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# Low-cost platforms used in Control Education: An educational case study

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# Outline

- Why think in low-cost platforms?
  - Subjects' contents
  - Students' interest
  - Easy accessibility
- Two criteria for selecting these low-cost platforms.
- Proposals in UPV/EHU
  - NXT - Arduino - Raspberry Pi - Kinect
- Conclusions

# Why think in low-cost platforms?

**Increase** and **improve** learning content related to **Control Education**

**Capabilities** and **interest** of students

**Low cost** ... even for students

# Learning contents

- Increase and improve learning content related to Control Education
  - Transition from...
    ... theoretical approaches + developments...
    ...to learning by practical + real developments.
  - Without removing...
    ... analytical part,...
    ... strengthen learning with real applications.
  - “New" teaching proposals...
    Beyond PCs and simulations

# Students: capabilities & interest

- Achieving the convergence in:

  **capabilities and interest** of students

  - New technologies are assimilated for students faster than tutors or teachers.

  - Using real platforms increases the possibility of theoretical and practical learning

# New platforms accessibility

- Low-cost
  - Investment in laboratories or classrooms.
    - Complementing the "classic" models.
  - ... even for students.
    - Curiously, before preparing works related to these platforms...

      ... some students had previously bought them for “playing” and implementing their solutions at home.

# Our proposal

- Practical works
  - Independents:  Without guidance
  - Outside of laboratory regular time table
  - Giving general objectives to obtain...

    ... services / system behaviour / final achievement...

- Advantages and stimuli
  - Thinking in a competitive environment...

    ... for stimulation of students' interest.
  - Evaluating as a complementary grade for the course
  - More close to the real solutions...

    ...further from the simulations

# Selecting low-cost platforms

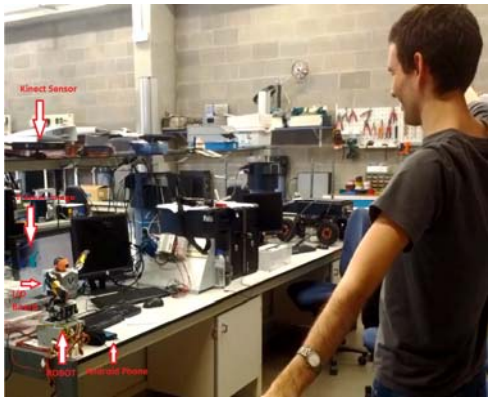
- Two criteria:

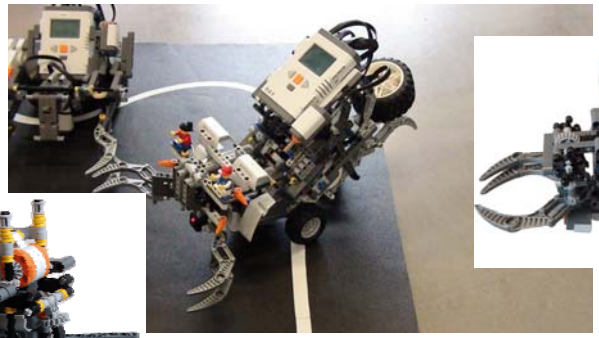
The particular **concern** of the teacher to include more didactic contents in courses and subjects

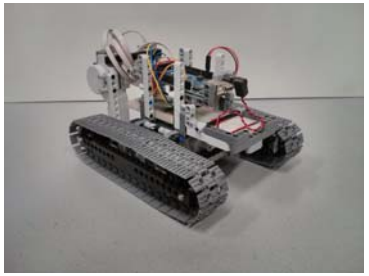
The continuously growing **experience** of students in relation to every low-cost platform

# Proposals in UPV/EHU

- Learning & Researching

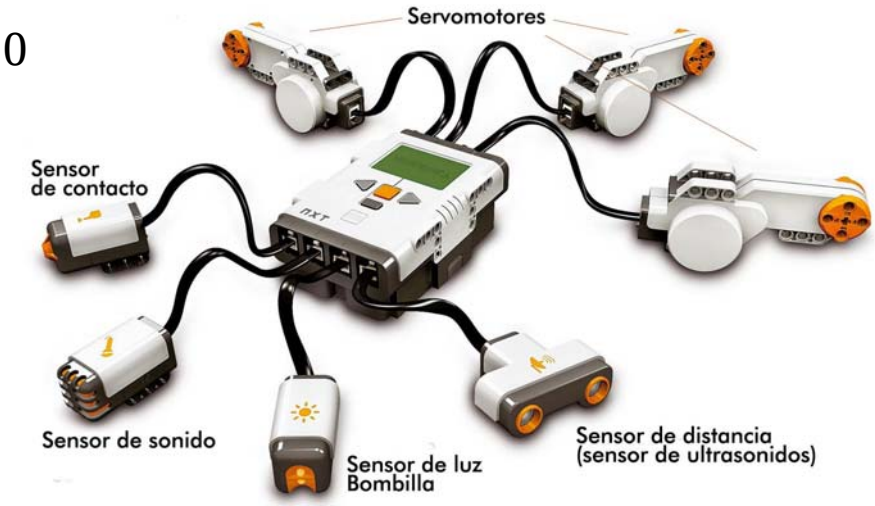




# LEGO NXT

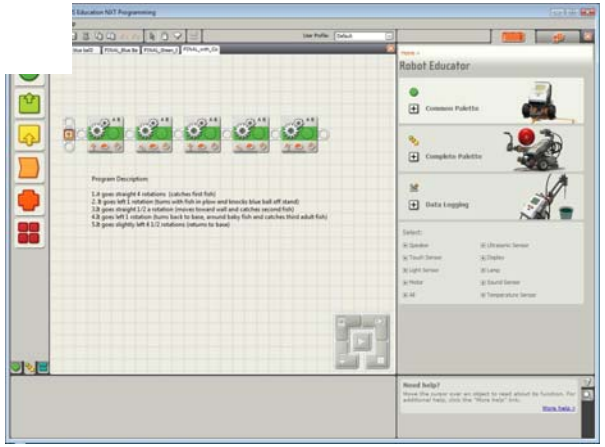
- Features of the equipment
  - LEGO® MINDSTORMS® NXT 2.0
    - Microcontroller ARM7 of 32 bits
    - 256 Kb Flash memory
    - 64 Kb de RAM
    - Ports: 4 I + 3 O
    - Communication: USB + Bluetooth
    - Firmware
    - Running: autonomous + remote
  - Specific sensoring
    - HiTechnic
  - New units EV3

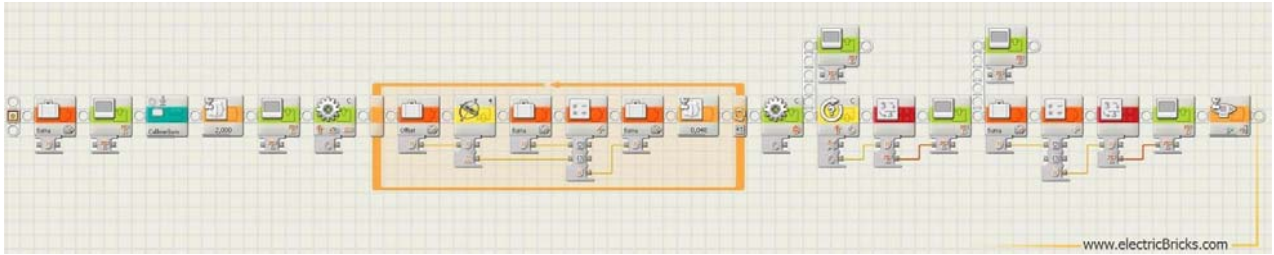



# LEGO NXT

- Programming
  - SW LEGO
  - RobotC
  - MATLAB - Toolbox
  - NI LabVIEW
  - ADA
  - JAVA
  - ROS





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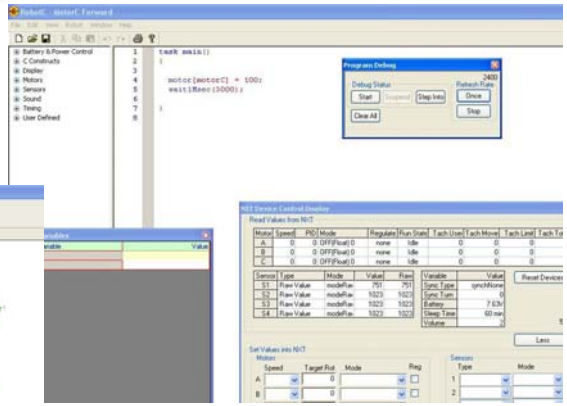
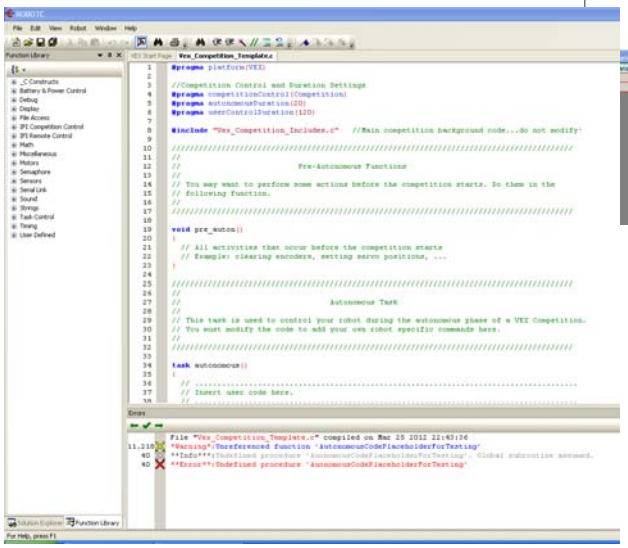
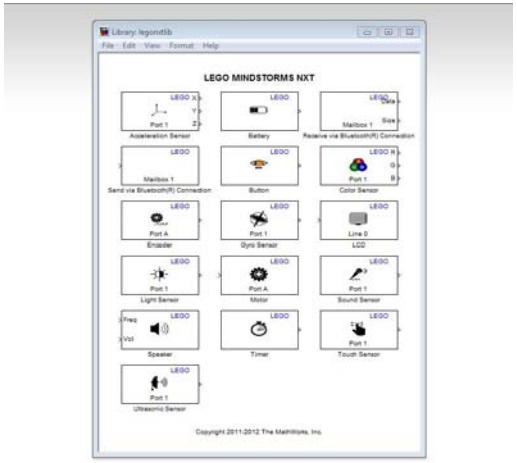


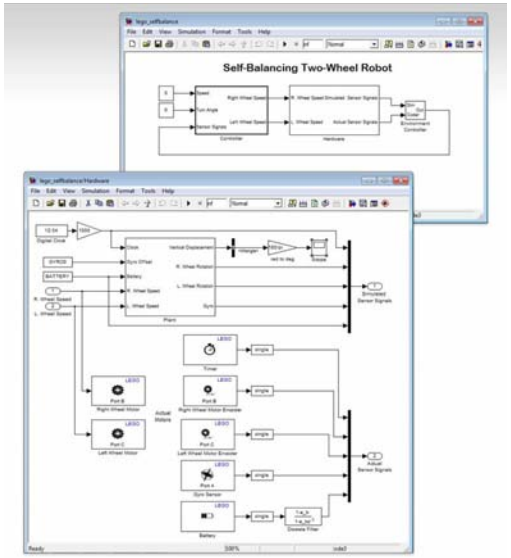


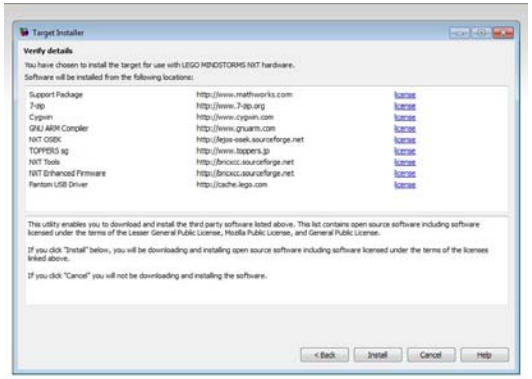
# LEGO NXT

- Programming
  - SW LEGO
  - RobotC
  - MATLAB/SIMULINK - Toolbox
  - NI LabVIEW
  - ADA
  - JAVA
  - ROS

MathWorks
Accelerating the pace of engineering and science



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  - JAVA
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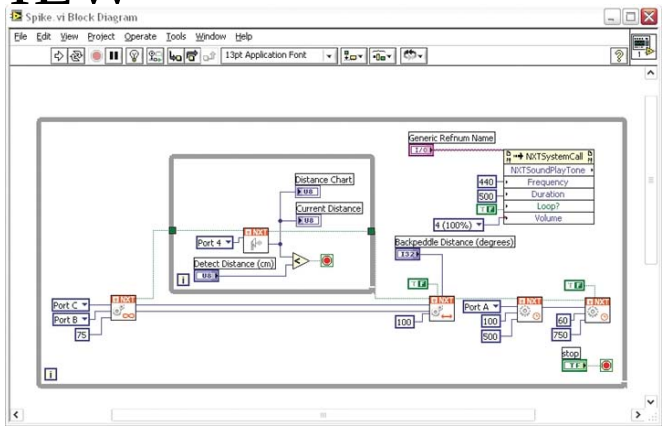


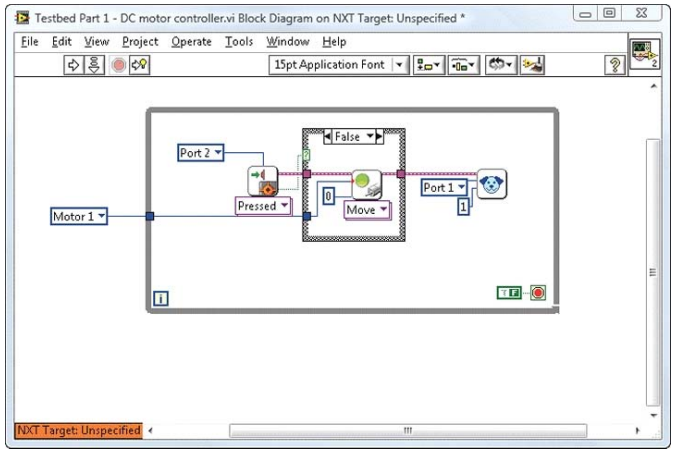

# LEGO NXT

- Programming
  - SW LEGO
  - RobotC
  - MATLAB - Toolbox
  - NI LabVIEW
  - ADA
  - JAVA
  - ROS


**Light Sensors**

```
with NXT.Display;   use NXT.Display;
with NXT.AVR;
with NXT.Light_Sensors; use NXT.Light_Sensors;
with NXT.Light_Sensors.Ctors; use NXT.Light_Sensors.Ctors;

procedure light_test is
  use NXT;
  Light  :  Integer;
  Light_Sensor_1  : Light_Sensor := make(Sensor_1, True);
begin
  loop
    Clear_Screen_Noupdate;
    Light := NXT.Light_Sensors.Light_Value (Light_Sensor_1);
    Put_Noupdate(Light);
    Screen_Update;
  end loop;
end light_test;
```

**Ultrasonic Sensor**

```
with Ada.Real_Time; use Ada.Real_Time;
with NXT.Display;   use NXT.Display;
with NXT.AVR;
with NXT.Ultrasonic_Sensors; use NXT.Ultrasonic_Sensors;
with NXT.Ultrasonic_Sensors.Ctors;

procedure Ultrasonic_Test is
  use NXT;
  Result : Button_Id;
  Cur_Sensor : NXT.Ultrasonic_Sensors.Ultrasonic_Sensor := NXT.Ultrasor
  Distance : Natural range 0..255;
begin
NXT.AVR.Await_Data_Available;
Put_Line ("Ultrasonic Test: Ping!");
  loop
    Ping(Cur_Sensor);
    Get_Distance(Cur_Sensor, Distance);
    if (Distance = 255) then
      Clear_Screen_Noupdate;
      Put_Noupdate("Nothing in sight!");
      Screen_Update;
    else
      Clear_Screen_Noupdate;
      Put_Noupdate("Hi Ken! Something is ");
      Put_Noupdate(Distance);
      Put_Noupdate(" cm away!");
      Screen_Update;
    end if;
  end loop;
end Ultrasonic_Test;
```

# LEGO NXT

- Programming
  - SW LEGO
  - RobotC
  - MATLAB - Toolbox
  - NI LabVIEW
  - ADA
  - JAVA
  - ROS

# LEGO NXT

- Programming
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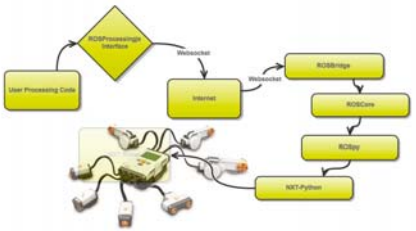
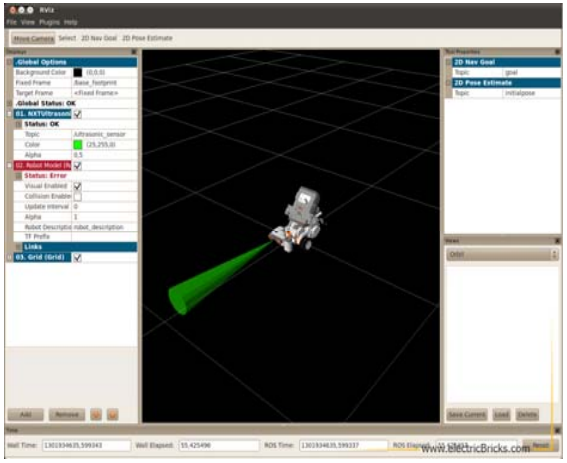
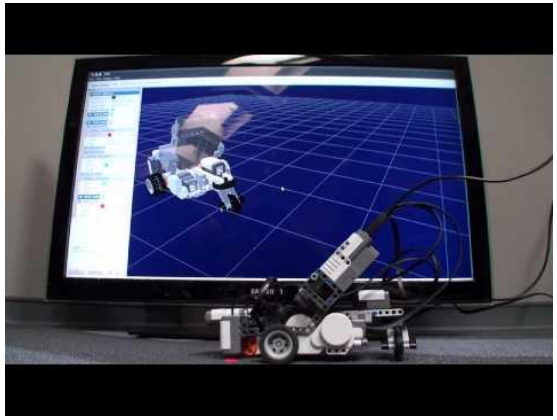
ROS.org

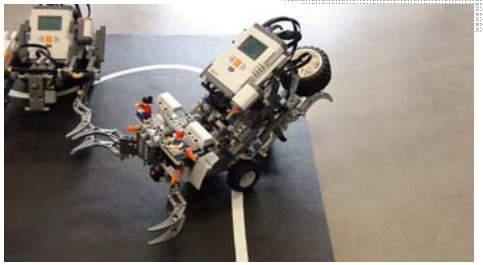




# LEGO NXT

- Student developments
  - Subjects:
    - RTOS
    - Perception Systems

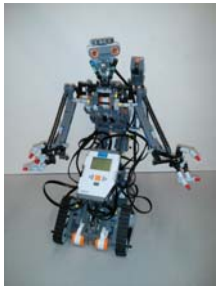


http://www.youtube.com/watch?v=TIcvtBaVg_c

  - Final career projects

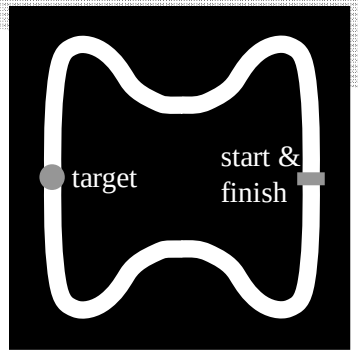
http://www.youtube.com/watch?v=3W6MwTS_syc

  - Participation on the competition of GT CEA de CI
  - Science week – Engineering working days:
    - Segway + Johnny 5

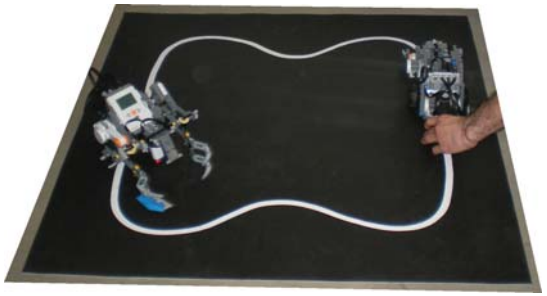


# LEGO NXT

- Handkerchief game
  - Surface for competition:
    - A black square surface (1x1 m) with a white line (1 cm of width)



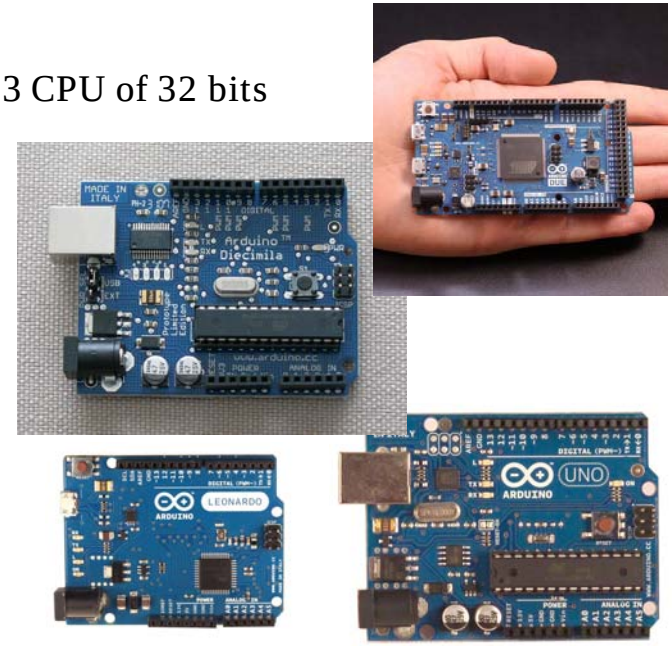

  - Rules
    - Each robot drives over a white line until the target, catch it and turn back to the start.
    - All robots have to be designed and created by students without any help from their teacher.
  - Robot structure
    - Based on LEGO NXT + HiTechnic sensors
  - Line identification and Driving control:
    - Applying several techniques learned at classes



http://www.youtube.com/watch?v=TlcvtBaVg_c

# Arduino

- Features of the equipment
  - Arduino Due
    - Microcontroller Atmel SAM3X8E ARM Cortex-M3 CPU of 32 bits
    - 256 to 512 Kb of Flash memory
    - 32 to 100 Kb of SRAM
    - 54 I/O digital pins (12 for PWM-O)
    - Clock: 84 MHz
    - Communication: USB 2.0
    - Running: autonomous + remote




  - Several sensors
    - Temperature, ultrasounds, accelerometer,...
  - Broad family of mother board and shields

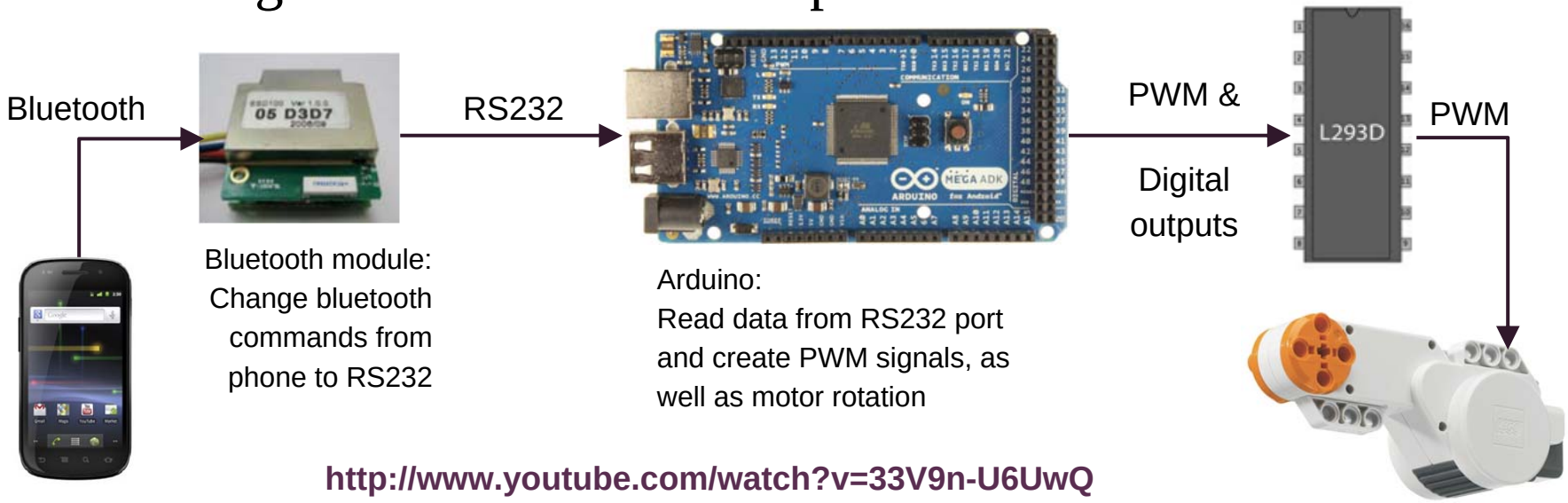
ARDUINO

# Arduino

- Student developments
  - Basic study of a ultrasound sensor

http://www.youtube.com/watch?v=b5Jfze6IthQ

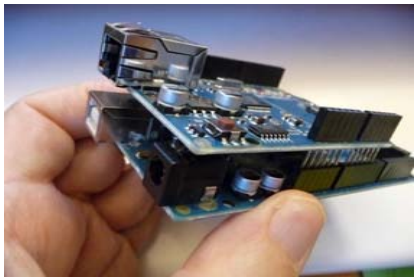
  - Integration of several components/elements

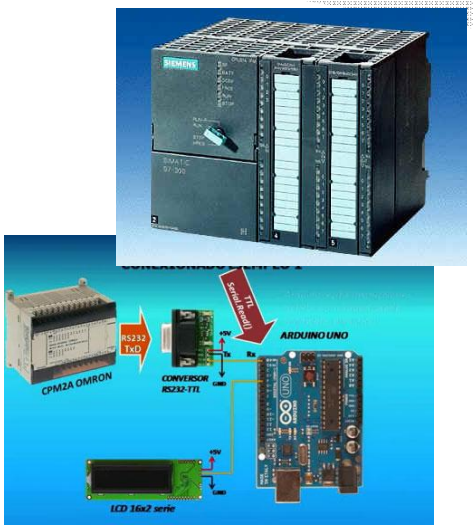



http://www.youtube.com/watch?v=33V9n-U6UwQ

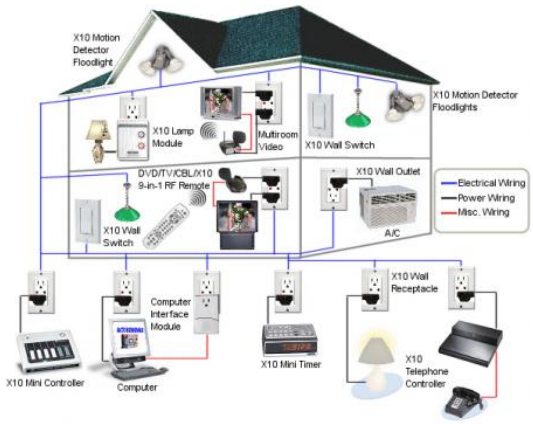
# Arduino

- Next developments
  - Combined with PLCs
    - Arduino Ethernet Shield






  - Domotica X10
    - With X10 protocol and domestic sensors

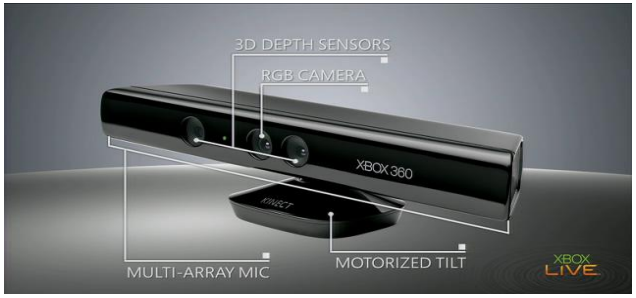


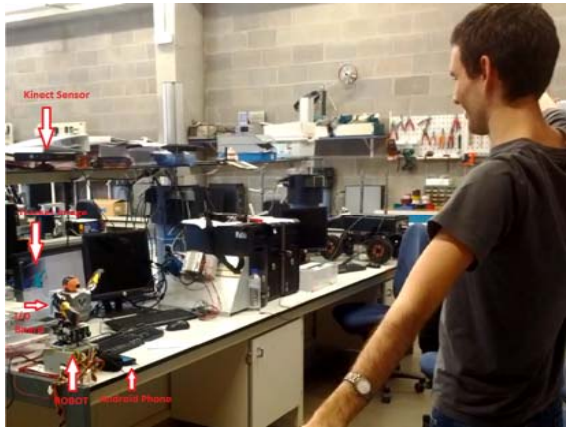
# Kinect

- Features
  - A multi-sensorial platform originally developed by Microsoft
  - Sensos: RGB camera;  depth sensor (infrared projector + monochrome CMOS sensor);  microphone
  - SDK developed by Microsoft

- Student development

KINECT

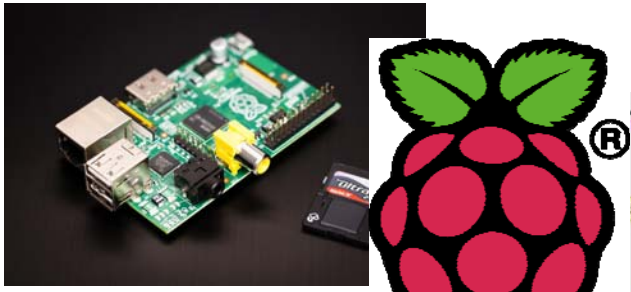


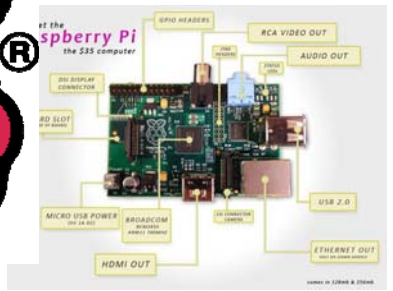




http://www.youtube.com/watch?v=UrYv1lArDJs

# Raspberry pi

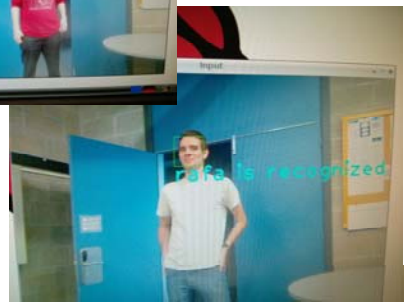
- Raspberry pi (http://www.raspberrypi.org/)
  - Processor ARM1176JZF-S to 700 MHz
  - Clock til 1 GHz
  - 512 Mb of RAM
  - SD card






- Student development
  - Access security system

Fresh!!

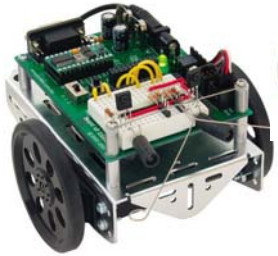


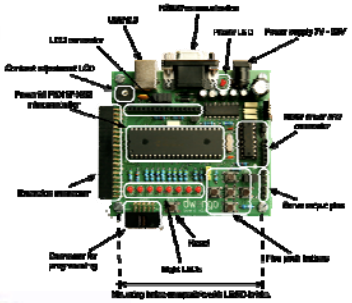
# … and next?

- Is it necessary to limit these works to the previously presented platforms?

**No… why?**

- There exist other platforms less known (among others):
  - Skybot
  - Boe-bot
  - Protobot
  - Dwengo board





- New platforms will appear in a next future…

# Conclusions

- This work deals with two questions:
  - What low-cost platforms select for teaching in Control subjects.
  - What new schedule configure in order to evaluate our students.
- Selection based on:
  - Concerns of the teachers.
  - Interest of the students.
- Laboratory practices framework:
  - Without guidance
  - General objectives
  - Competition
- Significant improvements:
  - Increasing of student involvement.
  - Reinforcement of Engineering basics.
  - Higher grade in students performing this activity.

# Thank you for your attention!

Thanks to:
*Computational Intelligent Research Group: www.ehu.es/ccwintco/*

*eloy.irigoyen@ehu.es*