16x62 Robot User's Manual

Introduction

Welcome to 16x62: Robot Programming Laboratory. This manual is your guide to the Nomad Scout robots that you will be programming this semester. This guide details the robot hardware, operation, communication, and user software.

Robot Hardware Description

Mechanical System

The Nomad Scout mobile base is a differential direct drive, non-holonomic system (can't go sideways) with zero gyro-radius (can turn on a dime). A dedicated 68332 board performs all the hard work, with help from an hc6811 that controls the 16 sonars. The base has a maximum translational speed of about 30 inches per second (approximately) and a maximum rotational speed of 50 degrees per second.

Electrical System

Each robot uses two large and heavy sealed 12-volt batteries. We *estimate* the maximum running time of a robot with fully charged batteries to be about 12 hours. This is based on the fact that the processors use a total of only 500 milliamps. But the batteries are sealed lead-acid batteries. If they are fully depleted (deep-cycled), they won't last through this semester. **Avoid using a robot for more than six hours straight.** The batteries can last hundreds of shallow cycles. Do not remove the batteries from the scouts and/or swap batteries between scouts. Ever.

The scout has a very nice feature: a built-in charging unit. To charge the scout, simply plug it into the wall. There is one huge catch: **THE ROBOT MUST BE ON FOR THE CHARGING CIRCUIT TO WORK**. This means no matter how long you leave it plugged in, if the scout is off, charging will not happen. So, at night, when you tuck the scouts in, leave them plugged in and on.

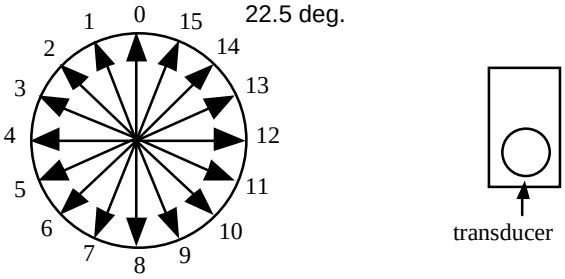
Like R2D2, the scouts communicate with you by beeping. When you plug them in (and they're on!), they will emit two short beeps. Then, if the batteries are half-full, you'll hear two long beeps. If the batteries are totally full, you'll hear 4 short beeps. **If you hear a continuous beep during operation, that's the low battery warning beep.** Plug the robot in (don't turn it off!!!) immediately.

Of course, the Toshiba notebook housed on top of the robot runs off its own battery (or ac adaptor). The Toshiba battery only lasts about 3 hours. In a cruel twist of fate, the Toshiba batteries are Lithium, which means deep-cycling them is good! One really nice feature of the Toshiba's is, if you close the lid, the monitor turns off (after a high-pitched

squeal) but your program keeps running! To preserve your notebook battery, close the lid whenever you don't need to see what's on the screen This makes a **huge** difference to the battery's discharge rate. Also, whenever you and your robot aren't moving, plug that portable into the wall. There are extension cords for this purpose awaiting you in the Lab. Important points to remember: ALWAYS leave the portables in the Lab overnight (they really, really don't want to go home with you).

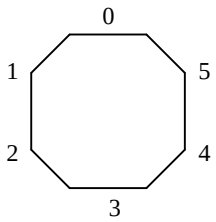
The Sonar System

The round gold 'coins' are the robots' only range sensors: sonars. These transducers provide surprisingly accurate range information from 6 inches to 255 inches. Each Polaroid Tranducer has a beam width of about 25 degrees, although there may be variation in this beam width, or half cone, from sonar to sonar. A single sonar unit works as follows: The transducer emits a series of 16 pulses at a frequency of 49.4 KHZ. The echo receiver circuitry is disabled, or "blanked," for about 1 millisecond during and slightly beyond this emission phase so that the initial pulses are not detected as echoes. This blanking has a serious effect at close ranges, known as double echo. If the robot is closer than about 3 inches to an object, then the return echo from that object could occur while the echo receiver circuitry is still blanking. Therefore, the object might appear to be farther away than it actually is. Also, a sonar signal will bounce away instead of returning if it hits a smooth object at a shallow angle of attack-- in effect, it can glance off coherently. This will also result in the strike distance being larger than it should be.



The Bumper System

The Scout's bumpers are not great—so consider yourself warned. There are six discrete, pressure-sensitive strips, arranged as in the following diagram.



The value of the bumper state communicates which bumpers depressed. The lowest order bit represents the status of bumper 0 (0 for no contact, 1 for contact), and so on. For example, the bumper state 0 means that the scout is touching nothing. **Checking for bumper state to be nonzero is about all you'll need to do for at least the first 50% of this course.**

Hardware Failures

If you suspect a hardware problem, send email immediately to illah@cs. Always use common sense. For instance, if the wheels of the robot are clicking violently or the robot is smoking profusely, stop using it to avoid further damage until we take a look at it.

Robot Operation

Turning Robots On

Each robot has a grey push-power switch. Simply turn the robot on using this switch. You'll notice that when you turn the robot on, nothing dramatic happens. The sonars won't even begin echoing. But the small green power LED turns on. To turn on the sonars and move the robot requires software "on" commands from the portable. That is where the fun begins.

If the robot's emitting a high-pitch squeal as it sits rammed into a wall, the motors are being overdriven. Turn the robot off using the red push-switch, then stop your program and debug away!

Moving the Robot Manually

You should never try to move the robot manually when the portable is sending motion commands to it. Doing so will cause damage to the robot and possibly to you. To push the robot around, stop sending commands to the robot and wait a few seconds to ensure that the command has timed out. Another way to move the robot is to turn it off before pushing, to ensure that the wheels are not locked. Pushing the robot around is perfectly fine, but if you want to show off your muscle, you can even lift the robot. Please, don't lift the robot with the portable on top of it over long distances, then cause both to come crashing down.

Now there *is* a solution to pushing the robot manually or lifting it: it's called the joystick! Just plug it in, turn the robot on, and away you go. Catch: when trying to use the joystick, as a dead-man's switch, you must be pushing down on one of the buttons beside the joystick. It doesn't matter which one.

Communication

The Setup

Each robot needs a portable as its brain. The robot and portable talk to one-another via the serial-port on the left side or back side of the portable, and the port labeled "host" on the robot. **This means you must plug the serial plug from the robot "host" port into the serial port on the portable.** I guarantee you that, the second time you think the robot's broken, you actually just forgot to plug the serial ports together (the first time, you forgot to turn it on).

On every portable, our class directory is "Robot User." Each group should create their own folder within the Robot User folder. In your group's folder, you may do whatever you want. Further down this manual, we tell you how to set up your own Symantec Visual Cafe JAVA development environment in your folder. Do that. The development environment that you create will include a source class called "RobotController." This is the code for the low level interface that allows the portable to talk to the robot. This JAVA code actually calls a C dynamic link library (cscout.lib and cscout.dll) where the goodies are really implemented. You can look at all the C side source code, if you care, in the Robocode site off of Illah's website.

Please remember to back up your work. Every laptop has a disk drive in its belly, and you have received a team disk for this class. Java code doesn't take up much room; thre is no excuse for you to lose your code. Also, there is no guarantee that, from one work session to the next, you'll be able to use the same notebook. So you probably want your code on disk anyway.

From You to the Robot: the simple version

The software section below will tell you how to create your robot development environment in Visual Cafe. Once that is done, your most important command to the robot is the function: **`setVel(leftwheel, rightwheel)`**. This function (like the several other robot commands) sends a stream of characters via the serial port to the robot. This stream of characters encodes your intended rotational velocities for the two wheels of the robot, in tenths of inches per second. For instance, `setVel(200,200)`, would mean, 'move forward at 20 inches per second.' The range of `velocity` is an INTEGER between -300 and 300 (a negative `velocity` indicates backward movement). The indoor spaces are very confined; thus, you should not specify `velocities` anywhere near 300 or -300 in any case.

The behavior of the robot when it receives a command of the form `setVel()` is precisely as follows (in this order):

1) Updates sonar and encoder values from the robot into `stateArray`.

2) Begins executing, *simultaneously*, the specified wheel speeds.
3) Continues executing this motion until the robot receives a new `command of any kind` or until the command times out. This timeout defaults to the value: 2 second. However, you have the power to change this default (to accomplish such feats, refer to the *For Experts Only* section of this manual, which describes all available robot commands.

You need to use two other commands at a minimum. Please note-- you can use only the four commands described in this section and will be able to complete all lab assignments and even win the final contest. You do not need to look at the *For Experts Only* section to do well in this course. I may be wrong.

The last two commands are the easiest to describe. To use the sonars, you'll need to turn them on. Do so by issuing the **`turnSonarsOn()`** command. To turn them off when they get on your nerves, use the **`turnSonarsOff()`** command. This is a good idea in general because it also saves battery power. When your program exits, it would be a good idea if it automatically send a **`SonarsOff()`** command to the robot, but if the robot doesn't receive this command, you can turn off the sonars by physically powering down the robot.

By the way, we *are* using a completely object-oriented environment. So, there is a class called RobotController. Strictly speaking, the way you use the above commands is by creating an instance of RobotController and calling it something like myDumbRobot. Then, you tell the robot to move by typing in myDumbRobot.setVel(20,20). Et cetera.

From the Robot to You

When you issue a command to the robot, the State_Array slot in your instance of RobotController is updated. The following is your guide to interpreting stateArray.

Note that we tell you more than you need to know for this class about this state vector. In particular, you will probably use the sonar readings and the integrated encoder/position readings, but you may never use the measured velocity readings or the motor status reading. Interesting idea: you can use the motor velocity readings to see if you're pushing against a wall or another robot!

NOTE: stateArray is an array of int's, so you access its elements using the C-based syntax, stateArray[index].

`Return Value`

The first element of the stateArray [0] is the C-side return value of the last executed command. You can ignore this unless you're a cool hacker.

Sonar Values - index 1 - 16

These are the 16 sonar sensor readings. Each element is an integer between 5 and 255, where the integer is precisely the number of inches from the sonar transducer to the object that caused an echo.

The sonars are arranged in a counterclockwise direction with the sensor in the twelve o'clock position being index 1 (element 1 of the array) and the sensor at the one o'clock direction of the robot being element 16 of the array.

Integrated Position Encoders - index 17 - 19

These provide the robot's idea of its position based upon its encoder values. 17 provides position along the x-axis, 18 provides position along the y-axis, 19 provides the angle of the robot with respect to their orientation when the robot was turned on. When you turn the robot on, the encoders are all set to zero. That means that the robot resets its Cartesian grid to be lined up with its current orientation, whatever that may be—with the robot pointing straight up the X axis, with Theta = 0.

As the robot moves, the encoders show the robot's position and orientation on that grid using tenths of inches and tenths of degrees. The range of values for the robot's encoded angle is from 0 to 3599. X position and Y position can have positive or negative values, depending on the quadrant that the robot is in within its make-believe Cartesian grid. The x-axis is aligned with the 0 degree orientation -- if you think about this a bit, it makes perfect sense.

There's an important reason why you shouldn't blindly trust your encoders: they are subject to compounding error-- the wheels slip asymmetrically on the carpet. Once the rotational encoder is off even a little, the entire x-y position will become more and more inaccurate as the robot moves.

You'll be accessing these elements often, and we wanted you not to have to remember numbers like 17, 18 and 19. So we've made static constants for you: XPOS, YPOS and THETA (among others). So, for instance, to check your robot's angle, if your RobotController instance is named RC, you'd type:

```
RC.stateArray[RC.THETA]
```

Wheel Velocities -- 20 and 21

These are the current translational velocities of the robot's wheels. You probably will never look at these, although it might be fun to look at them after issuing a command to see how well the built-in PID motor controller matches the actual velocities to the ones you requested. Again, we've defined constants for you: RVEL and LVEL.

```
Bumper Status -- 22
```

This is another really important sensor. The bumper status will be zero if none of the bumpers are depressed. If any bumper is depressed, this will be nonzero. By the way, there are really 6 separate bumpers on the robot, and each one can be on or off. And from this one number you can figure out which are depressed and which aren't. But don't you bother with that just yet.

User Software

You will be writing Java code in Symantec Visual Cafe Version ?.?. You need to create your own project directory, which will include all the interface code that we have written to enable your computer-robot communication.

To set up your own team directory, make a directory in C:\16x62 for your team, then copy the directory, C:\16x62\SampleBot, into your directory.

WARNING: Copy these files, don't move them!!! To select multiple files, hold down the Ctrl key. To copy instead of moving, just use Ctrl-C and Ctrl-V rather than drag-and-drop. If you move the files and wreak havoc, we will make you brand new a fresh 9 volt battery.

Now we are going to walk you through the code in SampleBot and lead you through a tour of how to use this stuff. To do this tour properly, you need a robot and a portable (duh).

<u>WARNING</u> Before you do this tour, it would do you well to go through our Java Primer (and set up the brainless calculator). We will assume that you have already done that when you do the following!

Let the Tour Begin

Let's go to the SampleBot directory in your team's directory. Look at the files. The ones you care about, and what they are:

> **Applet1.java** This is the java code for the outermost shell that we use. We always wrap things in an applet so that, someday, you can put your code on the web.
>
> **Cscout.dll, Cscout.lib** This is the C code that we link to your program to enable Java to talk to the robots via serial link.

Robot.java This is the sample code that we have written to control the robot. When you write your own Robot.java, you will have the robot doing your own things!

SampleBot.vep This is the project file that you double-click on to get the project open.

SonarConsole.java Simple code that allows you to draw a little graphic of the sonar hits on the screen.

Okay. Now start up SampleBot in the development environment by double-clicking on SampleBot.vep.

The project window at left shows the main ingredients: Applet1 is trivial, RobotController is what we supply for talking to the robot, SonarConsole is what we supply for drawing sonars and Robot is where you put your code.

Now double-click on Robot so we can show you key features of your coding environment.

Robot - Form Designer shows you the layout of our sample Robot Java window. We've put two buttons on this window and by looking at the code we've written for these two buttons, you'll learn just about everything you need to know to start hacking robotics.

Double click on the Form Designer, anywhere, to look at the source Java code.

As you can see, this is just a subclass of Frame. The extra global variable we added is a RobotController, RC. In the constructor, after the auto-generated code, you will see that we make this window visible, we instantiate RC to be a RobotController instance, and we open the serial port of the portable so it can gab with the robot.

Now choose the button2's MouseClick event code. This is the code that runs when you hit the button, "Run Sonar Loop." The interesting thing here is, first of all, that we create an instance of the one other class we're giving you: SonarConsole. This instance literally pops up a little window in which the sonar values are drawn. The method, DrawSonars() does the job, and takes as an argument the RobotController where SonarConsole can find the stateArray (where the sonar values are stored).

So, this code opens up a sonar drawing window, turns on the sonars of the robot, then goes into a loop, updating the stateArray each time, printing out the front sonar's value to the Messages window, and redrawing the sonars. In the meantime, it checks to see if the bumper is in. If it is, the whole program exits (to show you how to use exit()). It also waits half a second between subsequent cycles.

Connect up the portable to a robot and try this program out. Notice that in the Messages box you can see the front sonar's value printing out. Play with the sonars on the robot (hear them clicking?) and try stopping the program with the bumper. Notice that the

sonars stop too. That's because we were careful to turn them off in the program, right before the System.exit(0) call.

Note: if you couldn't have stopped the program with the bumper, the only way you could have terminated it would have been with Ctrl+Alt+Del. It's a pain, we know. The deal is, this is truly a single-threaded machine—for simplicity and to ensure that your robot control software gets plenty of processing cycles. So, once you're running an infinite loop, none of the other buttons on your program work any longer.

Now let's look at the MouseClick code for button1 ("Run Sample Program"). Go ahead and run this program—but make sure the robot has some space in front of and behind it, and unplug the portable and robot from the wall. The robot's looking at the values of the front-most and rear-most sonars, and moving away slowly from whichever is shorter. Hit the bumper and the loops stops, returning you to your "Robot" console. You can see how the front and back sonar values are retrieved from stateArray. Done deal.

Goodies

There are actually quite a few goodies that we'll give you over the course of the quarter. Some are edible, some are good functions to do cool things like get your robot to talk to another robot (not so edible). So look for them!

For Robot Experts Only (not really)

The following is a complete description of all robot interface functions available to send commands to the robot. They all update stateArray, identical to `setVel`. They are all methods in RobotController.

`int serialOpen()`
Open the serial port of the portable so it can communicate with the robot.

`int serialClose()`
Close the serial port of the portable. Now why would you want to do this?

`int turnSonarsOn()`
Turns all 16 sonars on in some nice firing pattern and firing speed. Use this at first. NOTE: this method actually just calls **configureSonars**() with delay of 4 and a simple circular firing pattern for all the sonars. Literally just a call to **configureSonars**!

`int turnSonarsOff()`
Turn all the sonars off when they get annoying.

`int GS()`
Get the stateArray all updated. You do NOT need to call this function if you call any other robot command function, since stateArray is updated when any robot communication is performed.

`int setVel(int leftVel, int rightVel)`
Your bread-and-butter. Set the velocities of the left and right wheels, in tenths of inches per second.

`int killMotors()`
This command is a much more graceful way of causing the robot to stop than `setVel(0, 0)` because the latter command causes the motors to freeze while `killMotors` simply cuts off power and allows the robot to coast to a halt.

`int setAccel(int leftAccel, int rightAccel)`
Configure the acceleration of the left and right wheels of the robot (make it the same please!), in tenths of inches per second per second. Default is: about 100.

`int configureSonars(int firingRate, int[] sonarOrder)`
You can use this command to specify how long the robot should wait between firing sonars and which sonars to fire and in which order. The firing rate is a number specifying how many 4 millisecond intervals the robot should wait between firings. Set it to a number between 2 and 254. *Hint:* use 4 or more. The sonarOrder is an array containing exactly sixteen integers. The order of the numbers indicates the firing order. If you want to fire only the front three sonars, sonarOrder would be {0,1,15,255,0,0,0,0,0,0,0,0,0,0,0,0}. As you can now guess, after you put in all the sonars you care about, put in a 255. Make sure the whole array is 16 long (buffer it with zeroes). If you want just the back sonar to fire, here's what you do:

```
int[] sonars = new int[16];
```

```
sonars[0] = 8;
sonars[1] = 255;
sonars[2] = 0;
sonars[3] = 0;
      ...
sonars[15] = 0;
configureSonars(4, sonars);
```

Note that the sonars' numbers are 0 through 15. 0 is straight ahead, 15 is 1 o'clock. Yes, I know, in State_Array, they're index numbers 1 through 16. But the sonars' actual numbers, for purposes of ordering them in ConfigureSonars, are 0 - 15. Furthermore, note that if you call turnSonarsOn() after calling this method, then your configuration will be clobbered. ConfigureSonars() actually causes the sonars to be "on" when used right, so never call turnSonarsOn() afterwards!

`int setTimeout(int timeout)`

This command allows you to reset the amount of time after which a velocity command is thrown away and the robot "limps" it if received no further communication. The default is two seconds. Remember, the best way to override a velocity command is to simply send another one! The parameter is an integer number of seconds. We believe if you set timeout to be 0 then a command never times out. In terms of safety, that's a bad idea!