The LEFT proposal

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***Abstract*:**

The proposed project aims to develop a line-following robot, a sophisticated autonomous system engineered to trace and follow a designated path with high precision. Utilizing an array of sensors and advanced Proportional-Integral-Derivative (PID) control algorithms, the robot will be capable of real-time path detection, seamless obstacle navigation, and maintaining consistent alignment with the marked course. This brief will outline the core components, anticipated challenges, and the robot's potential applications in enhancing efficiency in industrial automation and delivery systems.

Keywords:

P.I.D: Proportional, Integral and Derivative
C.I: Integrated circuit
LEFT: Line Following Robot
MCU: Microcontroller Unit

I. INTRODUCTION

The LEFT initiative envisions a fleet of five line-tracking robots working as a cohesive unit. They will follow a predefined path while steering clear of each other, employing precise stepper motors for navigation. The motion is regulated by PID controllers, ensuring fluid, natural responses from the robots. The wheels' motors will be controlled using a Microcontroller Unit (MCU), and the robot will also be equipped with 3-axis accelerometers which, by detecting acceleration changes, will help the robot adapt its speed according to the path's characteristics.

II. MOBILE ROBOT ARCHITECTURES

A. *Mobile robots: a taxonomy*

Figure 1 presents a classification of various mobile robots. The undertaken project, primarily focusing on the educational sector, aims to facilitate learning through working with robot colonies under P.I.D. control. However, its utility extends beyond educational purposes. By modifying the line-following feature, the robot can be adapted for different applications, such as tracking an object or following a worker in an industrial setting. Given its requirement for precise and controlled movement within its environment, this robot is not suited for a "legged" configuration, as depicted in the taxonomy.

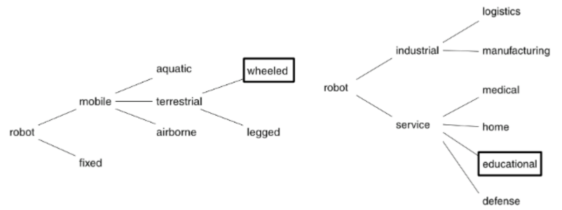
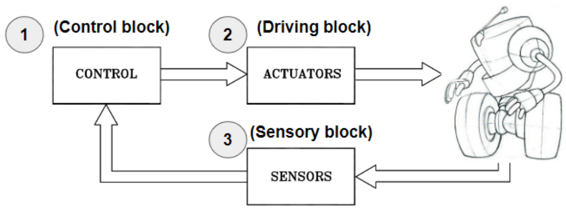


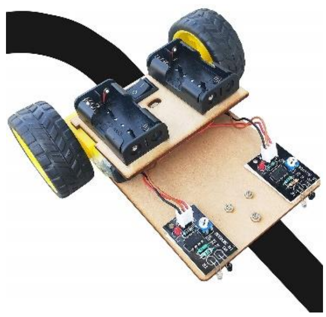
Fig. 1. Taxonomy of different mobile robots

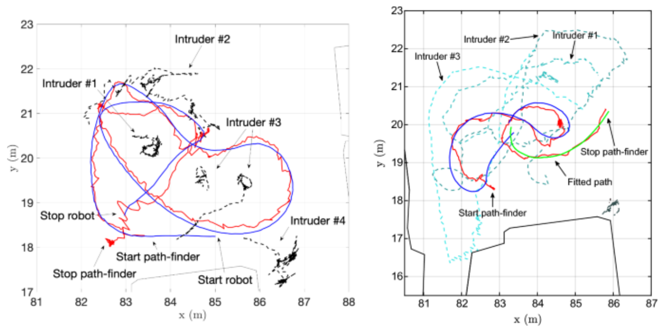
B. *Robot learning architectures: from educational robots to swarms*

The line-following robot we have designed is composed of three primary components. The foremost, the "Control" block, orchestrates the system's overall operations and signals the motors based on specific inputs. The "Actuator" block, comprised of motors equipped with wheels, facilitates the robot's movement. As the robot navigates, its sensors play a crucial role in closing the feedback loop, providing the microcontroller with essential data to determine whether to proceed or halt.



In essence, an instructional robot is constructed from a blend of a microcontroller, various actuators, and multiple sensors. This mix is pivotal in executing projects like the Sparki line follower, which also incorporates additional sensors, such as ultrasonic ones. These added components enable distinct control functionalities, like tracking a person's movement.





(a) (b)

III. Line Following Robots

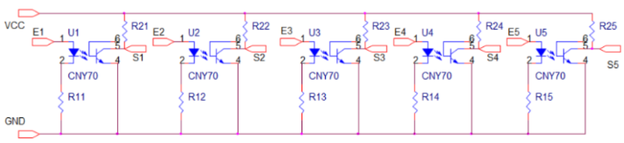
a. Architecture basics

The PIC16F877 microcontroller is lauded for its versatility and ease of programming, with FLASH memory technology allowing for repeated write-erase cycles. It's commonly used in diverse applications such as remote sensors, security devices, and industrial instruments. The microcontroller features an EEPROM for permanent data storage, useful for saving essential information like codes and frequencies. It operates on 4.2V to 5.5V, with a frequency of up to 20MHz, and lacks an internal oscillator, a detail to consider when designing circuits. Each of its ports can sink or source up to 100mA, with a limit of 10mA per GPIO pin.

In the context of a line following robot, the PIC16F877 would serve as the central processing unit, coordinating sensor input with motor output. The stepper motor, linked to the wheel, propels the robot, with its operation governed by the microcontroller via an A4988 driver, translating electrical signals into precise movements. The CNY70 reflective sensor provides crucial feedback to the microcontroller, enabling it to detect and follow the designated line. This setup exemplifies a closed-loop system, where the microcontroller continuously adjusts the motor's response based on real-time sensor data, ensuring accurate and responsive navigation.

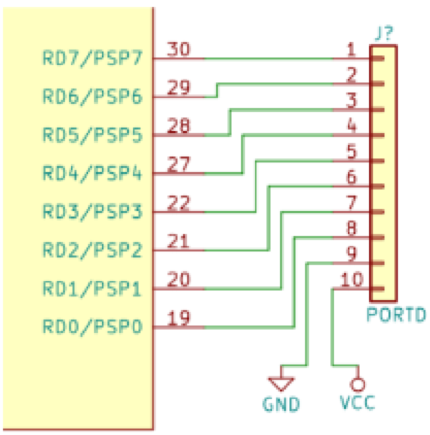
b. Hardware

To interface the reflective sensors with the microcontroller, they require two power connections: GND for ground and Vcc for a 5V supply. We will consider the following connections:



For sensor activation, the inputs E1 through E5 should be supplied with power. In our scenario, where sensor data is constantly monitored, these inputs are directly connected to Vcc, ensuring the sensors remain operational. The sensor outputs S1 to S5 will be read digitally for data acquisition.

Should there be no need for constant sensor activation, the E inputs could alternatively be linked to digital outputs on the microcontroller, energized only during the reading phase.



In the previous figure, we can see the exact connections that have to be made. The sensor inputs will be connected to PortD.

c. Control algorithms

TABLE I. CHARACTERISTICS OF LF CONTROL ALGORITHMS

Features	**Control algorithms for line following**	
	Pitching	***Rise time***
Heuristic w/ two sensors	Increased	Heuristic w/ two sensors
Heuristic w/ five sensors	Reduced compared to the case of 2 sensors	Heuristic w/ five sensors
P w/ one sensor	Decrease compared to the Heuristic case of 5 sensors	P w/ one sensor
PD	Decreases with respect to P	PD
PID	Decreases PD respect although if configured incorrectly it can oscillate and be the worst option	PID

For our design, as I have previously stated, we will choose Proportional Integral and Derivative (PID) control since its potential best results.

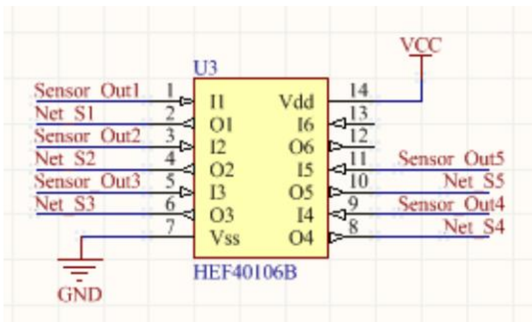
IV. Analysis Of Previous Design

a. *Functional block circuit decomposition and electronic operation*

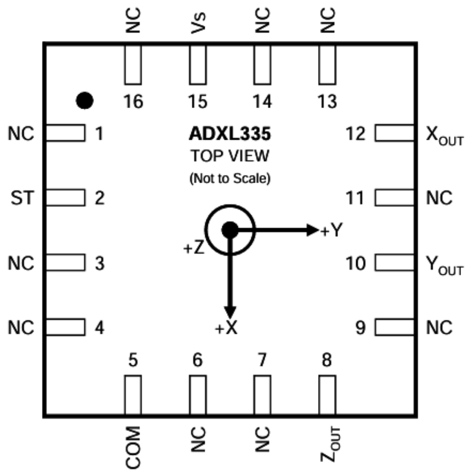
[INSERT HERE: Functional block circuit decomposition (determine in the circuit the perception, control and actuation blocks), electronic operation of the circuit (determine in which form the track is perceived and how does this affect the motor) and limitations (determinate the detected defects in the electronic circuit)]

b. *Robot behavior*

The sensors' part is made up of an IC HEF40106B MCU that allows managing the inputs and outputs of the line sensors and all the other components.



For the 3-axis accelerometer, we will use an ADXL335 board.



For this board, we can use pin 15 for the voltage supply (1.8 to 3.6 V), pin 5 for COM (GND) and pins 12, 10 and 8 for the output of the accelerometer from the X, Y and Z axis respectively. These outputs will help us calibrate the robot's speed in accordance with the 3 different acceleration values.

c. *Suggested improvements*

Implement PID control code which focuses on the received date from the lateralmost sensors, since they are always the first values which change when the robot gets out of line.

V. Basic mBot Design

a. Sensory array tuning

In general, the CNY70-based sensor array resistors of mBot can be computed through the following inequalities:

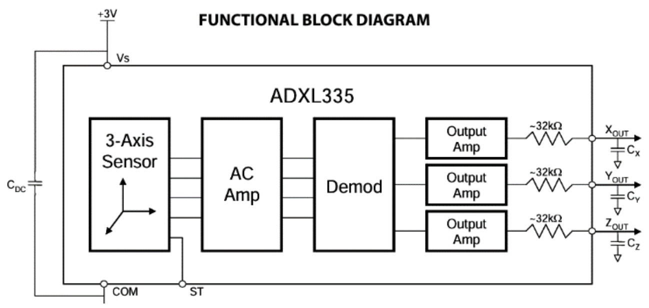
$a+b<c$

$d+e\geq f$

To calculate the resistor values for a CNY70-based sensor array like that used in the mBot, you can refer to the example provided by a robotics enthusiast who utilized the CNY70 sensor in a 3kg sumo robot to detect the color of the floor. They connected the sensor with a 220 Ohm and a 10kOhm resistor to obtain an analog output proportional to the observed color, resulting in a signal where a black surface would correspond to 5V (logical 1) and a white surface to 0V (logical 0). (reference: https://miscircuitos.com/cny70-connection/)

b. Board proposal

The board I proposed for using is an ADXL335 board with 3-axis accelerometers.



A short description of the board directly from Analog Devices' documentation:

The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

At a nominal temperature of 25°C, powered by a nominal voltage of Vs = 3V, the accelerometer can measure changes of 3G in acceleration at a minimum, and 3.6G for a typical product on all 3 axis.

This board is compatible with our mBot board, since it has analog outputs that can be easily read and, further, interpreted by the MCU.

The 3 outputs that we will get from this sensor can help us with:

- *Stability Control*: The primary role of an accelerometer in a line-following robot is to monitor and maintain stability. As the robot navigates turns or uneven surfaces, the accelerometer can detect changes in tilt and acceleration, enabling the robot to adjust its speed or wheel rotation to maintain balance and stay on the line.

- *Adaptive Speed Control*: By detecting acceleration changes, the accelerometer can help the robot adapt its speed according to the path's characteristics. For example, it can slow down when making sharp turns or speed up on straight paths, optimizing the robot's overall efficiency and response time.

- *Collision and Impact Detection*: Accelerometers can detect sudden changes in motion or impacts, which can be useful in identifying collisions or obstacles. This is particularly useful in conjunction with obstacle avoidance systems.

For this reason, I consider this 3-axis accelerometer board to be the most well-versed and multifunctional from the list, making it a perfect candidate for my choice.

VI. Conclusions

The project's outcomes highlight the potential of using evolutionary robotics in educational settings to foster an understanding of complex systems. as demonstrated through the implementation of the line-following robot using a PID control system. The need for an additional board pick gives depth to this educational experience, making us familiarize ourselves with the complex world of electronics and the different ways various components can contribute to a complete system.

References

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