North Texas FLL Coaches' Clinics
Intermediate FLL Programming

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Goals

Get more consistence performance
Learn advanced programming techniques
Share tips that have helped our team
Point out traps that cause frustration
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
Hopefully you already know about...

- Compiling and downloading programs to EV3
- Motor / move blocks
- Wait blocks
- Touch sensors
Moving forward a distance
Review of My Blocks
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

\[
\text{wheel\_circumference} = \frac{\text{distance}}{\text{motor\_rotations}}
\]

\[87.6 \text{ cm} / 5 = 17.52 \text{ cm}\]

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
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)

Example usage:
Robot game strategy
Consistency wins

Good programming and strategy are essential to consistently good performance

Programming overcomes the limitations of the hardware

Great robot + poor strategy $\rightarrow$ inconsistent scores

Fair robot + good strategy $\rightarrow$ consistent scores
The robot must always start from Base

Base is the only place where changes can be made
Robot Game Strategy - Time

Matches are 2:30

When the Robot is in Base, it's not scoring
  → minimize time spent in Base

Travel on the field takes time
  → minimize time spent moving from place to place
  → solve multiple missions in the same region
Distance:
- Error increases with distance
- Missions that are close become easier
- Missions that are far become harder
  → Use field elements (lines, walls, models) to guide the robot to make things seem "close"
The Robot does exactly what physics and programming say to do

Humans (drivers) make mistakes and are inconsistent

Design the robot and strategy to avoid human mistakes and reduce time in Base
Whenever the robot or humans make a mistake in scoring,

redesign the *robot* so that mistake *cannot* happen again.
Tip: Start every mission from same spot

Put solid edges on robot

Align robot with solid edges, not by sight-aiming

Robot can always start with known location and heading

Faster setup in Base between mission runs

Place flat edge against wall
Pick a marking to align robot
To save match time, always start from same spot
Navigation

A key to scoring is to move robot consistently.

Things a program(mer) needs to know to navigate:

- Where the robot currently is
- How precisely you know where it is
- Where the robot is going
- What's in the way, or what can guide you there

Robot needs to be able to move in a straight line.
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:

1. **Perform this once at beginning of program**
2. **Requires 2-3 seconds to complete**
3. **Gyro must be stationary while calibrating**

- **Measure – Angle and Rate**
- **Wait 0.5 sec**
- **Gyro sensor – Compare – Angle equal to 0**

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

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

A basic loop block

Flow control palette

Start     Wait     Loop     Switch     Loop
Interrupt

What to do each time

How long/often to repeat the 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?!?
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!
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?
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
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.
To follow a gyro angle other than zero, subtract the desired heading from the gyro angle:
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:

[Diagram showing a block structure with inputs for heading and power, and outputs connected to a loop labeled gyroloop.]
Example movement

Follow heading for rotations

Follow heading until black
Intermission
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.
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 be 0.5cm to 2.0cm from the 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

Measure Reflected light
Value of “edge” midpoint
Base forward speed
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.
More stuff goes here
Thank you!

Questions?

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Join the NorthTexasFLL group!