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. According to the LEGO website, the (only) officially supported WiFi adapter is the NETGEAR WNA1100. This is a discontinued product but can currently still be bought second hand. I have found that the NETGEAR WNA3100M WiFi USB mini adapter works with the V1.09D firmware. The Edimax EW-7811Un adapter is also recommended online.

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 may 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 follow the ev3_communication example. At the MATLAB command line, type >>ev3_communication to run this. I have experienced occasional issues with connecting to the EV3 by WiFi in MATLAB, and often running the ev3_communication example helps resolve these issues (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 deployed to the EV3 brick. 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. Run the script gb_load.m in MATLAB and open the Simulink file xb_kf_pc_hp_nl.slx. 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. Once deployed, you should find the Gyroboy moves forward a short distance then attempts to maintain its position.

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.

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".