MARET

Mobile Autonomous Robotic Experimental Testbed

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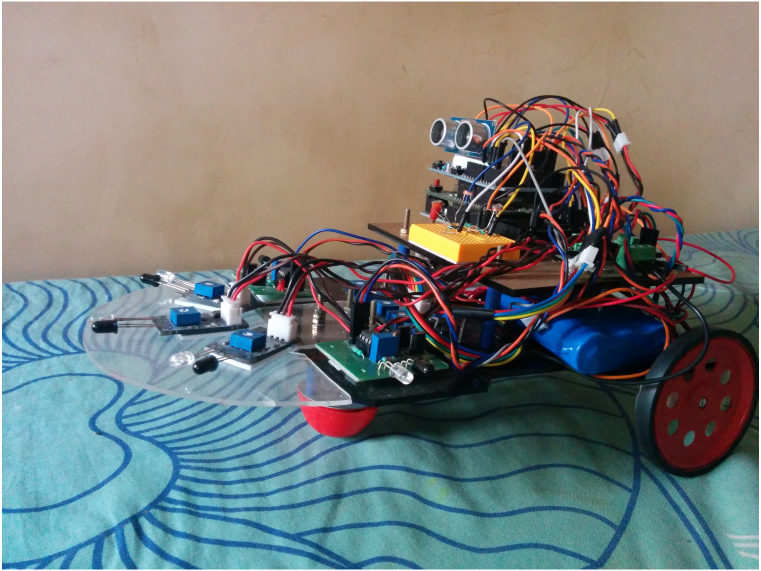
August 22, 2016

MARET

- An experimental platform for Control Systems and Mobile Robotics
- Uses open source/low cost hardware
- Software will be hosted as open source under GitHub (version control)
- Concept, design and development at IIST, Trivandrum

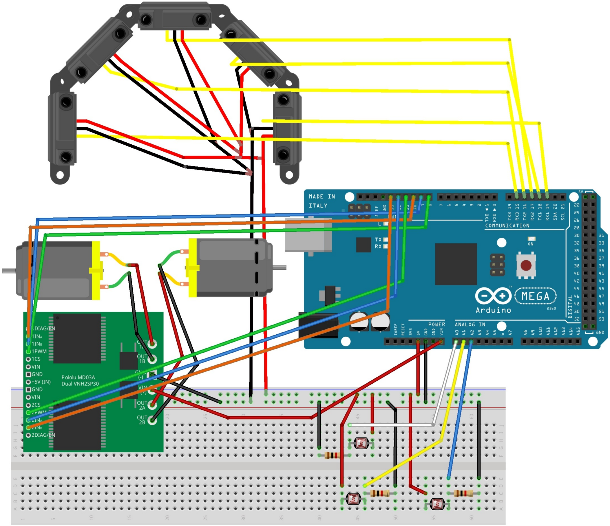


Components

- Robot chassis with motors, wheels and front castor wheel (from Elementz)
- Arduino Mega 2560 Microcontroller Development board
- Position encoder kit attached to motors (from Nex Robotics)
- Ultrasonic distance sensor HC-SR04
- Photoresistors (light sensitive), 1 kΩ resistors - 3
- Line sensor array (5 IR sensor/receiver) from SP robotics (online)
- 5 IR proximity sensors, mounted in a circle
- L293 based Motor driver board (from Elementz)
- Lithium Ion battery 11.1 V
- Arduino Bluetooth shield and a prototyping shield with mini breadboard

Circuit diagram

Made with Fritzing



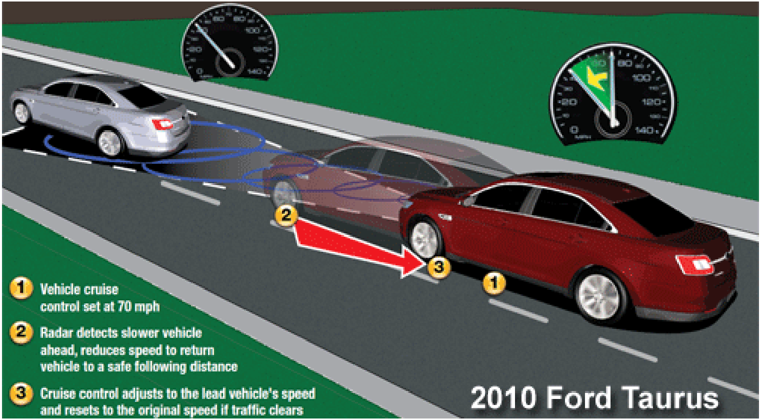
Modes

- Mode selection done through serial connection through bluetooth
- Mode 0: Stop
- Mode 1: PID control of distance using ultrasonic distance sensor
- Mode 2: Robot moves towards the direction of light using photoresistors
- Mode 3: Line follower, it moves on a black line on white board
- Mode 4: Obstacle avoidance- it tries to move around obstacles
- Mode 5: Encoder testing- Move in circle and measure x, y, θ

Mode 1: PID control of distance

- Values of P, I, D gains can be changed and the behaviour observed
- Without integral gain, Low value of P results in high steady state error (due to static friction)
- Integral gain drives the steady state error to 0
- High derivative gain causes system chattering (due to noise in the sensor)
- Integral windup can be demonstrated and avoided

Use: Adaptive cruise control

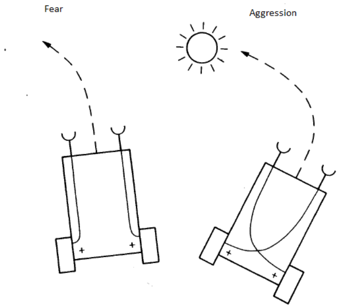


Mode 2: Light sensitive robot

- Two sensors at the back (L left and L right), one in front (L front)
- Difference between avg of back and front for forward/reverse motion, difference between left and right for differential steering
- Essentially this is a multi input multi output system with two proportional gains

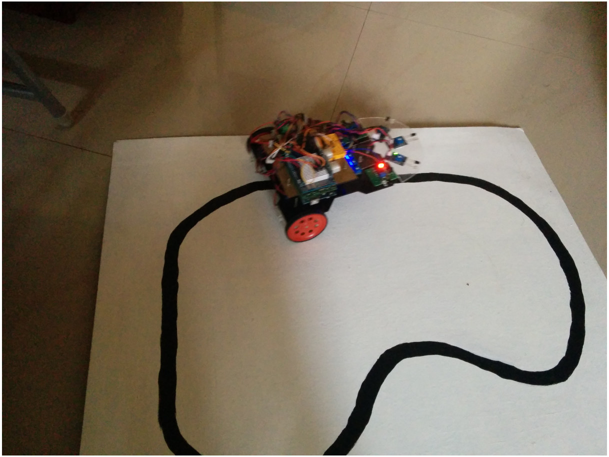
Braitenberg vehicle?

- This could be thought of as an implementation of Braitenberg vehicle concept - Machines as animals in an environment
- Vehicles with sensors and motors connected in different ways could be said to display emotions like fear, aggression, love, etc. (eg. this vehicle 'loves' the light)



Line follower

A simple line following robot using decision theory framework to move on a track. The parameters for decision making have been tuned empirically.

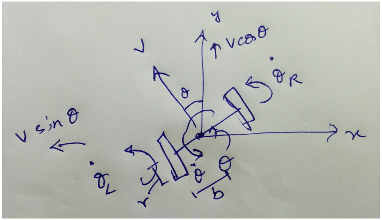


Obstacle avoidance

Reactive control strategy- turns left if obstacle is sensed on the right, etc.

Encoder testing

Calculation of pose (x, y, θ) from encoder measurements (θ_L, θ_R)



From no slip condition on the wheels:
Left wheel: $r\dot{\theta}_L = v - b\dot{\theta}$
Right wheel: $r\dot{\theta}_R = v + b\dot{\theta}$

Solving:
$v = r(\dot{\theta}_L + \dot{\theta}_R)/2$, $\dot{\theta} = r(\dot{\theta}_R - \dot{\theta}_L)/2b$

Decomposing v along x and y:
$\dot{x} = -v\sin\theta$, $\dot{y} = v\cos\theta$

Encoders (contd)

We have obtained the differential equations of motion in the previous slide. We can integrate them using Euler's method (others such as Runge Kutta method could also be used). This calculation is done on board the robot.

$x = x + \dot{x}dt, y = y + \dot{y}dt, \theta = \theta + \dot{\theta}dt$

Substituting from the previous equations, and putting $\dot{\theta}_L dt = d\theta_L$ (and same for θ_R), we get:

$$\theta = \theta + r(d\theta_R - d\theta_L)/2b$$
$$x = x - \sin\theta r(d\theta_L + d\theta_R)/2$$
$$y = y + \cos\theta r(d\theta_L + d\theta_R)/2$$

θ_L and θ_R are measured by the encoders at every sample time, and thus the pose is calculated. This data is then printed to the serial port.

Known issues

- Sometimes hard to connect using bluetooth (throws errors). Should stop serial connection before switching off bot. Can be fixed by restarting/removing and adding bluetooth device
- Obstacle avoidance sensors are blinded by IR (sunlight). Can be used at night time or in closed room
- Line sensor has one of its sensors digitization circuit broken. Can be fixed by tapping the analog voltage directly from the sensor and tuning.
- If battery 12V is connected to 5V pin, Arduino will get shorted. Very important!

Future work

- Distance control system can be analyzed more - System identification, gains tuning via root locus etc., Kalman filter, etc.
- Concept of Braitenberg vehicles can be explored more and demonstrated
- Line follower can be converted to analog system (linear) , PID control
- Model predictive control (MPC) using encoders and line sensor in a sensor fusion control strategy, given the map of the track.
- Reinforcement learning approach for line following -move slowly at first, 'learn' the track, then move faster
- Area coverage algorithm for automatic lawn mower, vacuum cleaner, etc. (eg. boustrophedon cell decomposition)