CS148 Laboratory Notes
Part A

Semester II, 1998-99

Introduction

Each pair gets a robot kit, which contains the supplies you will need to build your own mobile robot, including the microcontroller, motors, batteries, sensors, and, legos with which to build their robot base. We hope that you and your partner will have a fun and educational time building and programming your robot. However, parts of your kit such as the controller board are fragile, while others like the batteries and charger can be dangerous if used improperly. **Please do not use the kit until you have read and understood this handout, especially the section on the rechargeable batteries and charger.** If you have questions about the equipment you receive, or you didn't receive parts that you need for your project, please talk to a TA.

Administrative Notes

Since these kits are quite valuable, each participant in the course will be required to give us a deposit on their kit. The deposit should be a check for $50 made out to Brown University. The check will be returned uncashed when you turn in your disassembled kit in good condition at the end of the semester. You have been handed a phenomenal resource, please keep it in good shape.

Overview

Building and programming your robot will take place in stages. In the first stage, you will use the Legos, batteries and motors to build a simple mobile platform. In the next stage, you will add the microcontroller board and place your platform's motors under program control. Simple light sensors will be added so you can program your system to perform simple tasks such as light seeking. Finally, you will add more sensors and more sophisticated programming to enable your system to perform a more complex task of your choice.

At each stage, you will be required to use a new skill, such as building unbreakable Lego structures, programming the controller board, or not blowing up your batteries. For each of these tasks, this handout has a section to assist you.

The Kit

Your kit should have the following components, each of which is described in this handout:

- **Legos**

  Building indestructible Lego structures, making gear reductions to reduce speed and increase torque, and other Lego arts are covered in the handout, “Building with Legos”

- **2 Motors**

  Some notes about gearing, speed and torque are provided in Section 2, “Motors and Gearing”

- **1 Motor Battery Pack and Charger**

  Your robot will run its motors from three lead-acid batteries. These batteries are not standard D cells, and have very low internal resistance. This allows them to provide a lot of current to your robot’s motors, but also makes them dangerous if shorted or misused. The correct use of these batteries and charger is probably the most important thing in this handout, and is covered in Section 1, “Batteries and Battery Charger”

- **1 Motor Switch**

  This is a small board that will allow you to run your motors directly off the battery pack to test the design of your robot’s base. There is more detail about it at the end of Section 2.

Later in the semester (in a week or two) you will get more parts for your kit as you need them. A brief description of those parts follows, but you will get more in-depth information on them when you get them.

- **Sensors**

  Each team gets two light sensors and two bump sensors. An additional handout will cover the operation of these sensors and others that are available in the Lego Lab.

- **6.270 Board and 4 AA Batteries**

  This computer on a board, specifically designed to make reading your robot’s sensors and controlling its motors easy, will be fully detailed in a handout when you pick up your board. It uses 4 AA batteries, which we will supply for you.

- **Serial Line**

  This is the connection between your 6.270 and the Sparcs for downloading programs. Downloading programs will be explained in a future handout.

1. Batteries and Battery charger

Powering your robot

Your robot depends upon two types of batteries to operate. The computer board is run by four standard alkaline or NiCad AA batteries. These batteries run the low current portion of your robot, such as the computer, LCD panel and sensors. The motors the computer board will control were given to us by Mabuchi Motor and are small, low speed and high torque. They also may require a large amount of current, especially if your robot is pushing something or has gotten stuck, so a separate battery system is needed. The motor batteries consist of a pack of three rechargeable lead acid batteries. The battery pack also plugs into the computer board, which turns the current from the battery pack on and off at the motor outputs under the control of your program. **Though the battery pack looks like three standard D batteries, it is similar to a small car battery, and the precautions outlined below should be taken when handling it.**

Improper use or charging of the batteries could lead to shorting or overloading the batteries, which means they could leak or explode. Battery acid is nasty stuff, so let's leave it in there. When using the batteries, the main caution is not to let them short. While there is a fuse wire to minimize any discharge of this sort, a battery short can cause burns or acid leaks. Please read this section carefully to avoid this.

Lead-acid batteries

The large battery pack is made up of three special lead-acid cells which have very low internal resistance, allowing them to provide a large amount of current to power your motors or lamps. These batteries should be connected to the controller board at the jack next to the power switch and the motor outputs.

Batteries that have low internal resistance can be dangerous to work with, becuase if the cell is shorted, huge currents can flow. These currents generate a large amount of heat, melting the insulation from the battery pack wires and potentially causing the batteries to burst. To reduce the liklihood of this situation, the connections between the cells in your battery pack contain a fuse. If too much current is drawn from the battery pack because of a short, the fuse will be destroyed within a few seconds, leaving no path for current flow. Regardless, you should treat your battery pack carefully. **Be sure that you don't short your batteries by connecting the positive and negative terminals!!!**

Charging lead-acid batteries

Since motor and onboard lamps can draw a large amount of current, the lead-acid battery pack is rechargeable. Each robot kit contains a charger which is specifically designed to charge a 6v battery pack in a few hours. To charge your battery pack, simply plug the batteries into your charger and plug the charger into a wall outlet. The charger will stop charging when the battery pack reaches 6v so you may leave your batteries charging over night.

There's no need to completely drain the batteries before charging them, so you may want to use the charger to top off the battery charge whenever your batteries are not in use. If you need a replacement battery pack while yours are charging, there should be a couple on the black shelf in the LegoLab. See a TA about borrowing a battery pack if necessary.

Charger warnings

Two years ago we purchased new chargers which are safer than those usually used in a 6.270 robot course. Unfortunately, not all of them returned over the last two years so not everyone has one. Specifically, you have an old charger if your charger has switches on the end where you plug in the batteries. If you have an old charger, always leave the switch on the SLOW setting.

The new chargers should be able to be left plugged into your battery pack for several days without overheating, and have no exposed wires or hot external parts. However, charging lead-acid batteries can be dangerous if done improperly. Please observe the following precautions:

- Treat your charger and battery pack carefully and inspect them for broken or frayed wires
- Carefully check the charger body occasionally to ensure it is not overheating
- Do not charge the batteries upside down or smoke near the batteries when charging
- Plug the charger into the batteries before you plug the charger into the wall, so your hands and face are away from the batteries when the power goes on.

It's better to be a little scared of these batteries, which are very safe if handled properly, than to be handling them sloppily right when that one in a million unprovoked battery burst happens.

2. Motors and Gearing

In each kit are two motors. Later in the semester, if you need more motors for a special project, talk to a TA. Each motor has a flat Lego piece epoxied to the top and bottom, so you can integrate the motor into your Lego platform, and a Lego axle glued onto the motor output shaft, so you drive a Lego gear with the motor. The motor drives a wheel by placing the wheel on an axle with a gear, which then meshes with the gear on the motor shaft. Of course, the motor and axles should be well supported by the structure of your robot.

While you are welcome to try any drive arrangement, the simplest to build and control is differential drive. In this scheme similar to a bulldozer or tank, the robot has one drive wheel on either side and a skid or third wheel on a caster for support. Each motor is geared to one drive wheel, and differences in motor speed controls steering: if both wheels turn at the same speed, the robot goes straight; if the wheels turn in opposite directions, the robot turns in place.

Gearing

The power delivered by a motor is the product of the speed at which its output shaft is turning and the torque, or push, which is required to turn the shaft at that speed. Gearing allows the motor output shaft to turn a second shaft at a higher or lower speed. Since the power remains constant (not withstanding any losses to friction in the gear train) the amount of torque supplied at the second shaft changes proportionately. In fact, the motor of a trailer truck and that of a race car produce roughly the same power, while with only a few times the power NASA's tracked space shuttle transporter carries 17 million pounds. The race car's motor is simply geared to produce low torque at very high speeds, while the transporter is geared for unimaginable torque at up to one mile per hour.

If not geared down at all, the motors supplied with your kit will probably not even supply enough torque to move your robot when fully loaded with batteries and sensors. If efficiently geared down several hundred times, they could probably supply enough torque to pull you over. Exactly how far to gear down your robot is something you will have to determine by experimentation with the gears and axles supplied in your kit. If geared too high, the robot will not have enough torque to overcome rough surfaces or may move too quickly to be easily controlled. If geared too low, the robot may move at an annoyingly slow pace. In addition, Legos are flexible and imprecise, so the more gears that are used the more power will be lost to friction and the greater the liklihood the gear train will jam or break. For examples of gearing strategies take a look at the “Building With Lego” section.

The Motor Switch

Also in the kit is a motor switch, a small circuit board with four switches and with connectors similar to the motor ports on the 6.270 . It allows you test your robot with the motors running at full power before you have added your controller board and programs to your system. Simply connect the motor to the connector on one of the switches and plug in the battery pack, and you can run your motors in either direction. Be careful not to short the connections on the bottom of the circuit, and mind the diodes opposite the motor connectors as they heat up a fair bit.

3. Building with Legos

Each kit contains a few hundred Lego pieces which can be used to build a wide variety of robot platforms. Unlike the Legos commonly sold in stores, these kits were assembled from the Lego Technic collection. Many of the Lego blocks have holes that are used to support cross braces or axles, and there are a variety of parts such as gears, universal joints and bracing pins which you may not have used with Lego as a child. To help you build an indestructible, properly geared robot as quickly as possible, a section on Lego design from the MIT 6.270 robot course is attached to this section.

Extra Pieces

The legos in your kit should be enough for many projects, but are not particularly specialized. If you want to seek out new directions in Lego engineering, or need a few extra pieces here or there, there are an assortment of surplus and specialized pieces in the LegoLab. There will also be a sign-out sheet so that we can keep track of who has extra and specialty pieces. Please use it. When taking extra Legos, please consider that they are relatively rare, or we would have given them to everyone. Take only those parts that you intend to use. If you finish with something or find it is not useful, put it back so that someone else will get the chance to use it. Also, please make sure your robot platform is robust before taking the time to festoon it with miniature Lego radar dishes and jet pods.

Other Rules

Remember that your robot kit has to be turned in at the end of the semester, so irreversible construction techniques such as gluing or carving Lego blocks are forbidden. If you are having problems integrating non-Lego parts such as custom-made sensors into your robot, you may tape, rubber band, bolt or putty them to your robot. Keep in mind, however, that your robot design should allow you to replace both sets of batteries easily and must survive collisions and other abuse without repair.

Certain exceptions may be made to the gluing rule if you are interested in carefully building and documenting a customized sensor or other part which can be used in future classes. Please speak to a TA before undertaking such a project.