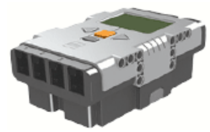
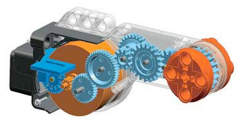
LEGO Mindstorms NXT

- Atmel 32-bit ARM processor
- 4 inputs/sensors (1, 2, 3, 4)
- 3 outputs/motors (A, B, C)
- 256 KB Flash Memory
- 64 KB RAM
- USB 2.0 Communication
- 4 programmable buttons
- 100x64 b/w LCD Display
- Sensors
  - Active:
    - Old light and rotation
  - Passive
    - Touch, sensors for NXT
  - Digital
    - Ultrasonic



- Motors
  - 170 RPM
  - 360 RPM for old motors, why?



Preview

What five steps would the robot have to take in order to go forward for 2 rotations?

1 Spin left motor

2 Spin right motor

3 Wait until the motors have spun two rotations

4 Stop left motor

5 Stop right motor

Preview

Now lets examine what that would look like in the NXT Educational Programming Software.

1 2 3 4 5

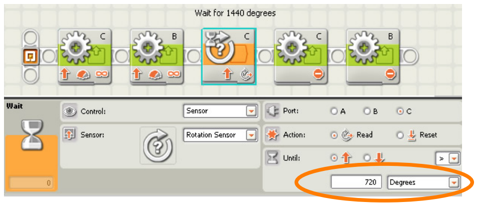
1. Spin left motor
2. Spin right motor
3. Wait for 2 rotations
4. Stop left motor
5. Stop right motor

Preview

While programming your motor blocks, make sure you select the proper output ports, and set both motors to the same direction and power level.

Preview

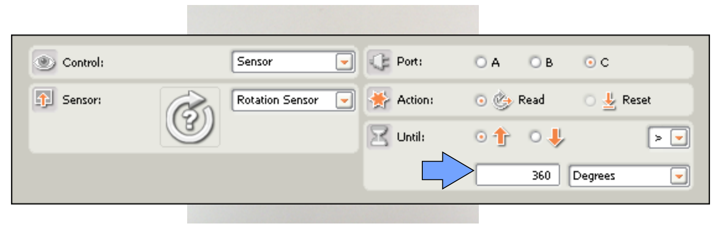
- Don't forget, the *comments* you include in your program don't actually have any effect on what your robot will do.
- Comments simply act as reminders for you when you edit your program. Here, the "wait for 1440 degrees" won't do anything because the actual Wait Block is set to wait for 720 degrees.



Opening Activity

Many things affected how far your robot traveled.

- The number of degrees your Wait For block is set to wait for
- The size of your tires



Review

Let's start with the basics. Answer the following:

1. What is a radius of a circle?

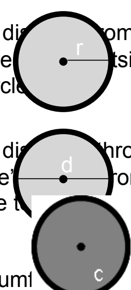
The di[...]om the cente[...]tside of a circl[...]

2. What is a diameter of a circle?

The di[...]hrough a circle[...]om one edge t[...]

3. What is the formula for the circumference of a circle?

Circumf[...] diameter * π

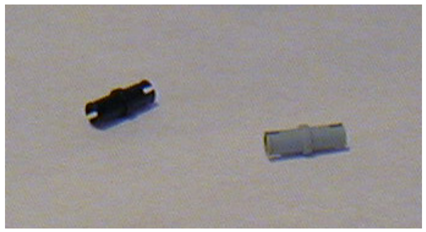


Goals:

- Build better robots
  - Minimize mechanical breakdowns
  - Build robots that are easy to control
  - Encourage good design strategy
  - Strive for elegant, clever solutions
- Know your materials
  - Plastic bricks since 1949 (wooden blocks prior)
  - On average, 2100 different parts each year
  - Manufacturing tolerance: 1/1000 of an inch
  - Number of ways of combining six 8-stud bricks: 102,981,500
  - Widely used by scientists and engineers as a rapid prototyping tool

Connector pegs

- Black pegs are tight-fitting for locking bricks together.
- Grey pegs turn smoothly in bricks for making a pivot



Structure

- LEGO bricks are finicky:
  - They *HATE* duct tape.
  - They *HATE* hot glue.
  - They *HATE* super glue.
  - They *HATE* epoxy.
- You should never need adhesives to build reliable LEGO structures

Drivetrain

- LEGO Gears

8T

16T

24T

40T

1T Worm

24T Crown

Bevel

Design Strategy

- Incremental design
  - Test components parts as you build them
    - Drivetrain
    - Sensors, sensor mounting
    - Structure
  - Don't be afraid to redesign
  - KISS
- Testing
  - Don't wait until you have a final robot to test
    - Interaction of systems
    - Work division (work concurrently)
  - Develop test methods
  - Repeatability

Philosophy

- Build for accurate, precise control
  - Slow vs. fast?
  - Gear backlash
  - Stability
  - Skidding
- Have fun
- Be creative, unique
- Strive for cool solutions, that work!
- Aesthetics: it's fun to make beautiful robots!

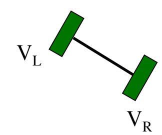
Differential drive

Most common kinematic choice

All of the miniature robots…

Khepera, Braitenberg

- difference in wheels' speeds determines its turning angle



Questions (forward kinematics)

Given the wheel's velocities or positions, what is the robot's velocity/position ?

Are there any inherent system constraints?

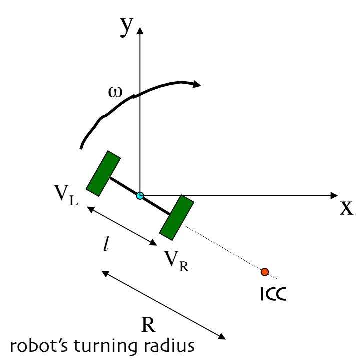
1) Specify system measurements

2) Determine the point (the radius) around which the robot is turning.

3) Determine the speed at which the robot is turning to obtain the robot velocity.

4) Integrate to find position.

Differential drive



(assume a wheel radius of 1)

1) Specify system measurements
- consider possible coordinate systems

2) Determine the point (the radius) around which the robot is turning.
- each wheel must be traveling at the same angular velocity *around the ICC*

3) Determine the robot's speed around the ICC and then linear velocity

$\omega(R+d) = V_L$

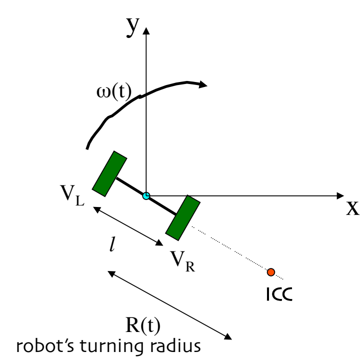
$\omega(R-d) = V_R$

Thus,

$\omega = (V_R - V_L) / l$

$R = l(V_R + V_L) / (V_R - V_L)$

Differential drive



What has to happen to change the ICC ?

4) Integrate to obtain position

$V_x = V(t)\cos(\theta(t))$

$V_y = V(t)\sin(\theta(t))$

Thus,

$x(t) = \int V(t)\cos(\theta(t))\,dt$

$y(t) = \int V(t)\sin(\theta(t))\,dt$

$\theta(t) = \int \omega(t)\,dt$

Kinematics

with

$\omega = (V_R - V_L) / l$

$R = l(V_R + V_L) / 2(V_R - V_L)$

$V = \omega R = (V_R + V_L) / 2$