LEGO® MINDSTORMS® EV3 Programming using Simulink

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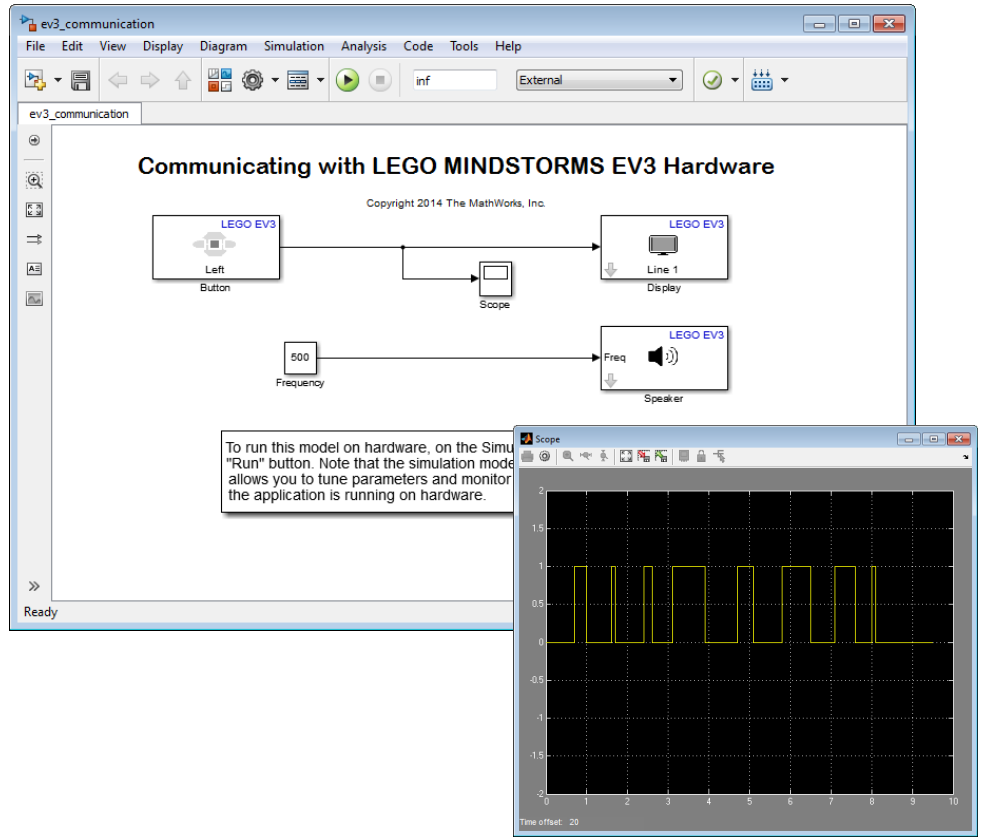
Agenda

- Introduction to LEGO MINDSTORMS EV3
- Software Setup
  - Installation of Simulink Support Package for LEGO MINDSTORMS EV3 Hardware
- Hardware Setup
  - Setup and connect EV3 to computer
  - Test with example: EV3 Communication
- Examples
  - Line Tracking Robot
  - Self Balancing Robot
- Wrap-up



Introduction to LEGO MINDSTORMS EV3

Introduction to LEGO MINDSTORMS EV3

- *What is it?*
  - LEGO MINDSTORMS is a programmable robotics construction set. EV3 is the third generation of the LEGO MINDSTORMS platform and the “EV” stands for evolution.
  - You can build a robot with provided instructions, or design and share your own creation

- *What is in a set?*
  - Intelligent EV3 Brick (ARM9-based microcontroller)
  - Sensors such as infrared, color, and touch
  - Actuators including three servo motors
  - Variety of LEGO structural and connection pieces
  - 2 sets available: Retail and Education

Introduction to LEGO MINDSTORMS EV3

- *What's the main difference between Retail and Education sets?*
  - Retail set (31313) has infrared sensor and beacon
  - Education set (45544) has rechargeable battery, gyro sensor and ultrasonic sensor

- *How much does it cost?*
  - Approximately $350 US

- *OK, where do I get one?*
  - LEGO Shop (for Retail Set)
  - LEGO Education (for Education set)
  - Various online vendors (Amazon and others)

For more info: http://www.lego.com/en-us/mindstorms/support/faq/

Software Setup

Software Setup

- *What software do I need?*

  - *MathWorks Software:*
    - MATLAB and Simulink (also works with Student and Home versions) Release R2014a, or later

    Note: LEGO EV3 support is available on 32-bit and 64-bit Microsoft Windows and 64-bit Linux.

  - *Simulink Support Package for LEGO MINDSTORMS EV3 Hardware*

  - *Optional: Compiler (for MathWorks software):*

    You need a compiler if you want to use a MATLAB Function Block
    (MATLAB function which operates inside of Simulink and can be deployed to hardware)

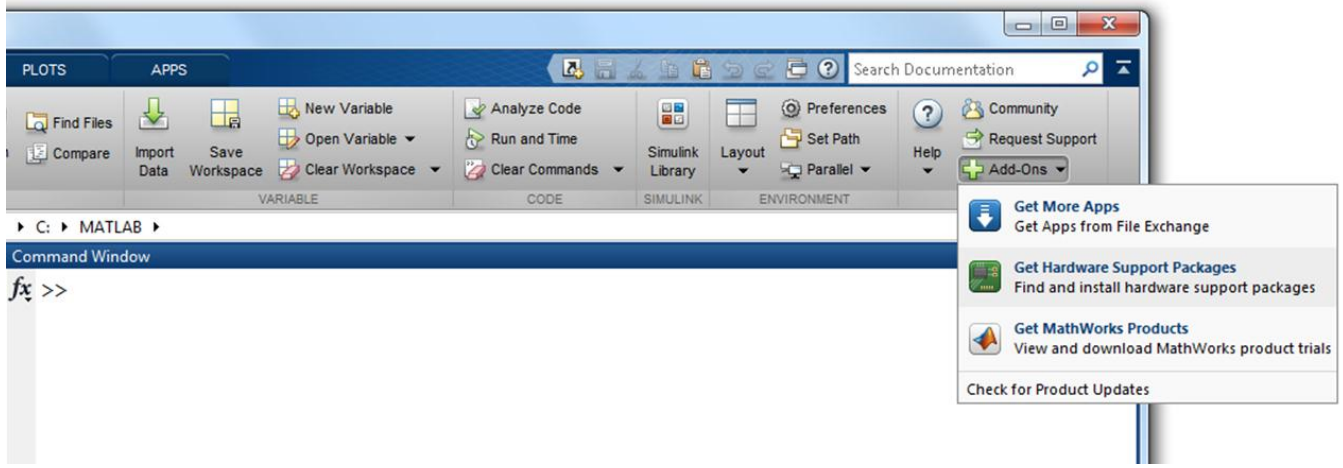
    - See **Supported and Compatible Compilers**

      http://www.mathworks.com/support/compilers/
    - For my 64-bit Windows 7 installation, I use Microsoft Windows SDK 7.1 (available at no charge)

Simulink Support Package for LEGO MINDSTORMS EV3 Hardware

- *What is it?*
  - A set of Simulink blocks that allow you to generate programs that run on a LEGO MINDSTORMS EV3
  - It's downloadable and it's free!

- *Where do I get it?*
  - Get from the MATLAB Toolstrip: Add-Ons → Get Hardware Support Packages

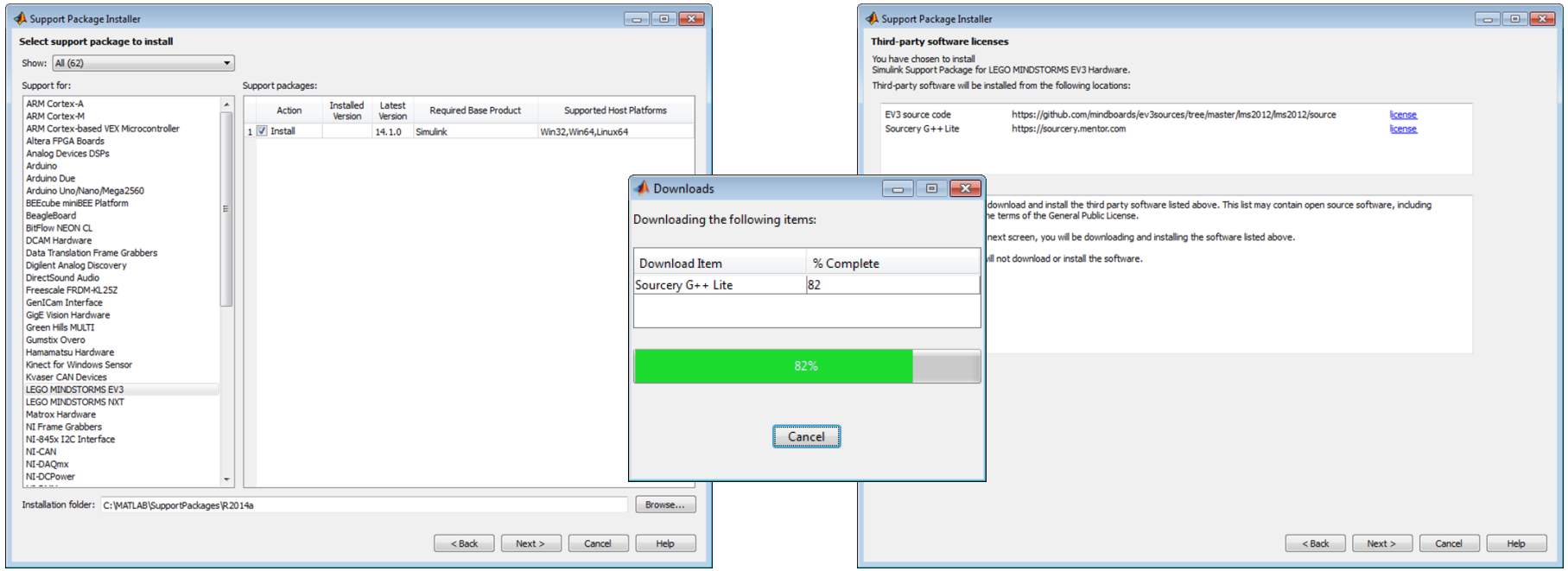


  - Get from the MATLAB Command Line: >> `supportPackageInstaller`

Simulink Support Package for LEGO MINDSTORMS EV3 Hardware

- *Installation Process:*
  - The Support Package Installer will lead you through the installation process and install all the software you need to run on a LEGO MINDSTORMS EV3 from Simulink

Let's go get it!



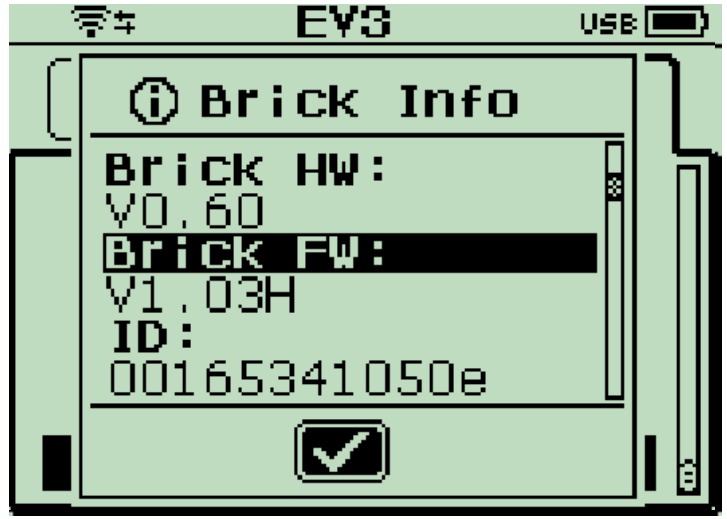
Summary: Simulink Support Package for LEGO MINDSTORMS EV3 Hardware

- Support Package Installer installs all the software elements you need to connect to and run on a LEGO MINDSTORMS EV3

EV3 source code	https://github.com/mindboards/ev3sources/tree/master/lms2012/lms2012/source	license
Sourcery G++ Lite	https://sourcery.mentor.com	license

- Requires MathWorks Account Login
  - (but don't worry if you don't have one, you can create one when you get to the screen)

- Verify LEGO EV3 Firmware Version
  - In the EV3 Brick Interface, go to the settings and select **Brick Info**.
  - Check that **Brick FW** is `V1.03E` or later.
  - If the firmware is earlier than `V1.03E`, use the *LEGO® EV3 Software* to update the firmware.



Hardware Setup

Hardware Setup

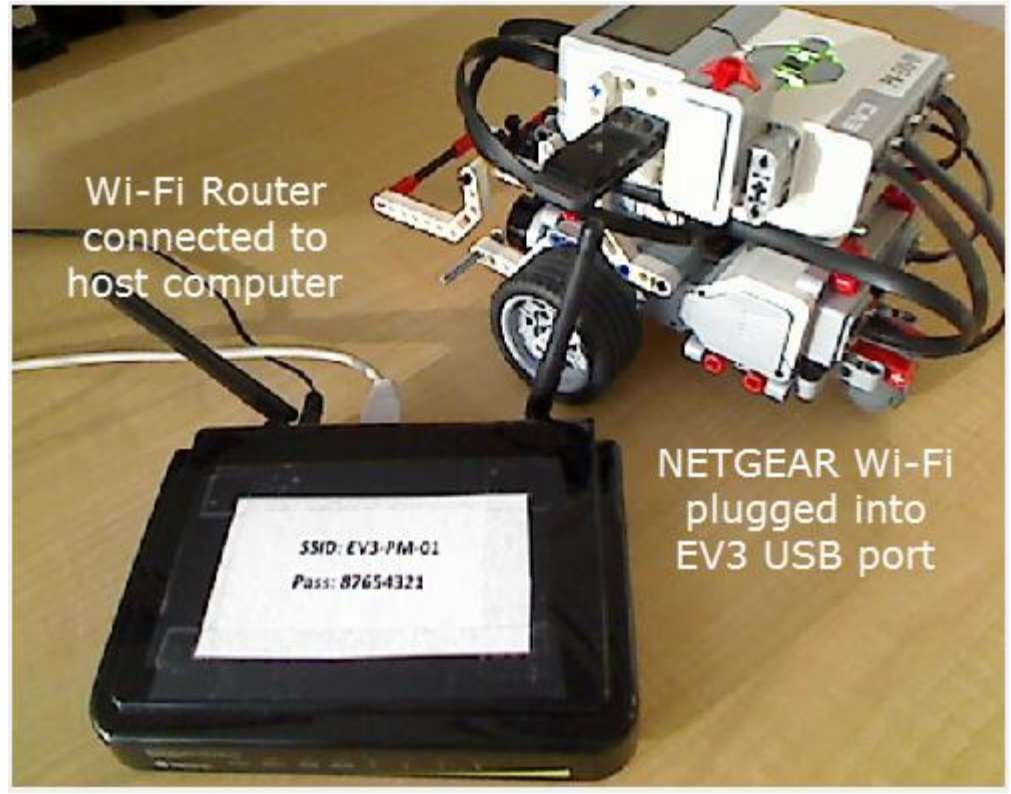
- *What hardware do I need?*
  - LEGO MINDSTORMS EV3 kit
    - LEGO MINDSTORMS EV3 retail set (31313)
    - LEGO MINDSTORMS EV3 Education Core set (45544)
  - Wi-Fi Router (802.11n)
  - NETGEAR N150 Wireless Adapter (WNA1100)
    - Recommended by LEGO
  - Connectivity from host computer to Wi-Fi router
    - Can directly connect via Wi-Fi adapter in host computer
    - Or can connect via Ethernet cable from host computer
  - Optional but useful:
    - EV3 Rechargeable DC battery (45501) + DC Charger (8887)

Robot Educator

- Build directions in Education Core Set and online

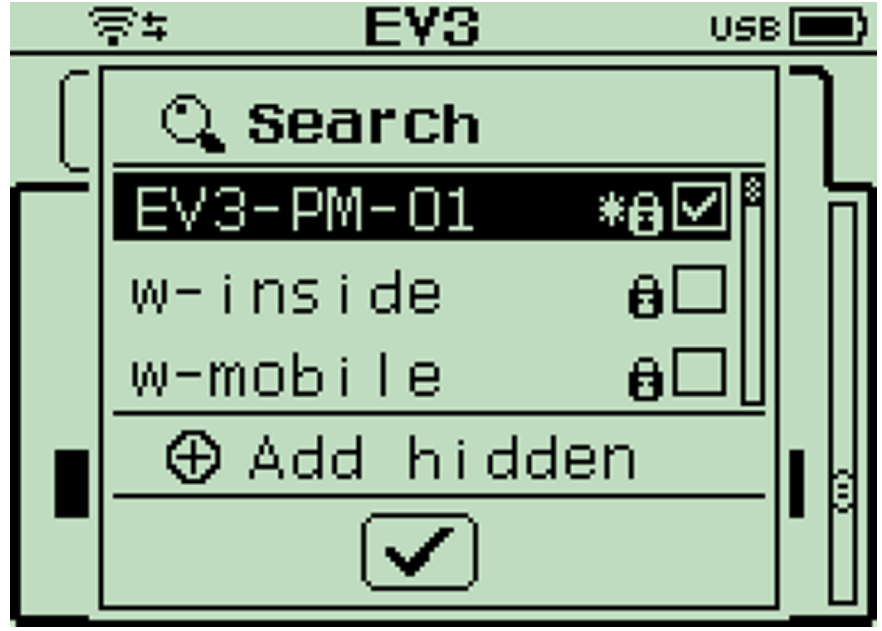
Hardware Setup

- *Connect up the hardware*
  - Power on Wi-Fi Router
    - Wi-Fi Router Configuration:
      - DHCP (dynamic host configuration protocol)
      - Encryption = None or WPA2
  - Connect Wi-Fi router to host computer
    - Use Wi-Fi adapter or Ethernet cable to port 1
  - Plug Wi-Fi dongle into EV3
  - Power on EV3 by pressing and holding center button
    - Wait for LEGO EV3 to boot up



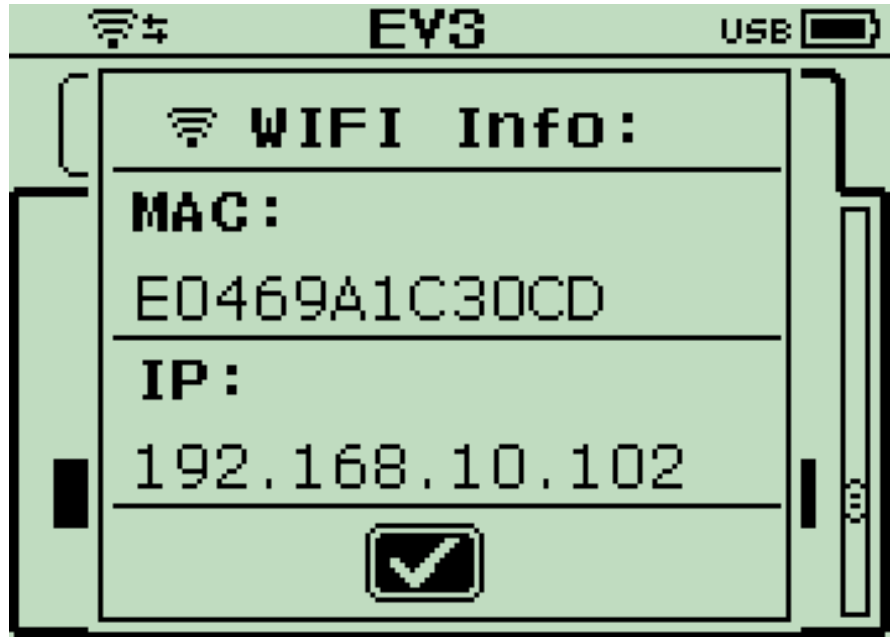
Hardware Setup

- *Connect EV3 to Wi-Fi Router*
  - In the EV3 Brick Interface, go to settings and select `WiFi`
  - Select `WiFi` and turn it on (look for checkmark in the box and WiFi icon on top left)
  - Select `Connections`
  - Select your Wi-Fi Router SSID and select `Connect`
  - Select your Encryption
    - EV3 only works with Encryption settings of None or WPA2, so make sure your Wi-Fi router is configured correctly
  - Type in your Wi-Fi Router password using the EV3 buttons and select enter
  - Look for check mark next to your Wi-Fi Router SSID



Hardware Setup

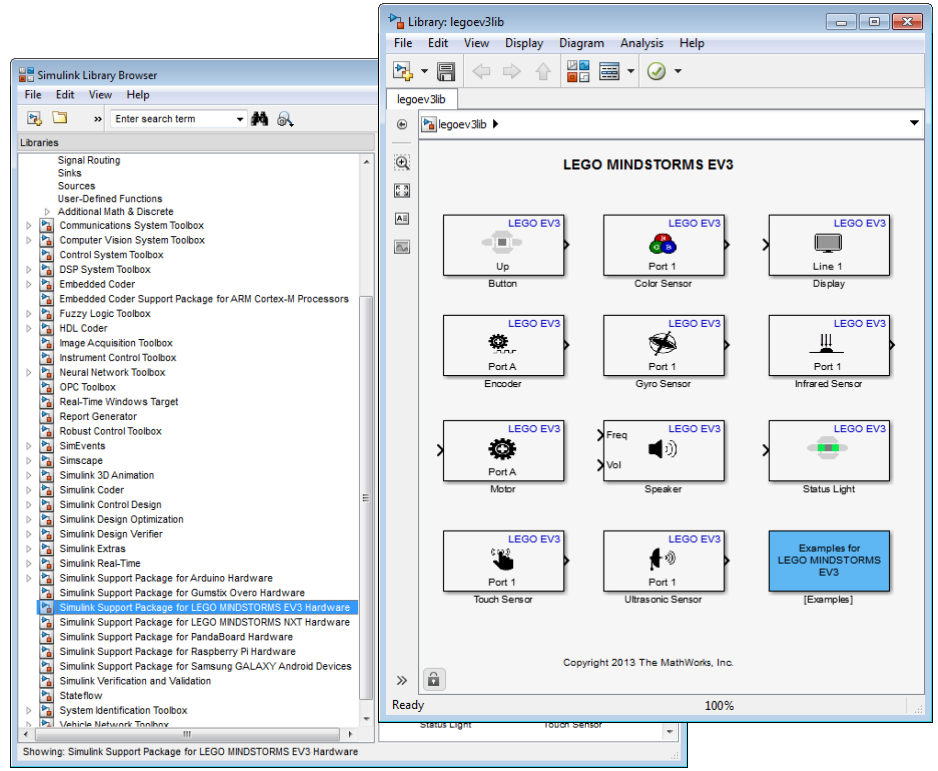
- *Get EV3 IP Address*
  - In the EV3 Brick Interface, go to the settings and select `WiFi`
  - Click center button with WiFi Router selected
  - Note down the IP Address of your brick
    - IP Address is in a range determined by your Wi-Fi Router configuration
    - IP Address is dynamically allocated – it may change next time you power on your EV3 brick!



Let's go test it!

Summary: Simulink + LEGO EV3 Testing

- Check for Support Package Installation
  - Simulink Support Package for LEGO MINDSTORMS EV3 Hardware should be in your Simulink Library
  - Can also type at MATLAB Command line:
    `legoev3lib`



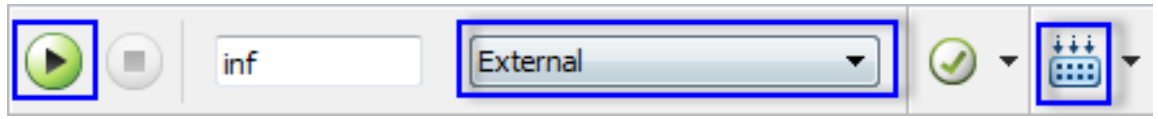
- Test your connection (computer to LEGO EV3)
  - Type at the MATLAB command line:
    `!ping ip.add.re.ss`
  - OR type at the MATLAB command line:
    `legoev3('ip.add.re.ss')`

```
>> !ping 192.168.10.102

Pinging 192.168.10.102 with 32 bytes of data:
Reply from 192.168.10.102: bytes=32 time=5ms TTL=64
Reply from 192.168.10.102: bytes=32 time=3ms TTL=64
Reply from 192.168.10.102: bytes=32 time=3ms TTL=64
Reply from 192.168.10.102: bytes=32 time=3ms TTL=64

Ping statistics for 192.168.10.102:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss)
Approximate round trip times in milli-seconds:
    Minimum = 3ms, Maximum = 5ms, Average = 3ms
fx >>
```

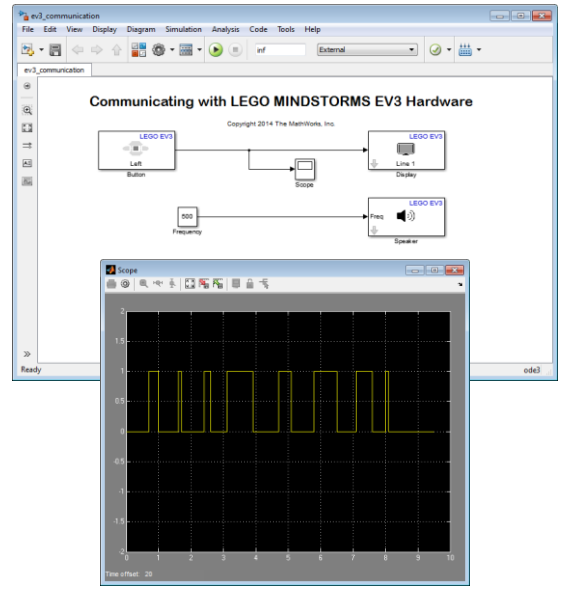
```
>> legoev3('192.168.10.102')

ans =

  legoev3 with properties:

    ipAddress: '192.168.10.102'

fx >>
```

Summary: Simulink + LEGO EV3 Testing (con't)

- Open LEGO EV3 Communication model: `ev3_communication`
- Click Tools -> Run on Target Hardware -> Options
  - Check to make sure Target hardware = LEGO MINDSTORMS EV3.
  - Also check / update the IP Address.
- Click Run button



  - We used the "External" simulation mode.
  - External mode allows you to tune parameters and monitor signals in the model while the application is running on hardware
  - You can use "Deploy to Hardware" button if you want to run on the hardware with no interaction from the host

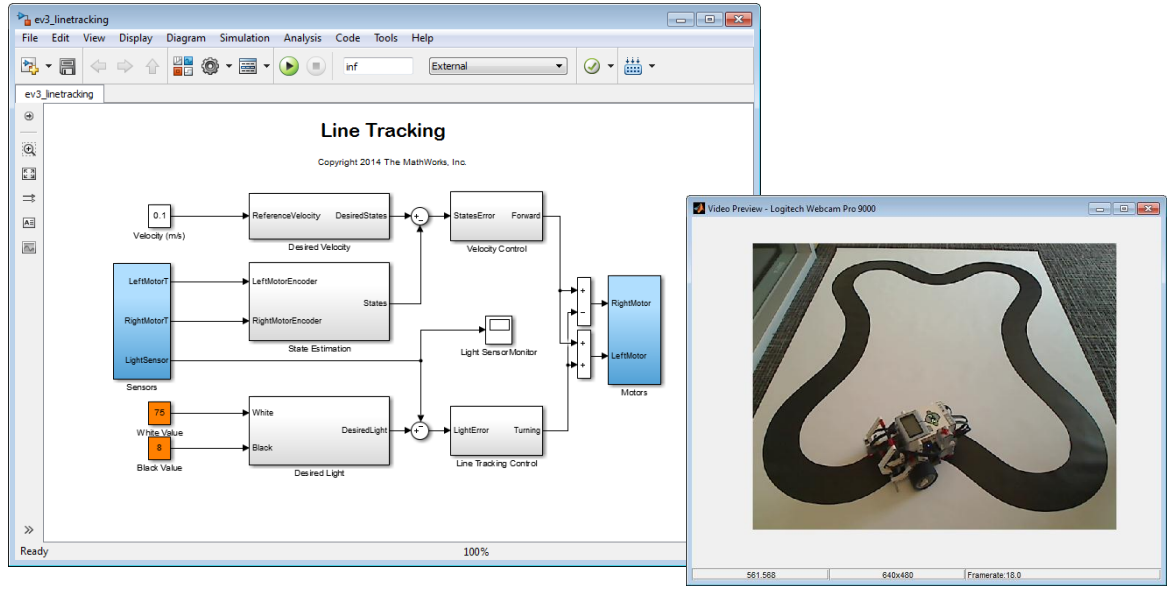


- The model is now running on the LEGO EV3 robot

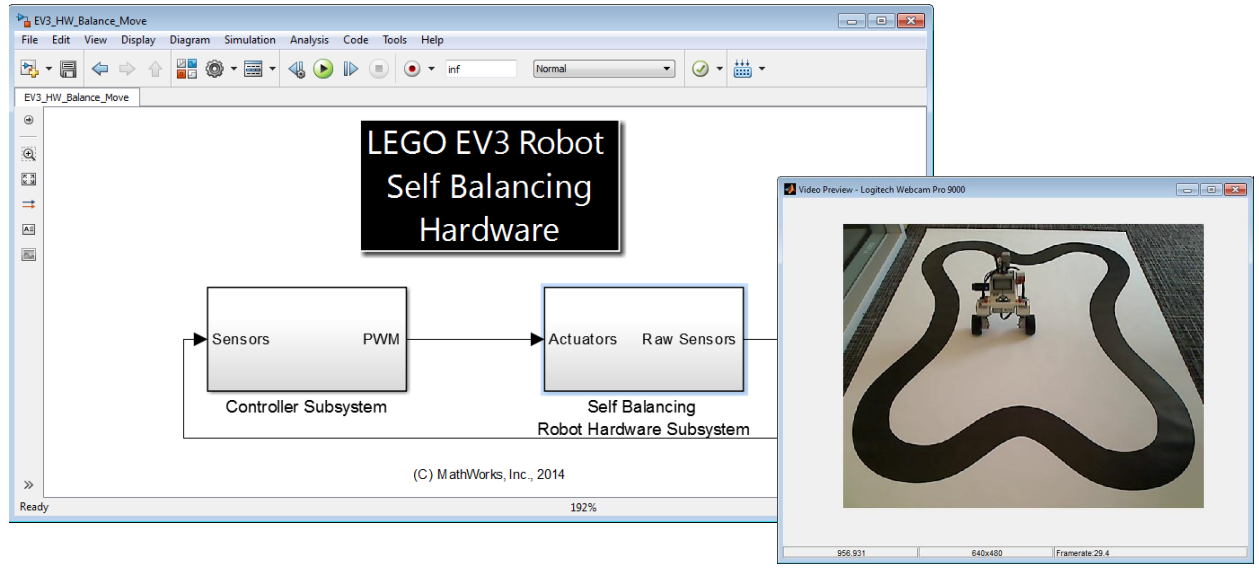
Examples

Two Examples

- Line Tracking Robot
  - Follow a black line using the light sensor to control both motors

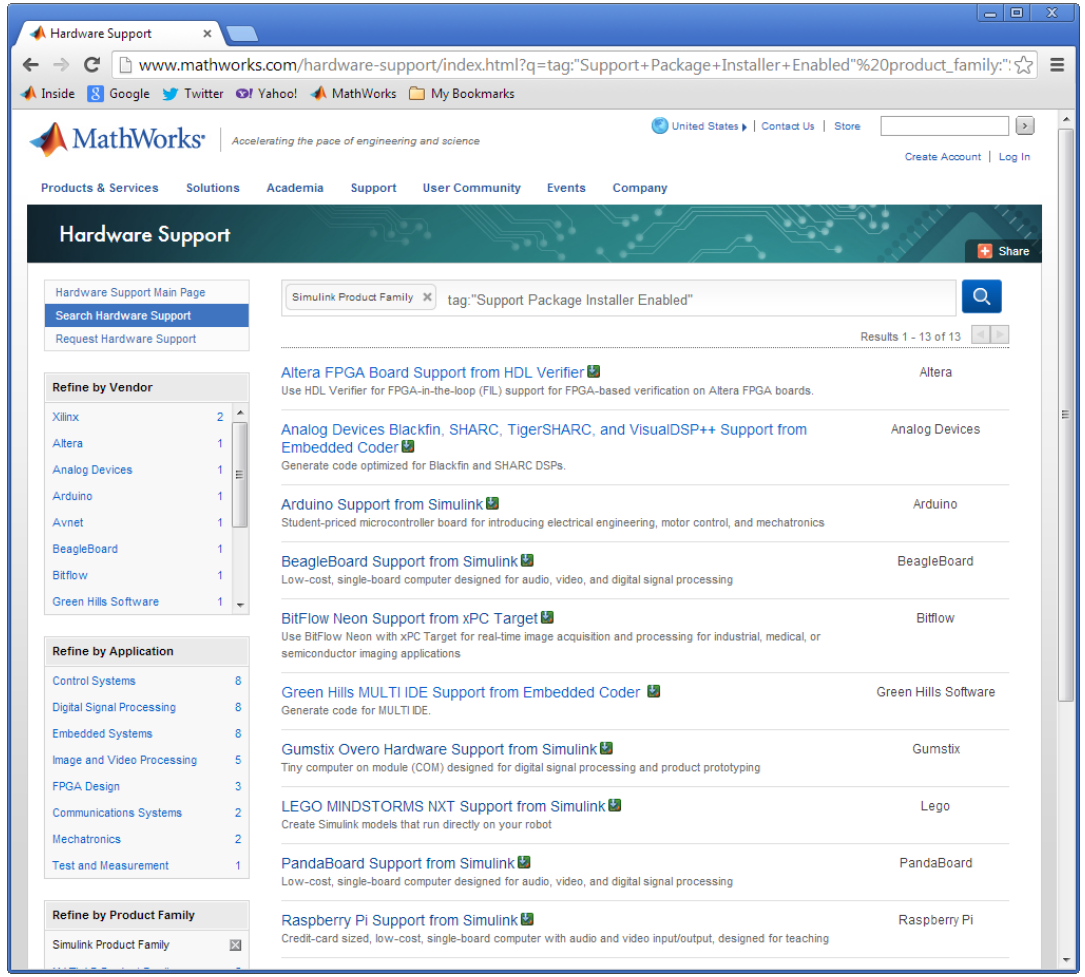


- Self Balancing Robot
  - Use gyro sensor to control both motors to balance robot



Wrap-Up

Simulink Hardware Support



http://www.mathworks.com/hardware-support/home.html

Arduino

Lego EV3 & NXT

Raspberry Pi

BeagleBoard

PandaBoard

Samsung GALAXY

Selected Simulink Supported Hardware:

- LEGO® MINDSTORMS® EV3 and NXT ($350)
- Arduino® Uno, Due, Mega 2560 and more: ($30-$70)
  - ➢ Also support for Ethernet and WiFi Shields
- Raspberry Pi Model B and B+ ($40)
- BeagleBoard-xM ($150) and PandaBoard ($180)
- Samsung GALAXY Android Devices ($50-$500)

Available in Student and Home Versions!

Additional Resources

makerzone.mathworks.com

www.mathworks.com/academia

www.mathworks.com/student_version

www.mathworks.com/matlab-home