

Robot Remote

In this chapter, you'll create an app that turns your Android phone into a remote control for a LEGO MINDSTORMS NXT robot. The app will have buttons for driving the robot forward and backward, turning left and right, and stopping. You'll program it so that the robot automatically stops if it detects an obstacle. The app will use the Bluetooth capabilities of the phone to communicate with the robot.

LEGO MINDSTORMS robots are fun to play with, but they are also educational. Afterschool programs use robots to teach elementary- and middle-school children problem-solving skills and introduce them to engineering and computer programming. NXT robots are also used by kids aged 9–14 in FIRST Lego League robotics competitions.

The NXT programmable robotics kit includes a main unit called the NXT Intelligent Brick. It can control three motors and four input sensors. You can assemble a robot from LEGO building elements, gears, wheels, motors, and sensors. The kit comes with its own software to program the robot, but now you can use App Inventor to create Android applications to control an NXT via Bluetooth connectivity.

The application in this chapter is designed to work with a robot that has wheels and an ultrasonic sensor, such as the Shooterbot robot pictured here. The Shooterbot is often the first robot that people build with the LEGO MINDSTORMS NXT 2.0 set. It has left wheels connected to output port C, right wheels connected to output port B, a color sensor connected to input port 3, and an ultrasonic sensor connected to input port 4.

Figure 12-1.



What You'll Learn

This chapter uses the following components and concepts:

- The `BluetoothClient` component for connecting to the NXT

- The `ListPicker` component to provide a user interface for connecting to the NXT
- The `NxtDrive` component for driving the robot's wheels
- The `NxtUltrasonicSensor` component for using the robot's ultrasonic sensor to detect obstacles
- The `Notifier` component for displaying error messages

Getting Started

You'll need Android version 2.0 or higher to use the application in this chapter. Also, for security reasons, Bluetooth devices must be paired before they can connect to each other. Before you get started building the app, you'll need to pair your Android with your NXT by following these steps:

1. On the NXT, click the right arrow until it says Bluetooth and then press the orange square.
2. Click the right arrow until the word Visibility appears and then press the orange square.
3. If the Visibility value is already Visible, continue to step 4. If not, click the left or right arrow to set the value to Visible.
4. On the Android, go to Settings.
Steps 5–7 might vary slightly depending on your Android device.
5. Ensure that Bluetooth is ON.
6. Click "Bluetooth" and then "Search for devices."
7. Under "Available devices," look for a device named "NXT." If you've ever changed your robot's name, look for a device name that matches your robot's name instead of "NXT."
8. Click "NXT" or your robot's name.
9. On the NXT, you should see a prompt for a passkey. Press the orange square to accept 1234.
10. On the Android, you should see a prompt for the PIN. Type 1234 and then press OK.
11. Your robot and your Android are now paired.

Connect to the App Inventor website at ai2.appinventor.mit.edu. Start a new project and name it "NXTRemoteControl", and set the screen's title to "NXT Remote"

Control”. Click Connect and set up your device (or emulator) for live testing (see <http://appinventor.mit.edu/explore/ai2/setup> for help setting this up).

Designing the Components

For this app, we’ll need to create and define behaviors for both non-visible and visible components.

NON-VISIBLE COMPONENTS

Before creating the user interface components, you’ll create some non-visible components, listed in *Table 12-1* and illustrated in *Figure 12-1*, to control the NXT.

Table 12-1. Non-visible components for the Robot NXT controller app

Component type	Palette group	What you’ll name it	Purpose
BluetoothClient	Connectivity	BluetoothClient1	Connect to the NXT.
NxtDrive	LEGO® MINDSTORMS®	NxtDrive1	Drive the robot’s wheels.
NxtUltrasonicSensor	LEGO® MINDSTORMS®	NxtUltrasonicSensor1	Detect obstacles.
Notifier	User Interface	Notifier1	Display error messages.



Figure 12-2. The non-visible components displayed at the bottom of the Component Designer

Set the properties of the components in the following way:

1. Set the BluetoothClient property of NxtDrive1 and NxtUltrasonicSensor1 to “BluetoothClient1”.
2. Check BelowRangeEventEnabled on NxtUltrasonicSensor1.
3. Set the DriveMotors property of NxtDrive1:
 - If your robot has the left wheel’s motor connected to output port C and the right wheel’s motor connected to output port B, the default setting of “CB” doesn’t need to be changed.
 - If your robot is configured differently, set the DriveMotors property to a two-letter text value, where the first letter is the output port connected to

the left wheel’s motor and the second letter is the output port connected to the right wheel’s motor.

4. Set the SensorPort property of NxtUltrasonicSensor1.
 - If your robot’s ultrasonic sensor is connected to input port 4, the default setting of “4” doesn’t need to be changed.
 - If your robot is configured differently, set the SensorPort property to the input port connected to the ultrasonic sensor.

VISIBLE COMPONENTS

Next, let’s create the user interface components shown in *Figure 12-2*.

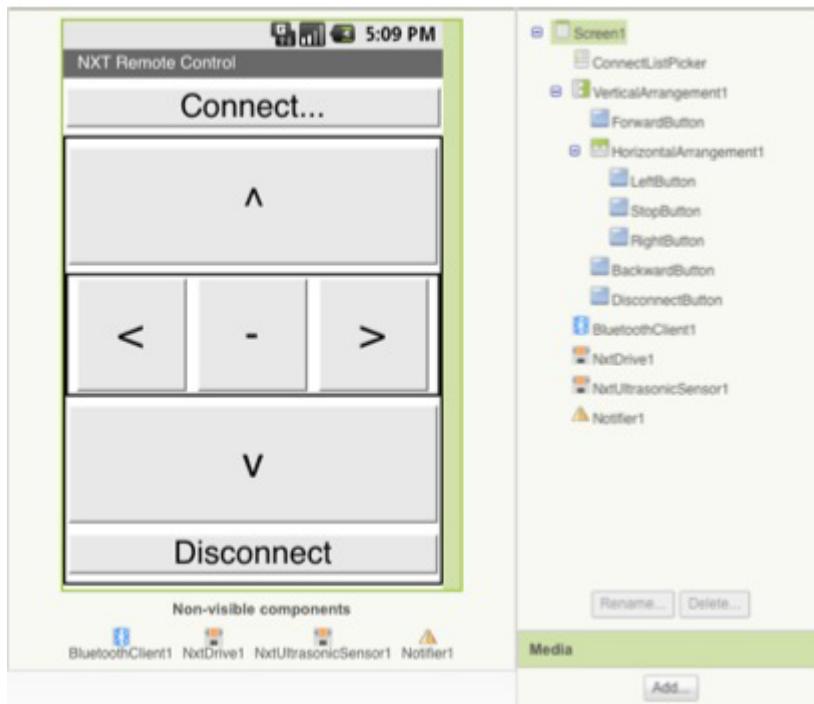


Figure 12-3. The app in the Component Designer

To make the Bluetooth connection, you’ll need the unique Bluetooth address of the NXT. Unfortunately, Bluetooth addresses consist of eight two-digit hexadecimal numbers (a way of representing binary values) separated by colons, making them very cumbersome to type. You won’t want to type in the address on your phone every time you run the app. So, to avoid that, you’ll use a `ListPicker` that displays a list of the robots that have been paired with your phone and lets you choose one. You’ll use buttons for driving forward and backward, turning left and right, stopping, and

disconnecting. You can use a `VerticalArrangement` to lay out everything except for the `ListPicker`, and a `HorizontalArrangement` to contain the buttons for turning left, stopping, and turning right.

You can build the interface shown in *Figure 12-2* by dragging out the components listed in *Table 12-2*.

Table 12-2. Visible components for the Robot NXT controller app

Component type	Palette group	What you'll name it	Purpose
ListPicker	User Interface	ConnectListPicker	Choose the robot to connect to.
VerticalArrangement	Layout	VerticalArrangement1	A visual container.
Button	User Interface	ForwardButton	Drive forward.
HorizontalArrangement	Layout	HorizontalArrangement1	A visual container.
Button	User Interface	LeftButton	Turn left.
Button	User Interface	StopButton	Stop.
Button	User Interface	RightButton	Turn right.
Button	User Interface	BackwardButton	Drive backward.
Button	User Interface	DisconnectButton	Disconnect from the NXT.

To arrange the visual layout as shown in *Figure 12-2*, place `LeftButton`, `StopButton`, and `RightButton` inside `HorizontalArrangement1`, and place `ForwardButton`, `HorizontalArrangement1`, `BackwardButton`, and `DisconnectButton` inside `VerticalArrangement1`.

Set the properties of the components as follows:

1. Uncheck `Scrollable` on `Screen1`.
2. Set the `Width` of `ConnectListPicker` and `DisconnectButton` to “Fill parent.”
3. Set the `Width` and `Height` of `VerticalArrangement1`, `ForwardButton`, `HorizontalArrangement1`, `LeftButton`, `StopButton`, `RightButton`, and `BackwardButton` to “Fill parent.”
4. Set the `Text` of `ConnectListPicker` to “Connect...”.
5. Set the `Text` of `ForwardButton` to “^”.
6. Set the `Text` of `LeftButton` to “<”.
7. Set the `Text` of `StopButton` to “-”.
8. Set the `Text` of `RightButton` to “>”.

9. Set the Text of `BackwardButton` to “v”.
10. Set the Text of `DisconnectButton` to “Disconnect”.
11. Set the `FontSize` of `ConnectListPicker` and `DisconnectButton` to 30.
12. Set the `FontSize` of `ForwardButton`, `LeftButton`, `StopButton`, `RightButton`, and `BackwardButton` to 40.

In this application, it makes sense to hide most of the user interface until the Bluetooth is connected to the NXT. To accomplish this, set the `Visible` property of `VerticalArrangement1` to `hidden`. Don't worry—in a moment, we'll make the application reveal the user interface after it connects to the NXT.

Adding Behaviors to the Components

In this section, you'll program the behavior of the app, including:

- Letting the user connect the app to a robot by choosing it from a list.
- Letting the user disconnect the app from a robot.
- Letting the user drive the robot by using the control buttons.
- Forcing the robot to stop when it senses an obstacle.

CONNECTING TO THE NXT

The first behavior you'll add is connecting to the NXT. When you click `ConnectListPicker`, it will show a list of the paired robots. When you choose a robot, the app will make a Bluetooth connection to that robot.

DISPLAYING THE LIST OF ROBOTS

To display the list of robots, you'll use `ConnectListPicker`. A `ListPicker` looks like a button, but when it's clicked, it displays a list of items from which you can choose one. You'll use the `BluetoothClient1.AddressesAndNames` block to provide a list of the addresses and names of Bluetooth devices that have been paired with the Android. Because `BluetoothClient1` is used with NXT components, it automatically limits the devices included in the `AddressesAndNames` property to those that are robots, so you won't see other kinds of Bluetooth devices (such as headsets) in the list. *Table 12-3* lists the blocks you'll need for this step.

Table 12-3. Blocks to add a ListPicker to the app

Block type	Drawer	Purpose
ConnectListPicker.BeforePicking	ConnectListPicker	Triggered when ConnectListPicker is clicked.
set ConnectListPicker.Elements to	ConnectListPicker	Set the choices that will appear.
BluetoothClient1.AddressesAndNames	BluetoothClient1	The addresses and names of robots that have been paired with the Android.

How the blocks work

When ConnectListPicker is clicked, the ConnectListPicker.BeforePicking event is triggered before the list of choices is displayed, as shown in *Figure 12-3*. To specify the items that will be listed, set the ConnectListPicker.Elements property to the BluetoothClient1.AddressesAndNames block. ConnectListPicker will list the robots that have been paired with the Android.

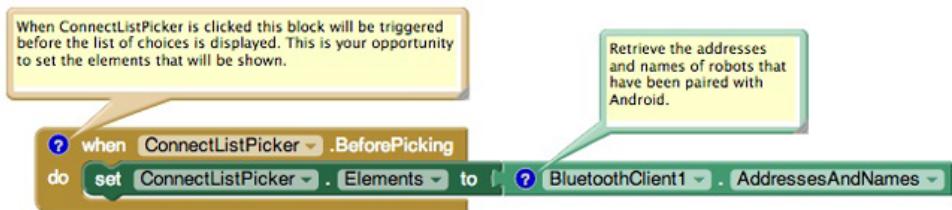


Figure 12-4. Displaying the list of robots



Test your app On your phone, click “Connect...” and see what happens. You should see a list of all the robots your phone has been paired with. If you just see a black screen, your phone hasn’t been paired with any robots. If you see addresses and names of other Bluetooth devices, such as a Bluetooth headset, the BluetoothClient property of NxtDrive1 and NxtUltrasonicSensor1 has not been set properly.

MAKING THE BLUETOOTH CONNECTION

After you choose a robot from the list, the app will connect to that robot via Bluetooth. If the connection is successful, the user interface will change. ConnectListPicker will be hidden, and the rest of the user interface components will appear. If the robot is not turned on, the connection will fail and an error message will pop up. You’ll use the BluetoothClient1.Connect block to make the connection. The

`ConnectListPicker.Selection` property provides the address and name of the chosen robot. You'll use an `if then` block to test whether the connection was successful. We'll add `else` to the `if then` block, so it will have three different areas where blocks are connected: `if`, `then`, and `else`. The `if` area will contain the `BluetoothClient1.Connect` block. The `then` area will contain the blocks to be executed if the connection is successful. The `else` area will contain the blocks to be executed if the connection fails.

If the connection is successful, you will use the `Visible` property to hide `ConnectListPicker` and show `VerticalArrangement1`, which contains the rest of the user interface components. If the connection fails, you will use the `Notifier1.ShowAlert` block to display an error message. *Table 12-4* lists the blocks you'll need for this behavior.

Table 12-4. Blocks for using Bluetooth to connect with the robot

Block type	Drawer	Purpose
<code>ConnectListPicker.AfterPicking</code>	<code>ConnectListPicker</code>	Triggered when a robot is chosen from <code>ConnectListPicker</code> .
<code>if then</code>	Control	Test whether the Bluetooth connection is successful.
<code>BluetoothClient1.Connect</code>	<code>BluetoothClient1</code>	Connect to the robot.
<code>ConnectListPicker.Selection</code>	<code>ConnectListPicker</code>	The address and name of the chosen robot.
<code>set ConnectListPicker.Visible to</code>	<code>ConnectListPicker</code>	Hide <code>ConnectListPicker</code> .
<code>false</code>	Logic	Plug into <code>set ConnectListPicker.Visible to</code> .
<code>set VerticalArrangement1.Visible to</code>	<code>VerticalArrangement1</code>	Show the rest of the user interface.
<code>true</code>	Logic	Plug into <code>set VerticalArrangement1.Visible to</code> .
<code>Notifier1.ShowAlert</code>	<code>Notifier1</code>	Show an error message.
<code>text "Unable to make a Bluetooth connection."</code>	Text	The error message.

How the blocks work

After a robot is picked, the `ConnectListPicker.AfterPicking` event is triggered, as shown in *Figure 12-4*. The `BluetoothClient1.Connect` block makes the Bluetooth connection to the selected robot. If the connection is successful, the `then` blocks are executed: the `ConnectListPicker.Visible` property is set to `false` to hide `ConnectListPicker`, and the `VerticalArrangement1.Visible` property is set to `true` to

show `VerticalArrangement1`, which contains the remote control buttons. If the connection fails, the else blocks are executed: the `Notifier1.ShowAlert` block displays an error message.

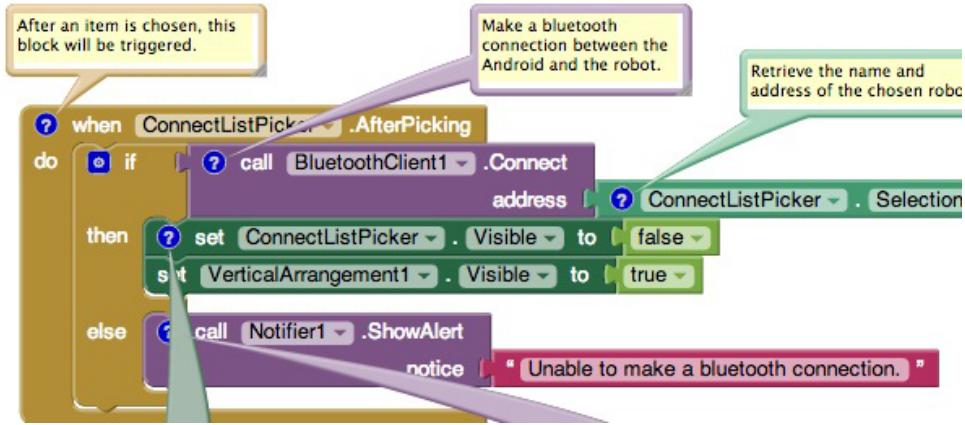


Figure 12-5. Making the Bluetooth connection

DISCONNECTING FROM THE NXT

You’re probably excited about connecting your Android to your NXT, but before you do that, let’s do one more thing: add the behavior for disconnecting. That way, you’ll be able to test both connecting and disconnecting. When `DisconnectButton` is clicked, the app will close the Bluetooth connection and the user interface will change. `ConnectListPicker` will reappear and the rest of the user interface components will be hidden. Use the blocks listed in *Table 12-5* to build the `BluetoothClient1.Disconnect` block that closes the Bluetooth connection. You will use the `Visible` property to show `ConnectListPicker` and hide `VerticalArrangement1`, which contains the rest of the user interface components.

Table 12-5. Blocks for disconnecting from the robot

Block type	Drawer	Purpose
<code>DisconnectButton.Click</code>	<code>DisconnectButton</code>	Triggered when <code>DisconnectButton</code> is clicked.
<code>BluetoothClient1.Disconnect</code>	<code>BluetoothClient1</code>	Disconnect from the robot.
<code>set ConnectListPicker.Visible to</code>	<code>ConnectListPicker</code>	Show <code>ConnectListPicker</code> .
<code>true</code>	Logic	Plug into <code>set ConnectListPicker.Visible to</code> .

Block type	Drawer	Purpose
set VerticalArrangement1.Visible to	VerticalArrangement1	Hide the rest of the user interface.
false	Logic	Plug into set VerticalArrangement1.Visible to.

When DisconnectButton is clicked, the DisconnectButton.Clicked event is triggered, as shown in *Figure 12-5*. The BluetoothClient1.Disconnect block closes the Bluetooth connection. The ConnectListPicker.Visible property is set to true to show ConnectListPicker, and the VerticalArrangement1.Visible property is set to false to hide VerticalArrangement1, which contains the remote control buttons.

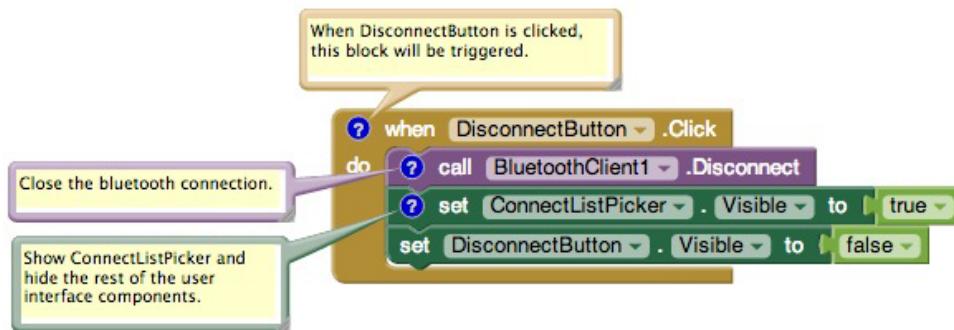


Figure 12-6. Disconnecting from the robot



Test your app Make sure that your robot is turned on and then, on your phone, click “Connect...” and choose the robot you want to connect to. It will take a moment to make the Bluetooth connection. After the robot connects, you should see the buttons for controlling the robot, as well as the Disconnect button. Click the Disconnect button. The buttons for controlling the robot should disappear, and the Connect button should reappear.

Driving the NXT

Let’s get to the really fun part: adding behavior for driving forward and backward, turning left and right, and stopping. Don’t forget about stopping—if you do, you’ll

have an out-of-control robot on your hands! The `NxtDrive` component provides five blocks for driving the robot's motors:

- `MoveForwardIndefinitely` drives both motors forward.
- `MoveBackwardIndefinitely` drives both motors backward.
- `TurnCounterClockwiseIndefinitely` turns the robot to the left by driving the right motor forward and the left motor backward.
- `TurnClockwiseIndefinitely` turns the robot to the right by driving the left motor forward and the right motor backward.
- `Stop` stops both motors.

The `Move...` and `Turn...` blocks each have a parameter called `Power`. You'll use a number block, along with all the other items listed in *Table 12-6*, to specify the amount of power the robot should use to turn the motors. The value can range from 0 to 100. However, if you specify too little power, the motors will make a whining sound but not turn. In this application, you'll use 90 (percent).

Table 12-6. Blocks for controlling the robot

Block type	Drawer	Purpose
<code>ForwardButton.Click</code>	<code>ForwardButton</code>	Triggered when <code>ForwardButton</code> is clicked.
<code>NxtDrive1.MoveForwardIndefinitely</code>	<code>NxtDrive1</code>	Drive the robot forward.
number (90)	Math	The amount of power.
<code>BackwardButton.Click</code>	<code>BackwardButton</code>	Triggered when <code>BackwardButton</code> is clicked.
<code>NxtDrive1.MoveBackwardIndefinitely</code>	<code>NxtDrive1</code>	Drive the robot backward.
number (90)	Math	The amount of power.
<code>LeftButton.Click</code>	<code>LeftButton</code>	Triggered when <code>LeftButton</code> is clicked.
<code>NxtDrive1.TurnCounterClockwiseIndefinitely</code>	<code>NxtDrive1</code>	Turn the robot counterclockwise.
number (90)	Math	The amount of power.
<code>RightButton.Click</code>	<code>RightButton</code>	Triggered when <code>RightButton</code> is clicked.
<code>NxtDrive1.TurnClockwiseIndefinitely</code>	<code>NxtDrive1</code>	Turn the robot clockwise.
number (90)	Math	The amount of power.

Block type	Drawer	Purpose
StopButton.Click	StopButton	Triggered when StopButton is clicked.
NxtDrive1.Stop	NxtDrive1	Stop the robot.

How the blocks work

When ForwardButton is clicked, the ForwardButton.Clicked event is triggered. The NxtDrive1.MoveForwardIndefinitely block shown in *Figure 12-6* is used to move the robot forward at 90% power. The remaining events function similarly for the other buttons, each powering the robot backward, left, and right.

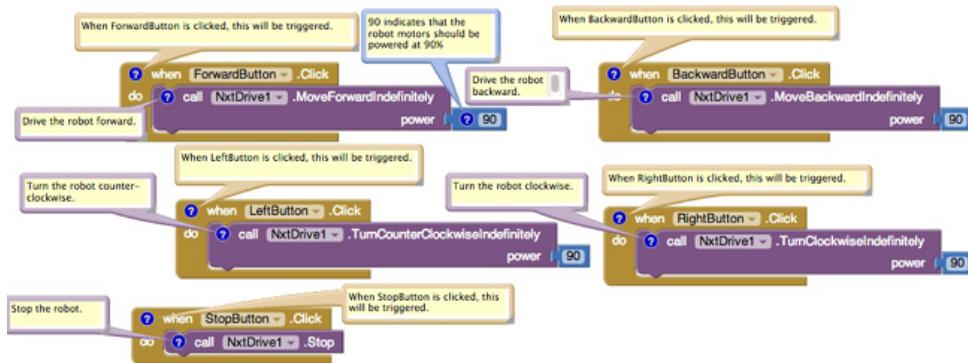


Figure 12-7. Driving the robot

When StopButton is clicked, the StopButton.Clicked event is triggered. The NxtDrive1.Stop block is used to stop the robot. Test your app. Follow the instructions in the previous “Test your app” section to connect to the NXT. Make sure the robot is not on a table where it could fall, and then test its behavior as follows:

1. Click the forward button. The robot should move forward.
2. Click the backward button. The robot should move backward.
3. Click the left button. The robot should turn counterclockwise.
4. Click the right button. The robot should turn clockwise.
5. Click the stop button. The robot should stop.

If your robot doesn't move, but you can hear a whining sound, you might need to increase the power. You can use 100 for maximum power.

Using the Ultrasonic Sensor to Detect Obstacles

Using the ultrasonic sensor, the robot will stop if it encounters an obstacle within 30 centimeters, such as the obstruction shown in *Figure 12-7*.

You can use the `NxtUltrasonicSensor` component to detect obstacles. It has two properties named `BottomOfRange` and `TopOfRange` that define the detection range in centimeters. By default, the `BottomOfRange` property is set to 30 centimeters and `TopOfRange` is set to 90 centimeters.

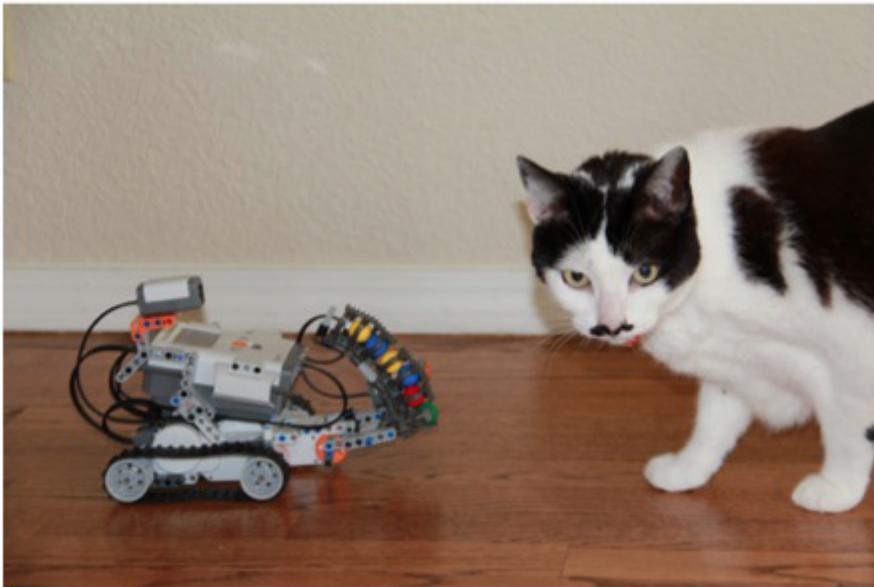


Figure 12-8. A common household obstacle for your NXT robot

The `NxtUltrasonicSensor` component also has three events called `BelowRange`, `WithinRange`, and `AboveRange`. The `BelowRange` event will be triggered when an obstacle is detected at a distance below `BottomOfRange`. The `WithinRange` event will be triggered when an obstacle is detected at a distance between `BottomOfRange` and `TopOfRange`. The `AboveRange` event will be triggered when an obstacle is detected at a distance above `TopOfRange`.

You'll use the `NxtUltrasonicSensor1.BelowRange` event block, shown in *Table 12-7*, to detect an obstacle within 30 centimeters. If you want to detect an obstacle within a different distance, you can adjust the `BottomOfRange` property. You'll use the `NxtDrive1.Stop` block to stop the robot.

Table 12-7. Blocks for using the NxtUltrasonicSensor

Block type	Drawer	Purpose
NxtUltrasonicSensor1.BelowRange	NxtUltrasonicSensor1	Triggered when the ultrasonic sensor detects an obstacle at a distance below 30 centimeters.
NxtDrive1.Stop	NxtDrive1	Stop the robot.

How the blocks work

When the robot's ultrasonic sensor detects an obstacle at a distance below 30 centimeters, the `NxtUltrasonicSensor1.BelowRange` event is triggered, as shown in *Figure 12-8*. The `NxtDrive1.Stop` block stops the robot.

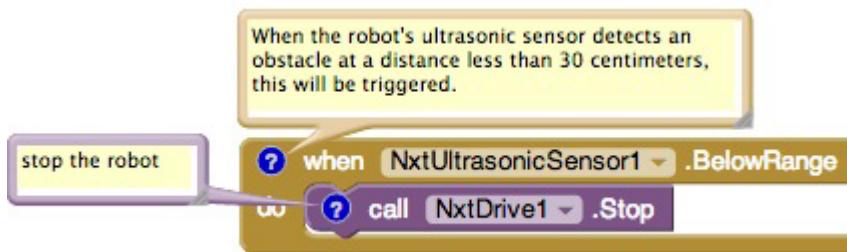


Figure 12-9. Detecting an obstacle and stopping the robot



Test your app Follow the instructions in the previous “Test your app” section to connect to the NXT. Using the navigation buttons, drive your robot toward an obstacle, such as a cat. The robot should stop when it approaches within 30 centimeters of the cat.

If the robot doesn't stop, the cat might have moved away from the robot before it drew within 30 centimeters. You might need to test your app with an inanimate obstacle.

Variations

After you get this application working—and you've spent enough time actually playing with your NXT robot—you might want to try the following:

- Vary the amount of power when driving the robot.

- You can do this by changing the numeric value that you plug into the `MoveForwardIndefinitely`, `MoveBackwardIndefinitely`, `TurnCounterclockwiseIndefinitely`, and `TurnClockwiseIndefinitely` blocks.
- Use the `NxtColorSensor` to shine a red light when an obstacle is detected.
 - You can use an `NxtColorSensor` component and its `GenerateColor` property.
 - You'll need to set the `DetectColor` property to `false` (or uncheck it in the Component Designer) because the color sensor cannot detect and generate color at the same time.
- Use an `OrientationSensor` to control the robot.
- Use LEGO building elements to physically attach your phone to the robot. Create applications that make the robot autonomous.

Summary

Here are some of the concepts we covered in this tutorial:

- You can use the `ListPicker` component to choose from a list of paired robots.
- The `BluetoothClient` component makes the connection to the robot.
- The `Notifier` component displays an error message.
- You can use the `Visible` property to hide or show user interface components.
- The `NxtDrive` component can drive, turn, and stop the robot.
- You can use the `NxtUltrasonicSensor` component to detect obstacles.