Capítulo

4

A placa Gogo: robótica de baixo custo, programável e reconfigurável

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Abstract

We present the Gogo Board, a small, low-cost, extensible microcontroller-based device, aimed at extending various programming environments to the physical world. We will learn how to construct and use low cost sensors and actuators, using found materials and cheap parts. An introduction to the construction of the board itself is also presented, as well as references and websites for further information. Examples of projects developed by students and teachers are shown.

4.1. Introduction

This hands-on workshop will consist of an introduction to the GoGo board, a small electronics board that belongs to the "Programmable Brick" family (such as the commercially available LEGO Mindstorms RCX brick, the Handy Cricket[1] and the Tower system[2]). Thus, the usability of the GoGo board builds on more than a decade of research that proves how beneficial it can be in learning environments ((Martin, 2000), (Resnick, 1996)).

However, the Gogo board has its own set of design principles:

- *It is an alternative to the much more expensive commercial devices* (US$ 120.00 and up). The GoGo board costs less than US$ 30.00 (parts purchased in the USA) or US$ 25.00 (purchased in São Paulo, Brazil).

- *The board's design only uses components that are widely available* at a reasonable price in different countries. The printed circuit board was specially designed to make the soldering of the components straightforward, with thick and clearly visible tracks and holes. Anyone with basic soldering skills can put together a GoGo board.

- *The GoGo board design can be simple* but yet it can be used in a wide variety of sensing and control projects. There is a vast space for creativity, which opens up many windows for people to adapt and redesign the board for their particular interest.

- *It is an open source design* and was heavily optimized for low-cost.

The GoGo board allows computer programs to interact with the physical world. The GoGo board shares its fundamental functionalities with other devices in the programmable brick family. Users can connect various sensors and actuators to the board and write programs to read the sensor data and control the behavior of various physical objects using motors, small lamps, LEDs, and relays. Logo has been the most used programming language with the GoGo board. We have developed logo libraries for LCSI Microworlds and Imagine Logo. Libraries are also available for other environments including Squeak, Visual Studio (Visual Basic, Visual C++), and Microsoft Office (Excel, Access, PowerPoint, Word). Other languages can communicate with the GoGo board provided that serial communication is possible. However, the programmer must study the GoGo board serial protocol. The board has also been used with Macromedia Director, MAX MSP, and Java.

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[1] See http://www.mindstorms.com and Gleason Research at http://handyboard.com/cricket.

[2] See http://gig.media.mit.edu/projects/tower

4.2. Getting Started

4.2.1. Getting to know the GoGo board

There are a few parts in the GoGo board with which you need to be familiar. Figure 1 illustrates the basic GoGo board layout.

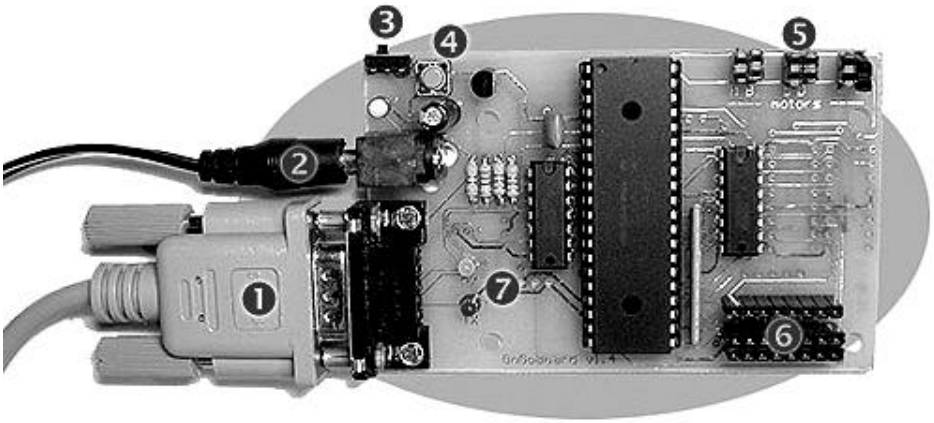

Figure 4.1 - GoGo board layout

1. Serial cable. This cable connects the GoGo board to the computer.
2. Power Jack. The board is typically powered at 9V.
3. On-Off switch. Once turned on, the red LED right below the switch should be on.
4. Reset button. Each time this button is pressed, the status LEDs (7) should blink once or twice.
5. Output Ports. There are six output ports (A-F) available. You can connect to it output devices such as motors, light bulbs, and relays.
6. Sensor Ports. There are eight sensor ports (1-8).
7. Status LEDs. These LEDs help you see whether or not the board is communicating with the computer.

4.2.2. What you need

The following is a list of things you need in order to use the GoGo board

A GoGo board

9V power adapter

Serial cable

Sensors and output devices (like motors, lights)

4.2.3. Powering the GoGo board

The GoGo board is designed to work at 9 volts. However, this is quite flexible. Generally, anything between 6-12V should be fine. The power can come from a standard power supply or from a battery.

Once the board is powered, turn it ON. The status LED should blink. Hit the reset button if you want to reinitialize the board. If your version of the board does not have a reset button (version 2.2), turn it off and on again.

4.2.4. Connecting the GoGo board to the computer

The GoGo board uses a standard DB9 male-to-female serial cable. These cables are available at computer retail stores. You should connect the male side to the GoGo board and the female side to the serial port (COM port) on the computer. These ports are usually located at the back of the computer. Some older computers have more than serial port. In this case, I recommend using the first port (COM1); otherwise you will need to change the configurations of the GoGo board software to match the port you use. Figure 4.2 shows how a serial port looks like at the back of a computer.

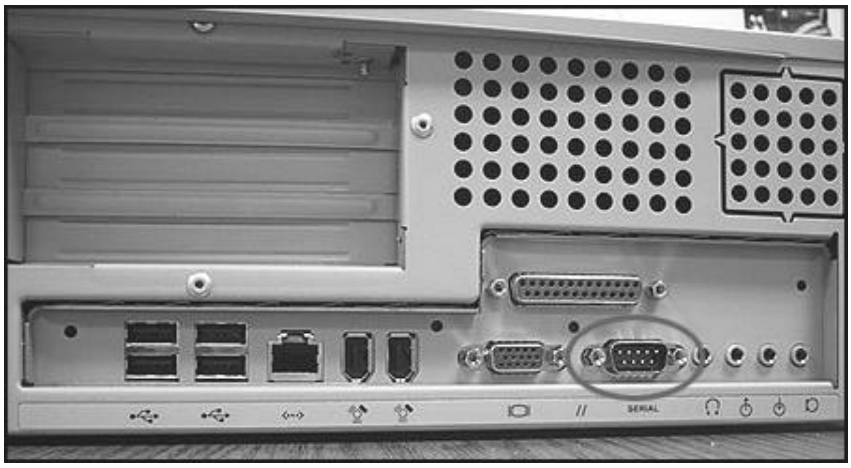

Figure 4.2. An example of a serial port at the back of a computer.

4.2.5. Testing the GoGo board

The easiest way to test the GoGo board is to use the **GoGo board monitor program**, which is downloadable from the GoGo website (www.gogoboard.org) You should simply start the

program and click on the “Connect” button. If there is no error message, it means that you are connected! You can then try to read sensor values and turn on or off output ports. Figure 4.3 shows a screenshot of the GoGo board monitor software.

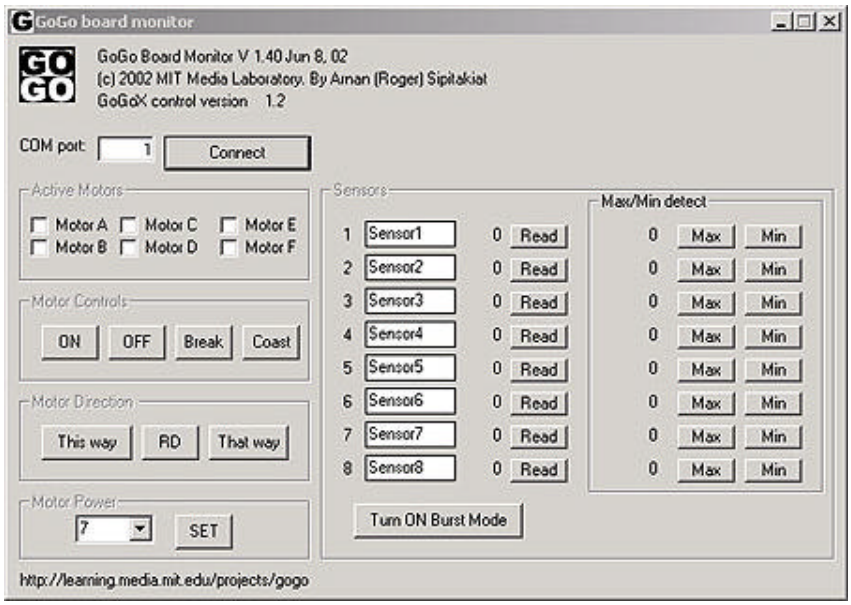

Figure 4.3. A screenshot of the GoGo monitor software

4.2.6. Which programming environments are supported?

Now that the GoGo board is working, you can start using it in many programming environments. Currently the GoGo board supports Microworlds Logo, Imagine Logo, Active-X compatible languages (i.e. Visual Basic, Visual C++, MS-Office VBA) and Squeak. Please visit the software download webpage for more information.

4.3. Project examples

This section will briefly present some of the projects developed by teachers and students using the GoGo board.

4.3.1. Horse Race Game

We made a “step-on sensor” out of ice-cream sticks and kitchen aluminum foil. This is a simple touch switch that controls how fast the character on the screen runs. In this case, the sensor controls the human runner. The goal is for the player to outrun the horse. The horse may simply run at a random speed or be controlled by another sensor. If there is an audience, the second sensor could be a microphone so that the louder the crowd cheers the faster the horse runs.

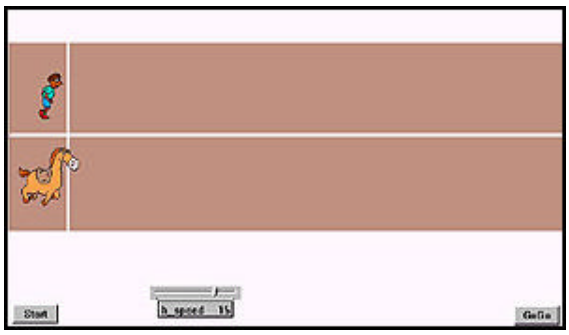

Figure 4.4. A screenshot of the horse race game

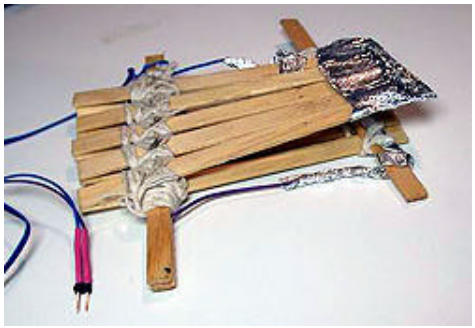

Figure 4.5. The step-on sensor

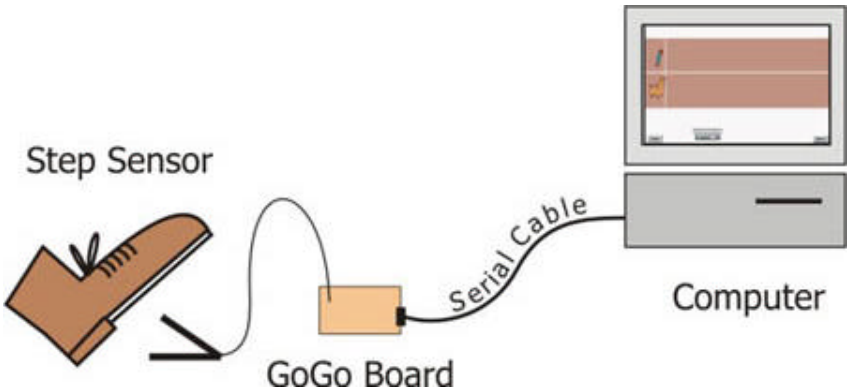

Figure 4.6. The completed system of the horse race game

4.3.2. A smart bathroom model

This project was implemented by a group of schoolteachers in Brazil who wanted to educate their students about hygiene. Some students at their school after using the bathroom they often forget to flush the toilet. Therefore, the teachers created a model of a bathroom that has an infrared sensor on the entrance so that the computer (through the GoGo board) knows when there is someone entering or leaving the bathroom. The toilet has a touch sensor that detects when someone flushes it. With these two sensors, they wrote a program that detects when someone tries to exit the bathroom without flushing. The computer will then play an audio file reminding the child of his or her responsibility. The model was made of Styrofoam, paper, and clay.

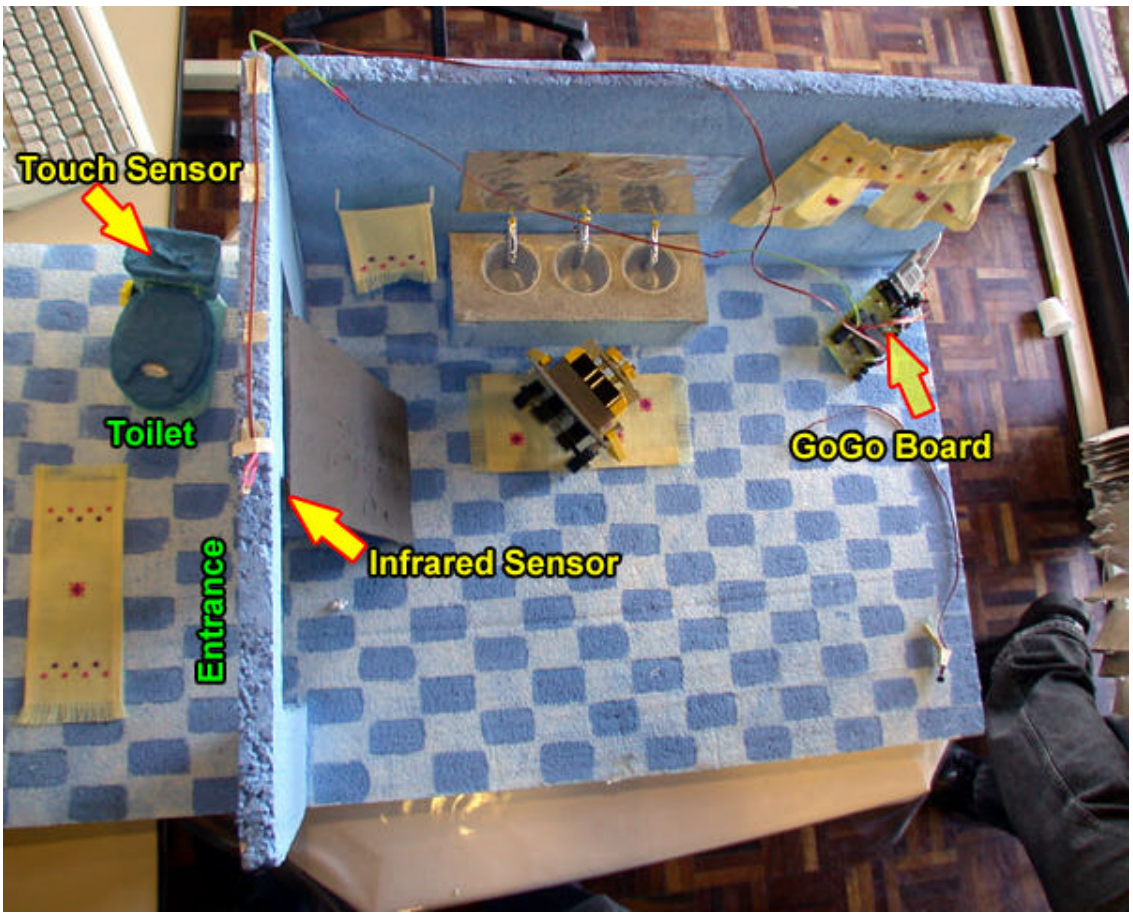

Figure 4.7. The smart bathroom model

4.3.3. A Calorie scale

This project was also implemented by a group of schoolteachers in Brazil. The idea is to have a scale that can tell you how many calories your food is giving you. This is to create awareness of what people eat. The scale was made of Lego. A bend sensor was used to measure the weight of the food and convert to calories. As the amount of calories is different for each type of food. A set of buttons were made to allow users to specify the kind of food that was being weighed (e.g. rice, chicken, vegetable etc). The buttons were built with plywood and kitchen aluminum foil.

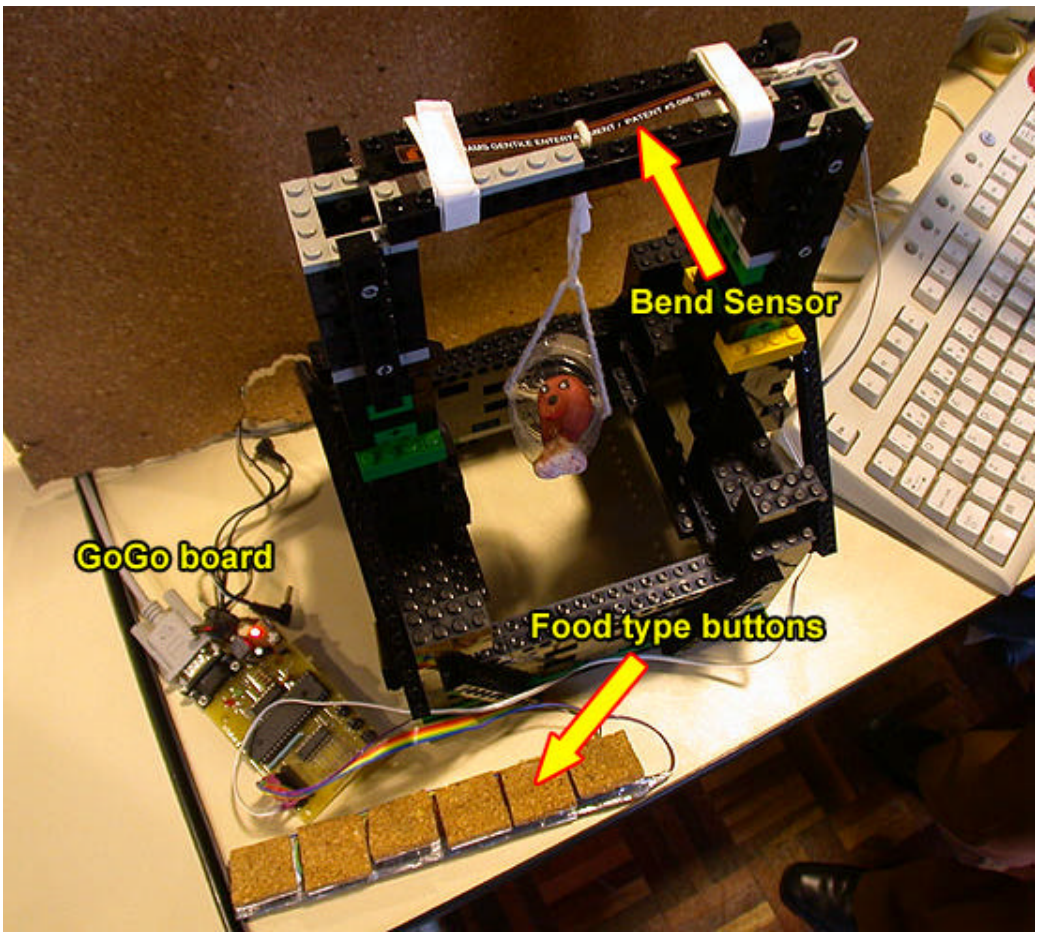

Figure 4.8 The calorie -scale

4.3.4. Dance-Dance-Revolution

This game is a replica of a famous arcade game where players dance on a set of step-on sensors on the floor following instructions on the computer screen. The GoGo board is used to connect four step-on sensors to the computer. The sensors were made of thick paper and kitchen aluminum foil.

Figure 4.9. Teacher playing Dance-dance revolution

4.4. How to power the GoGo board

4.4.1. General Information

The GoGo board can be powered by either an AC adapter or AA batteries. NEVER leave batteries in the board when using an AC adapter! The batteries would be destroyed over a few hours and could lead to a fire hazard.

4.4.2. Powering the GoGo with an AC wall adapter

There are generally two parameters you should know when powering an electrical device: voltage and current.

- ***Voltage:*** *The GoGo board is designed to be powered at 9 volts. However, you can actually supply it with any voltage between 6-12 volts.*

- ***Current:*** *It is recommended to supply the board with at least 600 mA (miliamperes). The more current you have, the more juice you have to power the components you use. The board itself consumes around 50 mA, but the big power consumers are the devices you connect through the output ports. A single motor normally consumes 100-250 mA. Therefore, if you plan to connect all six output ports to motors, then you may need to supply the board with at least 1.55 mA [50 + (250 x 6)]. If you do not supply enough current, the motors will suck away all the current from the board, which usually cause the board to halt or reset. Sensors, on the other hand, usually do not consume so much power. So, if you plan to use only sensors, supplying the GoGo board with as little as 100 mA would work just fine.*

4.4.3. Getting the right power adapter for the GoGo board

There are four things that you have to keep in mind when shopping for a GoGo board power adapter.

- ***Output Voltage:*** *As mentioned in the previous section, it is recommended to use a 9V adapter, but anything between 6-12 volts will work.*
- ***Current:*** *Using 600-1000 mA is recommended. The trade-off here is simple: the higher the current, the higher the price of the adapter.*
- ***Barrel (connector) size:*** *The GoGo board uses the standard 2.1 mm input jack.*
- ***Polarity:*** *There are two possible polarities as shown in the figure below. You need the inner connector to be positive [B] (note: many power adapters have a switch that allows you to specify the polarity that you want).*

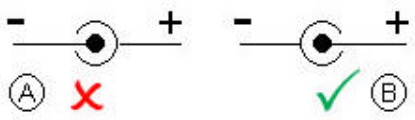

Figure 4.10 - Using the correct polarity

4.4.4. Powering the GoGo board with batteries

Sometimes it is convenient to power the GoGo board with batteries, especially when using it in the autonomous mode. Rechargeable batteries are recommended.

4.5. Making Sensors

4.5.1. Knowing how sensors work on the GoGo board

- *Resistance*

In most cases, the value you get from a sensor indicates the "resistance" of the sensor. Resistance is a very basic property of any material. Metal has extremely low resistance. Thus, they conduct electricity very well. On the other hand, plastic or rubber has very high resistance. They almost do not conduct electricity. That is why we use them to coat electricity wires.

Here is a simple rule: the higher the resistance, the higher value you will get from the GoGo board. Since air does not conduct electricity (unless you have a very high voltage), your get 1023 (the highest reading) from a sensor port without a sensor connected. It is then not hard to guess that when you get a reading of zero, it means your sensor has no resistance (like a piece of wire).

There are also many sensors that change their resistance accordingly to some particular property of the environment. Examples of these sensors include light, temperature, pressure, etc.

- *Calculating the sensor readings*

For those who are interested in the deeper technical details, there is a 33kOhm reference resistor on each sensor port, which is used to determine the readings you get. The figure below shows how the reference resistor is arranged. The microcontroller measures the voltage drop across the sensor, which can be calculated from the following equation.

$V = 5 \times (Rs / (33K + R_s))$

Where R_s = Sensor resistance

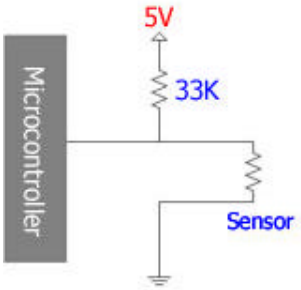

Figure 4.11. Schematics of the sensor ports

Now, we know that if the voltage drop is 5V, we get a reading of 1023. We can use the same equation to determine the sensor readings directly.

Sensor Readings = $1023 \times (R_s / (33k + R_s))$

For example if our sensor has a resistance of 10kOhm, our sensor reading will be:

$1023 \times (10000 / (33000 + 10000)) = 238$

- *Sensor ports on the GoGo board*

The GoGo board has eight sensor ports. Each of them has three pins, as shown in the illustration below. The first two rows of pins (ground and sensor input) are the ones most simple sensors use. The third row is an extra power supply for sensors that needs a power source to function properly (active sensors).

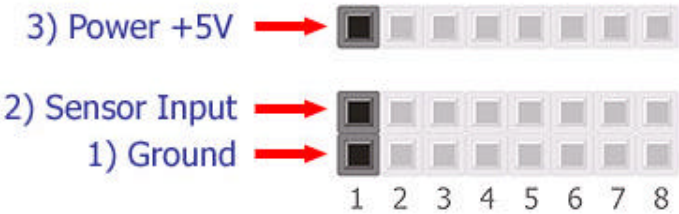

Figure 4.12. Detail of the sensor connectors

4.5.2. Active and Passive Sensors

Sensors that were mentioned so far are called passive sensors. They do not need separate power to operate. Active sensors, on the other hand, are sensors that need their own power.

An easy way to distinguish active sensors from passive ones is to count the number of pins it has. Active sensors have an extra third pin to get the power it needs while passive sensors have only two.

Active sensors are more complex, but they open up a broad range of sensing possibilities. Examples of active sensors include Infrared sensors [it detects presence, distance], Hall effect sensors [detects magnetic field], noise sensors, vibration sensors, etc.

4.5.3. Making Passive Sensors

Here you will learn how to make three passive sensors: touch, light, and temperature. All passive sensors only need two pins (pin 1 and 2).

- *Touch Sensors*

Touch sensors are one of the simplest sensors but yet they are most useful. The general ideas is very simple: you have two conductive objects that would touch each other when activated (i.e. pressed, stepped on) or vise versa. Here are some examples of touch sensors:

Paper and Aluminum foil: This is probably the easiest way to make a touch sensor. You attach some aluminum foil to two pieces of paper that are folded in a way that will make the foil touch when pressed. You then connect one lead to each foil. You can, of course, replace aluminum foil with other conductive elements (i.e. paper clips or nails).

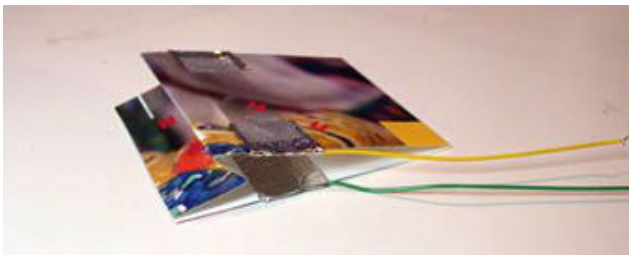

Figure 4.13. Aluminum foil touch sensor

Ice-cream sticks and aluminum foil: Ice-cream sticks are excellent for making simple structures. It is stronger than paper. Therefore, when used with aluminum foil, we can make touch sensors that are much more rigid. The following picture shows one example.

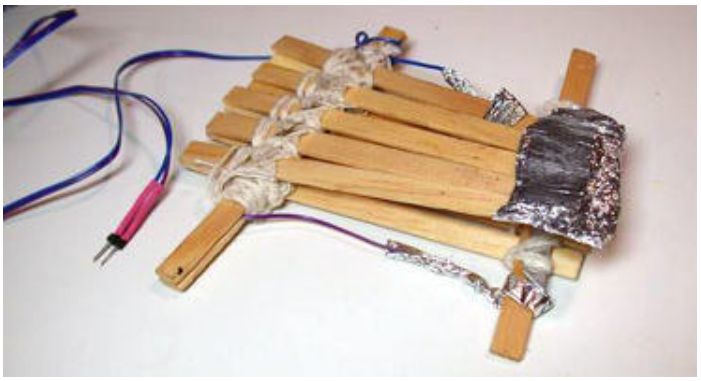

Figure 4. 14. Step sensor made from aluminum foil and ice cream sticks

Sandwich touch sensors: making this type of sensor you need two conductive contacts sandwiching a non-conductive material. Overhead transparency films are nice as they are flexible. You can stick or glue aluminum foil to them and use two of them to sandwich a piece of cardboard paper. You punch holes in the cardboard allowing the foils to touch when pressed.

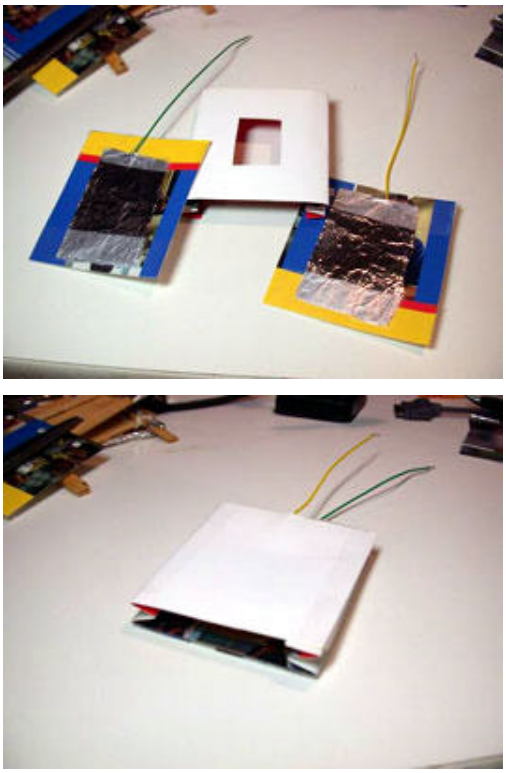

Figure 4.15. Sandwich touch sensor

Commercial switches: you can also buy switches from electronic stores and attach them to the GoGo board. These switches come in many shapes and sizes. The most common ones are lever switches and push buttons.

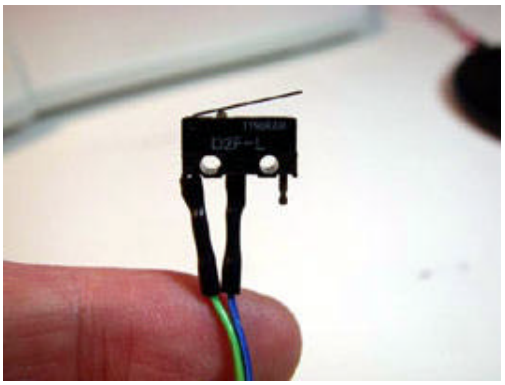

Figure 4.16. Commercial switch

- *Light Sensors*

The most common light sensor is called **LDR** (Light Dependant Resistor). They are also known as "photo cells". A LDR is basically a resistor that changes its resistance when light intensity changes. You often see them in automatic light stands. Since LDRs are simply resistors, you can just simply connect the two pins from the sensor to the GoGo board.

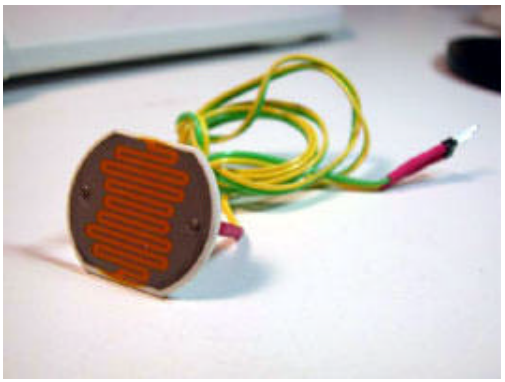

Figure 4.17. Light sensor (LDR)

- *A Simple Humidity Sensor*

You can simply connect two wires or paper clips to pins 1 and 2 of the GoGo board to measure humidity in the soil. When the soil gets moist, it conducts more electricity. Thus, the sensor readings you get will change as the soil humidity changes. This same idea can be used to make a water detector sensor. When the two wires touch water, the sensor readings will change.

You can improve the humidity sensor by connecting the two wires to a piece of gypsum, plaster, or any other material that absorbs water. The idea is still the same but you are improving the purity of the conductive medium. The sensor's behavior will not change too much from one place to another. Gypsum is the material they use to make building interiors (ceilings, walls, etc). Plaster is also used to cover walls and to make a patient's cast.

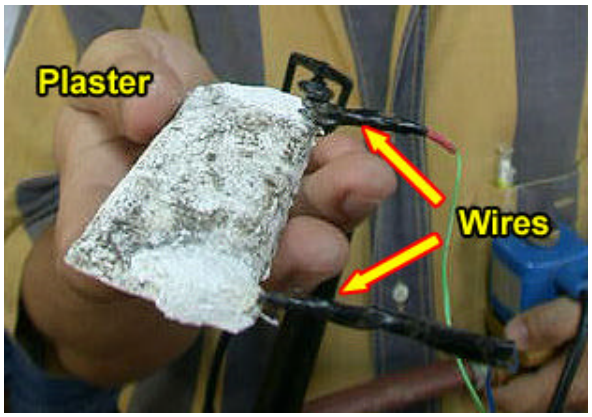

Figure 4.18. Humidity sensor made from plaster

- *Temperature Sensors*

To make a temperature sensor, you will need to find a thermistor. Some thermistors are simply resistors that change their resistance as temperature changes. Other thermistors are active sensors that need extra power to function.

Figure 4.19. Temperature sensor

4.5.4. Making Active Sensors

Here are examples of useful active sensors.

- *Reflective Light Sensors*

This type of sensor is useful when you want to detect object presence without touching it. For example, you want to detect when someone walks through a door, or when someone's hand gets too close.

A simple idea for this sensor is to beam light on to a LDR (light sensor). If something passes by, it blocks the light and the LDR detects it. If the light source is a light bulb, then you are simply detecting shadows. If you use a laser pointer as you light source, you detection range can be very far and you readings will be very precise.

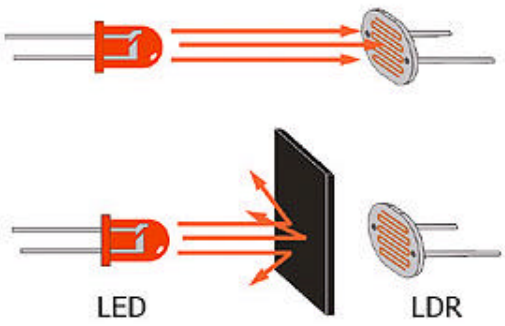

Figure 4.20. Active light sensor

There is another idea to accomplish the same task. You can beam light and measure the amount of light that is reflected back. When there is nothing to block the light, the reflected light will be very small. However, if an object blocks the light, it reflects more the light back. This is what we call a **reflective light sensor**. The benefit of this kind of sensor is that the

sensor is located all in one place and no alignment is needed when you change the direction of the sensor.

You can make reflective sensors simply with an LED and an LDR. You need to use a bright LED. This works but the detection range will be very limited (less than 1 inch). There can also be a lot of interferences from external light sources as well.

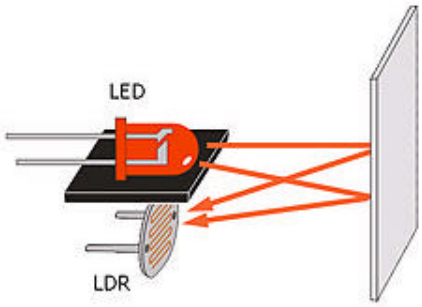

Figure 4.21. Reflective light sensor

Here is a schematic of how this sensor can be built for the GoGo board. The **resistor** is there to limit the current that goes through the LED. The smaller the resistor's value, the brighter the LED.

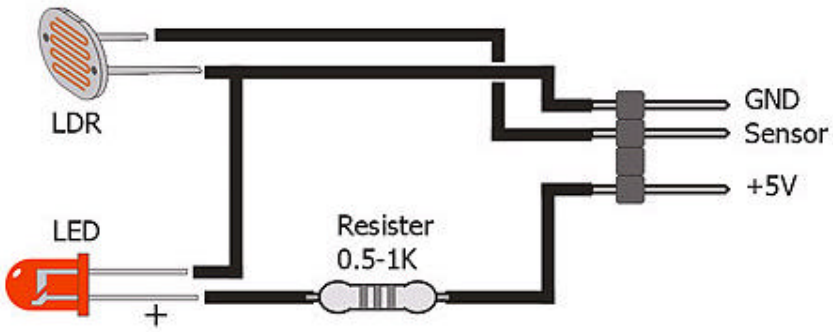

Figure 4.22. Building the active light sensor

- *Using Infrared (IR) Light*

A better version of the above reflective sensor is to use **Infrared light** (IR), as there is much less interference. IR is a kind of light that humans cannot see. This is nice when you do not want people to see your sensor (i.e. in security systems).

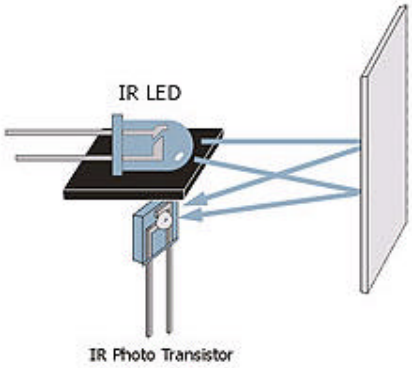

Figure 4.23. Reflective infrared sensor

Notice in the diagram that we use an **IR phototransistor** instead of the LDR. In this case, the two functions the same way, but the IR phototransistor is much more sensitive to IR light than an LDR. The following is a schematic of how to build this sensor.

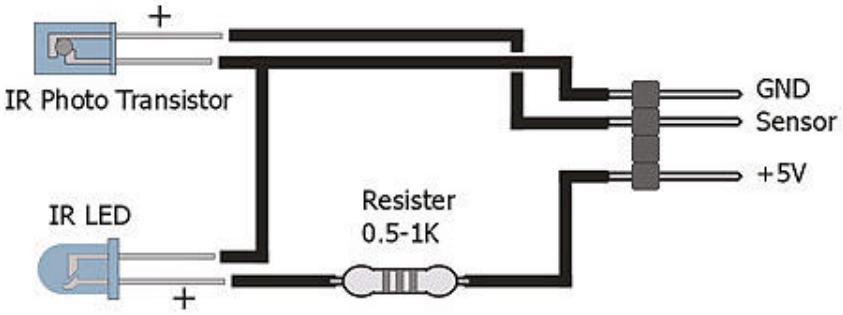

Figure 4.24. Schematic of the reflective infrared sensor

- *Commercial Reflective Sensors*

You can also buy commercial IR reflective sensors as well. They normally come in a compact size and the special packaging provides readings that are more reliable.

Here is an example of how to assemble a commercial IR reflective sensor (digikey.com part number QRD1114-ND).

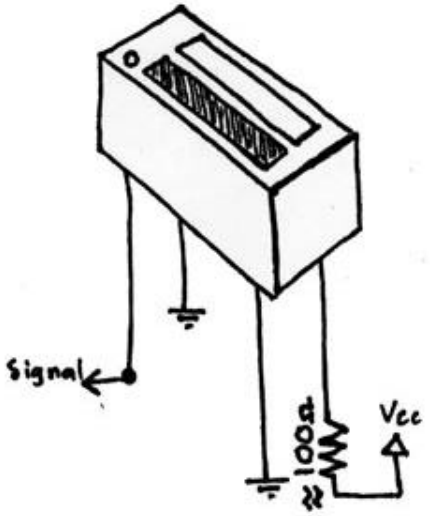

Figure 4.25. Example of commercial reflective infrared sensor

- *Hall Effect (magnetic field) sensor*

You can use this sensor to detect the presence of magnets. The applications are similar to the IR reflective sensor but they do not depend on light, which often means they are more reliable. However, you need to have a magnet while light is almost everywhere.

Here's an example of how to assemble a Hall Effect sensor (from digikey.com, part number DN6848-ND)

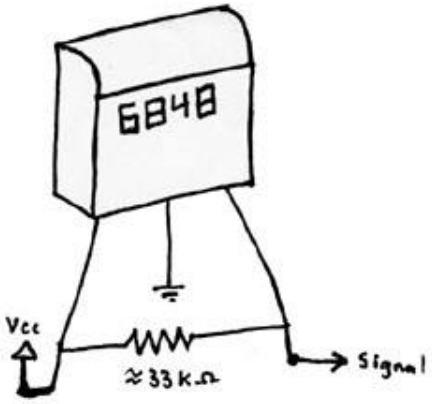

Figure 4.26. Schematics and picture of how to assemble a magnetic sensor

4.5.5. Where to find sensors

In the US, many places sell sensors. Radio shack is one of the most common places to look for. There are also on-line stores that provide even larger collection of sensors. Here is a list of a few websites that you should know:

- ***www.radioshack.com*** *- website of the famous electronics retail store.*
- ***www.allelectronics.com*** *- This site has a huge collection of low-cost electronics parts. If price is your biggest concern, this is where to go.*
- ***www.digikey.com*** *- This is one of the largest on-line electronic stores on the Internet.*

Here are a few digikey sensor part numbers:

- *Thermistor: KC005T-ND*
- *Push button: SW411-ND*
- *Lever switch: SW152-ND*
- *IR reflective: QRD1114-ND*
- *Hall Effect:DN6848-ND*

4.6. How to make a GoGo board

The GoGo board that is referred to here is the GoGo 2.x version. The board is designed to make the construction process as easy and as inexpensive as possible. We present here a brief introduction about the steps in building your own board. Further information in available on the website and constantly updated. Here is basically what you need to do:

- ***Get the parts.*** *In the United States, you can get all parts from* ***digikey.com****. It should cost roughly $30 ($20 if you do not use the output ports). In other countries such as Brazil, Mexico, and Thailand, we have found that some of the parts are more than 50% cheaper than those in the US. Please refer to the part list for* ***each board***

version *for detailed info. In São Paulo, Brazil, good places to find parts are located along the Santa Efigênia street.*

- ***Get the printed circuit board (PCB).*** *The PCB layout technical files (called Gerber files) are available for free but you need to either make it yourself or send the files to some PCB manufacturing companies (one is* ***AP Circuits****).*

- ***Making the PCB yourself****. Some versions of the PCB have large enough traces for you to make it yourself with a simple PCB kit.*

- ***Ordering PCBs.*** *This is easy but you pay more. PCB manufacturing companies (such as* ***AP Circuits****) normally charge you something like US$40 for a setup fee. Then you pay roughly US$10 per board. The more you order the cheaper the cost per board.*

- ***Burn the GoGo board firmware to the micro-controller.*** *The MCU we use is the PIC16F877 (Or PIC16F871) from Microchip. The firmware can be downloaded for free, but you need a PIC programmer to burn it to the PIC. This burner will cost you anywhere between $20 and $200. The firmware for each* ***board version*** *are different.*

- ***Putting them all together.*** *This means soldering everything to the PCB. Please refer to the board assembly guide of* ***each board****.*

4.7. References and further information

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Resnick, M., Martin, F., Sargent, R., and Silverman, B. (1996). **Programmable Bricks: Toys to Think With.** IBM Systems Journal, vol. 35, no. 3-4, pp. 443-452.

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Sipitakiat, A., Blikstein, P., Cavallo, D. (2002) **The GoGo Board: Moving towards highly available computational tools in learning environments**, Interactive Computer Aided Learning International Workshop., Carinthia Technology Institute, Villach, Austria.

Gogo board: www.gogoboard.org

Future of Learning Group: learning.media.mit.edu

Tower system: http://gig.media.mit.edu/projects/tower

Cricket: http://www.handyboard.com/cricket/