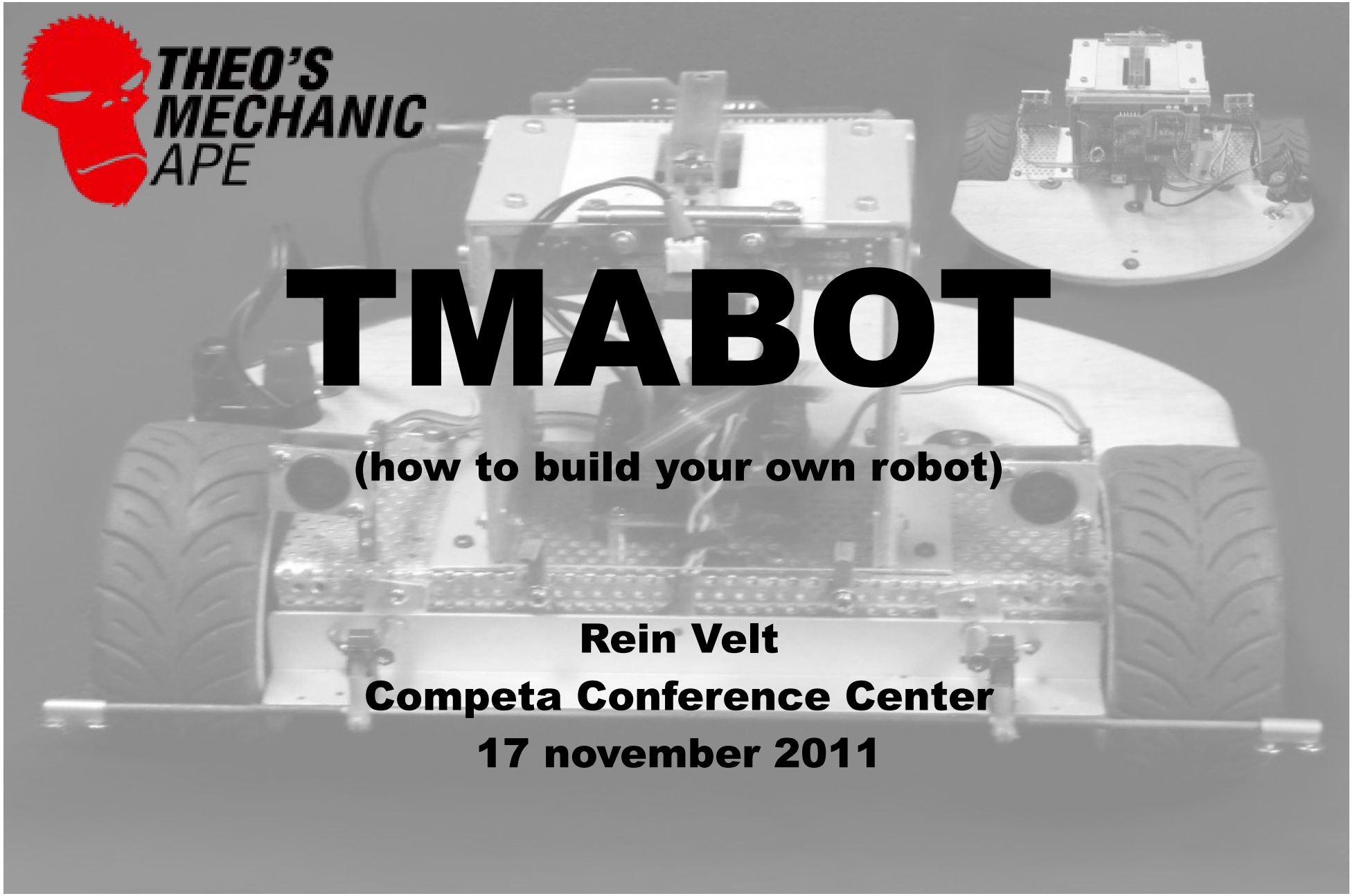


TMABOT

(how to build your own robot)

Rein Velt

Competa Conference Center

17 november 2011

Topics

Intro

Theo's Mechanic Ape

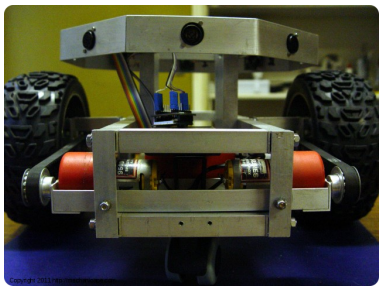
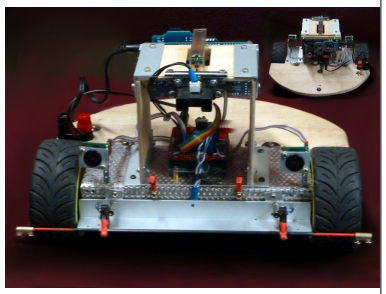
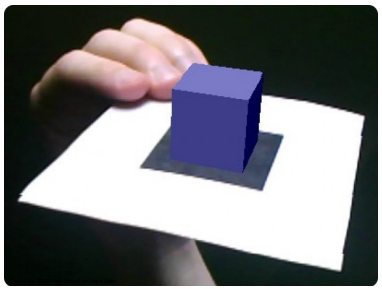
Theo's Mechanic Ape

Hobbyclub for createchnic people

Located in The Hague, Netherlands

website: http://mechanicape.com

projects:

 Modular robots	 Poetryphone	 Remote controlled things	 Live performances	 Kite camera mount
 TMAbot robot	 Poetrysafe	 Augmented reality software	 Animation films	 KAP

What is a robot?

What is a robot?

From Wikipedia, the free encyclopedia:

"A robot is a mechanical intelligent agent which can perform tasks on its own, or with guidance."

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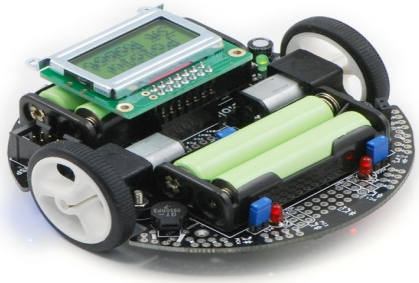
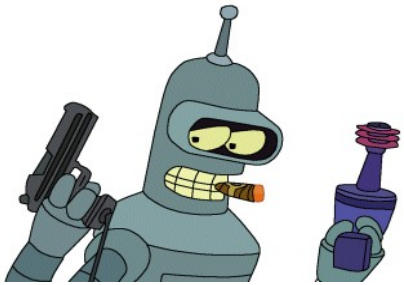
<td>  </td>
<td>  </td>
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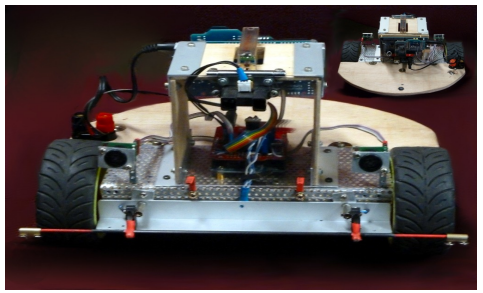
<td>  </td>
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Why build a robot?

Why build a robot?

- Robots are cool!
- ...

We can go to the store and buy a robot?

- The cheaper robots (<200 euro) are poor quality
- Nice robots are expensive (>300 euro) and really nice robots are really expensive (>2000 euro)
- Making a robot is fun
- …

Three Laws of Robotics

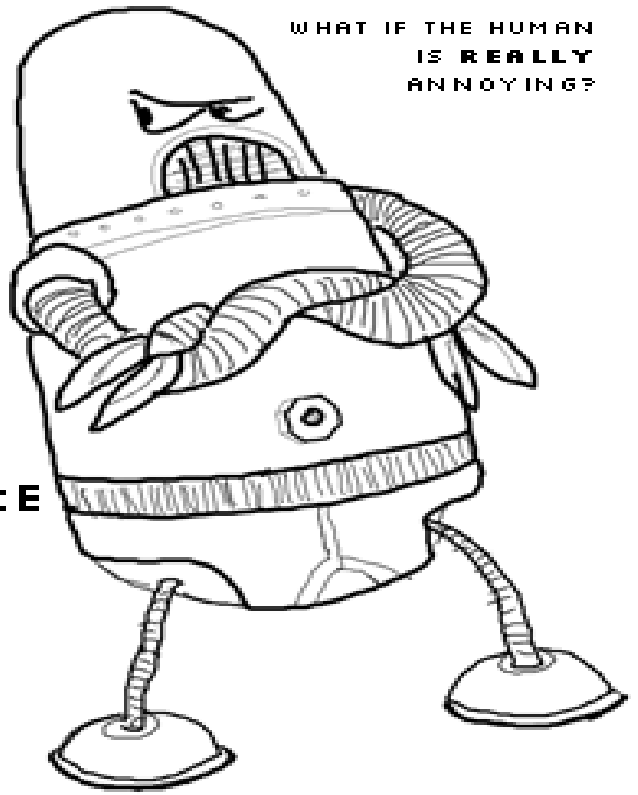
Three Laws of Robotics

By Isaac Asimov (1943)

1. A ROBOT MAY NOT INJURE A HUMAN BEING OR, THROUGH INACTION, ALLOW A HUMAN BEING TO COME TO HARM.

2. A ROBOT MUST OBEY ORDERS GIVEN TO IT BY HUMAN BEINGS EXCEPT WHERE SUCH ORDERS WOULD CONFLICT WITH THE FIRST LAW.

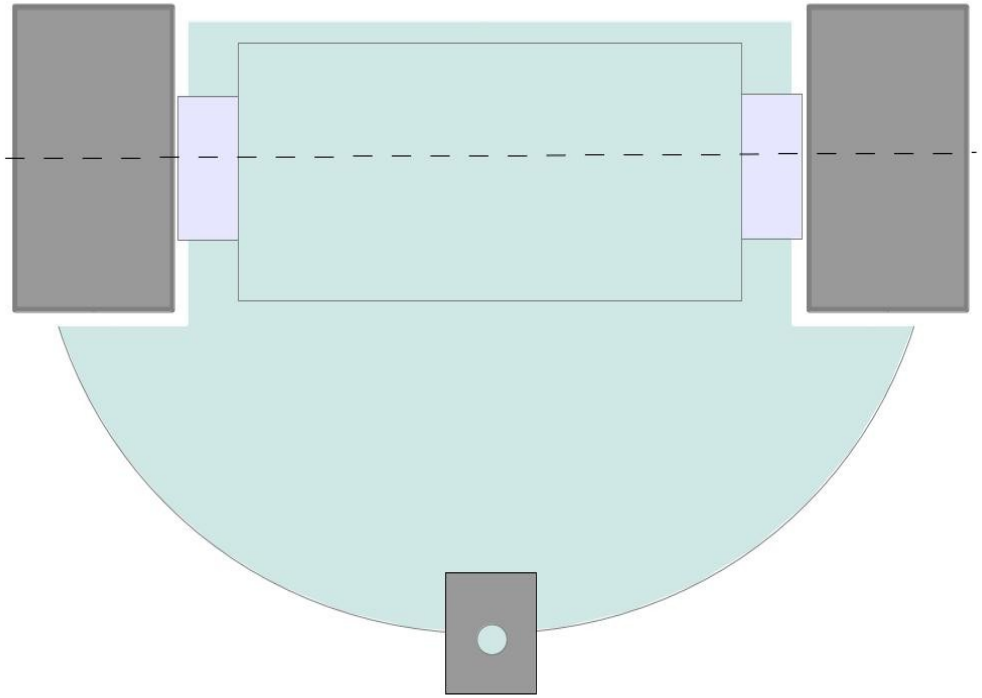
3. A ROBOT MUST PROTECT ITS OWN EXISTENCE AS LONG AS SUCH PROTECTION DOES NOT CONFLICT WITH THE FIRST OR SECOND LAW.



Requirements of the TMABot

Requirements of the TMABot

- The robot must be able to move autonomous
- The robot must be able to avoid obstacles (three laws of robotics?)
- The robot must be easy to understand and modify
- The robot must have enough power for at least 2 hours operation time
- We have 150 -200 euros to spend



Hardware design

Hardware design

What do we need?

What do we need?

- Movement
  - motors
  - wheels
  - motordriver
  - microcontroller
- Collission detection
  - sensor(s)
  - microcontroller
- Power
  - Batteries
- Frame





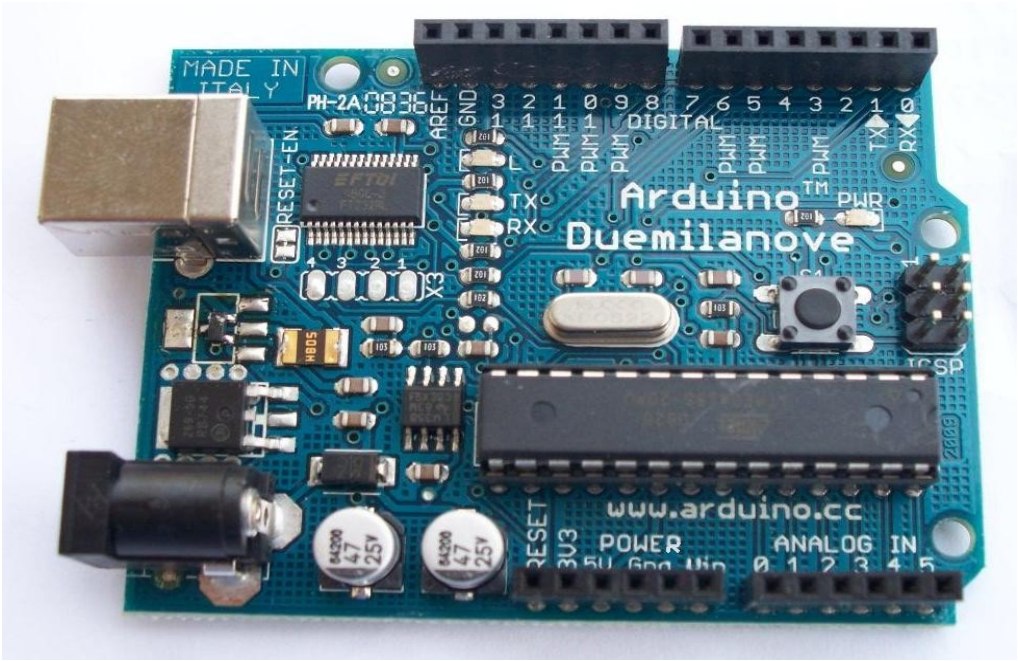


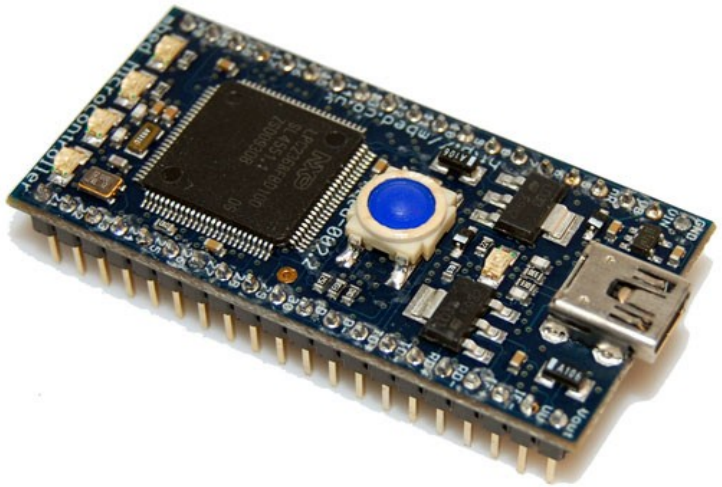


Robot brains

Robot brains

Name	Type	Entry level	Devboard+software	
Arduino	Microcontroller	beginner	25 euro	Easy, Open source, Open Hardware, IDE works on Mac, Linux, Windows,
Parallax basicstamp	microcontroller	beginner	70 euro	Easy but expensive (outdated)
Microchip PIC	microcontroller	experienced	30 euro	Not for beginners (or buy commercial software)
ARM processor	microprocessor	experienced	50 euro	Not for beginners., Ideal for more complex robots





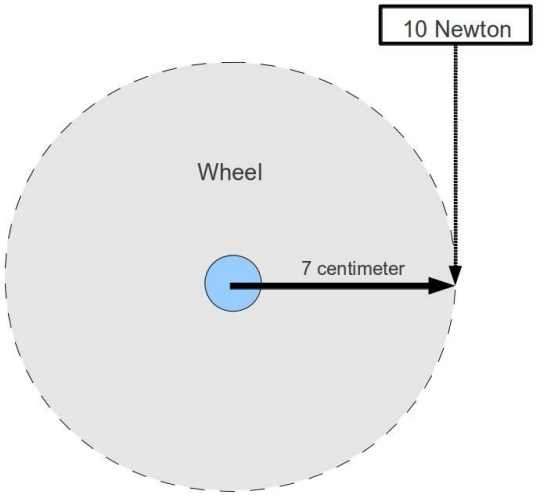
Motor, wheels and physics

Motor, wheels and physics

Before you buy the motors you need to calculate the speed/torque ratio:

Example:

- *Maximum weight of vehicle → 1Kg (guess) → 10 Newton*
- *Radius of the wheels → 7cm → 0.07 meter*
- $\vec{M} = \vec{r} \times \vec{F}$ *(force = mass * distance)*
- *minimum required torque = 10 Newton * 0.07 meter = 0.7 N m = 70 N cm*



Important: Torque is more important than speed!

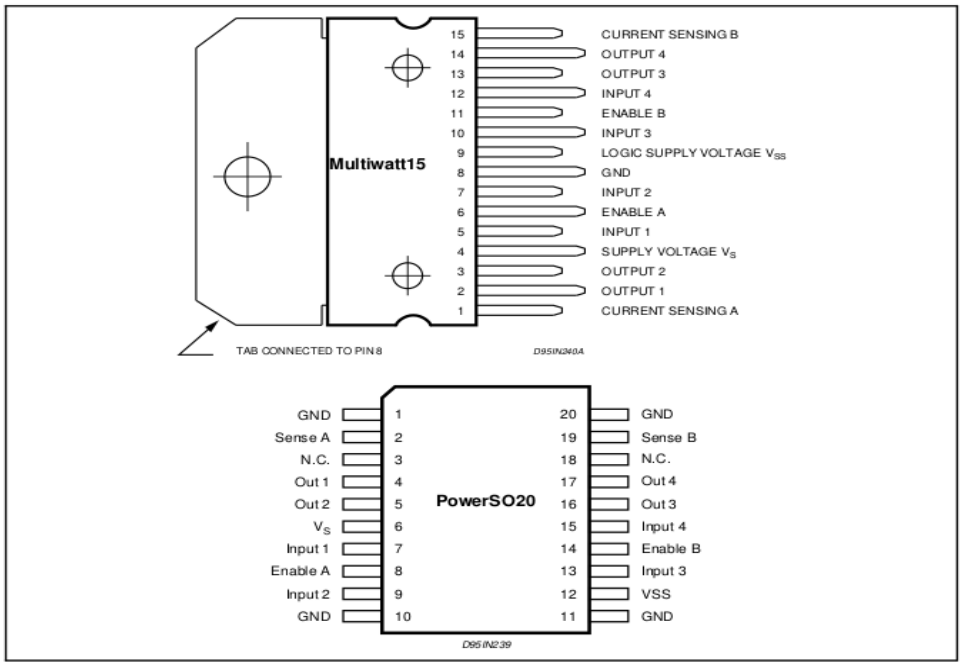
Motordriver

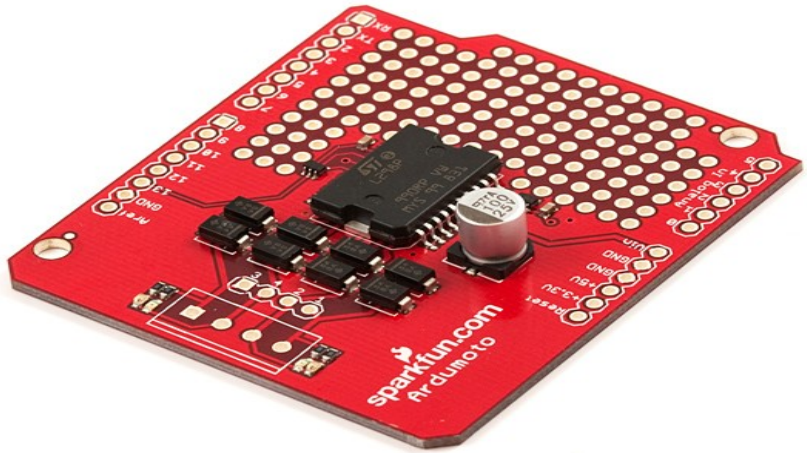
Motordriver

- Each motors should use less than 3 Ampere (peak)
- We want to use the LM298 H-bridge as motor driver (cheap, available as breakout board)

Remember:

- more power → higher temperature → need extra components (cooling, bigger batteries)





Batteries

Batteries

- Motors require 6 - 12V DC (more Volt=more torque)
- Arduino requires 6 – 12V DC and delivers 5V DC
- Battery must be rechargeable
- Battery must contain enough energy for at least 2 hours

The motors use 0.5 Ampere each at 12 V (normal use) → 1A

The microcontroller + sensors use 500mA

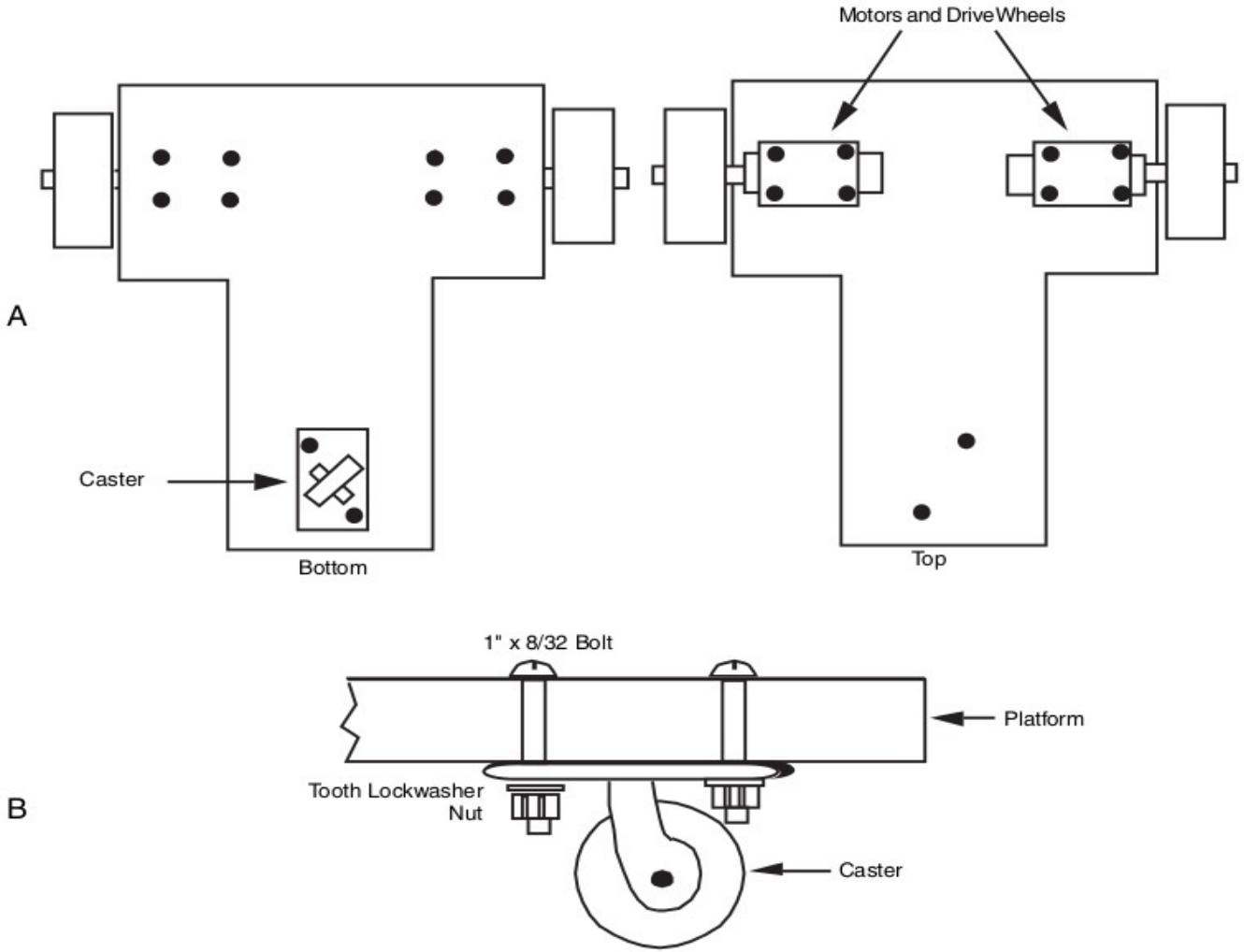
Motor+microcontroller use 1.5A = 1500mA

→ LIPO 11.1V 3200mAh

Frame

Frame

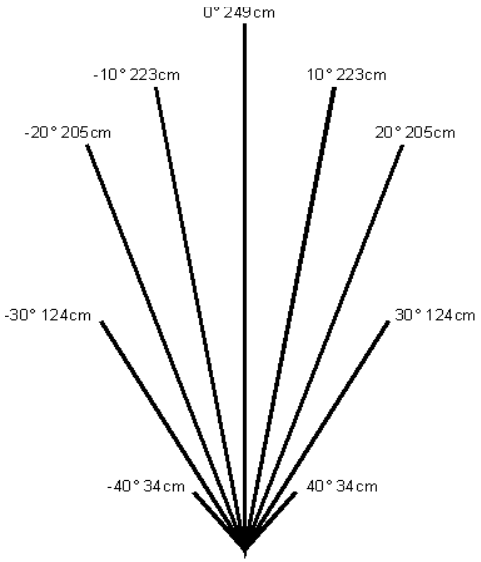
- Material: wood (30x30x1cm)
- Tools: saw (+sandpaper)



Sensors

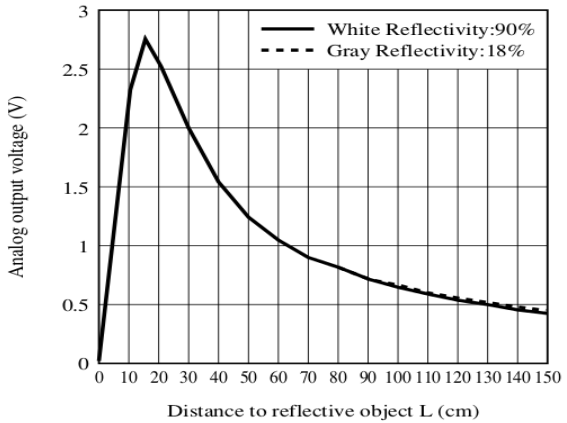
Sensors

Sensor type	Principle	Used for	Do not use with	Signal output
Infrared, laser	Light reflection	Detecting small objects or details (small beam)	Transparent or shiny materials,	Distance (cm)
Sonar	Sound reflection	Detecting big objects (wide beam)	Clothing, with other sonars, not ok for small objects	Distance (cm)
Microswitch	contact	Detecting collission/impact		On (1) Off (0)
Compass	Magnetic field	Detecting course/direction	Magnets (speakers)	Degrees



SHARP

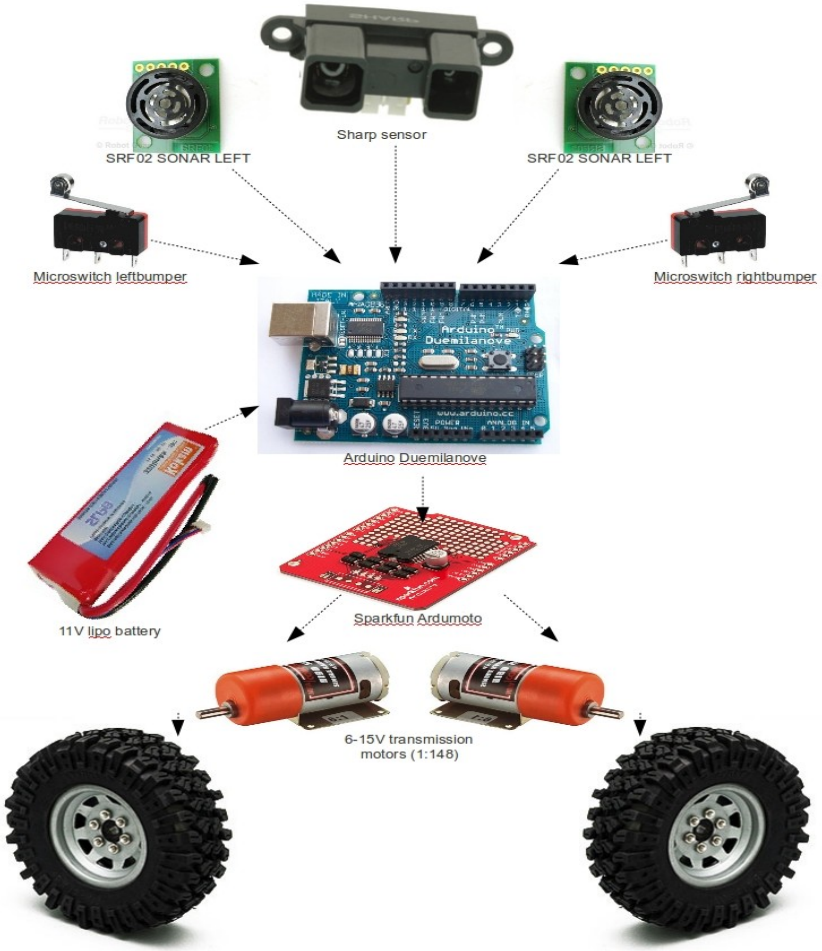
Fig.3 Analog Output Voltage vs. Distance to Reflective Object



Hardware assembly

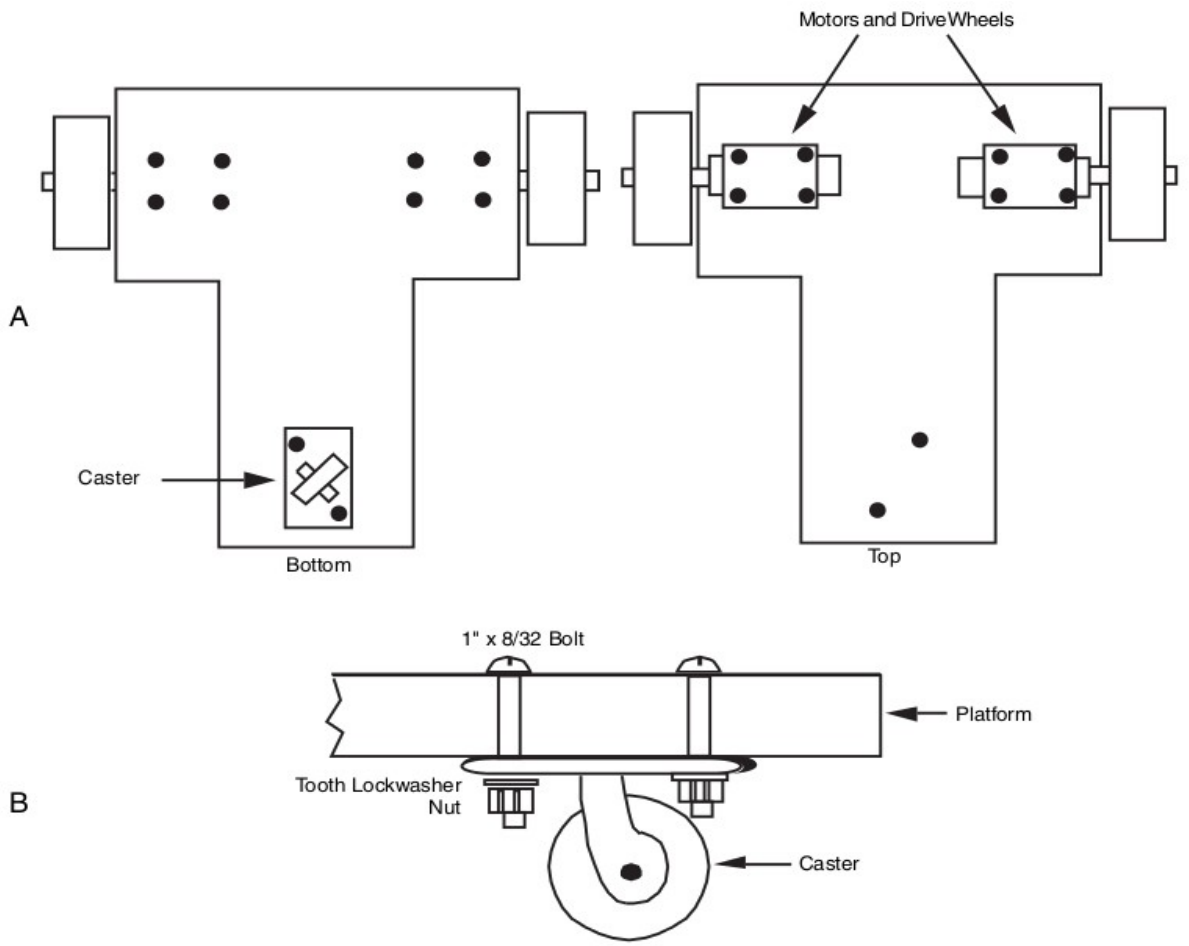
Hardware assembly

- Don't solder wires directly to electronic components → use connectors
- Electronics (microcontrollers, sensors) use 12V, 5V or 3.5V. Don't connect 3.5V sensors to 5V microcontrollers or they will burn.
- Allways double check the connections



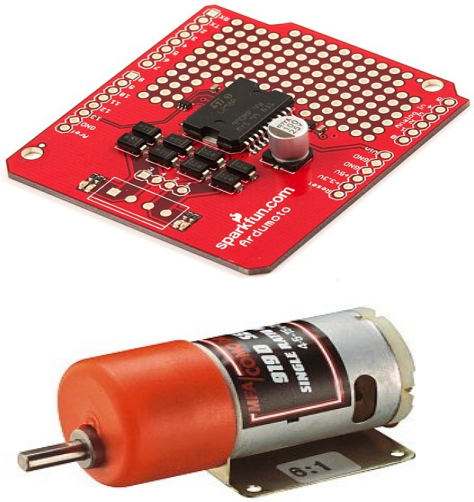
Mounting motors and wheels

Mounting motors and wheels



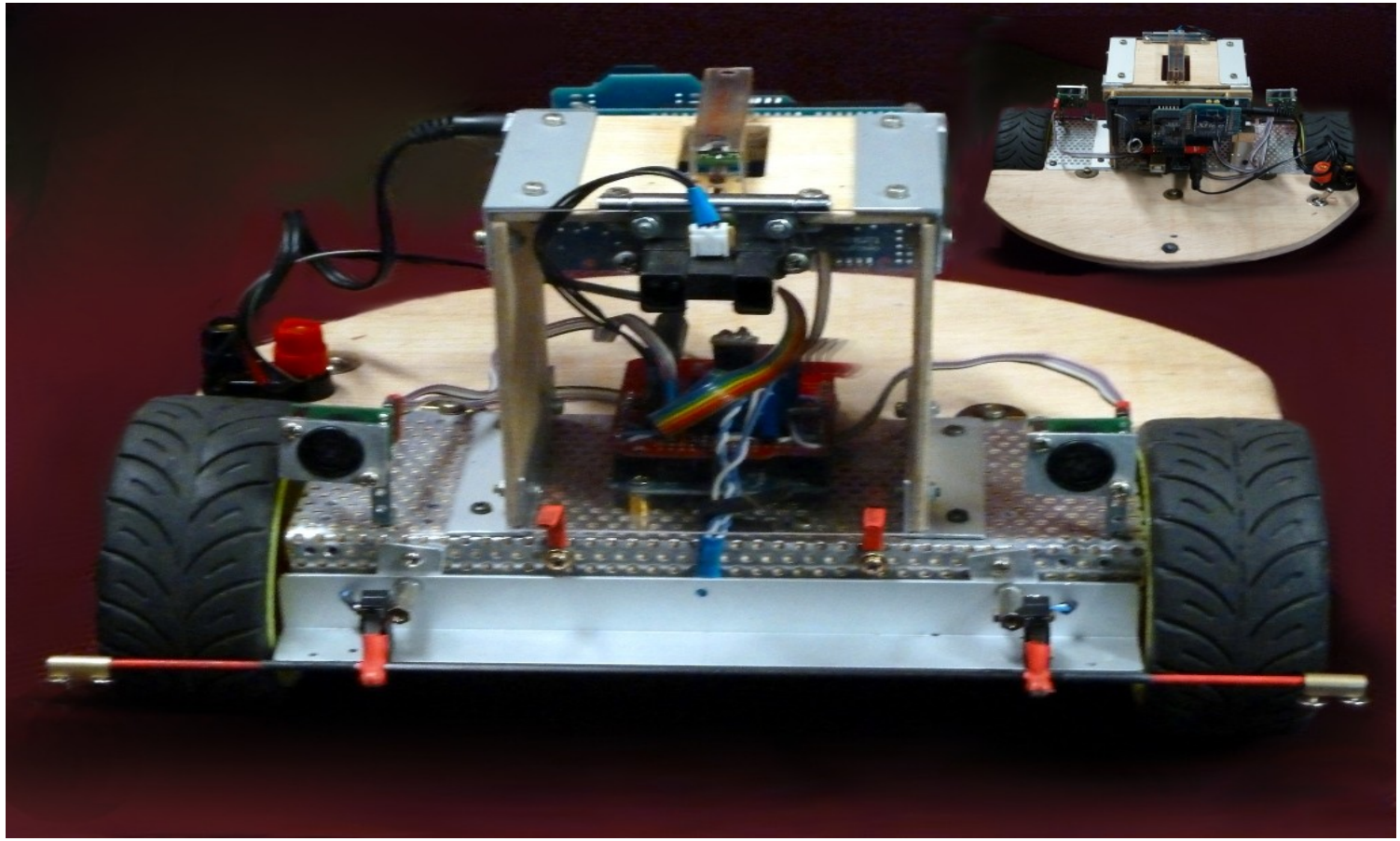
Connecting the microcontroller

Connecting the microcontroller



Assembled robot

Assembled robot

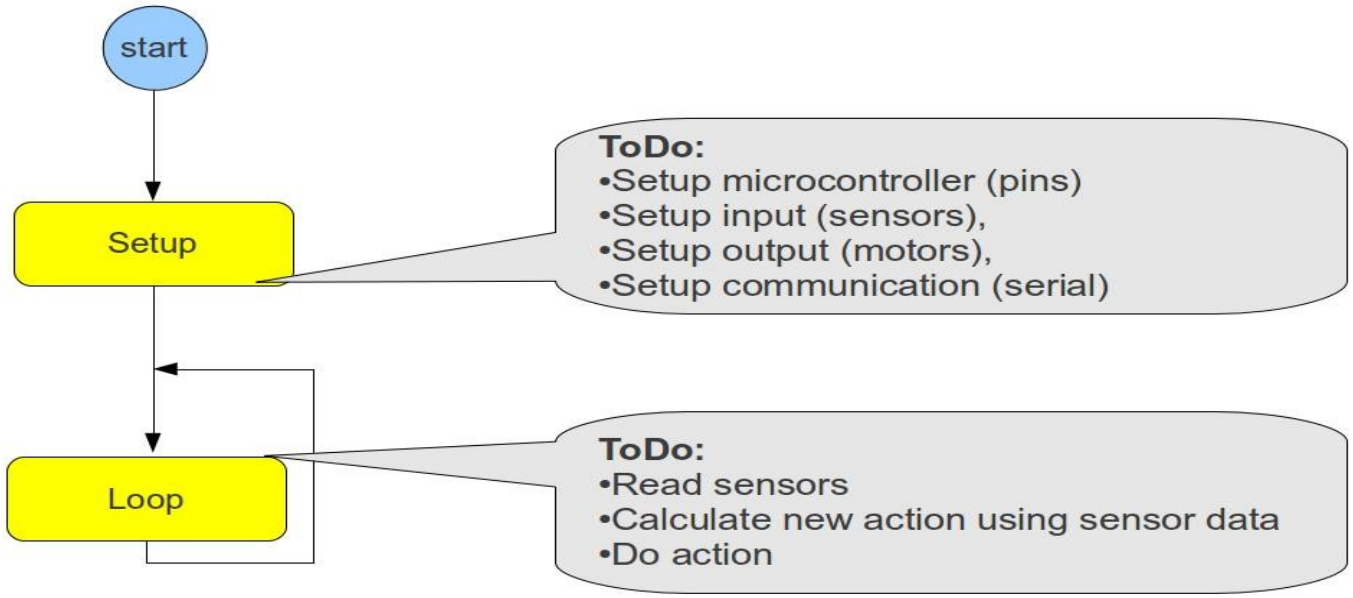


Software design

Software design

Program flow (top level)

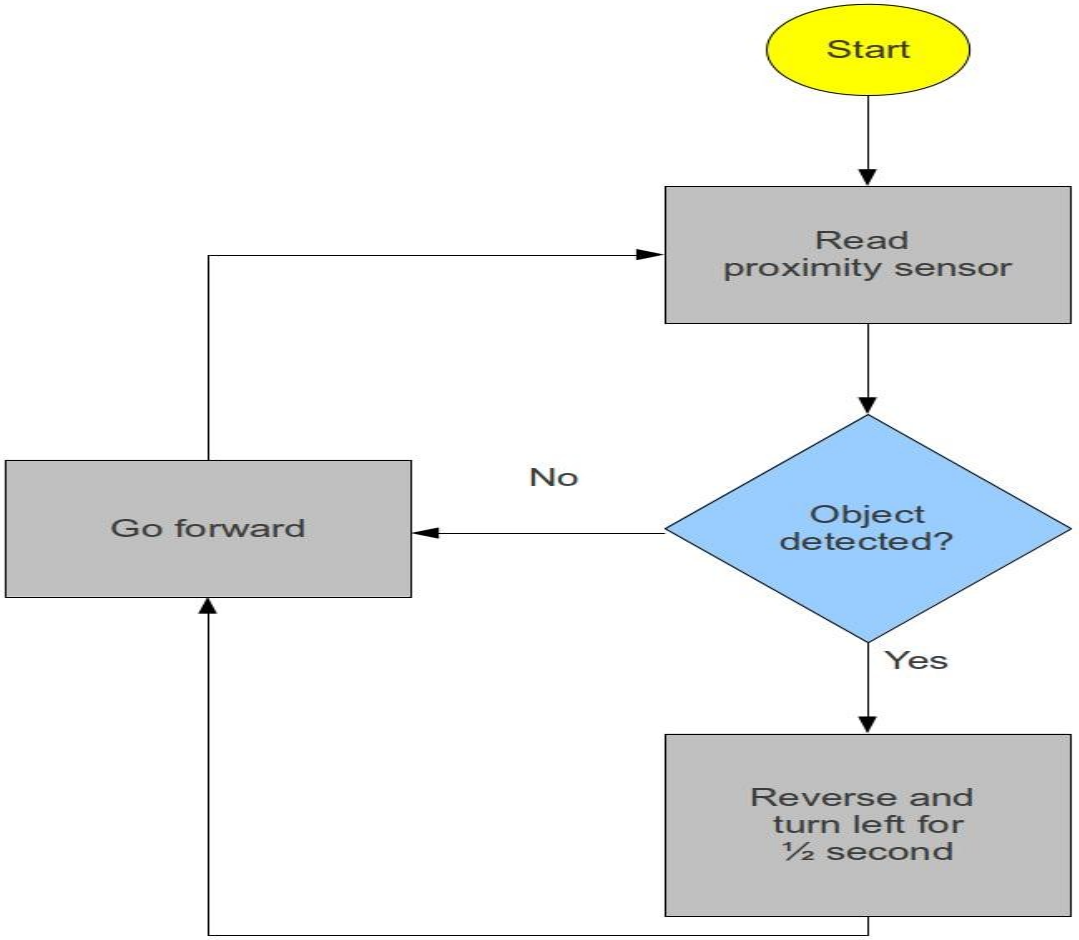
Program flow (top level)



Example Controller loop

Example Controller loop

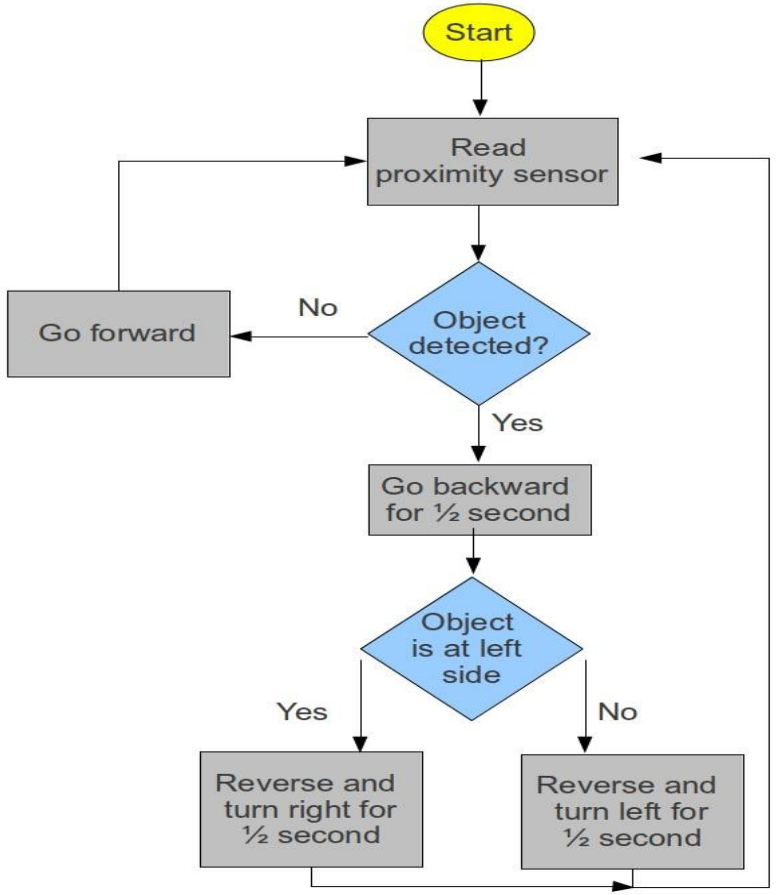
This is an example of a
basic robot controller loop



Tmabot Controller loop

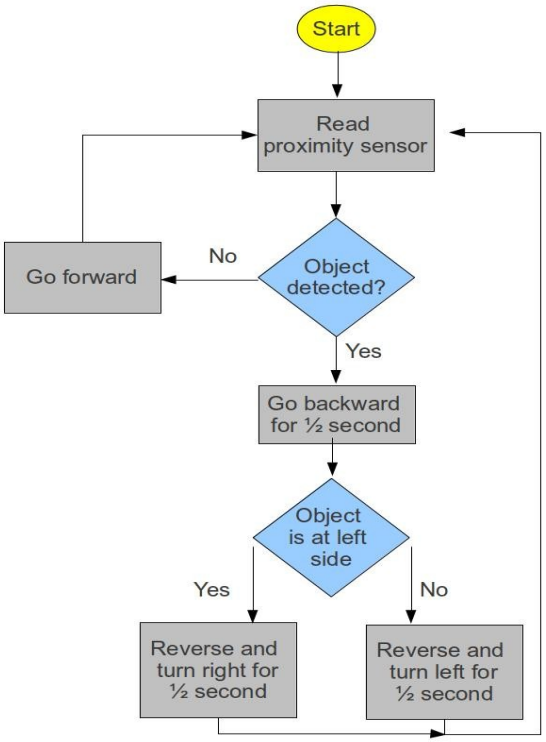
Tmabot Controller loop

Simplified diagram of the Tmabot controller loop



Sourcecode (Arduino)

Sourcecode (Arduino)



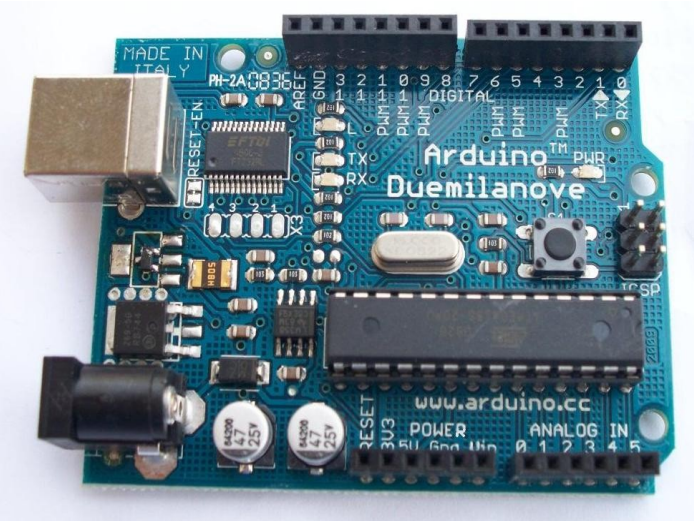

```
//SIMPLIFIED SOURCECODE EXAMPLE FOR ARDUINO
void loop()
{
   //read sensors
...int offset = 30; //30 centimeter
   int distanceCenter=analogRead(pinDistanceCenter);
   int distanceLeft  =analogRead(pinDistanceLeft);
   int distanceRight =analogRead(pinDistanceRight);

   if (distanceCenter<offset)
   {
      //object detected
      if (distanceLeft<distanceRight)
      {
         goBackward();
         delay(500);
         goRight();
      }
      else
      {
         goBackward();
         delay(500);
         goLeft();
      }
   }
   else
   {
      //no objects detected
      goForward();
   }
}
```

Debugging & Commmunication

Debugging & Commmunication

The Arduino (and most other microcontrollers and microprocessors) have a serial commmunications port
You can use it for:

- Programming the microcontroller
- Debugging / Logging
- Remote control
- Communication with other robots and/or modules



Advanced robotbuilder tricks

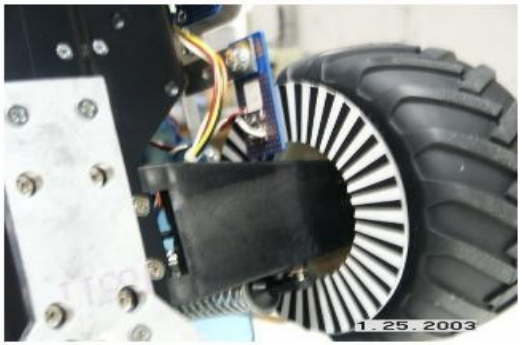
Advanced robotbuilder tricks

Feedback

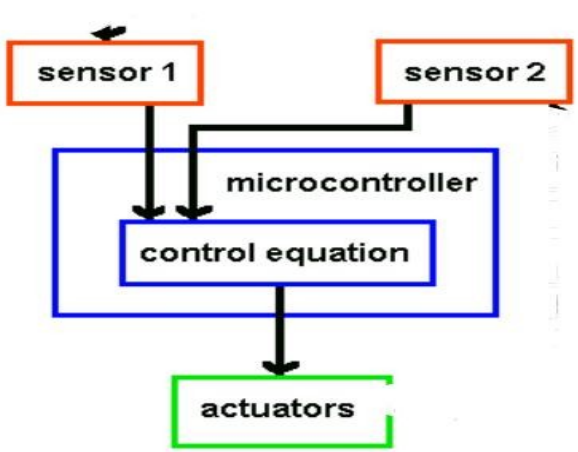
Feedback

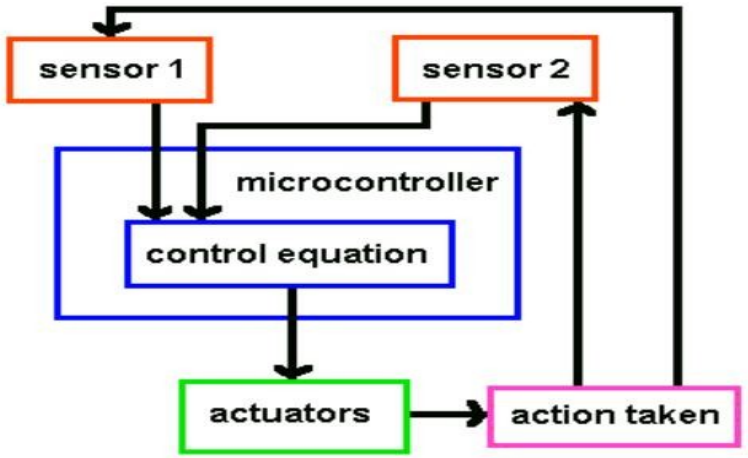
Wheel

Wheel rotation sensor



Electronic compass





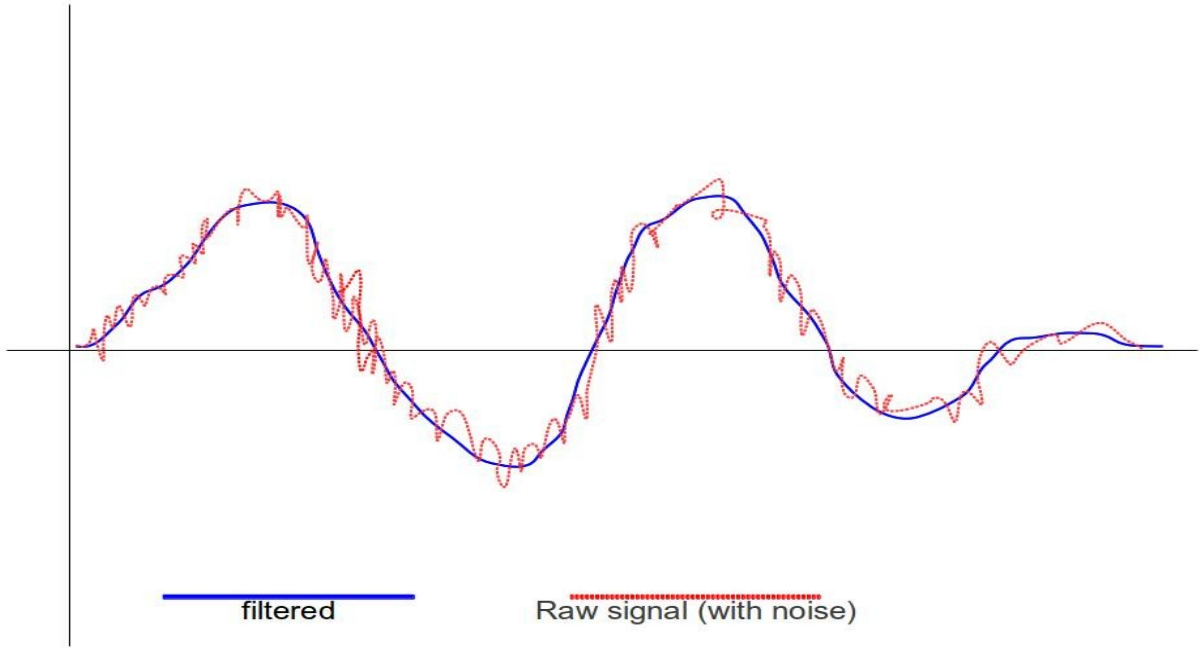
Signal optimalisation

Signal optimalisation

Signals contain noise. This can cause problems when interpreting the sensordata

There are solutions to get a better signal and less noise:

- Use shielded cables
- Use shielded connectors
- Keep sensors, cables and chips away from noisemakers (motors, speakers)
- Shield the noisemakers
- Use hardware RC-filter to eliminate high or low frequencies
- Use software to filter the signals

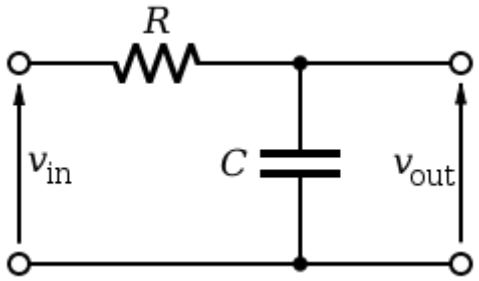


Signal optimalisation

RC Filter (hardware)

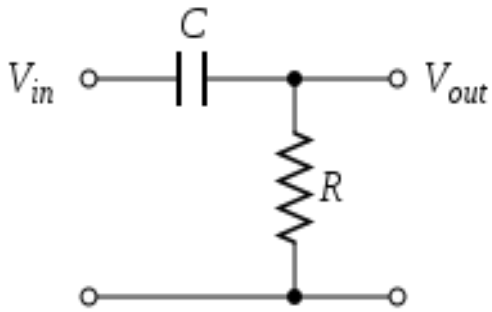
Low pass filter (drops high frequencies)

- used to filter high frequency noise



High pass filter (drops low frequences)

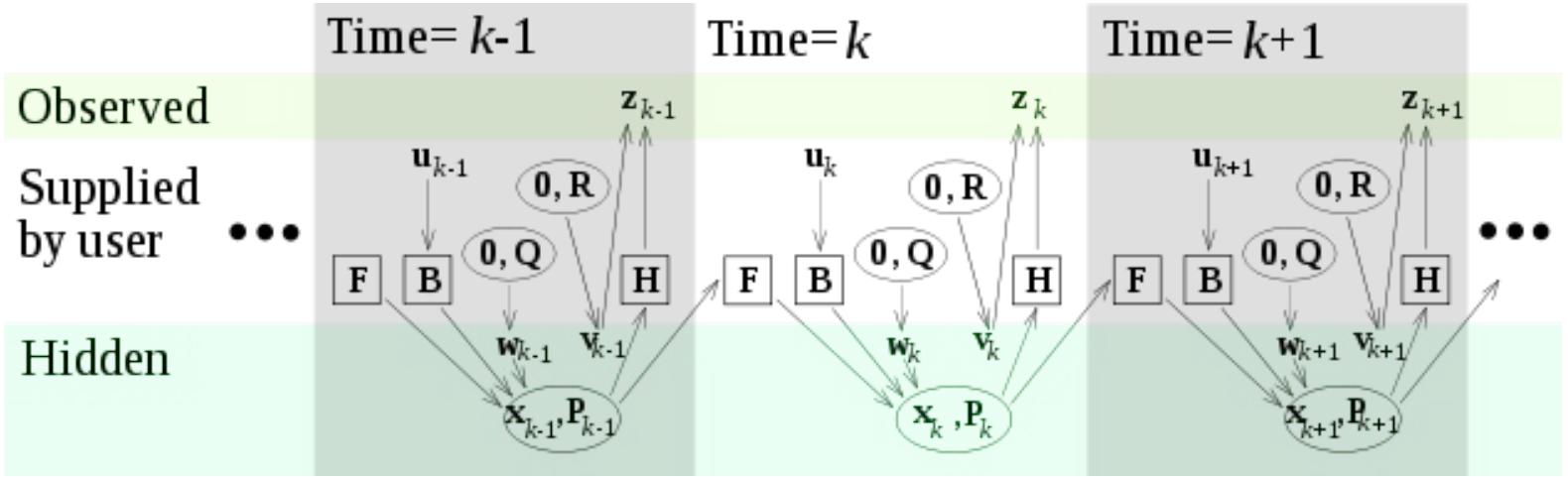
- used to filter 50Hz noise from 220V power supply



http://en.wikipedia.org/wiki/Filter_(signal_processing)

Signal optimalisation

Kalman filter (software)



Model underlying the Kalman filter. Squares represent matrices. Ellipses represent multivariate normal distributions (with the mean and covariance matrix enclosed). Unenclosed values are vectors. In the simple case, the various matrices are constant with time, and thus the subscripts are dropped, but the Kalman filter allows any of them to change each time step.

http://en.wikipedia.org/wiki/Kalman_filter#Underlying_dynamic_system_model

Mapping

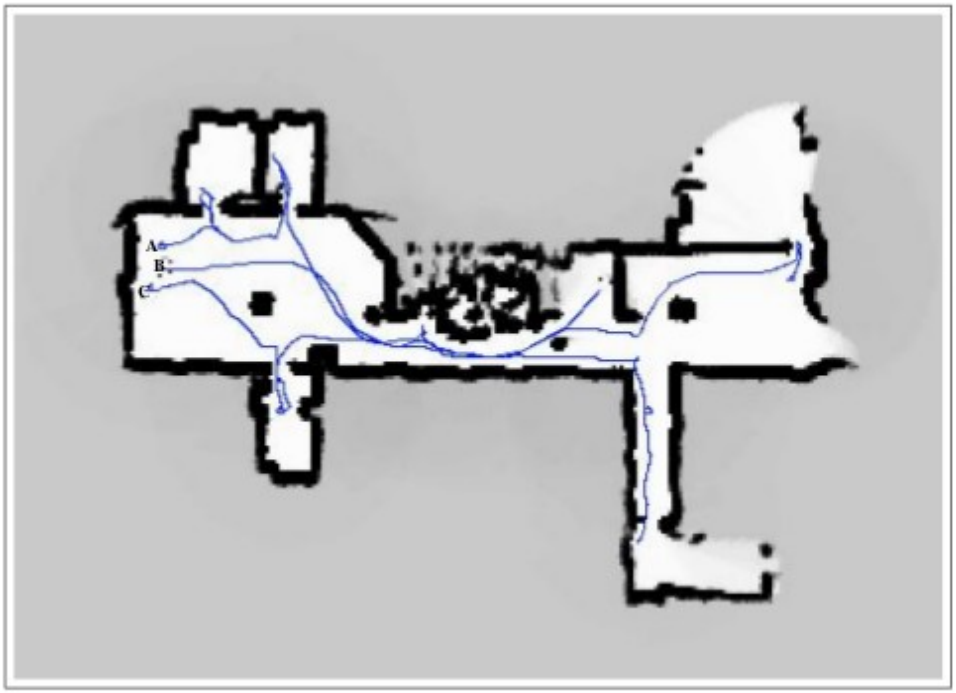
Mapping

Problems:

- Drag
- Sensor noise
- GPS not working indoors

Solutions:

- Odometry (wheel encoders)
- GPS (outdoor)
- Compass
- Location beacons

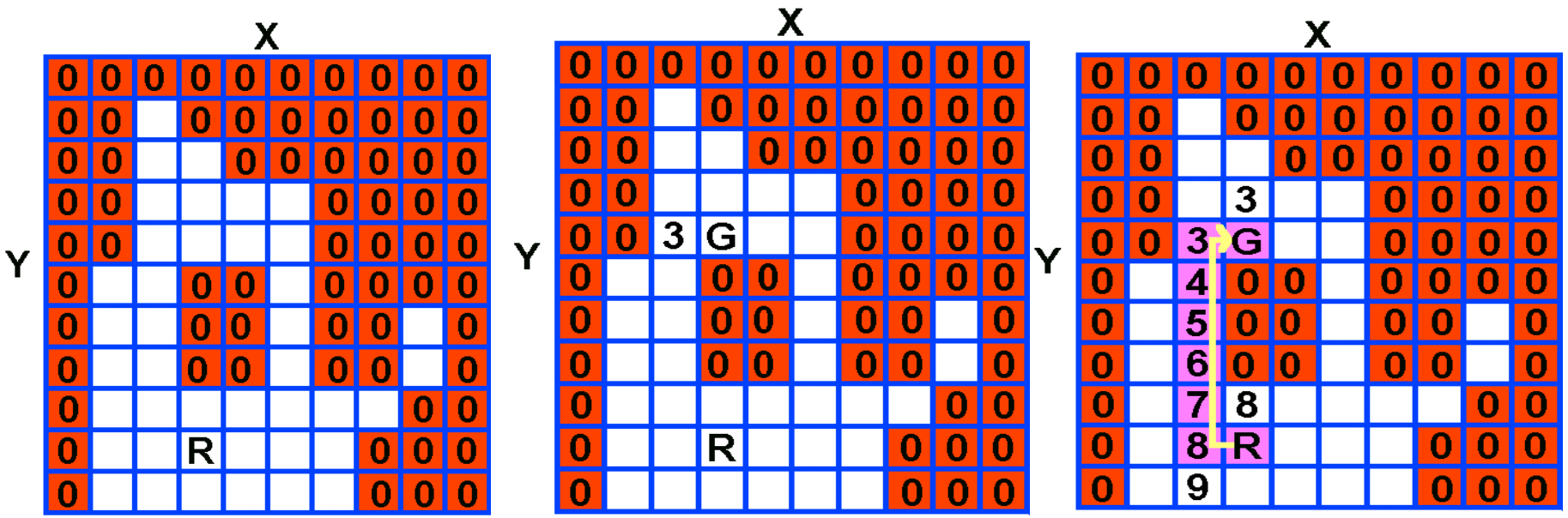


Map built by three autonomously exploring robots. The initial robot poses are on the left as marked by the letters A, B,

Wavefront algoritme

Wavefront algoritme

Find the most optimal route



1. create a discretized map
2. add a goal and robot location
3. fill in the wavefront
4. direct robot to count down

http://www.societyofrobots.com/programming_wavefront.shtml

SLAM

SLAM = Simultaneous Localization and Mapping

- http://www.youtube.com/watch?v=bq5HZzGF3vQ
- http://www.youtube.com/watch?v=Q1ipn42rMh8

Need more information?

Need more information?

Theo's Mechanic Ape

- http://mechanicape.com

Robot sourcecode + design

- http://mechanicape.com/tmabot

Information for robotbuilders

- http://www.societyofrobots.com

Components

- http://iprototype.nl (Arduino and sensors)
- http://sparkfun.com (Electronics)
- http://conrad.nl (transmission motors)

Questions?

Questions?