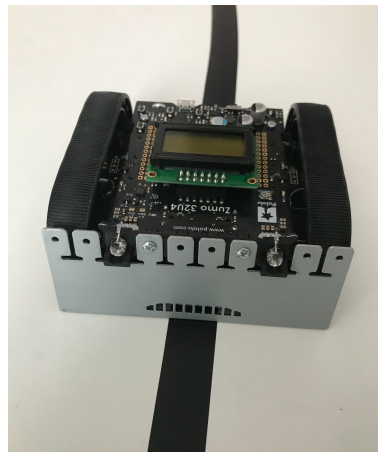# Lab n° 6

Leader-follower formation control for the Zumo mobile robot

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Contents

Lab 3

Obstacle detection and leader-follower formation control for the Zumo mobile robot

The work done in pairs during this lab will be noted in a report and marked. You are asked to follow the instructions given below to write your report.

Instructions for writing your laboratory report

A report is a scientific document. It must therefore respect a certain structure. Your report should be structured as follows:

- a general introduction specifying the objectives of the lab

- For each assignment:

    ▷ a brief presentation of the expected outcomes

    ▷ a reminder or presentation (if necessary) of the theoretical results

    ▷ a description of the obtained results in graphical or numerical form

    ▷ a critical analysis of the results related to the expected theoretical ones

    ▷ a short conclusion

- a general conclusion explaining what has been understood during the lab and any difficulties encountered.

Future intelligent transportation systems are hard to imagine without autonomous wheeled vehicles. One important application is an automated platoon of vehicles on highways that can drive autonomously in so-called virtual train formation. Vehicles in this platoon should precisely and safely follow their leader vehicles with minimal safety distance required. This would increase vehicle density on highways, avoid traffic jams, and increase safety.

In this lab, a control algorithm of mobile robots driving in linear formation will be designed. To obtain automated driving formation precise sensor systems are required, measuring global information such as GPS or relative information such as distance and bearing or both. Here we will implement a decentralized line-following control strategy relying only on an infrared (IR) sensor. Suppose that each vehicle has IR to measure the distance of the leading vehicle. This information is then used to record and track the leader vehicle from a desired distance. The distance from the leading vehicle is measured from the IR measurement (distance D)

Files needed for the lab

- Download the zipped file **Lab6.zip** from the course website and unzip it on your disk.

1.1 Objectives and layout of the Lab

This lab is structured into three main parts:

1. The development of a PID-based control program for line tracking with a Zumo robot from Pololu;

2. A first additional improvement for handling obstacle detection;

3. A second additional improvement for designing simple leader-follower formation control.
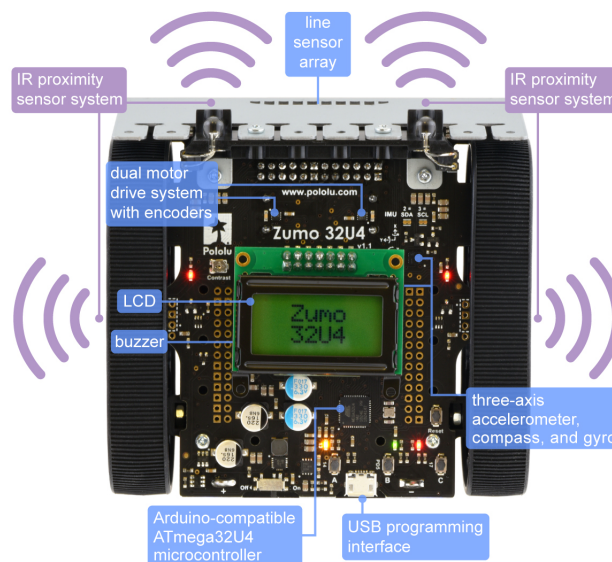
1.2 The Zumo robot

Figure 1.1: Zumo 32U4 robot from Pololu and its main components

The required hardware for this section includes:

- a Zumo 32U4 Robot from Pololu as shown in Figure 1.1;

- a USB A to Micro-B cable to connect the robot to your computer for programming and debugging. The USB connection can be used to transmit and receive data from the computer and program the board over USB;

- Four rechargeable AA NiMH batteries;

- a test track.

The Zumo 32U4 robot is a complete, ready-to-program robot platform. The brain of the robot is an integrated, USB-enabled, Arduino-compatible ATmega32U4 microcontroller from

Atmel, clocked by a precision 16 MHz crystal oscillator. The Zumo's ATmega32U4 comes preloaded with the same Arduino-compatible USB bootloader as the A-Star 32U4, which allows it to be easily programmed using the Arduino IDE. A choice of three motor gear ratios offer different combinations of torque and speed. Different versions of the assembled Zumo 32U4 robots exist. They can be identified with a sticker on the underside of the main board, visible inside the battery compartment of the Zumo without batteries installed. The color of the sticker indicates the gear ratio of the robot's motors:

- Green: 50:1 HP

- Blue: 75:1 HP

- Red: 100:1 HP

Determine the version of your Zumo 32U4 robot from the color of the sticker.
Find the maximum speed in cm/s for your Zumo 32U4 robot by searching this information in the user guide available at: `www.pololu.com/docs/0J63`.

1.2.0.1 On/off and user pushbuttons

The Zumo 32U4 has three user pushbuttons, labeled A, B, and C, located along the rear edge of the main board close to the USB programming interface as shown in Figure 1.1.
Pushbutton A will be only used for running the Zumo robot. On the left of the USB programming interface, there is a sliding button to switch on or switch off the Zumo robot.

1.2.0.2 Operating System required

The Zumo 32U4 robot can be programmed from a computer using any operating system that supports the Arduino environment. This includes Microsoft Windows 10, 8.1, 8, 7, Vista, XP (with Service Pack 3), Linux, and Mac OS X.

1.2.0.3 Software required

To get started with your Zumo robot, follow the instructions given below. They are more detailed in Section **5. Programming the Zumo 32U4** of the Zumo robot user guide which can be downloaded from `www.pololu.com/docs/0J63`.

1. If necessary, download and install on your PC the Arduino compiler from `www.arduino.cc/en/Main/Software`.

2. To help interface with all the on-board hardware on the Zumo 32U4, Pololu has provided the Zumo32U4 library. Follow carefully all the instructions given in `www.pololu.com/docs/0J63/5.2` to install the Zumo 32U4 Arduino library.
   Depending on your Arduino version, you can also try the following: from Arduino, go to the "Sketch" menu, select "Include Library", then "Manage Libraries...", then search for "Zumo32U4" and install the library.

3. Several example sketches are available that show how to use the Zumo robot with the library. You can access the example codes available from the Arduino IDE by opening the "File" menu, selecting "Examples", and then selecting "Zumo32U4". If you cannot find these examples, the library was probably installed incorrectly and you should

retry the installation instructions above. Another option is to download and copy the folders including the code examples for Pololu's Arduino-based Zumo 32U4 robot from `github.com/pololu/zumo-32u4-arduino-library/tree/master/examples`.

For help in getting your computer set up with the Zumo robot, you can also see this video: `youtu.be/L6iX8ZJ6nNo`.

1.3 Robot line following with obstacle detection and leader-follower formation

1.3.1 Control algorithm for line following

Adapt the line following control algorithm you developed for the 3pi+ robot to the Zumo Robot.

1.3.2 Control algorithm for robot line following and obstacle detection

Extend the line following algorithm in adding an obstacle detection module such that the robot would stop, spin and go in reverse if an obstacle is detected by the IR proximity sensors, in a range of 10 cm for example.

1.3.3 Control algorithm for robot line following and leader-follower formation

A decentralized leader-follower controller will be designed for vehicles designated as followers. Using information from the IR sensor, the follower vehicle should maintain a desired distance from the leader vehicle. The reference given for distance is within the range 100-150 mm. The follower vehicle should follow the track and maintain the desired distance from its leader. There is no communication between the different vehicles, therefore the formation should be maintained purely by the local controller on the follower vehicle.

Implement a linear formation of several Zumo robots. Start with leader follower formation with two robots, then extent it to three or more.

1.4 Summary and reflections

Summarize and reflect on what you have seen and learned during this lab.