green, indicating that each of the three cells in the 3S battery are fully charged. If not, ask the lab instructor or TA for help.

4. The red Deans T connector on the battery is our first safety feature. It prevents you from connecting the battery in the reverse polarity, which often results in a short circuit and a fire. Connect the battery to the in-line fuse.
5. The in-line fuse is our second safety feature. It contains a sacrificial metal filament that will melt and break the circuit in the event of a short circuit. Connect the fuse to the remote kill switch via the 5.5 mm barrel connector.
6. The remote kill switch is our third safety feature. It allows the system to be shut down with a small remote control in the event of an emergency.
7. Connect the male end of 5.5 mm barrel on the remote switch to the barrel connector you connected to the motor driver board. The system should now look like Fig. 2.
8. Test the remote kill switch. You should be able to toggle the Cytron motor driver board ON and OFF with the remote key fob.
9. Download the user manual for the Cytron motor driver board from the lab webpage. Read Section 8.1 – RC Input Mode.
10. Connect the any two channels of the RC receiver to the motor driver board, as shown on page 15 of the manual.
11. Choose two motors, both with the same no-load speed. Solder wires to them, and connect them to the motor driver board.
    a. Solder red and black 20 gage wire to the + and – motor terminals. The wires should be about 10 inches in length. Use the wire strippers in your plastic tote box.
    b. Seal and protect the solder joints with red and black shrink tubing.
    c. Connect the motors to the black screw terminals on the motor driver board, as shown on page 15 of the Cytron manual.
12. Turn the system ON with the remote kill switch. Turn ON the RC transmitter, and check that it binds correctly with the receiver.
13. Try using either of the joysticks on the remote control to adjust the speed of the motors.
14. **Demonstrate the working subsystem to the TA, so you can be awarded points on your score sheet.**
15. Use the remote kill switch to turn OFF the electrical powertrain subsystem. Disconnect the motors from the Cytron board. Leave the rest of the subsystem intact, and set it off to the side.

Subsystem B: Chassis and Vehicle Structure

Safety First: You must wear safety glasses when working with lithium batteries.

You will now design (choose parts) and assemble the mechanical structure of your vehicle.

1. Choose a vehicle structure from Figure 1. (We recommend beginning with 2 driven wheels and a caster wheel.) Sketch it in your lab notebook.
2. Design and construct a rectangular chassis out of slotted 2020 rail.
   a. Choose the dimensions based on the available parts.
   b. Add the dimensions to the drawing in your lab notebook.
   c. Attach the pieces using the right-angle brackets and sets screws in the black and orange tackle box on the counter.
3. Fasten the vehicle suspension components to the chassis (motor mounts, caster wheel(s), idle wheels, etc.).
   a. Use screws and drop-in T-nuts. Sizes M3, M4, and M5 are available. Make sure the screw and T-nut size match.
   b. Insert T-nuts into the slots sideways. Then, use an allen wrench to push them in, so the rounded side faces down and the flat side faces up.
   c. The allen wrench can also be used to slide the T-nut to various positions along the slot.
   d. Add more 2020 rails for additional support, if necessary.
4. Attach the motors you chose to the motor mounts using M3 screws.
5. Attach wheel hubs to the motor shafts.
   a. Make sure the set screw bites down hard on the flat part of the motor shaft.
   b. Make sure there is space between the wheel hub and motor.
6. Secure the rubber wheels to the hub. Using the special retaining ring pliers, place a retaining on the groove on the hub to secure the rubber wheel in place.
7. Mount a piece of Masonite peg board to the top of the chassis using M5 screws and T-nuts. (You will use this to mount your electrical powertrain in the next part.)
8. Add square plastic endcaps to the ends of the 2020 rails.
9. **Show your fully assembled chassis and vehicle structure to the TA, so you can be awarded points on your score sheet.**

Subsystem C: Remote Controls and HMI

You will now put everything together and program the remote control to steer and drive the vehicle.

1. Use 3M Velcro command strips and zip ties to mount the electric powertrain to the Masonite peg board on top of the chassis.
2. Lift up the vehicle and set the chassis on wood blocks, such that the wheels are not touching the lab bench and are free to spin.
3. Reconnect the DC motors to the Cytron motor driver board and any other wires that may have come loose.
   a. Refer to the schematic on page 15 of the Cytron manual for details on the wiring.
   b. Use zip ties to strap down any loose wires.
   c. Refer to your previous lab notebook entry to see what channels on the receiver correspond to which knobs and joysticks on the transmitter.
4. Turn on the power and test the remote controlled vehicle. Move the joysticks on the remote control to make the wheels spin.
5. If necessary, adjust the wiring of the receiver and motors so the wheels spin in a logical way corresponding to the controls. Remember, this is the system you will use when you compete in the time trials on Monday.
6. Place adhesive foam corner pads on the corners of your chassis.
7. If you are confident that the remote control is causing the wheels to spin correctly, place the vehicle on the floor and *carefully* drive it around the lab.
8. **Demonstrate your vehicle to the TA by driving it around the lab, so you can be awarded points on your score sheet.**

Subsystem D: Robotic Gripper

Safety First: You must wear safety glasses when working with lithium batteries.

Procedure

10. Assemble the robotic gripper. Refer to the 2 minute instructional video on the product webpage. https://www.servocity.com/standard-gripper-kit-a/
11. Use M3 screws, nuts, and washers to attach the gripper to a piece of GoBilda low-side U-channel. Choose the length wisely, as this will be the length of your mechanical arm.
12. Connect the gripper servo to the RC receiver. You should be able to open and close it with the RC transmitter.
13. Determine which channels on the receiver corresponds to the small knobs on the top of the RC transmitter. Connect the gripper servo to one of these channels, so you may open and close it with one of the small knobs.
14. **Demonstrate this working subsystem to the TA, so you can be awarded points on your score sheet.**

Subsystem E: Mechanical Arm

You will now mount a servo to the chassis and mount the arm to the servo using the same GoBilda servo block that you used in the previous RC system lab.

9. Assemble the GoBilda servo block, as you did in the previous lab, and use the GoBilda hardware to mount it to the vehicle chassis.
   a. **Design Decision:** Choose either a regular servo (position control) or a continuous servo (speed control).
   b. You may need to rearrange the electrical power train to make room for the mechanical arm.
   c. Various examples for mounting the servo block can be found on the product page linked below.

      https://www.servocity.com/compact-servoblock-43mm-width-for-standard-size-h25t-spline-servo-hub-shaft/
10. Use M4 screws to attach the robotic arm to the servo hub. Note that the goal is to pick up an empty soda can and place it in a shallow basket.
11. Connect the servo to the RC receiver. You should be able to control it with the RC transmitter.
12. Test the remote control of the mechanical arm. Determine what controls will be the most user-friendly.
13. **Demonstrate the working subsystem to the TA by raising and lowering the arm with the remote control, so you can be awarded points on your score sheet.**

Design Challenge 1 – 4-bar Mechanism

As you probably noticed, the servo does not have very good holding torque, and the arm tends to sag down to the ground. The user control is also a bit too sensitive and small adjustments on the RC transmitter result in large swings of the arm. You will alleviate these deficiencies by incorporating a 4-bar mechanism to provide increased holding torque and mechanical advantage. It should also make the controls more user friendly.

- Remove the arm from the servo hub. Use the GoBilda hinge to create a revolute joint on the end of arm.
- Use additional GoBilda hardware to create a 4-bar mechanism.
- Do not directly copy the mechanism from the video. Be creative. Be original. Come up with something better.
- If you are using a regular servo with position control, use the remote to check the range before you connect any linkages. That is, make sure the servo shaft is not already at or near the limit of travel, which would prevent it from rotating any further.
- The 4-bar mechanism should increase the mechanical advantage and allow for finer user control. It should also allow for enough range that a soda can may be lifted from the ground and placed into a 4” tall basket.
- **Demonstrate your working 4-bar mechanism to the TA.**

Design Challenge 2 – Retrieval

The final goal is for the vehicle to drive to a soda can, pick it up with the mechanical arm, and deliver it to a 4” tall basket.

Safety First! – Your vehicle must have foam corner pads on the corners of the chassis.

- Make sure the electric power train, motor driver board, and RC receiver are all properly connected and securely fastened to the vehicle chassis.
- You should be able to drive the vehicle with the remote control as you did in the previous lab.
- Test the system in the hallway. Modify the remote control connections to make it more user-friendly.
- **Demonstrate to the TA that you are able to pick up a soda can from a random location and place it in the basket.**

Clean-up

- Disconnect the battery from the vehicle. Return it to the flame retardant LiPo safe bag on the counter.
- Disconnect all the wires and remove all electronics from the vehicle.
- Remove the wheels, wheel hubs, and motors. Return them to their appropriate bins.
- Remove the motor mounts and Masonite peg board.
- Return all screws and hardware to the appropriate compartment of the tackle box.
- Put anything that belongs in your tool kit back into the tote bin.

Appendix A

Equipment

- 3S LiPo battery, 5200 mAh, fully charged
- 5A In-line fuses with Deans T connectors
- Remote kill switches with key fobs
- Cytron dual motor driver board - SmartDriveDuo-10 MDDS10
- DC motors (greartisan 37mm)
    - 100 RPM
    - 200 RPM
    - 550 RPM
- BaneBots Wheels, Hub Mount, 60A, Black
    - 2" x 0.8"
    - 2-7/8" x 0.8"
    - 3-7/8" x 0.8"
    - 4-7/8" x 0.8"
- BaneBots T81 Hub, 6mm Shaft with retaining rings
- Retaining ring pliers
- Flysky FS-i6X 2.4G 10CH Radio Transmitter and Receiver iA10B – Amazon Part # B0B3T2R65X
- 2020 T-slot rail, various lengths
- Fasteners for 2020 T-slot rail
- Caster wheels
- Pillow block bearings for 6mm shafts
- 6 mm steel shafts
- Tape measure