LibrE Robotics:

Educational Robotics for
Learning and Sharing Knowledge
to Build Conditions for a Better World

Educational Robitics for Learning and Sharing Knowledge to Build Conditions for a Better World

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Abstract

The aim of this document is to point out the importance of the development of a free world-class education in Robotics for kids by proposing, designing and building low-cost robots with high standards of quality. On account of Open Source Software and Hardware is freely licensed to use, copy, study and change in any way, ten open-source educational robots were reviewed. Consequently, it has been proposed a low-cost robot that is based on an Arduino UNO board, two hacked continuous servos, and some extra material such as recycled CDs, glue gun, etc.; the total cost of the material in local stores is around \$ 699 Mexican Pesos ($\approx$ \$ 53.86 USD). It has also been proposed that Ardublock is going to be the main programming language for the low-cost robot considering that it is a programming tool which is very interactive and simple to use for inexperienced users. Independently, however, of the low cost of the proposed robot, it is robust for basic activities, namely: left and right rotations, movements in forward and backward directions to name but a few, and more importantly it is also being capable of recognising voice control commands. On the other hand, since LibrE Robotics has been thought to be a non-profit organization, people from different fields of study can help us to improve the project in different ways by which possible activities and open-source software to use have been proposed. As a timeline, a ghantt chart is also presented in which six tasks have been considered to be implemented in 16 months: namely; T1) development of the low-cost robot; T2) implementation of new tools in Ardublock; T3) development of the speech recognition tool; T4) integration of the tasks T1, T2 and T3; T5) design of the first workshop, and T6) evaluation of the complete project. Finally, as a future work two projects have been briefly reviewed: 1) the implementation of inductive wireless power systems to get rid of batteries that are enviromental unfriendly and the USB cable that is an issue for the mobility of the robot, and 2) the importance of the facilities' enviroment that have a significant role in influencing participants for their academic performance and mainly that they can discover and develop their own capabitilies.

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1

Introduction

*Let us try teaching children **how to think** instead of what to think.*

1.1 What is LibrE Robotics?

LibrE Robotics is inspired by KHAN academy [23] which is a non-profit organization with the goal of changing education for the better. In the same fashion, LibrE Robotics has also been thought to be a non-profit organization in which the main goals are fivefold:

- to contribute to the development of a free world-class education in Robotics for anyone anywhere;
- to design and build low-cost robots with high standards of quality;
- to improve current open source software projects so as to be more approachable by inexperienced users;
- to design free access material in educational Robotics, and develop activities where organization and cooperation of the participants can foster possible solutions for environmental, social and healthcare issues; and
- to design and build environments where participants can discover and develop their own capabilities.

LibrE Robotics will provide software and hardware for educational robots that are extremely reliable (robust), modifiable, and very cheap in order to be accessible to anyone and to enable a much more rapid development of the community.

In addition to that, LibrE Robotics has been adopted the philosophy of free software foundation, since free and open-source software and hardware licences state that anyone is freely licensed to use, copy, study and change in any way, and the source code is openly shared so that users are encouraged to voluntarily improve the design of the software. As Meyer [30] put it,"Libre software offers scientists the possibility of sharing with their peers how they have solved problems. This, of course is basic for the evolution of science; but libre software goes beyond tha and makes this happen in a cost-effective way."

1.2 What are the Benefits for Learning and Sharing with LibrE Robotics?

There are many benefits that can be derived from LibrE Robotics, mainly because the creation of strong links between industry, government, education and sociecity. Robotics is a multidisiplinary field in which mathematics, physicis, mechanics, computational science and electronics to mention but a few are applied. Robotics applications have been proven to be many and these are ranging from agriculture to factory automation, from healthcare to education [6]. Aditionally, robotics is a fascinating and fun way to develop creativity as well as the design, implementation, and integration of ideas that are essential for the development of skills that provides participants to cooperate and build conditions for a better world. Henceforth, similar projects of educational robotics that epitomise benefits for their communities are reviewed in the following section.

Valeria Larrar, a primary professor from Argentine, designed various workshops in educational robotics for participants between 10 and 15 years old in public schools. Valeria at a TED talk [25] in October 2013 mentioned that having seen the succefulness and possibilities of his first workshop, the educational ministery of Argentine afforded her school to buy 30 Robotics LEGO kits. It is important to mention that one of the goals for workshops is to tackle common issues in the community, for example, having known the problem of usefulness of traffic lights in busy highways, students built an automatized bridge to transport mainly disable people. Valeria emphasised that the power of interest is really great that what it looks like a professor guiding his pupils (Figure 1.1), in reality that person is the school caretaker who is delighted by the educational robotics software. Valeria's projects showed that by learning robotics,

Fig. 1.1 A school caretaker watching the boys using educational robotics software.

students can create many oportunities, relationships among parents and sibilings, friends, and most importantly finding joyness and optimismn in doing something that they love.

Similarly, the Ashesi Robotics Experience (ARX), an annual robotics workshop in Africa, is designed to provide a stimulating, fun and refreshing environment for students to learn robotics [5]. At ARX 2013 mentors were selected from Ashesi University College who possessed the right set of skills and attributes to mentor, train, and take responsability of students. During one week, students were working on building Lollybots and LEGO Mindstorm Robots and on the last day, the community where invited to see students' projects so as to show that Robotics can be used as a way of critical thinking to solve social problems. ARX also provides statistics of the participants in which the number of boys were 34, representing 57% of participants, while girls were 26, representing the other 43%. Participants were between the ages of 15 to 21 and came from all nine regions of Ghana, as well as two international students from Ethiopia and Swaziland (Figure 1.2). Additionally, Ashesi Robotics posted several final projects at their webpage [6],

Fig. 1.2 Ashesi Robotics Experience Workshop 2013

for instance, exploration robots, Planning in Dynamic Environment, Building a Sorter Robot, Follow the leader, Tic-tac-toe, Dynamic balancing and Robot Navigation using colors as road signs. It is important to note that all projects were documented by using these outline: Introduction, Approach, Algorithm, Results, Conclusion, and Appendix.

Having checked the positive benefits, one can see that many of the previos-mentioned projects were implemented with LEGO Mindstorm Robots which represent a signigicantly economical inversion. To this end, The African Robotics Network (AFRON) community presented a project called “Ultra Affordable Educational Robot” in which many participants around the world are called to present their robot designs that can inspire young children worldwide about Science, Technology, Engineering, and Math [24]. One of the primary goals for Ultra Affordable Educational Robot is to make robots that are more functional, more realiable, easier to use, less expensive and easier to manufacture. At the AFRON Design Challenge 3 categories were considered: 1) hardware 2) software, or 3) curriculum (Figure 1.3). First places are going to be cited, however, second and third places are worth of reviewing in the future. Both in the hardware and curriculum categories, The MIT SEG: An Origami-Inspired Segway Robot won the first place mainly because of its accesible price of approximately $20 US dollars [29]. MIT SEG’s software is based on ardublock [26] for which activities were taught using finite state machine concepts. In the software category, AERobot: an Affordable Education Robot won the first place [4]. AERobot’s software is based on Minibloqs, a graphical programming environment [21], that allow novice programmers to easily program their little Robot.

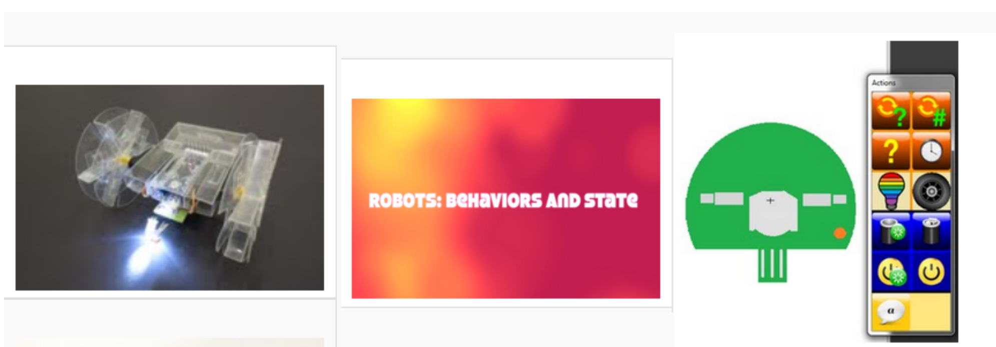

Fig. 1.3 First places at the AFRON Design Challenge: The MIT SEG, Behaviors and states with finite state machine concepts, and AERobot’s software based on minibloq (from left to right).

It is also important to note that there are many related projects for educational robots, that are not open source software and hardware projects with high prices that are out of the current economical posibilities, for instance, Finch Robot [9] and Bee-Bot [8]; however, both provide a good references for lessons and software tools.

2

Low-Cost Robot: Hardware and Software Requirements

La semplicitá é lúltima sofisticazione.
Leonardo Da Vinci

2.1 Hardware Requirements

Different educational robots are reviewed in order propose a low-cost robot for LibrE Robotics.

2.1.1 A Review of Educational Robots

According to the Finch Robot which was proposed by a lab at Carnegie Mellon University [9], there are five features that are essential to be considered when one is designing educational robots:

- Works everywhere;
- Rich Interactivity (Programming should be less tedious);
- Aesthetically Appealing;
- Robust Hardware; and,
- Minimal Curricular Changes.

The Finch Robot hardware includes: light, temperature, and obstacle sensors, Accelerometers, Motors, Buzzer, Full-color beak LED, Pen mount for drawing capability and Plugs into USB port (Figure 2.1). One of the main advatange of the Finch robot is that use the USB port as a power device thus there are no batteries to charge and robot behavior can not be affected by on-board power levels. The Finch Robot cost is $ 99.00 USD and it has got both hardware and software as closed licences.

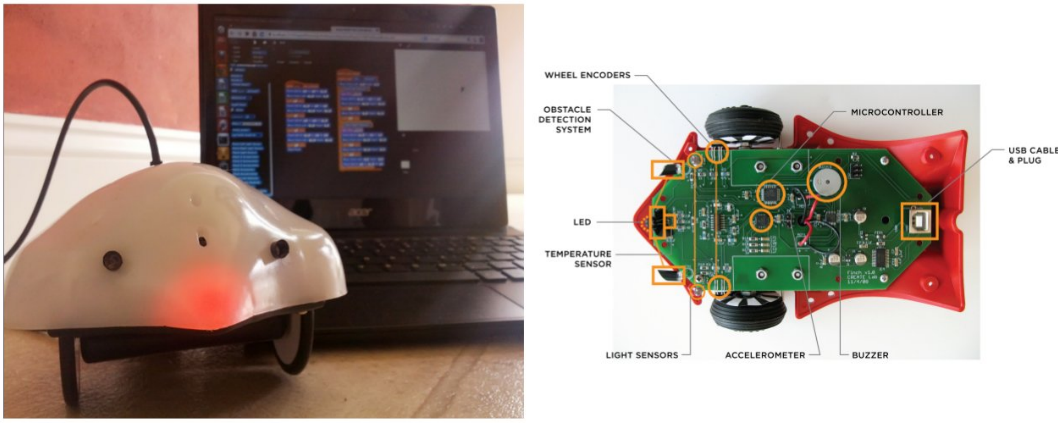

Fig. 2.1 Finch Robot (left) and Finch' Sensors (right)

Bee-Bot is a robot designed for use by young children [8]. Directional keys are used to enter up to 40 commands which send Bee-Bot forward, back, left, and right (Figure 2.2). Pressing the green GO button starts Bee-Bot on its way. Bee-Bot blinks and beeps at the conclusion of each command to allow children to follow Bee-Bot through the program they have entered and then confirms its completion with lights and sound. Bee-Bot is powered by a built-in rechargeable battery. Recharging is done via a standard USB recharger or USB computer port. Bee-Bot cost is \$89.95. Additionally, a full line of Bee-Bot materials are available to enhance teaching and learning with Bee-Bot in the classroom: Bee-Bot lessons \$100.00, problem-solving with Bee-Bot \$100.00, and mats from \$29.95 to \$79.95.

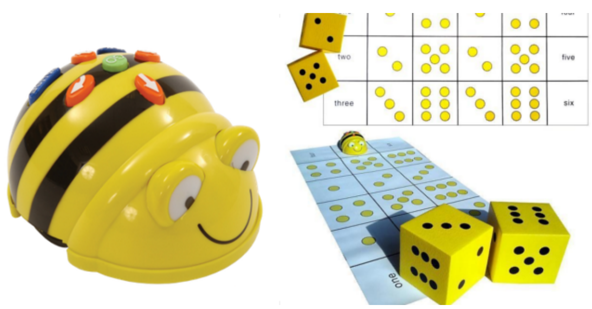

Fig. 2.2 Beebot: Robot (left) and Dice Mat (right).

On the other hand, Thymio II robot is an open hardware and open source project [12]. Thymio II has got over 20 sensors, 40 lights, 2 motors (Figure 2.3). It occupies a Micro-USB cable for charging and programming. Thymio II Robot can be used with the integrated behaviours: Friendly (green), Explorer (yellow), Fearful (red), Investigator (cyan), Obedient (purple), and Attentive (blue). Thymio II Robot can also behave as : Slope avoidance, Balancing on a ball, Musical instrument, Light show, Positions in English, Thymio top model, Thymio as a dragon, Drawing machine, Learning commands, Special Effects and Light painting. Nonetheless, Thymio II's price is \$189 USD which is higher than Finch' Robot cost of \$ 99.00 USD.

Androutsopoulos *et at.* [14] at the Department of Computer Science at Middlesex University from London have designed the MIddlesex Robotic plaTfOrm (MIRTO) (Figure. 2.4) which is an open-source platform built using Raspberry Pi, Arduino, and Racket as the core coordination mechanism. Robot's hardware has got two platforms: 1) base platform: two HUB-ee wheels with motors and encoders (to measure actual rotation), front and rear castors, two bump

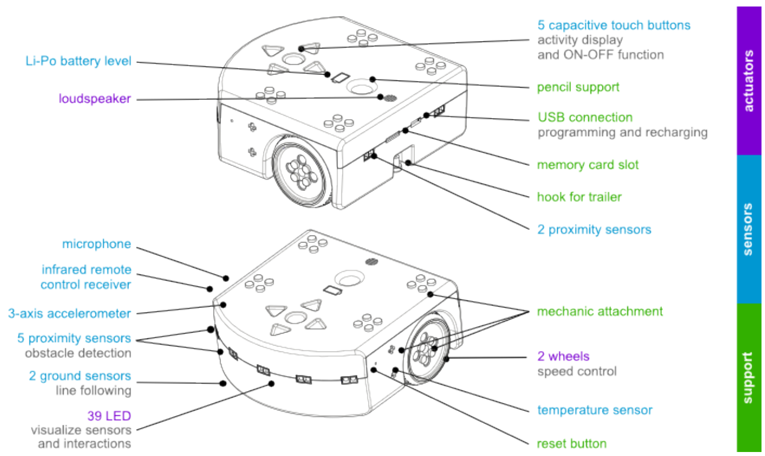

Fig. 2.3 Thymio II Sensor Actuators

sensors, an array of six infra-red sensors, a rechargeable battery pack, an Arduino microcontroller board; 2) top layer: a Raspberry Pi connected to the Arduino, Linux with Racket (current version 5.93), USB-WiFi adapter for SSH and network. Additional: cameras, microphones and text to speech with speakers. Since it is an educational project, it is not available for being bought; however, robot's hardware and software provide a good refeerence.

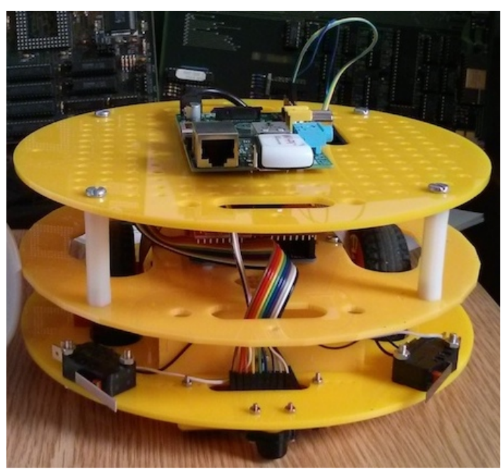

Fig. 2.4 MIddlesex Robotic plaTfOrm (MIRTO)

Equally important, Lil'Bot, a low-cost, open-source, Arduino-compatible balancing robot for learning, hacking and delight [22], is worth to cite since many of its features are quite similar to the aim of LibrE Robotics. The main robot characteristics are: 1) Arduino Uno compatible; 2) Front, right and left obstable detection using IR LEDs; 3) Edge detection using an IR LED; 4) A buzzer plays musical tones and astromech droid sounds; 5) Wheel encoders for precise odometry-based control; and 6) the most important feature is that Lil' Bot project is released as Open-source hardware and software (Left Figure 2.5). More features are shown in Left Figure 2.5. Lil' Bot can alternatively be energised with an energy source that is based on Hydrogen Fuel Cells designed by Open Fuel Cell. Lil' Bot is integrated with a matrix of LEDs so as to express emotions such as afraid, amused, angry, blissful, cool, crying, disappointed, embarrased happy, impatient, naughty, neutral, nonplussed, outtraged, proud, resigned, sad, sarcastics, shocket, smiling and very sad (Right Figure 2.5). Since it is a project under development, there is no price.

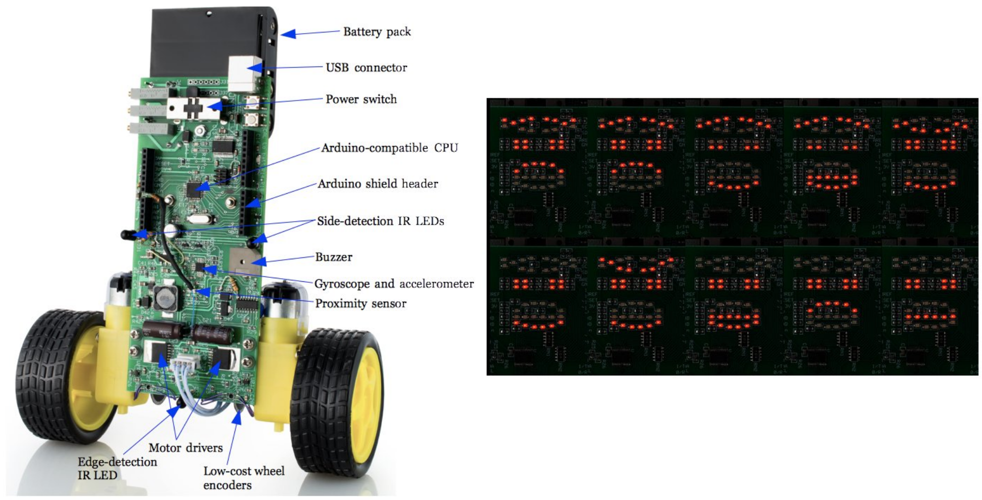

Fig. 2.5 Lil' Bot: Prototype (left), Emotion-like LED display (right)

Sparki is an affordable, easy to use, and fun intro to programming, electronics, and robotics [10]. Sparki is affordable, featured-packed, open-source Arduino robot. Sparki comes with a bluetooth module, and array of onboard sensors, precise geared stepper motors, a motorized gripper to mention but a few (Figure 2.6). Sparki has got the following features: 1) Ultrasonic distance sensor (get distance from Sparki to walls/objects); 2) 3-Axis Accelerometer (pick-up detection, fall detection, hill climbing); 3) 3-Axis Magnetometer (sense the magnetic field around Sparki, coordinate with accelerometer to detect compass heading); 4) Light-sensing phototransistors (light following, darkness seeking); 5) Line-following and edge detection sensors (mazes, line follow, sumo); 6) 128X64 Graphic LCD; 7) RGB LED (RGB = generate any color); 8) Buzzer (beeping, booping, and musical tones); 9) IR Transmitter (like your TV remote control); 10) IR Receiver (like your TV); 11) IR Remote control (lots of buttons to control Sparki with); 12) TTL Serial port for expansion (talk to an Arduino/Raspberry Pi); 13) Bluetooth Serial Module; 14) Powered by 4xAA batteries (not included); and, 15) Geared stepper motors (precise, measured movement down to millimeters/ sub-degrees). Furthermore, Arcrobotics have develop a module to learn about robotics and to test programming capabilities which are available at [11]. Total cost of the robot is \$150 USD. Sparki is released as a open-source project; yet, there are no further information regarding the Chassis and PDB designs other than basic examples of its library.

Fig. 2.6 Sparki: Prototype (left), bottom part (center) and geared stepper motors (right)

Mirobot is **a 100% open source robot** to which PCB designs and schematics, firmware code, and chassis designs are available at [31]. Mirobot uses WiFi so that it is easy to get up and running and has been carefully designed to eliminate a lot of the difficulties that children would normally have in building something like this (Figure 2.7).

Fig. 2.7 Mirobot

In contrast to the previos-mentioned educational robots, low-cost robots are more suitable for the aim of the proyect. For instance, Bug-bot is build with five touch sensors, two antennea and three bumbers on the back (Figure 2.8). It has also got a Xbees wireless board to operate the robot with a joystick. Besides, DXF files are available to download in order to be easily sent to a laser cutter. PCB diagrams, arduino and processing code is also available [20].

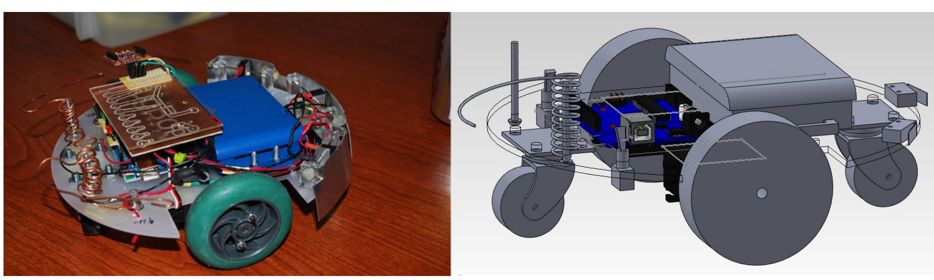

Fig. 2.8 Bug Bot: Prototype (left) CAD layout (right).

Boe Bot [3], an arduino line following robot, uses LEDs, light dependent resistors (LDRs), an arduino, and a boe bot chassis with 2 continuous rotation servos (Figure 2.9). Nevertheless, the price is not presented in both prototypes.

Linea is a line follower based on Arduino [2]. It is build with a robot chassis, infrared sensors array, two servo motors and batteries (Figure 2.10). Linea uses PID (Proportional-integral-derivative) control to compensate the mis-alignment from the line. The robot use a Pololu sensor with 8 IR leds (14 euros) which has an Arduino library (Right figure 2.10). Robot chassis uses a DF robot module (30 euros) which offers 2 gear motors, 2 motor sopports and 2

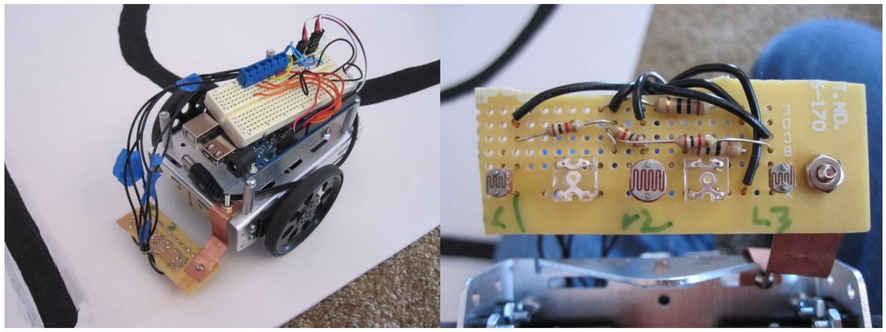

Fig. 2.9 Boe Bot: Prototype (left), LDR Sensor Array (right).

wheels. A motor driver from Sparkfun (8 euros), that can feed up to 1.2 Amperes. Others components such as ball caster, sensor support, batteries are also used, however, price was not added; henceforth, an estimated total price for Linea robot is 55 euros.

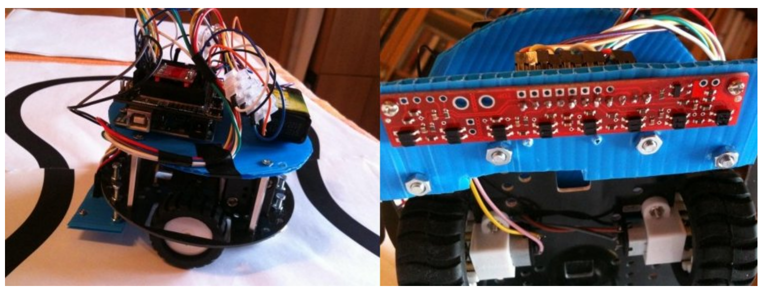

Fig. 2.10 Linea Robot: Prototype (left), IR Sensor Array (right).

Finally, ArdBot II's design is not an open-source project; nevertheless, it give access to the parts list and sources, Construction How-to Manual, Build Your First Robot FAQ, Where to Get Started sources, and probably the most imporant feature the Print and Cut Templates in a zip file (Rigth Figure 2.11) and Understanding the Build Your First Robot Programm [28]. Chassis material is fairly economical which cost $ 16.95.

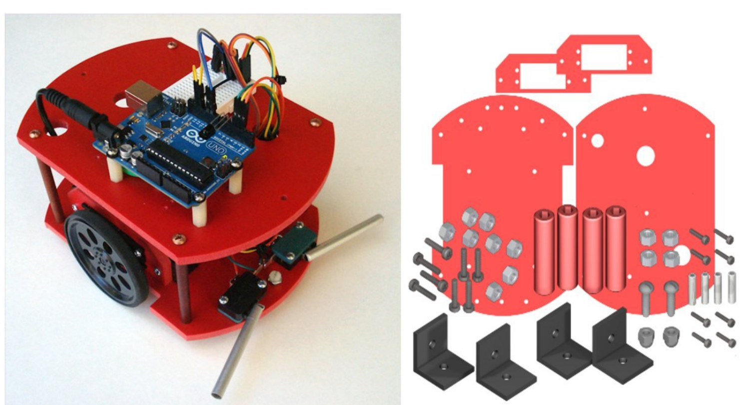

Fig. 2.11 ArdBot II

2.1.2 Proposed Low-Cost Robot for LibrE Robotics

The first proposed low-cost robot for LibrE Robotics is shown in Figure 2.12. It is ensambled by using an Arduino Uno-R3 with the USB port as a power device, two Micro Servos TowerPro SG90 that were hacked so as to be a continuous rotation servo [13, 15], two wheels (62mm of diametre), two balls caster, two LEDs, two LDRs, and four 100KOhms Resistors. The total cost accounts for $ 619 Mexican Pesos (≈ $ 48 USD). From the table 2.1, it can be seen detailed prices for the material. It has been thought that total cost can be reduced since material was bought in

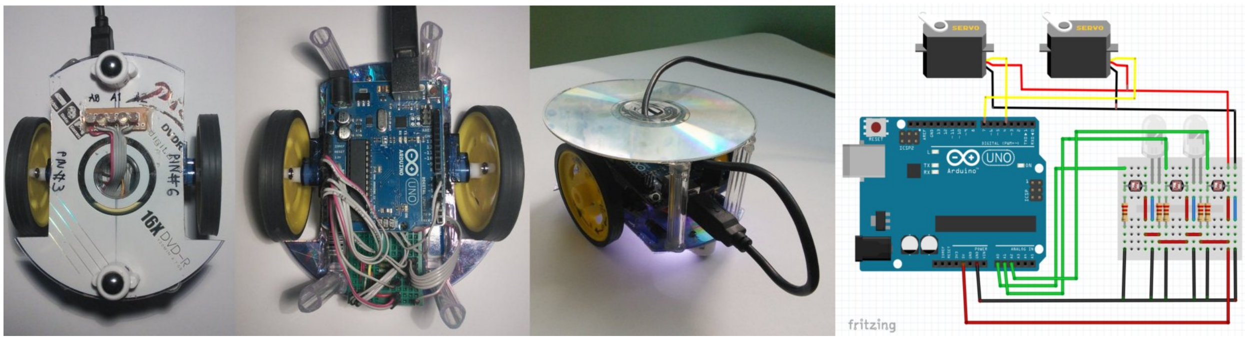

Fig. 2.12 Proposed Low-cost Robot: Bottom view, top view, front view and circuit connection (From left to right).

local stores. Additionally, the proposed low-cost robot is under a development stage and, it will therefore be evolving according to the possible issues at the testing stage and the needs that are considered to be a very low-cost Robot.

Material	Price (Mexican Pesos)
Arduino Uno-R3 con cable USB	$ 370
2 TowerPro SG90 - Micro Servos	$ 160
2 Wheels (62mm of diametre)	$ 38
2 balls caster	$ 82
Breadboard - Mini Modular	$ 20
3 LDRs	$ 18
2 LEDs	$ 10
4 100KOhms Resistors	$ 1
Total Cost	**$ 699 (≈ $ 53.86 USD)**

Table 2.1 Cost List of the proposed Educational Robot

Furthermore, two videos were recorded so as to show demo versions of the proposed low-cost robot: 1) A Demo Version of the low-cost Robot using Ardublok for LibrE Robotics Project, and 2) A Voice Controlled Low-Cost Robot Using Arduino, PocketSphinx [33], Firmata [32] and Racket [1]; both can be seen at `https://sites.google.com/site/librerobotics/videos`

It is worthwhile to mention that some setbacks with the non-linearity of LDR sensors have been faced, henceforth the line follower application has not been implemented well; it is assumed that array sensors will work well with IR sensors. Additionally, the hacked servos has been presented an hysteresis behavior since the angles controls have a variation of 1 or 2 when sending values to stop the servos and in the case of speech recognition, the voice commands are sometimes misrecognized.

2.2 Software Requirements

2.2.1 Arduino

The Arduino integrated development environment (IDE) is a cross-platform application written in Java (Figure 2.13), and is derived from the IDE for the Processing programming language and the Wiring projects. Arduino IDE includes a code editor with features are: syntax highlighting, brace matching, and automatic indentation. It is also capable of compiling and uploading programs to the board with a single click. A program or code written for Arduino is called a "sketch" [17].

2.2.2 Ardublock

Since LibrE Robotics is aimed to inexperienced users in coding, Ardublock is a suitable tool which is rooted in blocks that make programming both rich interactive and less tedious. Ardublock is a scratch-like programming based on blocks which is reflected by its clear transition to text-based coding, it also generates real Arduino code in the background. Like Arduino, Ardublock is also a run-time Java script.

Ardublock plugin can be downloaded at [27] and the source coude is available at `https://github.com/taweili/ardublock`. Ardublock Graphical User Interface is shown in Figure 2.13 in which three four parts are illustrated: programming blocks palate, zoommed out view, programming area, and arduino code. It also presents an example of the configuration of two servo motors that were programming in a loop routine of stop, counter clockwise, and clockwise. It is worth to note that settings for the angle values may differ because of the hacked servo version.

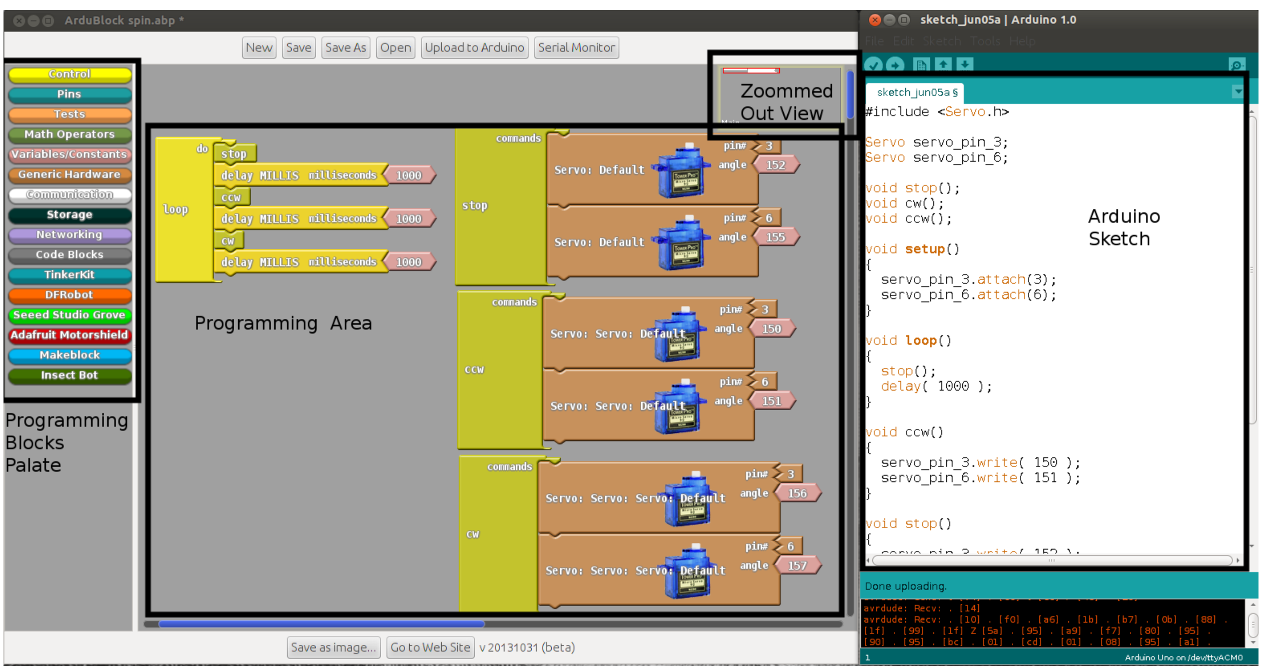

Fig. 2.13 Examples for Ardublock and Arduino IDE

3

Timeline

Lo imposible solo tarda un poco más.

Different tasks have been planned as follow:

- T1: Development of the Low-cost Robot
- T2: Implement new blocks and tools to Ardublock
- T3: Development of the speech recognition tool with pocketsphinx, racket and firmata.
- T4: Integration of T1, T2 and T3.
- T5: At the first workshop of Libre Robotics adecuate surveys, methods or plans will be implemented in order to evaluate mentors and participants. In this part, it is also going to be designed the activities for the workshop with the aim of learning and sharing knowledge to build conditions for a better world.
- T6: Week of the workshop. Evaluation of the first stage and plans for the second stage of the project.

Timeline is shown in the gantt chart (Figure 3.1). Document releases, low-cost robot designs, open-source software tutorials and web-page modifications are going to be under constant improvement and it is highly probably that new ideas are going to be generated during this process.

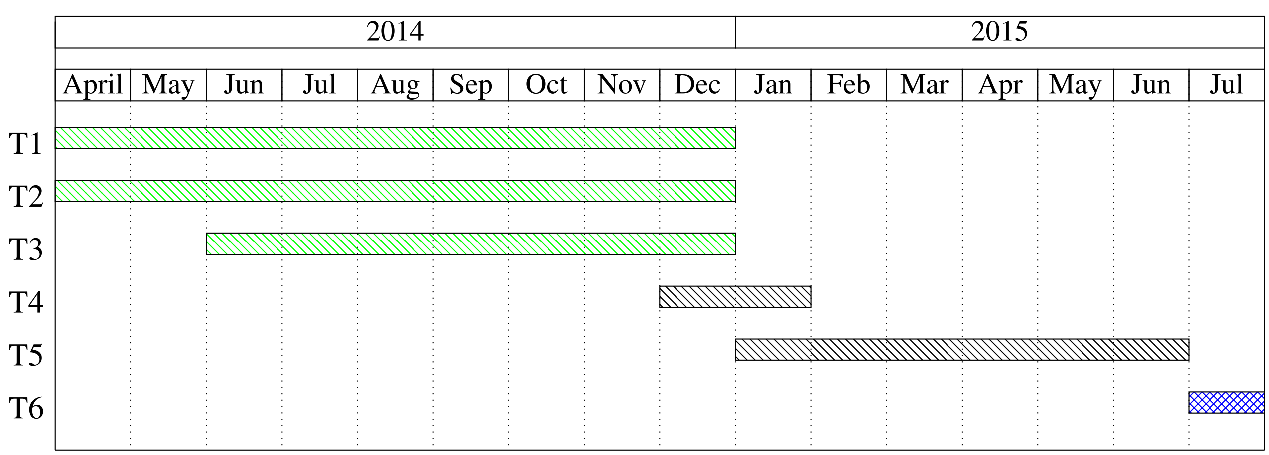

Fig. 3.1 Gantt Chart for LibrE Robotics project

4

Feeling like volunteering?

We are a proudly non-profit organization driven by a culture of openness and collaboration. It is a value we hold strong and it is how we work together, day in and day out [7].

People from different fields of study can help us to improve the project in different ways. Henceforth, some professions, possible activities and open-source software to use are described below.

Mechatronic/Electronic/Mechanical Engineers to help us to design, modify, improve the proposed low-cost robot. (Open source software/hardware to use: Arduino, BeableBone, Raspberry Pi, Blender, etc.)

Computer Engineers to help us to modify Ardublock code in order to create more fancy tools to inexperienced users. They are also going to help us to propose the computers's hardware and the process of installation. (Open source software to use: Ardublock, Apache Maven, Stable release of Debian, etc.)

Webpage and social-network maintainers to help us to be kindly in touch with subcriptors in different social networks, namely: facebook, tweeter, google+, and youtube. (Open source software to use: Mozilla Firefox)

Graphical designers/ animator /artists to help us to design friendly posters, logos, and videos. (Open source software to use: gimp, inkscape Vector, OpenShot Video Editor, etc.)

Architects to help us to design a building where serendipity and comfortable environmental factors would be the priority. (Open source software to use: Sweet Home 3D)

Psychologists to help us to produce the major development of each person. For instance, mentors should know how to treat each participant by knowing the answer of following questions: What are the potentialities of each person?. What are the necessities of participants who are between 10 and 15 years old?, By applying surveys to the participants, we can understand how to treat well each participant in order to know how to communicate better with them.

Pedagogues to help us to design free access material and develop activities where organization and cooperation of the participants can foster possible solutions for enviromental, social awarness, the use of crop rotation, healthcare and animal rights issues.

In the case that your field of study or profession were not included in the previous list, please let us know by either sending an e-mail to robotics.libre@gmail.com or contacting us at the forum https://sites.google.com/site/librerobotics/contact-us.

5

Future Work

The present is theirs; the future, for which I really worked, is mine.
Nikola Tesla

The following points give a brieft review of projects that can be considered as a future work for LibrE Robotics.

5.1 Inductive Wireless Power System

One of the main requirementes for educational robots is the source power that can mainly be covered by either onbaord batteries or an USB cable. However, batteries are environmental unfriendly and the USB cable is sometimes an issue for the mobility of the robot. Henceforth, in order to get rid of previos-mentioned drawbacks inductive wireless power system have proven to be the most suitable solution. For instance, Deyle *et al.* [19] in 2008 proposed a wireless power and bidirectional communication to a swarm of mobile robots in continuous operation on a bounded surface of 60cm x 60cm. Deyle's approachs is achieved by exciting a large, high Q L-C resonator. Deyle compared that cost of lithium ion batteries and their design is very favorable. A video of their work is available at `http://vimeo.com/1900725` which shows the mini-swarm of five battery-free, wirelessly powered autonomous mobile robots. In the same fashion, Arunkumar *et al.* [16] in 2010 developed an inexpensive, low complexity power system capable of providing wireless power from source to sink of multiple mobile robots.

5.2 Building Layout

Recently, Barrett *et al* [18] tested 751 pupils from 34 varied classrooms in seven different schools in the UK in which they found that environmental factors, namely: colour, choice, connection, complexity, flexibility and light, have a significant role to play in influencing academic performance. Henceforth, the building enviroment design is one important factor but mainly a challenging one that few have considered so as to provide appropriate facilities to the learners. We therefore belive that the enviromental quality where activities of LibrE Robotics will have been taken place must consider previous-mentioned factors to design and build enviroments where participants can discover and develop their own capabitilies.

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