Lego Mindstorms NXT Balancing robot

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Abstract

The aim of our project is to design a Segway-like, self-balancing robot, using Lego NXT 2.0.

To achieve the best results a gyroscope is usually used. However, to make the project more interesting (and because we don't have a gyroscope), we will use two ADXL312 accelerometers to derive the orientation of the robot in space.

1 Overview

The gyroscope is an instrument which measures the change in angular velocity. To approximate the same information using two accelerometers, which measure the change in linear velocity, we used the following method.

One of the accelerometers is aligned with the axis of the wheel shaft, so the rotation of the robot around this axis has no effect on the acceleration data obtaned from this sensor. On the other hand, the second sensor, which is mounted near the top of the robot, is influenced by the rotation – we can take the difference of these accelerations and obtain the rate of rotation around the wheels.

In theory, this information is enough to keep the robot upright, but in practice the solution diverges very fast and it is necessary to measure the orientation of the robot directly. The accelerometers have three axes, so the angle respective to the gravitational force vector can be easily calculated. Software controller manages robot by the PID control scheme.

2 Implementation

The project targets the Lejos firmware, which implements a rich subset of the Java platform on the Lego Mindstorms.

Apart from ROBOTC, this seems to be the only firmware which supports the 100 `kbaud` I^2C mode. The regular firmware can only communicate at 9600 `baud`. At this speed, the link budget is exhausted very soon.

Another reason for using Lejos is its use of a regular and widely used language.

2.1 Accelerometer interface

We have used two ADXL312 accelerometers connected to the NXT brick using the serial I^2C interface. The final schematic can be seen in the Figure 3.

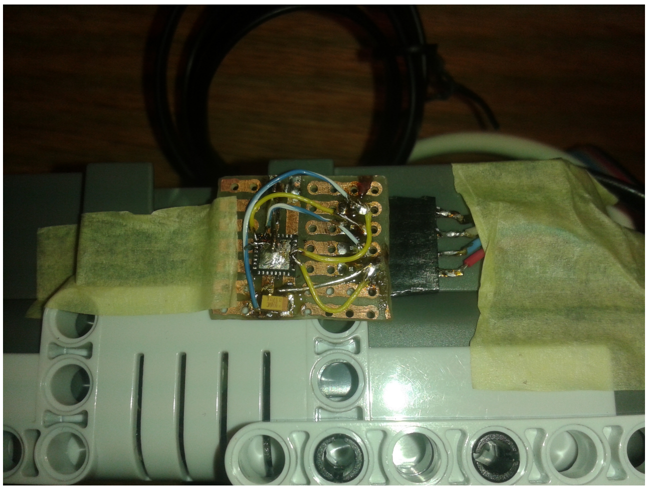

Figure 1: Detail of accelerometer ADXL312

The circuit is split into three subboards: two of them carry the accelerometers themselves and the third board contains auxiliary power and signal conditioning circuitry: the 4.5 V from the NXT is regulated down to the 3.3 V needed by the integrated circuits using a Zener diode. The I^2C pullups are also located on this board.

Both of the accelerometers are connected to the same I^2C bus of the NXT, one of them is configured with an alternate address. The only other components located on these boards are the power supply bypassing capacitors.

2.2 Software controller

The core functionality is provided by two threads: the `MotorThread` and the `SensorThread`. The `SensorThread` configures the accelerometers and reads and preprocesses their data, which is then stored in variables shared with the `MotorThread`. This thread executes the control loop and interfaces with the motors.

Meanwhile, the main thread waits for a keypress, after which the program is terminated.

2.3 Evaluation

We didn't manage to satisfy our original specification. The accelerometer interface works well, but the robot isn't able to keep the balance for more than a short while. We believe this is due to the mechanical imprecision in the motor gearing and the dependence of their speed on the remaining energy stored in the batteries.

This, combined with the low power and speed provided by the motors, makes finding the constants necessary for the proper operation of the PID control scheme difficult, if not impossible.

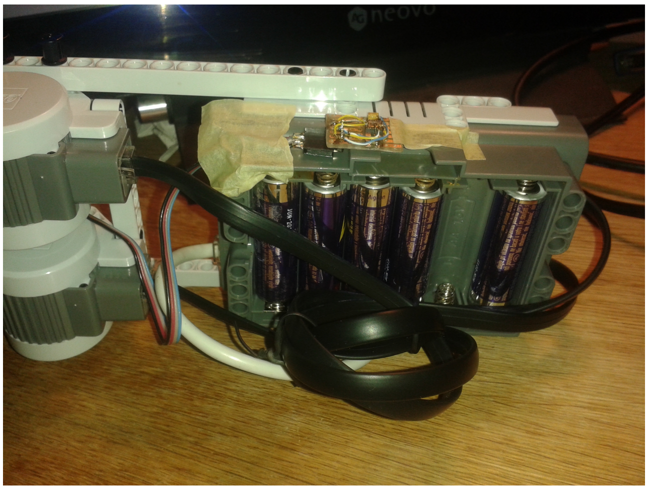

Figure 2: The upper part of "Segway" with accelerometer

3 Team

- Ondřej Herman - team leader, idea and physical construction of accelerometer cicuit, implementation of series of (un)balancing methods, testing, project report
- Ondřej Hlouša - implementation of series of (un)balancing methods, testing, project report
- Vladislav Malynyč - project abstract, testing, presentation
- Adam Třešňák - no communication from his side during whole semester

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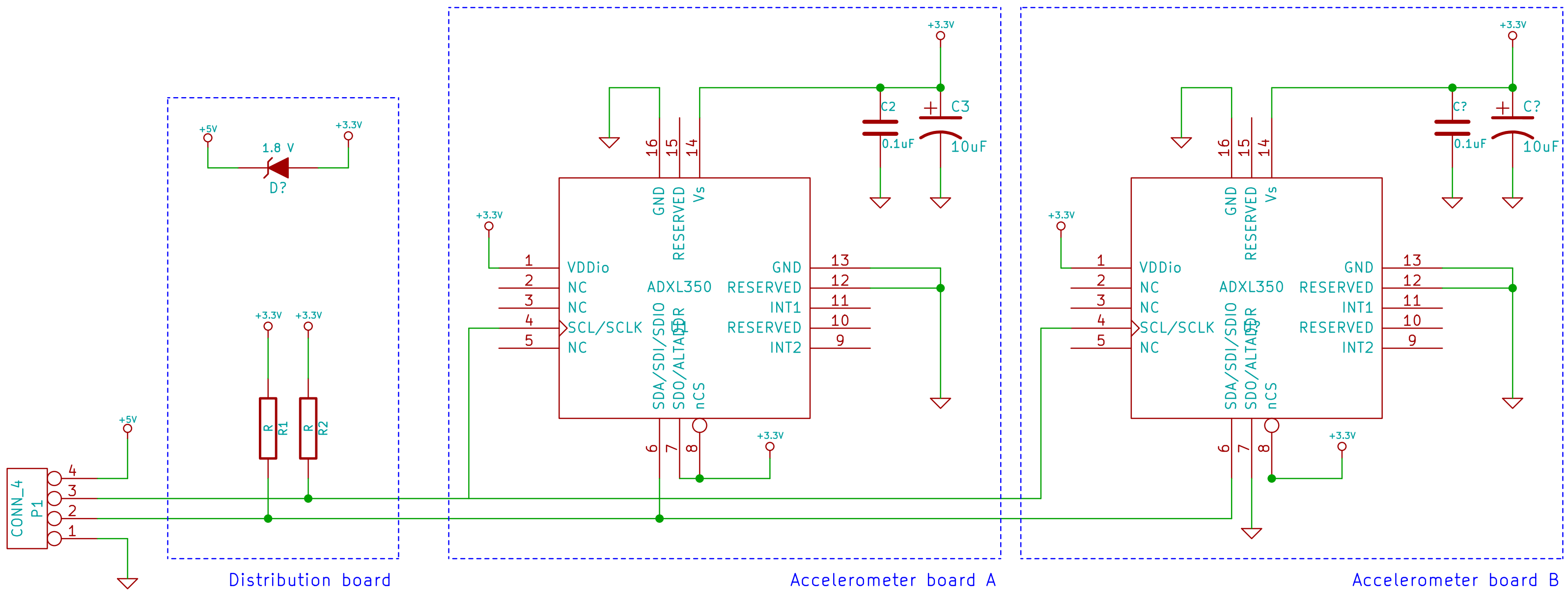

Figure 3: Accelerometer interface schematic diagram