# Getting Groovy with Lego Mindstorms

## Learn how to get your Groovy on with Legos!

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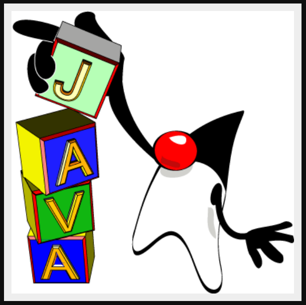
J
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Groovy

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LEGO
mindstorms
EV3
CREATE & COMMAND YOUR OWN ROBOT

= FUN!

## About Me

- Chief Architect @ ReachForce
- Father of 2 girls under 10
- Co-Chair Austin Groovy and Grails User Group
- Help maintain Grails Quartz plugin
- Maintain GVPS Plugin (Grails Video Pseudo Streamer)
- Maintain Struts-1 Plugin
- Submit pull requests for others when I can!

# What we will cover

- What is the EV3?
- What is leJOS?
- Layout and components of leJOS
- Programming Model
- How build components of leJOS with Gradle
- Overview of leJOS APIs
- Run some demo apps on leJOS
- Build and deploy a demo leJOS Groovy App
- More advanced topics - Sensors and Events
- Let's add some sensors to our apps we've built!
- WebRover 1 - Build, Run, and Play!

## What is EV3?

EV3 is the latest generation LEGO Mindstorm Platform

TI ARM9 Core CPU (Runs ARMv5 instruction set)

64MB RAM

16gb internal flash

microSD slot

bluetooth wireless

usb port

New generation of 'smarter sensors' (single sensors replace many nxt ones)

One big difference vs Raspberry Pi is it is a ARM11 with ARMv7 instruction set with hardfp(w/jdk!)

## What is leJOS?

leJOS is a Java-based implemention that started on the lego mindstorm RCX platform that runs on arm based processors. leJOS was forked oringally from the 'TinyVM' project in 2000.

Available in 3 flavors: RCX, NXJ, and EV3 that are all still maintained

## What is LeJOS?

- Replacement firmware for building Lego Robots in Java
- PC Tools for flashing Lego Brick
- PC Apps to communicate to your robot from your PC via bluetooth, Wifi, USB
- Creates a running jar package to deploy on your robot for execution

## Why no Groovy before now?

- Groovy was too slow before @StaticCompile (Soft FP)
- More limited audience
- Many Java people still not educated on Groovy(but this has grown!)
- leJOS didn't provide an easy way to run Groovy(core commiters indifferent to Groovy)

## Layouts and components of leJOS

- OS Image
- DBusJava
- EV3 Classes
- EV3 Menu
- Other components

## OS Image

This is the base linux install image leJOS runs on

- Runs minimal OS and kernel - only subset of basic shell options and commands available
- On code drop on your usb key, located in /ev3snapshot
- On Windows there is a exe installer
- On Linux or Mac, write sd500.img to your microSD card, then unzip sdcard/lejosimage.zip to roots
- Other components

## OS Image

Runs minimal OS and kernel - only subset of basic shell options and commands available

- shell is 'ash' nowhere near feature comparable to bash
- ps command only has 1 parameter 'w' for wide
- leJOS interacts with it by starting up a java app called 'EV3Menu'
- There isn't really enough RAM to run more than 1 VM besides what leJOS uses (hello oom killer!)

## DBusJava

JNI Layer that interacts with physical hardware

- This is the glue to makes JVM classes work
- Generally you don't need to do anything with it unless you are adding unsupported hardware
- see the README file under DBusJava/src for how to add modules (outside scope of us here)
- Feel free to use the artifact on my Bintray account, compile your own with the scripts, or use your own artifact server

# EV3Classes

Supporting Java classes for leJOS

- This is all the Java implementation classes for the system
- This is a monolithic code base/lib at this point all projects depend on this to work
- I've created some custom classes inside here to allow the Webrover to work (later)
- Divided into 4 sections - Hardware, Internal, Robotics and Utility
- Hardware - Java representation of the lego hardware items

## EV3Classes

Hardware

- Support for Tetrix metal robots
- Supports motors from EV3, NXT, RCX, Mindsensors Glidewheel-M, regulated and unregulated
- Supports GPS with this device http://www.dexterindustries.com/dGPS.html
- Ports - these are there the low level devices sensors are connected to (Mostly I2C/UART)
- Sensors - supports over 40 different kinds of sensors from Lego, Dextor, HiTechnic and Mindsensors
- LocalEV3 is the singleton class to get access to things (show example in code)
- Basic hardware objects on EV3 brick itself are in lejos.hardware base pkg (Audio, LCD, buttons and keys)

# EV3Classes

Internal

- Handles bluetooth pairing with DBusJava
- Internal EV3 implementation classes not part of public API
- Low level linux hardware access classes (NIO)
- If you use the classes they are subject to change without and kind of deprecation or notice

# EV3Classes

## Remote

- Mainly uses RMI
- RemoteEV3 is main classes to access remotely (give it IP address)
- Accessing hardware remotely pretty much as a 1:1 relation with 'Remote' in front of classs
- Wifi support most stable
- Bluetooth is not working, but not considered 100% stable
- When accessing ports, you must pass in the the proper 1 or 2 letter names (S[1-9] or letter A-F on motor ports
- Let's look at some RemoteEV3 code usage!

# EV3Classes

Robotics

- The fun stuff! Doing something with all of these classes, sensors and motors
- filters - filters for sample providers such as SumFilter which takes the sum of samples over time, or MedianFilter
- geometry - geometric shape support using float co-ordinates
- localization - BeaconPoseProvider, CompassPoseProvider, MCLPoseProvider, OdometryPostProvider
- mapping - adds support for maps- Main class is EV3NavigationModel which takes Pilot, Navigator, PoseProvider, RangeScanner, FeatureFinder

# EV3Classes

Robotics - continued

- navigation - classes for physically navigating the robot around - DifferentialPilot, SteeringPilot, OmniPilot
- object detection - Feature detector, Fusor detector, RangeFeature, and TouchFeature
- pathfinding - most of these use a map to determine a path for the robot to take (Dijkstra, Random, Shortest, Node)
- subsumption - Arbitrator and Behavior

# EV3Classes

Utilities

- general utility classes - things like Timers, property mgt, delays, debugs

## EV3Menu

This project keeps the JVM running, provides RMI services, WAP setup, UI on the front of the EV3 Brick

- Samples -> runs in separate jvm maps to /home/root/lejos/samples (Runs fine with @CompileStatic)
- Programs -> runs in separate jvm maps to /home/lejos/programs (Runs fine with @CompileStatic)
- Tools -> runs in same jvm maps to /home/root/lejos/tools (Runs Groovy fastest w/MOP)

## Let's Go!

Let's break into groups and start setting up leJOS+Groovy SD Card Images, setup wifi, and deploy the sample Groovy App

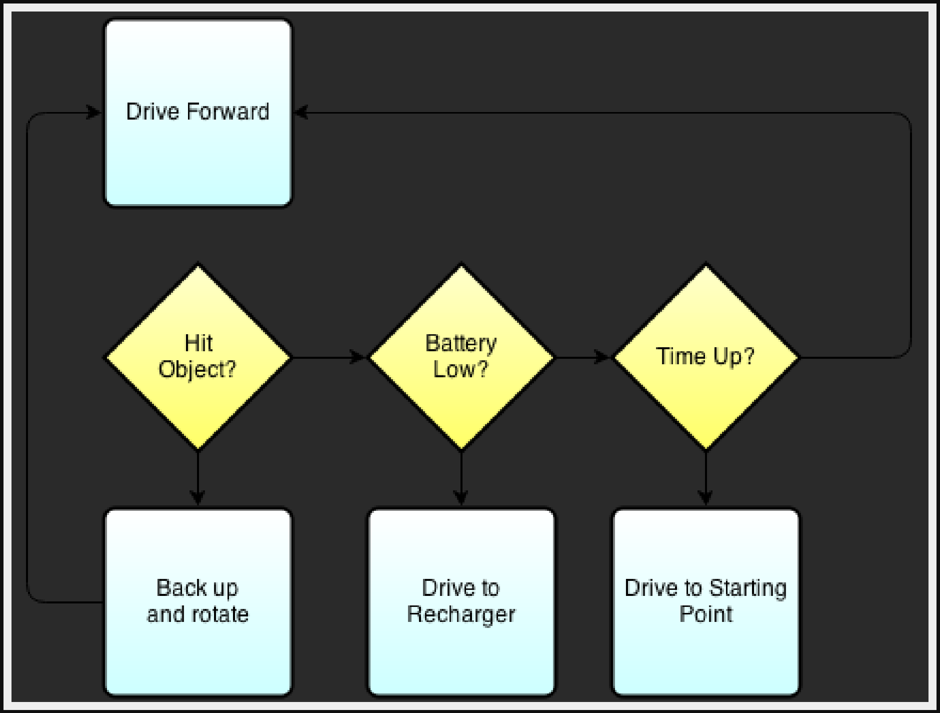
## Programming Model

Behavior Programming

- Why? Creates less spaghetti code of if-then-else statements
- Uses threads to keep multiple things going on to allow different 'behaviors' to react
- Interface uses only 3 methods - action, suppress, and takeControl
- Uses to main Interfaces - Behavior and Artibrator

# Programming Model

Behavior Programming



## Programming Model

Behavior Programming - continued

- Arbitrator takes over from your 3 behavior classes after they are complete
- Arbitrator regulates when behaviors become active
- Enter and escape will stop unless returnwheninactive is set upon creation
- Takes an array of behaviors

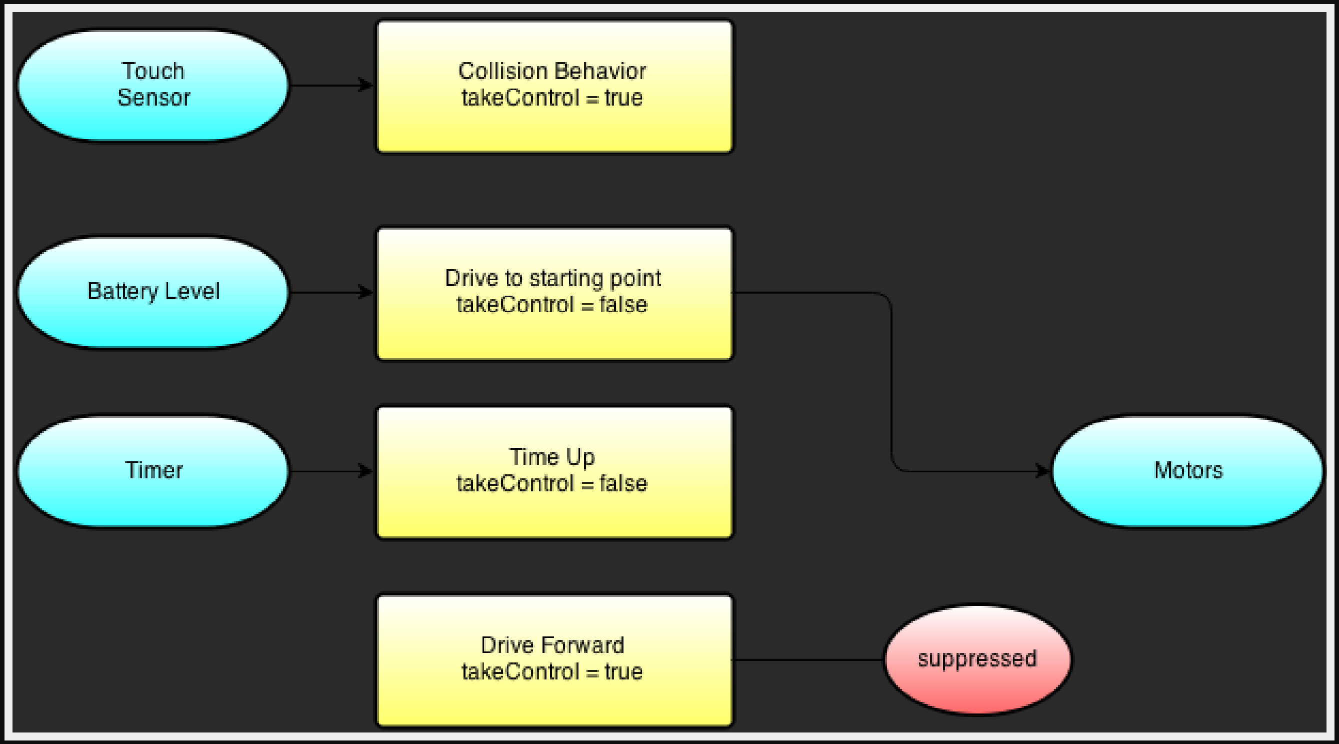
## Programming Model

Behavior Programming - continued

- Simple to use, only method is start() - higher level behaviors suppress lower ones
- The array of behaviors passed in, index order determines priority of arbitrator to control behaviors
- Recommended design pattern - define boolean flag 'suppressed' for each behavior, set variable to true by supress method, test in each action method. first thing in action method is to set this to false
- Action must be coded for prompt exit from method

# Programming Model

## Behavior Programming - suppression


Touch Sensor
Collision Behavior takeControl = true
Battery Level
Drive to starting point takeControl = false
Timer
Time Up takeControl = false
Motors
Drive Forward takeControl = true
suppressed

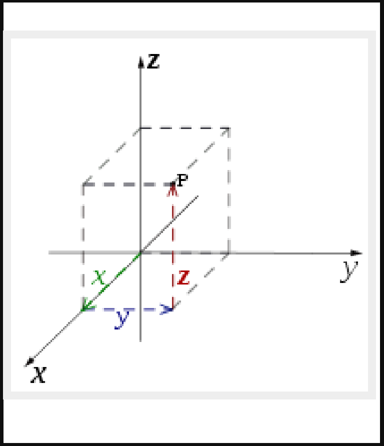
## Programming Model

Let's work on our example!

## Advanced - Sensors and Events

### Sensors

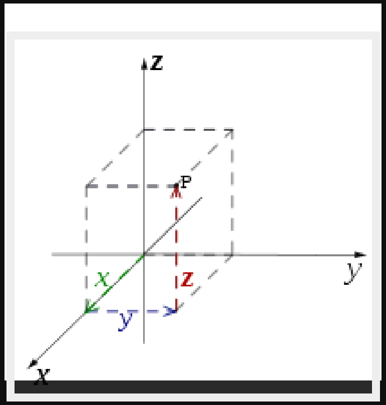
- Educational 'core' kit: Ultrasonic, Color, Gyroscopic, and 2x Touch
- Retail kit: Infrared, Color, 1x Touch
- Full difference part-by-part between the kits here
- All measurements are in SI-units
- LeJOS uses a cartesian coordinate system



## Advanced - Sensors and Events

### Cartesian Coordinate System

- The positive X-axis points in the same direction as the plug you plug into a sensor, also the direction the Ultrasonic sensors from Lego point to
- The positive Y-axis points to the left of the X-axis and the positive Z-axis points upwards
- Angles follow the right hand rule: This means that a counter clockwise rotation of a robot is measured as a positive rotation by the sensors on it
- On sensors that support multiple axes, like some gyroscopes and accelerometers, the axis order in a sample is always X,Y,Z



## Advanced - Sensors and Events - Filters

### Filters

Filters are used to alter a sample or alter the flow of samples

- Filters take a sample from a SampleProvider, modify it and then pass it on as a sample
- They are sample providers themselves
- Angles follow the right hand rule: This means that a counter clockwise rotation of a robot is measured as a positive rotation by the sensors on it
- On sensors that support multiple axes, like some gyroscopes and accelerometers, the axis order in a sample is always X,Y,Z

# Advanced - Sensors and Events - Filter Sample

```
// get a port instance
Port port = LocalEV3.get().getPort("S2");

// Get an instance of the Ultrasonic EV3 sensor
SensorModes sensor = new EV3UltrasonicSensor(port);

// get an instance of this sensor in measurement mode
SampleProvider distance= sensor.getModeName("Distance");

// stack a filter on the sensor that gives the running average of the last 5 samp
SampleProvider average = new MeanFilter(distance, 5);

// initialise an array of floats for fetching samples
float[] sample = new float[average.sampleSize()];

// fetch a sample
average.fetchSample(sample, 0);
```

## Advanced - Sensors and Events - Threads

Filters

Threads are spawned to facilitate:

- listeners
- regulated motors
- bluetooth
- timers
- navigation classes (Like NavPathController)
- On threads that don't need to terminate when program is done use setDaemon(true)

# Advanced - Sensors and Events - Threads

## Threads - example from startup menu

```
class Indicators extends Thread {
  private boolean io = false;

  public void ioActive() {
    io = true;
  }

  public void run() {
    String[] ioProgress = { ".   ", " .  ", "  . " };
    int ioIndex = 0;
    boolean rewrite = false;
    while (true) {
      try {
        if (io) {
          StartUpText.g.drawString("     ", 76, 0);
          ioIndex = (ioIndex + 1) % ioProgress.length;
          StartUpText.g.drawString(ioProgress[ioIndex], 78, 0);
          io = false;
          rewrite = true;
        } else if (rewrite) {
          LCD.drawString("   ", 13, 0);
          // invert when power is off
```

```
           //startup the code
Indicators ind = new Indicators();
ind.setDaemon(true);
ind.start();
```

# Advanced - Sensors and Events

Listeners & Events

The listener thread supports Button Listeners & Sensor Port Listeners

- Button listeners are used to detect when a button is pressed, whatever your program is doing at the time
- To listen for a press of a specific button, you register as listener for that button
-

```
public class ListenForButtons {
  public static void main(String[] args) throws Exception {
    Button.ENTER.addButtonListener(new ButtonListener() {
      public void buttonPressed(Button b) {
        LCD.drawString("ENTER pressed", 0, 0);
      }

      public void buttonReleased(Button b) {
        LCD.clear();
      }
    });

    Button.ESCAPE.waitForPressAndRelease();
  }
}
```

## Advanced - Sensors and Events - Threads

EV3BumperCar

Let's now build and deploy a Groovy verison of EV3BumperCar!

Should just need to add 1 touch sensor to port 1, ultrasonic port 2, 2 wheeled or tracked robot

# WebRover1

Based off WebRover1 Project for NXT for International Space Apps Challenge 2013

Original version for NXT - had to rewrite a lot of it and switch to RMI for it to work with EV3

Allows you to simulate a remote rover type of device you could drive from far away like Mars or across the globe

# WebRover1 - EV3

What is all if comprised of?

- Special RMIDifferentialPilot Class in the EV3Classes project
- Grails Application
- IP Camera App on Android or iOS via Wifi(Off the shelf)
- Javascript page with keybinding to actually input driving robot

# WebRover1 - EV3

RMIDifferentialPilot

- RMI Enabled version of DifferentialPilot
- Pilot contains methods to control robot movements: travel forward or backward in a straight line or a circular path or rotate to a new direction
- Will only work with two independently controlled motors to steer differentially, so it can rotate within its own footprint
- Let's go over the code!

## WebRover1 - EV3

Grails Application

- 2 Services, 2 Controllers, 1 GSP page
- 4 classes handle the robotics, brick abstraction, and remote comms
- Camera - using 'IP Webcam' free edition on Android
- Configure IP address of Camera and EV3 in Config.groovy before starting app
- Use the grails start/stop command interface to shut down app nicely, or you will have to keep rebooting the ev3

# WebRover1 - EV3

## Grails Application - Code Overview

- Camera Service - takes pictures and updates page to help you drive
- Robot Service - take input from GSP page to send commands to direct robott
- EV3Brick - abstraction class for robot, holds refs to motors
- EV3Robot - sets up comms and sensors references
- BasicRobot - bring Pilot, motors, and sensors together via RMI
- Let's look at the code and set yours up!

## More Information

- leJOS Wiki: http://sourceforge.net/p/lejos/wiki/Home/
- leJOS Forums: http://www.lejos.org/forum/
- leJOS SD Card creation repo: https://sourceforge.net/p/lejos/ev3sdcard/ci/master/tree/
- leJOS EV3 Code Repo: https://sourceforge.net/p/lejos/ev3/ci/master/tree/
- Ryan's Fork w/Gradle support: https://sourceforge.net/u/ryanv78665/lejos/ci/master/tree/
- Gitub repo for WebRover1 EV3: https://github.com/rvanderwerf/webrover1

## More Information - Buying parts

- You can buy random parts by the pound off ebay like this: http://r.ebay.com/4tvn8e
- Lego Store (Many things often out of stock, poor supply chain?)
- Brickowl.com - reseller part search used and new
- Bricklink.com: http://www.bricklink.com/
- Amazon - specific parts are available there sometimes cheaper but less selection

# THE END

## I hope you have enjoyed the workshop!

Free free to contact me on twitter or google+ @RyanVanderwerf or email rvanderwerf@gmail.com