Workshop 3: Feedback Control

1 Getting Started

Make sure you have everything you need to complete this lab. To get started you will need the following:

- a LEGO Mindstorms EV3 robot
- a computer with LEGO Mindstorms EV3 software application installed
- a USB cable that connects the robot to your computer
- two Colour sensors:

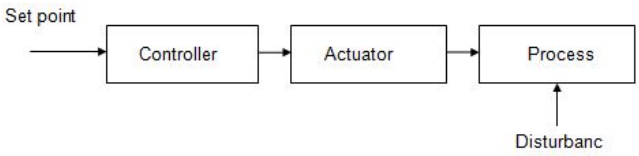
- a light

2 Open and Closed Loop Control

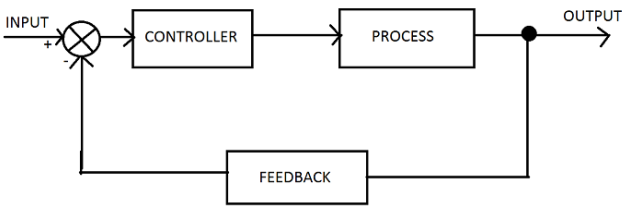
This week, we're going to learn how to connect sensors, and motors, to do different things with our robots. This is connected to **control theory**

In robotics, there are two major categories of controllers: **Open Loop Control** and **Closed Loop Feedback Control**. The difference is simple. . .

In *open loop* control, we program movements *without considering sensor feedback*



In *closed loop* control, we *connect the sensors back to the motors*, so that the robot *reacts* to its environment.



HINT: Can you think of any benefits of closed loop control? Why would we want to used open loop control?

3 Open Loop Control

To test open loop control, let's do a quick experiment with the 5-minute bot. We'll make use of the wheel sensor calibration that you did last week.

Follow these steps:

- First, open up the Open the LEGO Mindstorms EV3 Application and create a **New Project** and **Save** it.
- Next, you need to program the robot to **drive** $2\,m$ **forward**.

  HINT: Last week we did sensor calibration with the robot's wheel sensors. Can you think of how to use that to help you with the program?

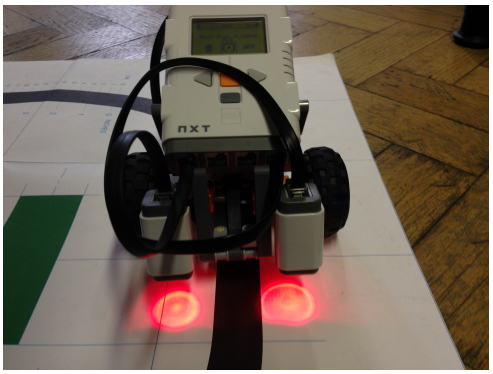
  Once you've written your program, download it onto the robot.
- Disconnect the robot, and place it on the floor behind the start line.
- **Go!** Set the program running. Keep an eye on how the robot moves!

Did the robot make it to the finish? If not, why not? How did the robot move?

4 Closed Loop Control

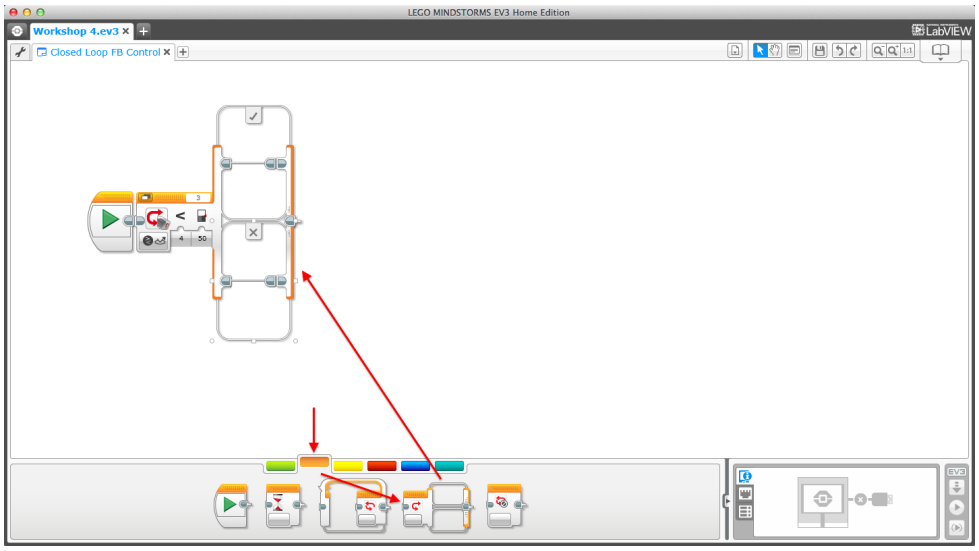
The great thing about closed loop control, is that it allows your robot to be **self adjusting**, which means that the robot can figure out what is happening, and react. Let's give it a go.

1. First, you need to attach **sensors** to your robot, so that it can sense what is going on. We'll use the **Colour Sensors**. Attach these to the front of your robot – it should look like this:

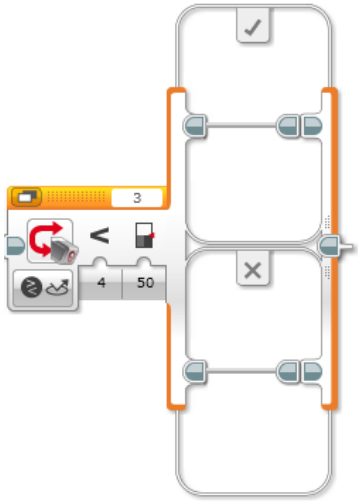


   HINT: Place the sensors so they don't touch the ground, to make the sensing and turning smoother.

2. Open the LEGO Mindstorms EV3 Application and create a **New Project** and **Save** it. From the bottom of the screen, you will have to drag a **Switch** block, located in the **Flow Control** tab:



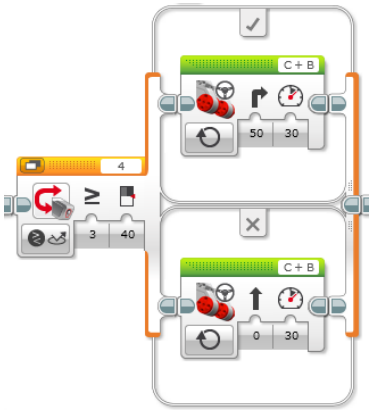
3. Once you have dragged the **Switch** block, you can set it up in the **Switch Block** option panel. In a switch statement there are two branches, the **True branch** and the **False branch**. Here's an enlarged image of the panel:



- **Port:** In the upper right corner, choose the port where the **Colour Sensor** on the EV3 brain is connected to.
- **Functionality:** In the block's drop down menu, you can choose between the Colour or the Light sensor. Now we will need the **Reflected Light Intensity Comparison** for this exercise.
- **Compare:** In the second option you can set up the comparison for the switch block, which will decide the behaviour of the robot, during run-time.
- **Threshold:** Finally we have a threshold which is compared to the sensor's input. In the image above, the **True branch** will run, if the sensor sees a dark object (less then 50 unit), otherwise the **False branch**.

4. Once you have everything set up, write a program that will allow the robot to drive to the finish line.

   HINT: You might want to include something like this into your code:



5 Robot Moths!

Did you know that some people use robots for studying biology, and especially animal neuroscience?

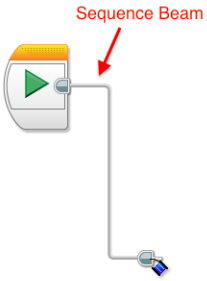
They are helpful in understanding how animals use their senses, and why they behave in different ways.

Let's have a go at building a robot moth!

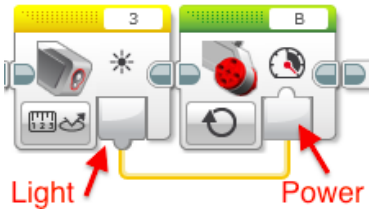
1. For this exercise, we need to reconfigure our robots, so that they have antennae, like the moth. Attach the **two Colour sensors** to two longer **LEGO sticks (stick 13 or 15)** and then attach it to the robot. It should look like this:

2. Once you have finished with the building, open the LEGO Mindstorms EV3 application and create a **New** project and **Save** it.

3. As we have **two Colour sensors**, what we will need is a parallel program. To create a parallel program just drag the **sequence beam** until you create a second sequence. Like this:



4. Now we will connect the sensors so that **one Colour sensor is connected to one motor**. You will need to **connect the input value we will get from the Colour sensor to the power of the motor.** Set it up, so that if one sensor is excited more than the other, the corresponding motor will work harder.



You also need set up the other sensor and motor in the same way.

HINT: Once you connected these two values we no longer need to set up the power of the motor.

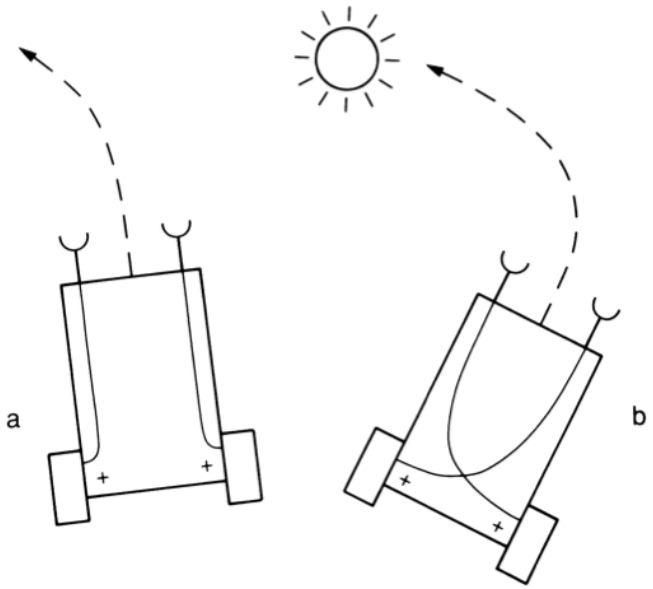
HINT: We know that our application needs to run forever and get the input from the Colour sensor, so you might want to consider using a loop (or two) somewhere in your app.

Shine a light at your robot. How does it behave? What happens if you switch the connections? Try plugging the motor cables into to opposite ports.

6 Reading: Braitenberg - Fear and Aggression

The above experiment is from Valentino Braitenberg's book: *Vehicles: Experiments in Synthetic Psychology, 1986*. You can find it in the King's College library. Braitenberg was a famous Italian neuroscientist who examined evolution and neuroscience through robotics.

The robot we have built is similar to Braitenberg Vehicle 2:



The robot shows *fear* or *aggression* depending on the connections between its sensors and actuators. Neuroscientists have found that animals, and even people, have similar connections in our brains!