Control systems demonstrators using the LEGO MINDSTORMS EV3 Gyroboy model from the Education Set.

Hardware requirements:

1 LEGO MINDSTORMS Education EV3 Core Set

1 USB WiFi adaptor. I have been using the Edimax EW-7811Un adapter which has been working well with the LEGO V1.09D firmware. The NETGEAR WNA3100M WiFi USB mini adapter has also worked for me. For older firmware, the officially supported WiFi adapter is the NETGEAR WNA1100. This is a discontinued product but can currently still be bought second hand. I have succeeded in getting this working with the V1.06 firmware.

1 WiFi router. I have been using the NETGEAR R6120 AC1200 Dual Band Wi-Fi router.

1 Xbox one controller.

Software setup:

MATLAB 2018a or later is advised. The setup described here has been carried out in MATLAB 2018a on a Windows 10 PC.

1. Install the following hardware support packages:
    - LEGO MINDSTORMS EV3 Support from MATLAB
    - LEGO MINDSTORMS EV3 Support from Simulink
    - VEX ARM Cortex Support from Simulink
    - You will also need to install the Control System Toolbox, Embedded Coder, Matlab Coder, Simulink Coder and MATLAB Support for MinGW-w64 C/C++ Compiler.
2. Download the EV3 Developer Kit Firmware 1.09D from https://education.lego.com/en-gb/support/mindstorms-ev3/developer-kits
3. Download the LEGO MINDSTORMS Education EV3 software from https://education.lego.com/en-gb/downloads/mindstorms-ev3/software
4. Install the EV3 Developer Kit Firmware 1.09D on the EV3 brick:
    - Connect to the EV3 brick through the USB cable and switch on the EV3 brick;
    - Open the LEGO MINDSTORMS Education EV3 software;
    - In the toolbar: select Tools -> Firmware Update;
    - In the pop-up window, select Show Details;
    - Select Browse and locate the firmware file EV3 Firmware V1.09D on your computer (downloaded in step 2);
    - Press Update Firmware.
5. Update the MATLAB files legoev3.m and ev3Shell_IO.m:
    - In the MATLAB command line, type >>edit legoev3
    - In the file legoev3.m, modify the try-catch clause around line 278 as follows:

```
try
    h = realtime.internal.Telnet_IO(ip, 23);
    h.open('login:');
    h.cmd('root');
    if str2double(obj.FirmwareVersion(2:5)) == 1.09
```

```
                h.waitForResponse('Password:', 1000);
                h.cmd('Just a bit off the block!');
            end
            h.waitForResponse('~#', 1000);
            h.cmd('dropbear');
            h.waitForResponse('~#', 1000);
            h.close;
        catch ME
            error(message('legoev3:build:EV3ManagerConnectFailed', ip));
        end
```

- Save the legoev3.m file
- In the MATLAB command line, type >>edit realtime.internal.ev3Shell_IO
- In the file ev3Shell_IO.m, modify the first clause as follows:

```
properties (Constant = true, Hidden = true)
    USERNAME = 'root';
    PASSWORD = 'Just a bit off the block!';
    PORT = 22;
end
```

- Save the ev3Shell_IO.m file.

Running the Gyroboy controller

To get started, it is a good idea to try the following examples:

1. Connecting to the EV3 by WiFi in MATLAB – Bluetooth connection is not required for this project, and so far as I am aware it is no longer supported by MATLAB, so there is no need to follow that part of the tutorial. Note that in this example you create a legoev3 object which should be cleared at the end of the example.
2. The Getting Started with LEGO MINDSTORMS EV3 Hardware example will take you through deploying programmes to the EV3 brick with Simulink. Neither Bluetooth nor Ethernet connections are required for this project, so these parts can be ignored.
3. The ev3_communication example will take you through running programmes on the EV3 brick from Simulink in external mode, allowing for data to be logged to the MATLAB workspaced.

I have experienced occasional issues with connecting to the EV3 brick with WiFi, in which case running the above examples often helps (if it does not, you may want to consider clearing the workspace and/or restarting the EV3 brick and/or reinstalling the firmware).

You will want to need to construct the standard Gyroboy model from the LEGO MINDSTORMS education EV3 set. The instructions are available in the EV3 software downloaded in stage 3 of the software setup. I have removed the proximity and colour sensors as this functionality is not used.

The Gyroboy controller can be run in external mode or can be deployed to the EV3 brick, as follows:

1. Save the files gb_load.m, sysnss.mat, xb_kf_pc_hp_nl.slx, sfun_keyboard_input_v1_01.m, KeyboardControl.slx, GamepadAnalog.slx and keyboard_input.mat to a folder and either add this to your MATLAB path or make it your current working directory in MATLAB.
2. Run the script gb_load.m in MATLAB and open the Simulink file xb_kf_pc_hp_nl.slx.

3. Set the configuration properties in the Simulink file to match your EV3 brick then deploy to hardware or run in external mode with the Gyroboy sat on its stand.
4. Once deployed, you should find the Gyroboy moves forward a short distance then attempts to maintain its position.
5. To run with the Xbox One controller, connect the Xbox controller to a PC via either USB or Bluetooth, open the Simulink file GamepadAnalog.slx, change the settings in the UDP Send to EV3 block to match your EV3 brick, and run the file.
6. To run with the keyboard, open the Simulink file KeyboardControl.slx, change the settings in the UDP Send to EV3 block to match your EV3 brick, and run the file. In the pop-up window, select “Re-enable exclusive figure-keyboard input”.

The Simulink model can also be run in simulation mode. To do so, open the script gb_load.m and change the flag HW on line 15 to HW = 0. Then change the run mode in Simulink to Normal. This runs a nonlinear simulation of the Gyroboy data, which takes simulated keyboard inputs from the file keyboard_input.mat.