FLL Workshop – Session 3
FLL intermediate programming

Patrick R. Michaud
pmichaud@pobox.com

University of Texas at Dallas
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Topics

Specifying distances in centimeters

Programming and robot game strategy

Loops and sensor blocks

Moving along a heading with gyros

Line following / edge following

Understanding navigation error

Moving forward a distance
Another My Block exercise

Move forward a distance

Specify distances in linear units (inches or cm)

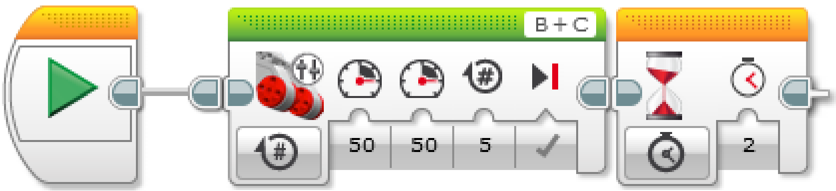
Need to know circumference of driving wheels

Several options:

- Calculate from printed wheel diameter
- Measure wheel diameter
- Use robot to determine circumference (best!)

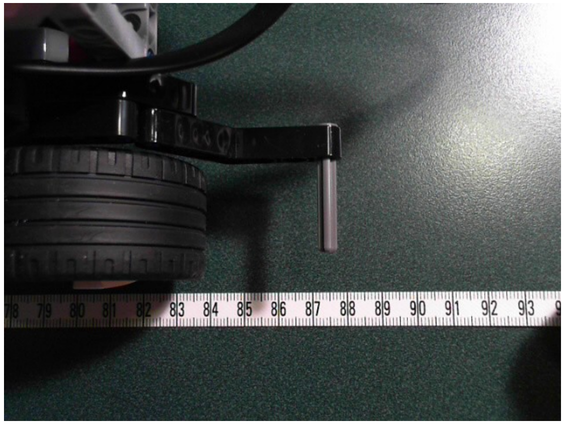
Calculating circumference

Create a program that moves forward 5 rotations, then waits for 2 sec



Run program and measure distance traveled by robot

wheel_circumference =
distance / motor_rotations



87.6 cm / 5 == 17.52 cm

TIP: Always have a measuring tape handy

TIP: Use centimeters for measuring units

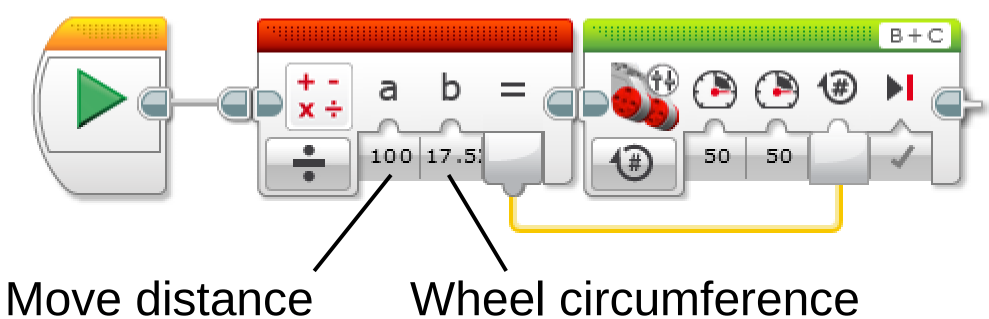
Move forward a distance

Start with empty program

Add a Math division block to calculate rotations

Add a Move block

Wire output of division to rotation input

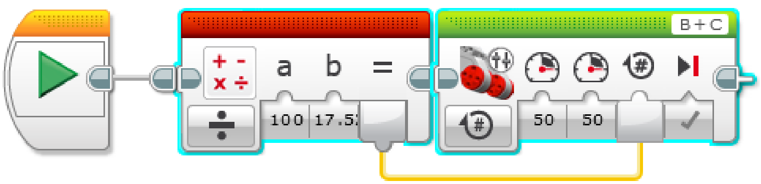


Test program to verify it works

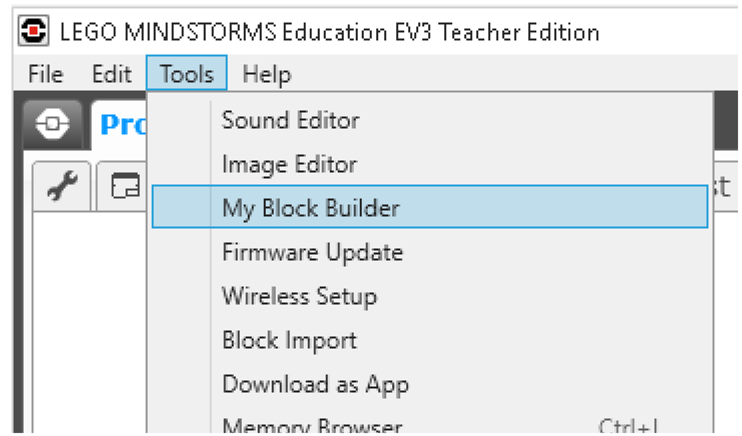
Adjust circumference value if distances are off

Make a My Block (review)

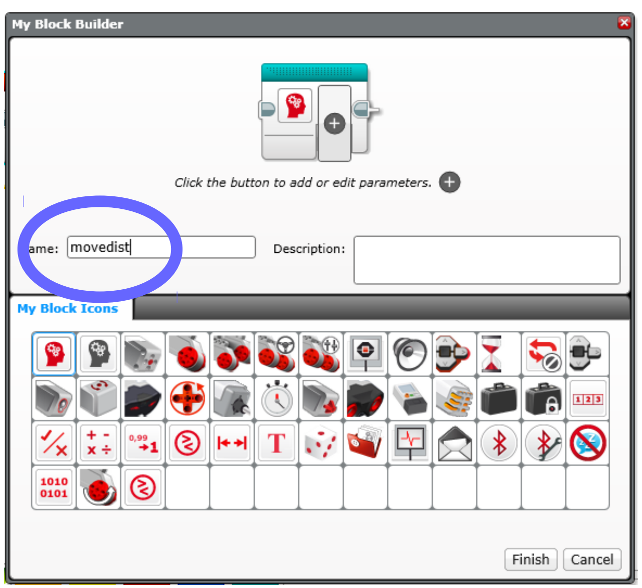
1. Select blocks



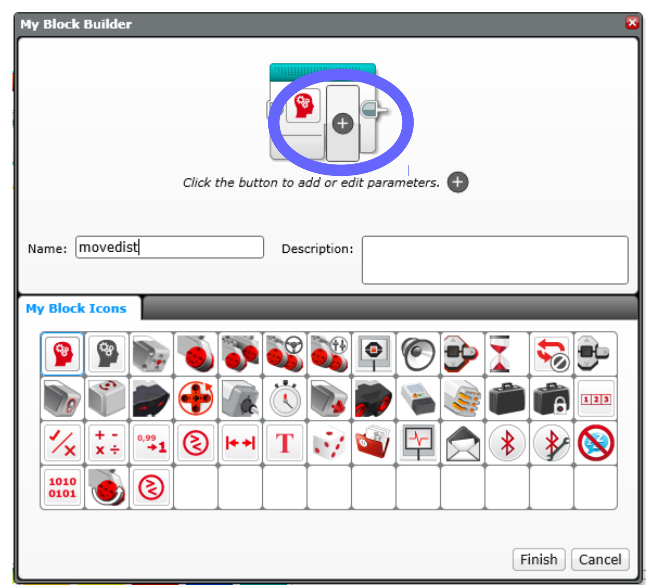
2. Tools → My Block Builder



3. Name the My Block

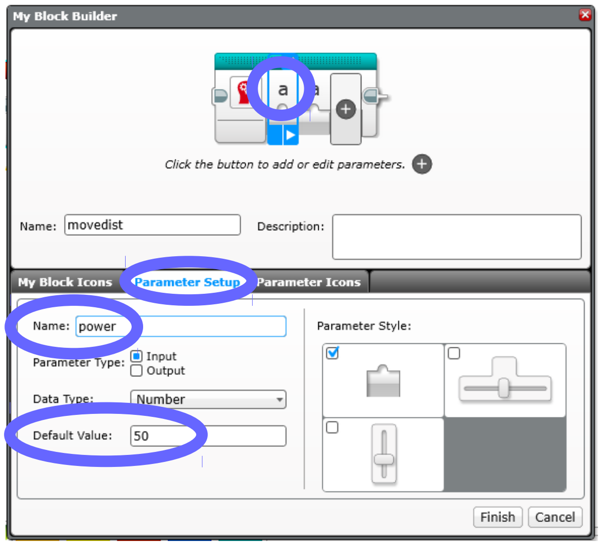


4. Add two parameters

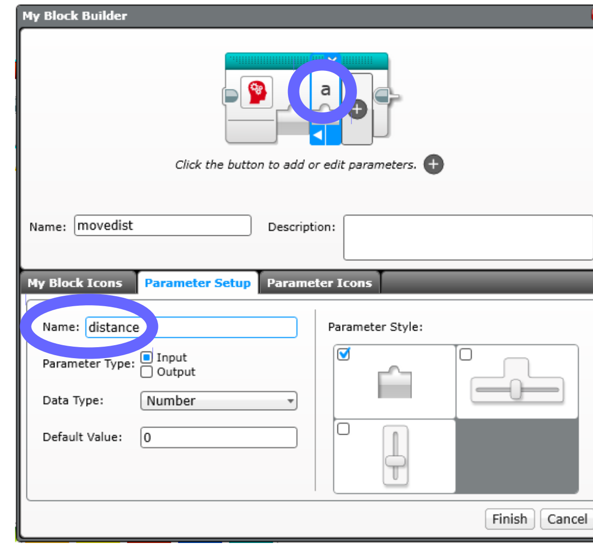


Make a My Block (review)

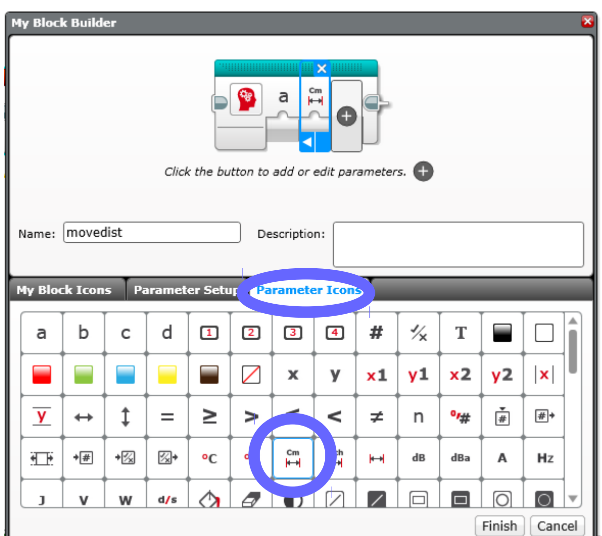
5. Set up power parameter



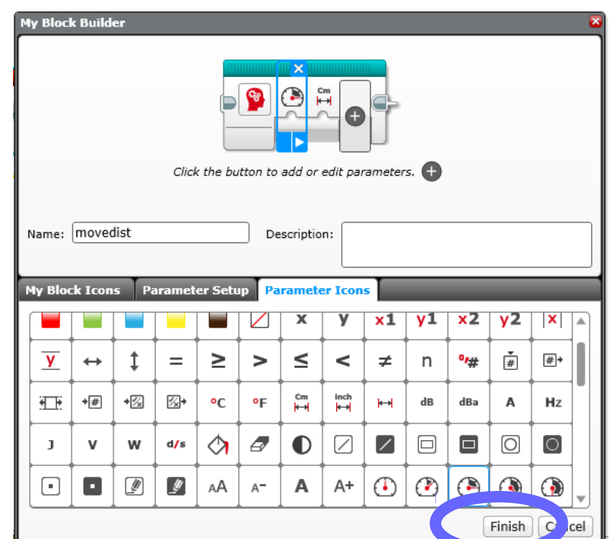
6. Set up distance parameter



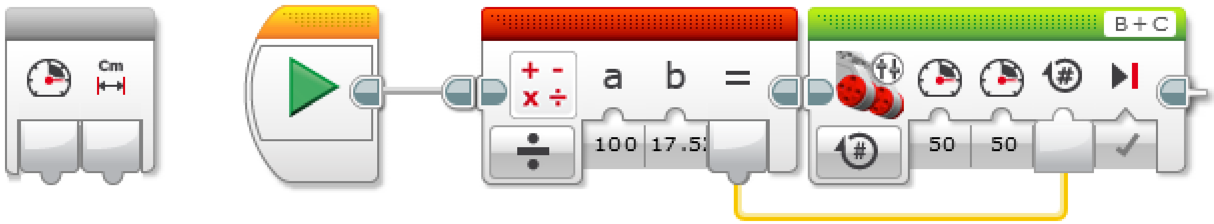
7. Select parameter icons



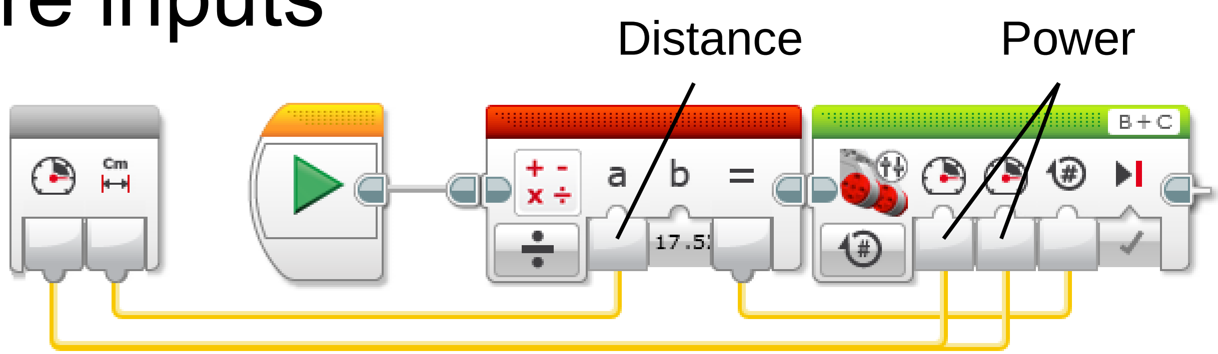
8. Click Finish



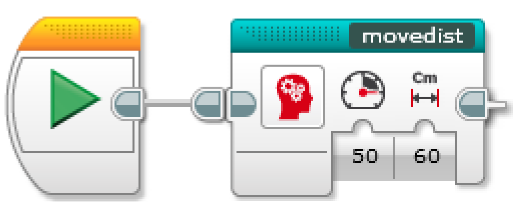
Make a My Block (review)



9. Wire inputs



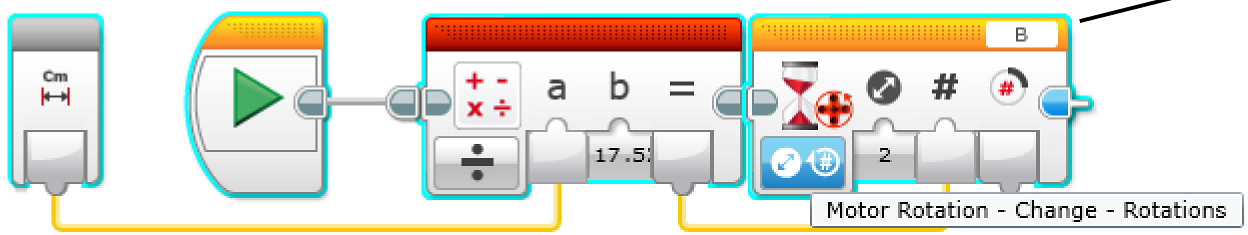
10. Test



Change power and distance settings here to test

Wait for distance My Block

Also useful: Wait for a distance (in cm)



Be sure to set correct motor port

Example usage:

Motors on

Wait 50cm

Wait for black

Stop

Strategy: Consistency wins

Good programming and strategy are essential to consistently good performance

Programming overcomes the limitations of the hardware

Great robot + poor strategy → inconsistent scores

Fair robot + good strategy → consistent scores

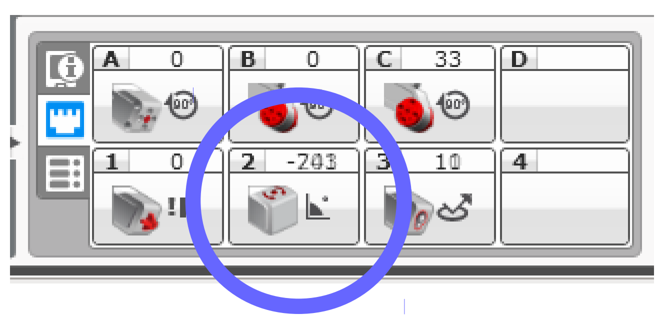
Moving in a straight line with gyro sensor

Gyro sensor detects rotation about an axis

It can help robot follow a straighter line (cf. driving a car)

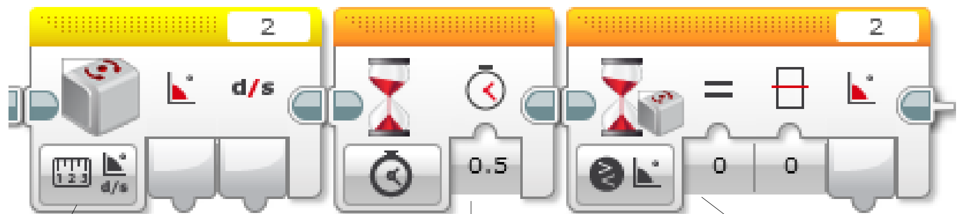
First must correct for sensor *bias* and *drift*

gyro sometimes shows movement even when still



Reducing gyro drift

The following block sequence recalibrates the gyro sensor to eliminate drift:



Measure – Angle and Rate

Wait 0.5 sec

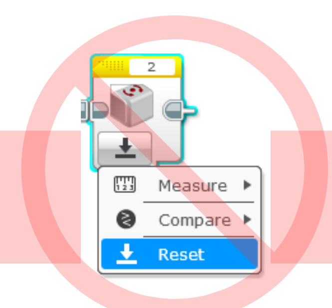
Gyro sensor – Compare – Angle equal to 0

Perform this once at beginning of program

Requires 2-3 seconds to complete

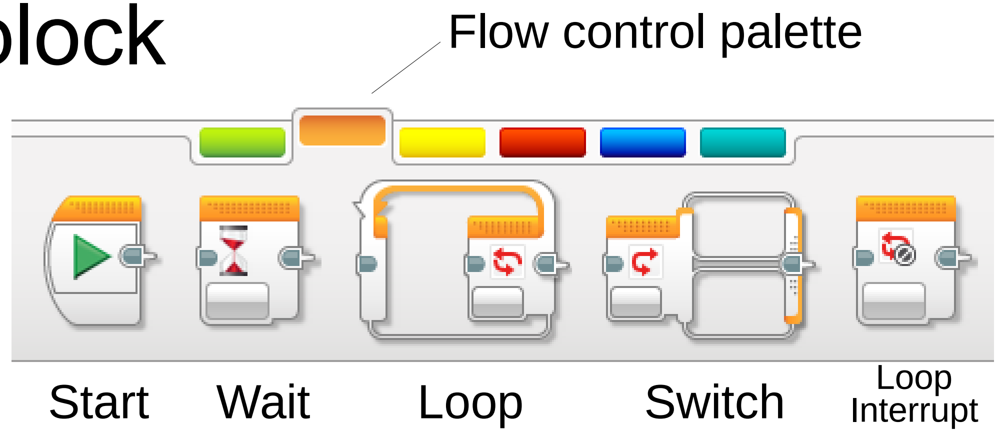
Gyro must be stationary while calibrating

Trap: “Gyro reset” block doesn't recalibrate gyro!

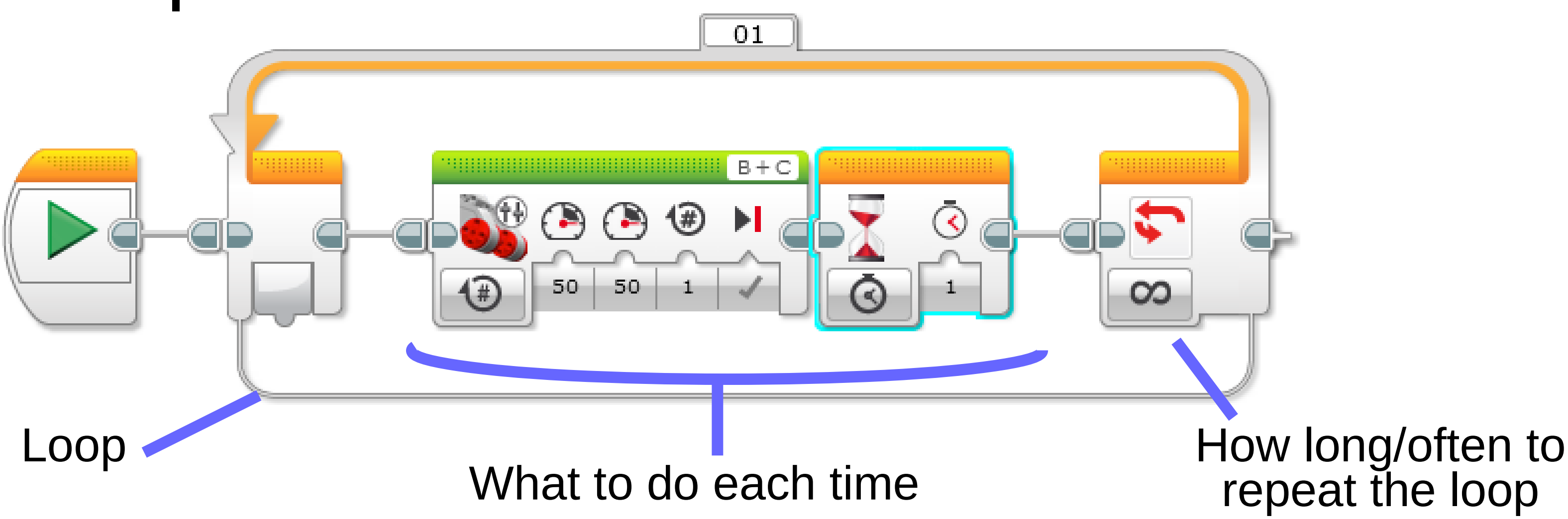


Loops

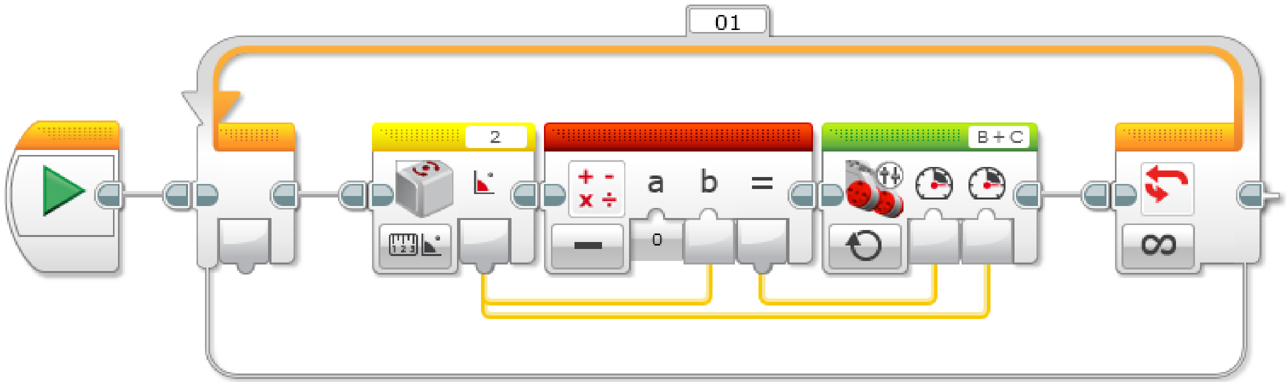
To do something repeatedly (like steering), use a “loop” block



A basic loop block



A gyro-following loop



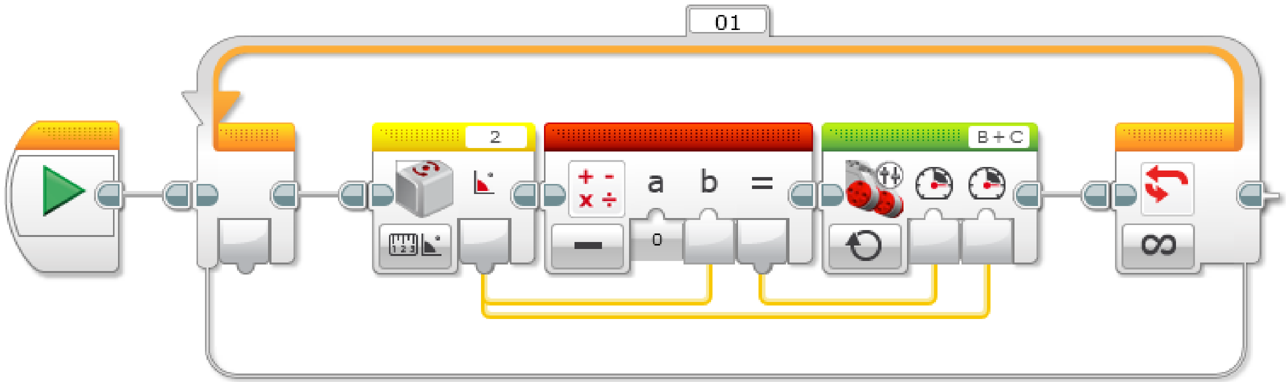
The gyro sensor block reads an angle

The math block flips the (+/-) sign of the gyro angle

One motor gets a negative value
the other gets a positive value

What happens?!?

A gyro-following loop



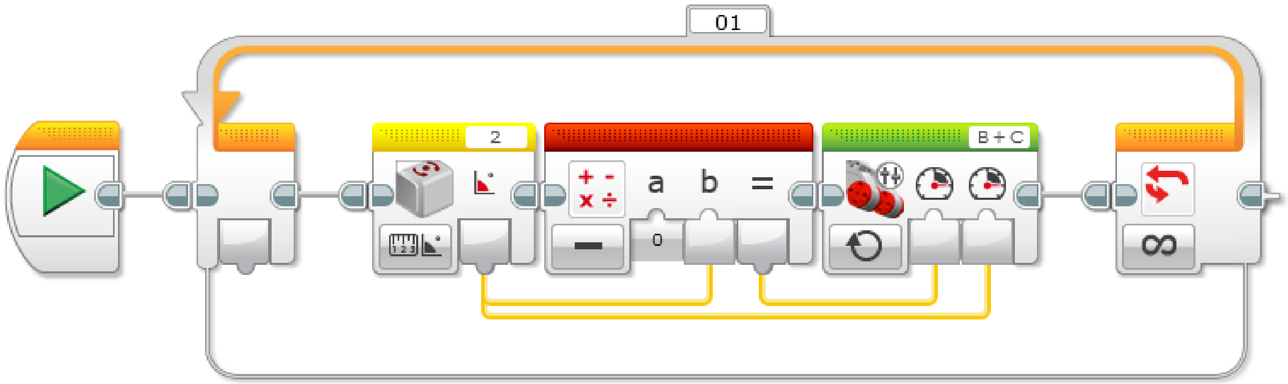
What happens when driving motors move in opposite directions?

What happens here when the gyro angle is zero?

What happens here when the gyro angle is not zero?

→ The robot always turns towards zero!

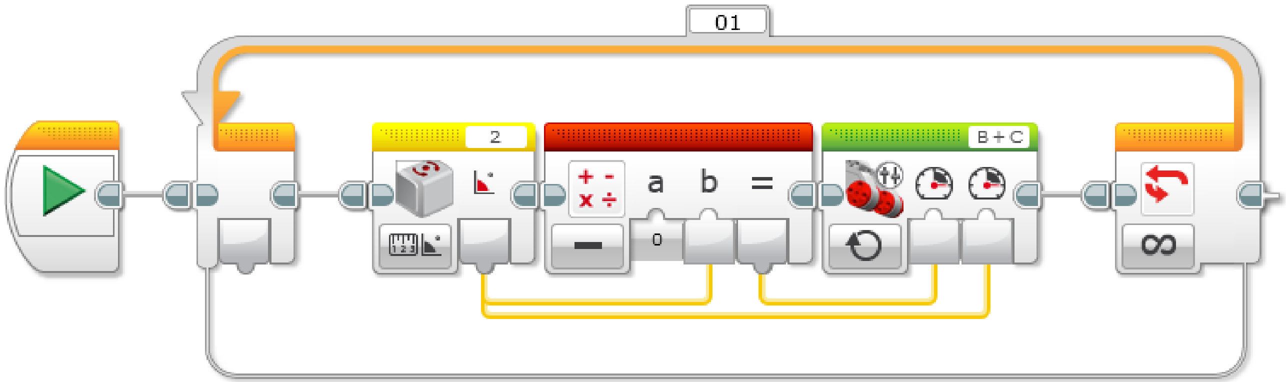
A gyro-following loop



Proportional control loop:

The power to the motors is proportional to how far the gyro sensor is away from zero (the “error”).

A gyro-following loop

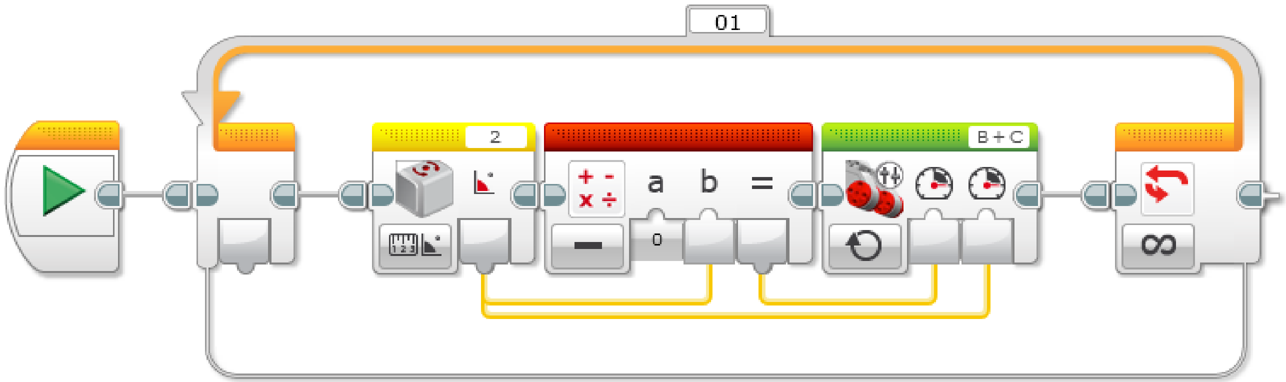


Try it yourself!

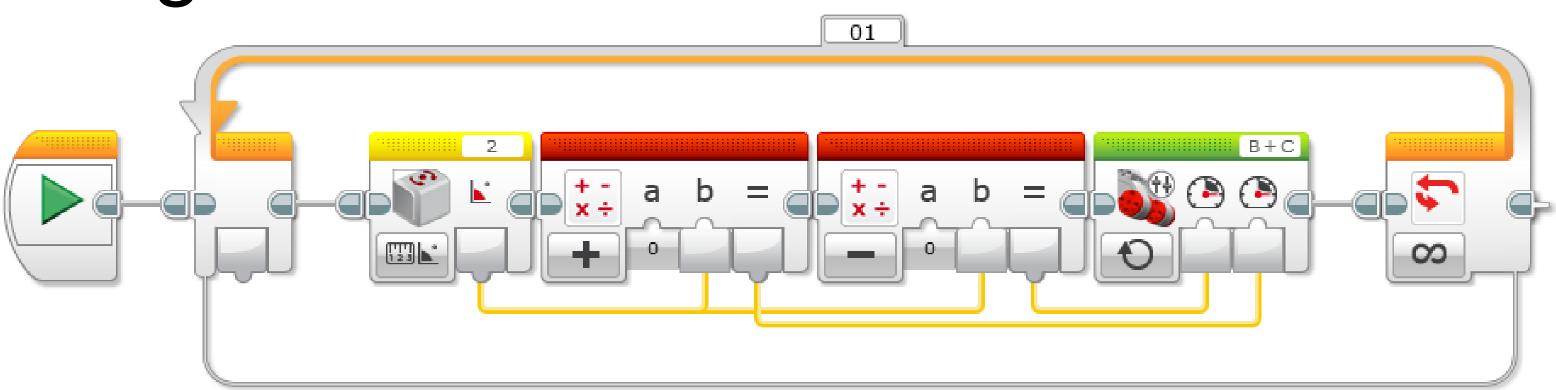
If the robot spins wildly out of control, try swapping the B+C inputs of Move Tank

You may need the gyro calibration code

A gyro-following loop

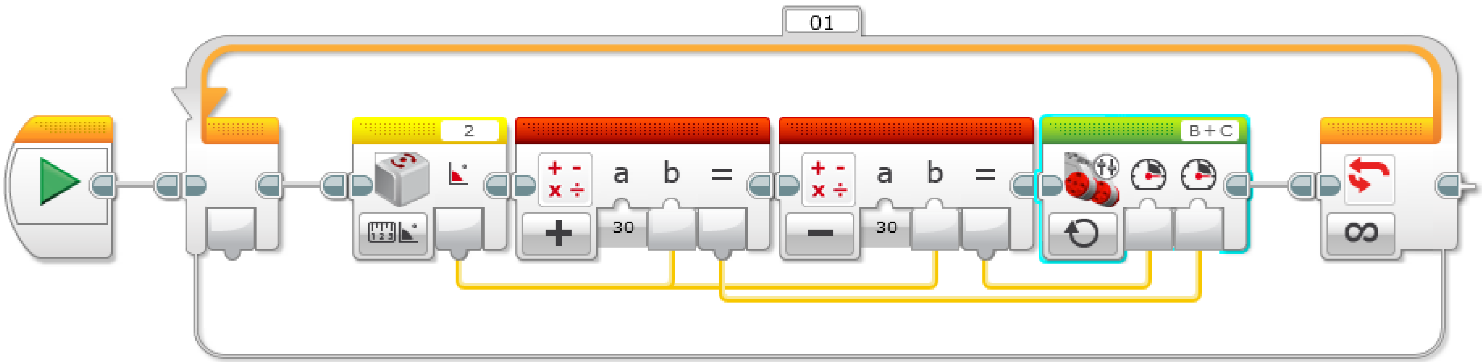


Let's add a math block to the loop that adds the gyro angle to zero:



Does this change anything?

A gyro-following loop



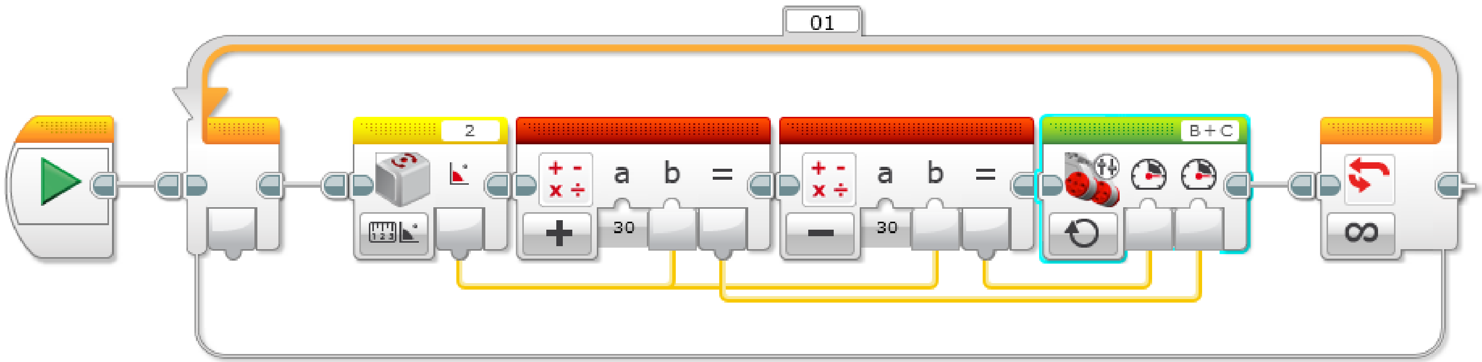
Now change the zeroes in the math block to 30.

What will this do...

...when the angle is zero?

...when the angle is not zero?

A gyro-following loop



When gyro angle is zero:

- both motors have a speed of 30
- robot moves straight ahead

When gyro angle is not zero:

- one motor moves faster than 30 and other moves slower than 30
- robot moves forward but turns toward zero angle

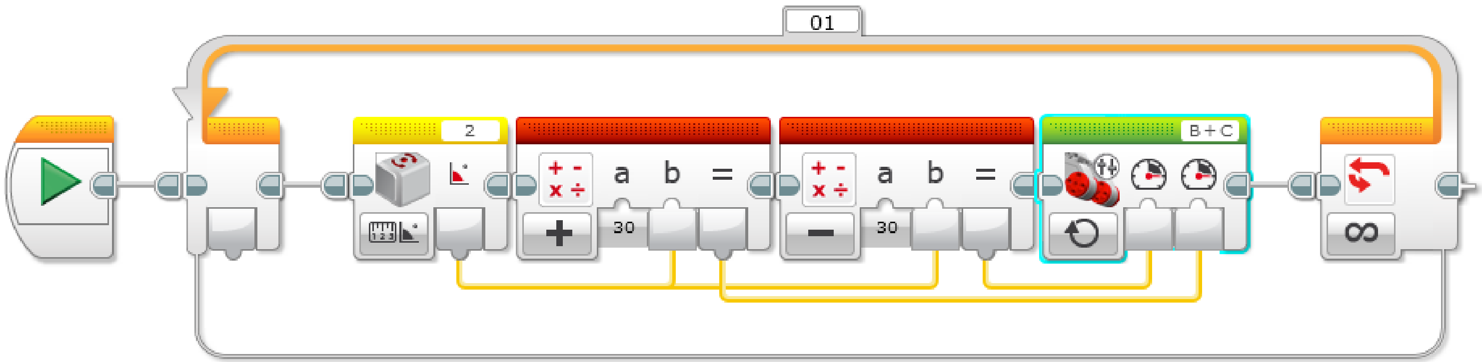
Fundamentals of turns

The robot turns when driving wheels move at different speeds

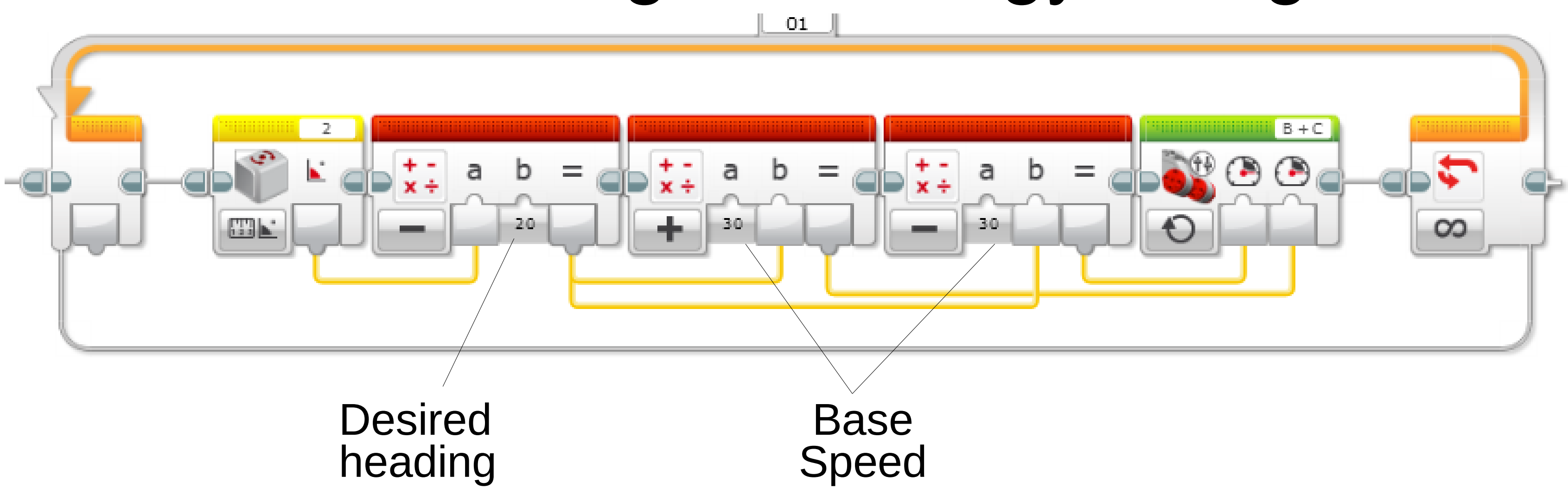
The robot turns towards the *slower* wheel

The greater the difference in speeds, the tighter the turn

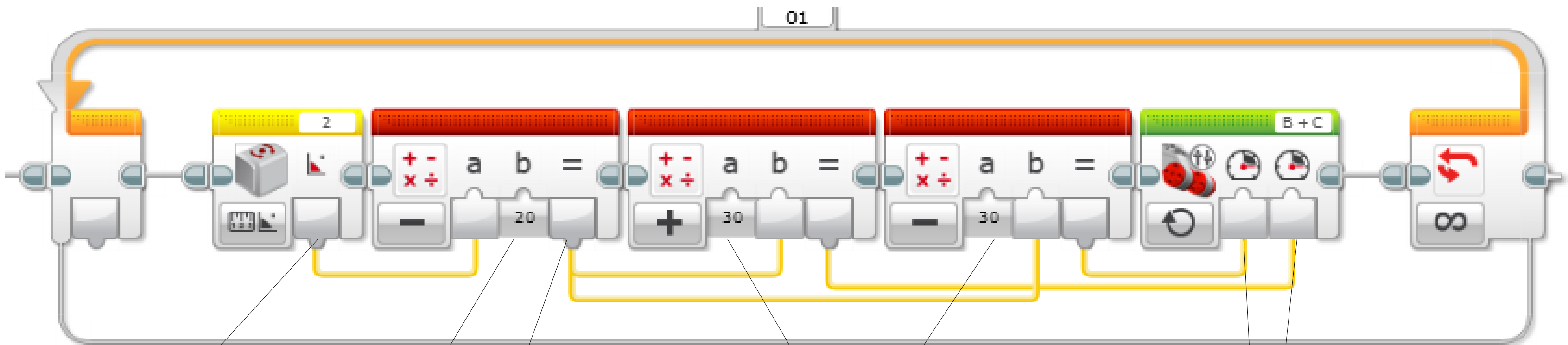
A gyro-following loop



To follow a gyro angle other than zero, subtract the desired heading from the gyro angle:



Gyro-following loop illustrated



This block gives us the current heading

This is the desired heading

The difference (“error”) is how far the robot needs to turn

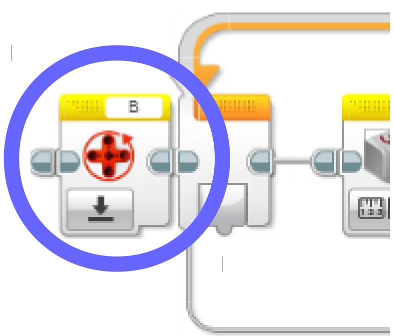
The base speed controls robot forward motion

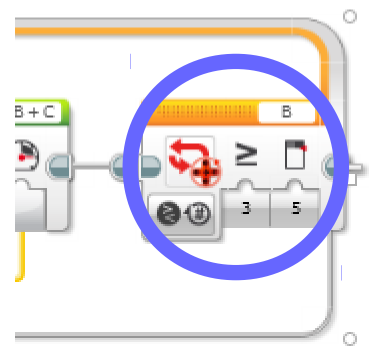
Adding and subtracting the “error” steers the robot towards the desired heading as it moves

Exiting the loop - version 1

One way to exit the loop

- Add a “reset motor” block before the loop
- Tell the loop to exit based on motor rotations

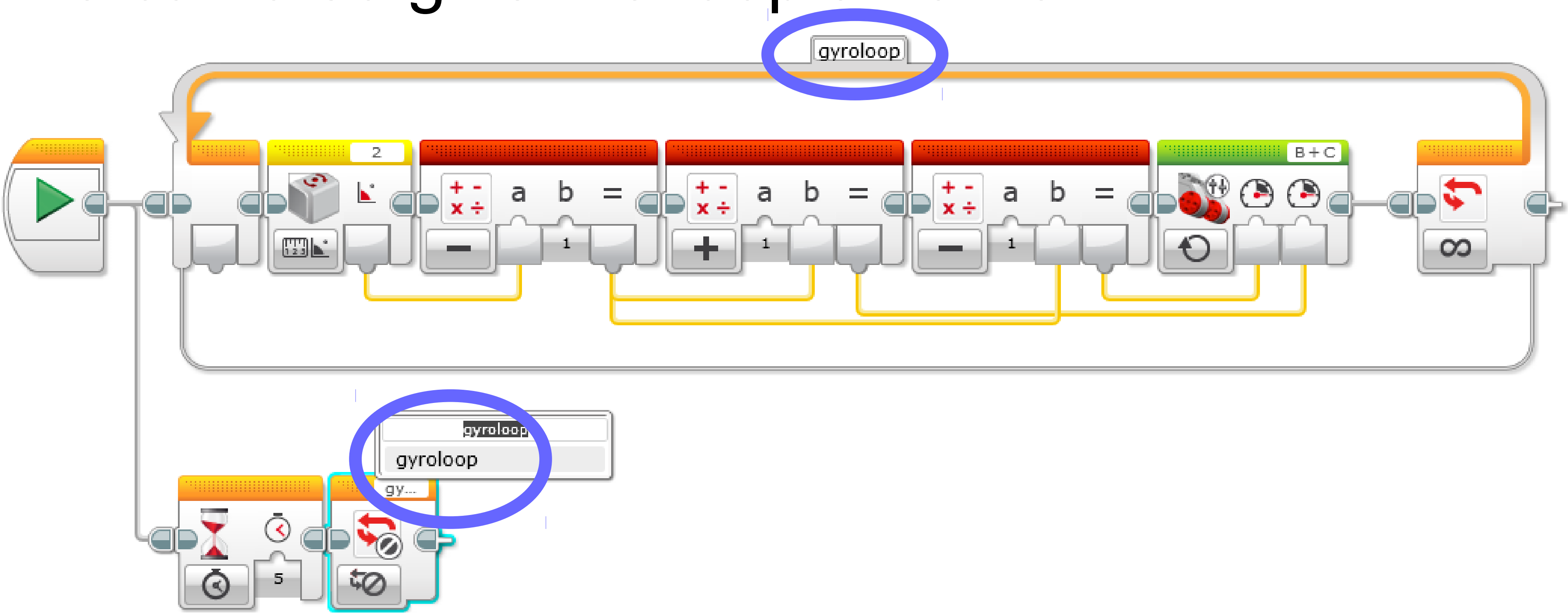




- Be sure to set the ports to a driving motor!

Exiting the loop - version 2

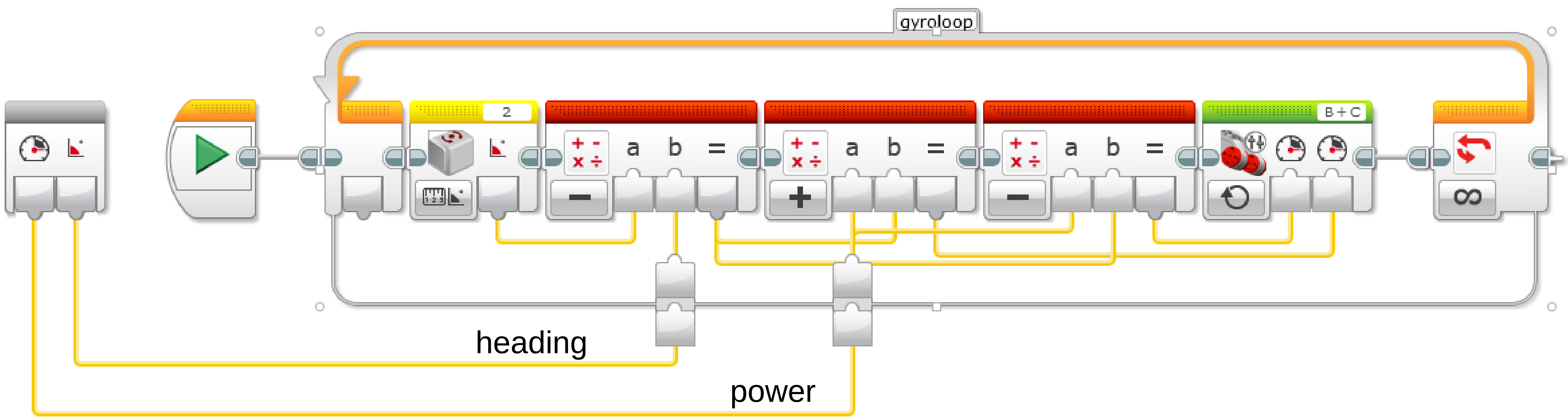
We can also give the loop a name

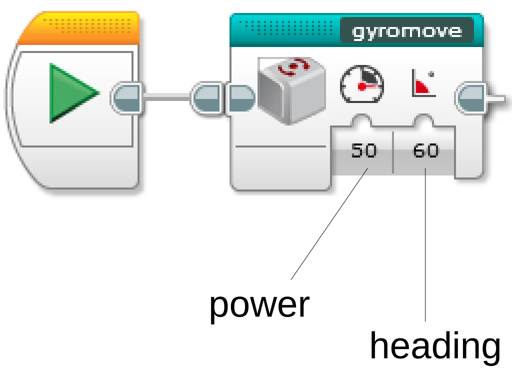


and use a “Loop interrupt” block in parallel to cause it to exit

A gyro-following My Block

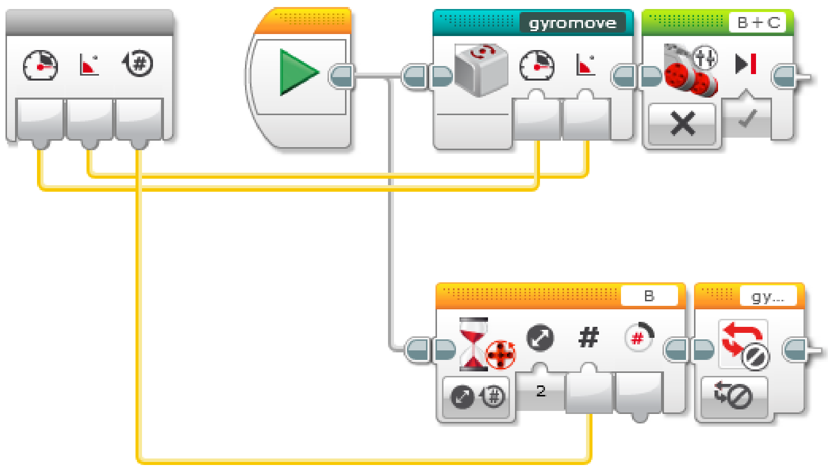
My Block to follow a heading until interrupted:



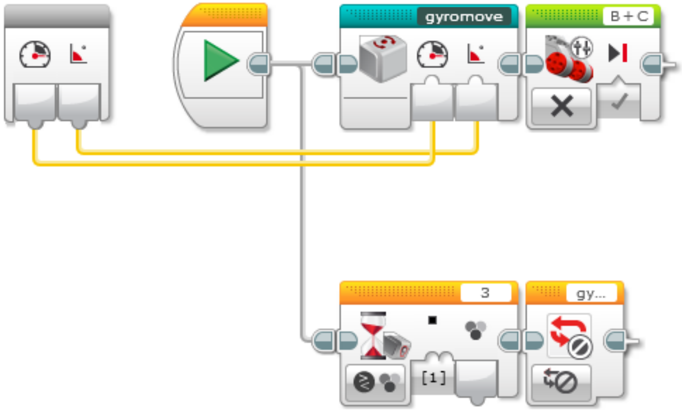


Example movement

Follow heading for rotations



Follow heading until black



Navigation error

Using distances and turn angles for navigation is called “odometry”

It's useful, but consistency depends on the quality of robot components

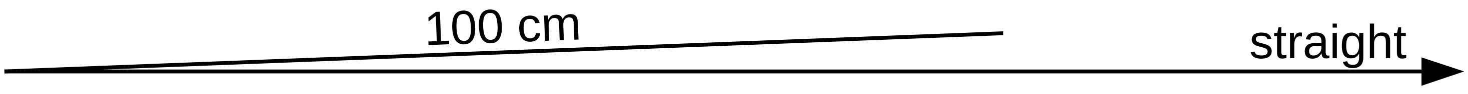
Mindstorms robots can have a lot of odometry error

Sources of odometry error

- Friction
- Gear slack
  - LEGO motors have 5°-15° degrees of gear play
- Wheel slippage
- Battery charge
- Timing issues
- Gyro drift
  - LEGO gyro can have +/- 3° of error

Small angles lead to large offsets

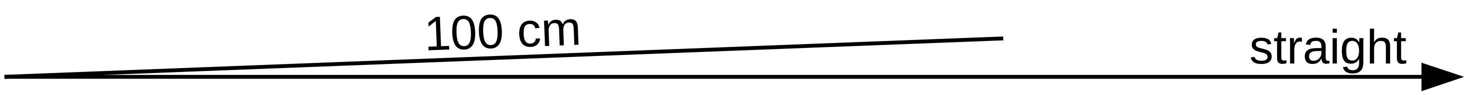
Suppose a robot travels 100 centimeters, but its heading is “off” by 1 degree



Q: How far off will it be after 100cm?

Small angles lead to large offsets

Suppose a robot travels 100 centimeters, but its heading is “off” by 1 degree



Q: How far off will it be after 100cm?

A: 1.74cm

If you're trying to reach something small on the far side of the table, you need more accuracy.

Overcoming error

Strategy: Use field elements for navigation

Lines	Walls
Mission Models	Other

If your robot can find a line, wall, model, or something on the other side of the field, you accurately know its location.

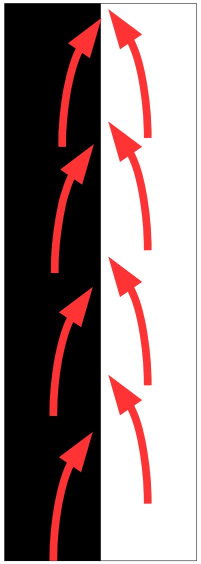
Our guideline: Never make more than two turns without re-orienting the robot using something on the field.

Line / edge following

Use the color sensor to follow lines (actually edges) on the field

Basic idea:

- When the robot sees black, turn right
- When the robot sees white, turn left



This causes the robot to alternate along the "edge" where white and black meet

Understanding LEGO light sensors

- Light sensors have several “modes”
  - Color – used to detect specific colors
    - black, blue, green, yellow, red, white, brown
  - Ambient light – amount of light reaching the sensor
  - Reflected light – same as ambient, but sensor's LED is turned on

- In all of these modes, external lighting can affect readings
- Sensor should 0.5cm to 2.0cm from surface
- Shielding helps a lot

Reflected light mode

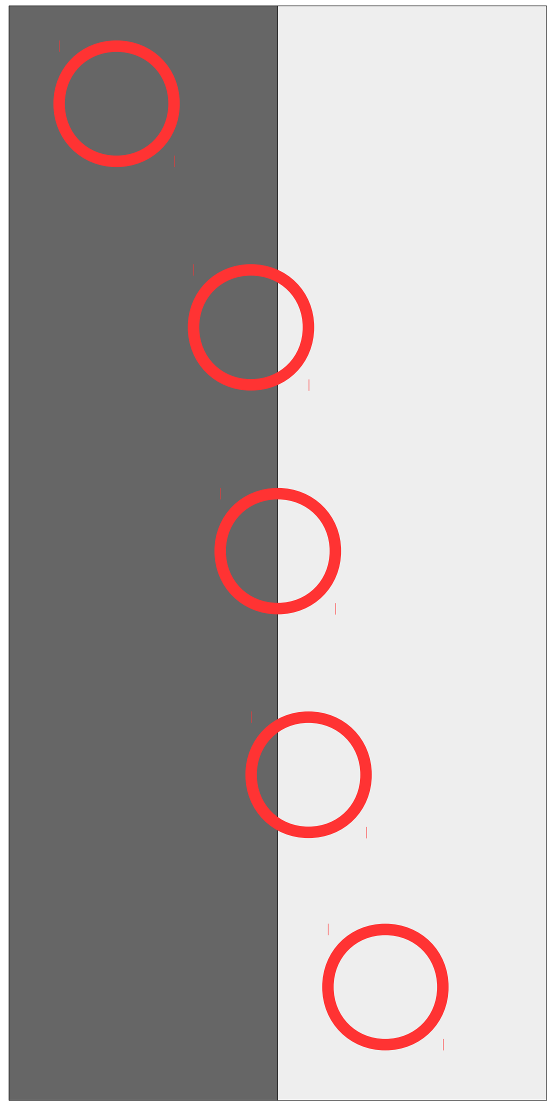
The sensor returns a value from 0 to 100

- 0 == sensor receiving almost no light
- 100 == sensor receiving a lot of light

Use port view to see what the robot is sensing

Reflected light mode

What sorts of values would the sensor see?



5 – turn right a lot

20 – turn right a little

35 – go straight

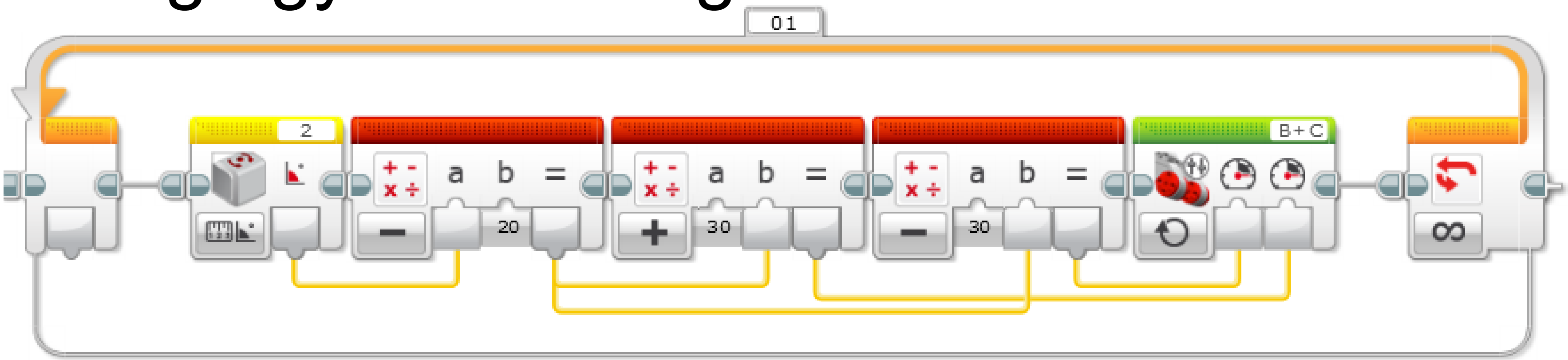
45 – turn left a little

58 – turn left a lot

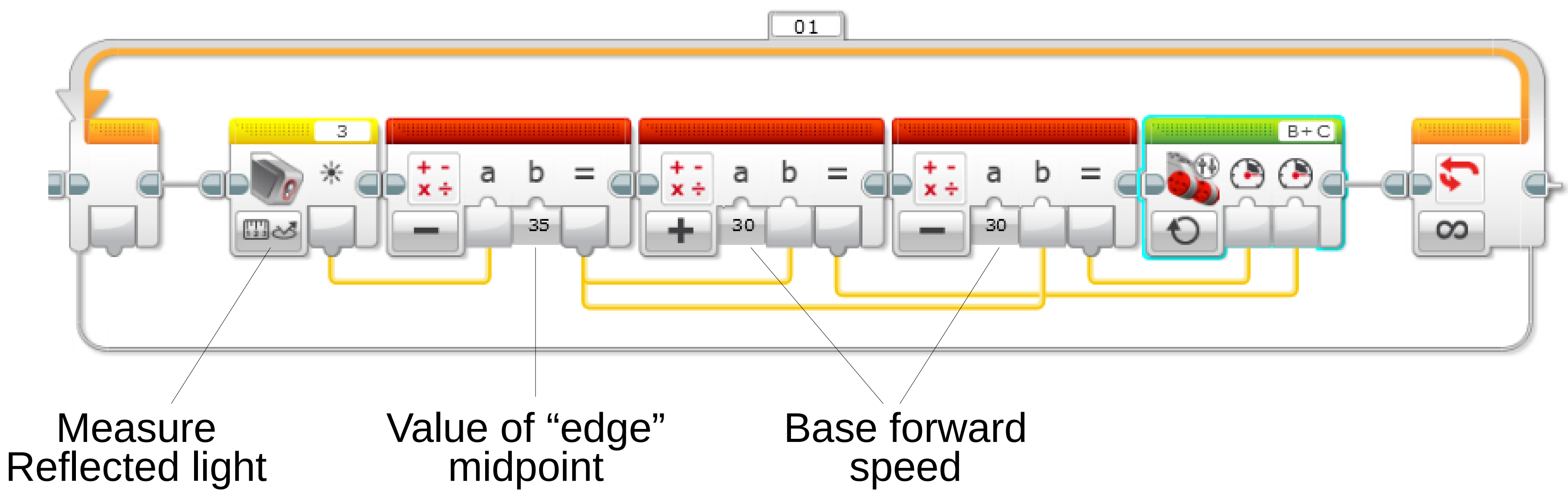
Proportional Control!

Proportional edge following

Change gyro-following sensor



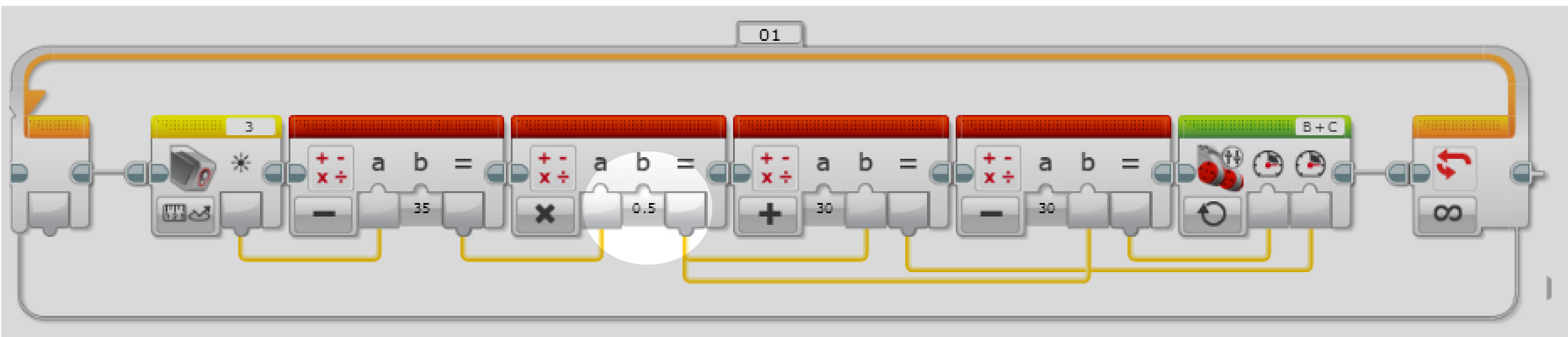
to reflected light sensor



Proportional edge following w/gain

Sometimes you also want a “gain” factor

- Higher gain → sharper turns
- Lower gain → shallower turns



- If robot is “waggling”, decrease gain
- If robot isn't finding the line, increase gain

Proportional edge following

The light sensor must be in front of the driving wheels for edge for edge following to work

With a little tuning, a robot can very precisely follow a line