University Carlos III of Madrid

Industrial Electronics and Automation Engineering

Bachelor Thesis

Design, construction and programming of a low cost, Open Source robot for assistive activities

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Contents

List of Figures

Part I

Introduction

1 Introduction

2 Scope of the project

3 Project phases

Part II
State of the art

Part III
Proposed Solution

4 Project components

4.1 3D Printer

3D printers are Computer Numerical Control (CNC) machines that are capable of transforming virtual 3D models created with a Computer Aided Design (CAD) software into real-world objects.

Created in 1984 by Chuck Hull of 3D Systems Corp this technology was little-known to the general public and was mainly used in industries for short runs of difficult pieces.
In 2005 Dr. Adrian Bowyer, from the University of Bath, UK, started the RepRap project. Its goal was "to produce a pure self-replicating device not for its own sake, but rather to put in the hands of individuals anywhere on the planet, for a minimal outlay of capital, a desktop manufacturing system that would enable the individual to manufacture many of the artifacts used in everyday life"

Today a vast range of 3D printers co-exist, varying in size, price and materials used.

→ [RepRap, Zcorp, chocolate, liquid sint, micro, house building]

→ [table with different methods?]

In this theses a RepRap Prusa Air 2 designed by Manuel Palacios is used. It is of a "fused filament fabrication additive manufacturing" type. This type of printers extrude mainly ABS or PLA plastics, and deposit new liquified material over ther previous layer, now solid, effectively building parts from the bottom up layer by layer.
→ **Terminal Imprusión Autorreplicante (T.I.A)** (add info + pic) Built within the scope of the Clone Wars project

4.2 Software

3D printers work by turning 3D models into plastic parts. These models are first modelled in a CAD program and then processed with a *slicing* software to divide the model into layers of G-code, which is the standard language interpreted by CNCs. This is then introduced in a third piece of software which feeds it to the printer.

4.2.1 3D Modelling

In this project Sketchup has been used to create the printed parts. Owned by the company Trimble Navigation it is a WYSIWYG (What You See Is What You Get) modelling editor with a large online warehouse of parts available for download.

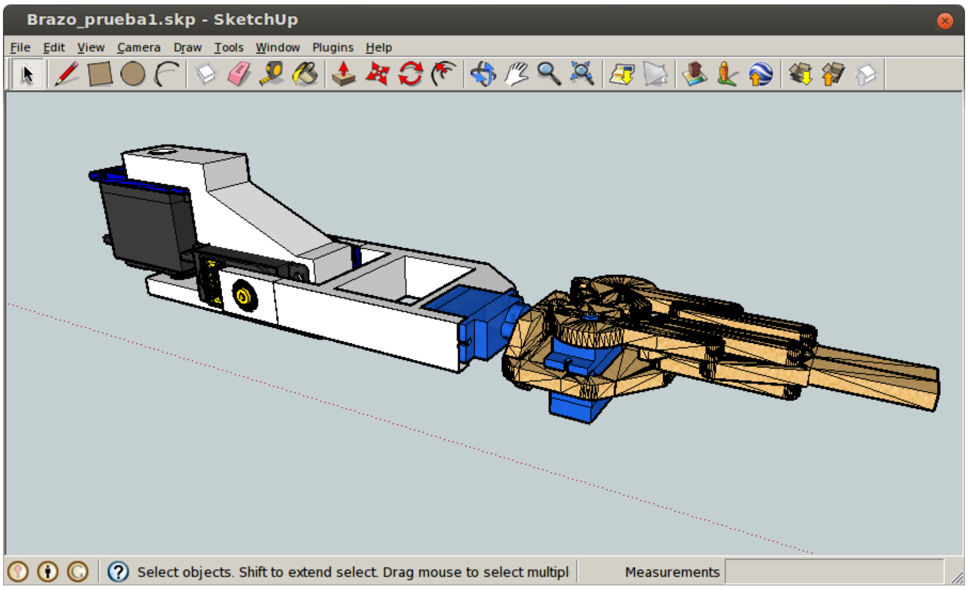

Figure 1: SketchUp software

In order to make it compatible with the slicing sofware, Sketchup's propietary format, *SKP*, has to be converted to the standard *STL*. In order to accomplish this the *Su2stl.rb* plugin is installed. A new *Plugins* menu appears in Sketchup which contains the Import/Export options, where the desired output format and model units are specified.

4.2.2 G-Code Generator

Once the model is converted to *STL* it then has to be sliced. Since 3D printers work by building layer upon layer of plastic, the model has to be transformed into the same format. The G-code generator converts the CAD model into layers of CNC instructions. There are three main slicing programs, each with their own benefits:

- Skeinforge:
  The first slicing program used in homemade 3D printers. It is by far the most complete of the three. It allows the user to control each and every imaginable setting of the printer, from the axis' speeds to the retraction distance of the plastic into the extruder while moving. However, because of this it has a very steep learning curve which makes it unsuitable for the average consumer.

- Slic3r:
  Slic3r was created as an user-friendly software, which only gives the final user a choice in the basic settings, such as printing speeds, filament widths or part infills. As a result it is an easier program to slice parts with a sufficient level of customization. It has nonetheless problems converting models with imperfections or broken shapes.

- Cura
  Finally, Cura is also designed with user-friendliness in mind. This slicer is more robust than Slic3r, in that it will accept models with imperfections, and will try to correct them. It also features a box simulating the print area in which the model can be moved around, turned or scaled before printing. This last feature is specially useful if minor changes need to be made, without returning to the CAD software.

4.2.3 CNC Controller

4.3 Li-Ion Battery

Figure 2: Li-ion 12V 6800mAh battery with charger

	NiCd	NiMH	Lead Acid	Li-ion	Li-ion polymer	Reusable Alkaline
Gravimetric Energy Density (Wh/kg)	45-80	60-120	30-50	110-160	100-130	80 (initial)
Internal Resistance (includes peripheral circuits) in mΩ	100 to 200[1] 6V pack	200 to 300[1] 6V pack	<100[1] 12V pack	150 to 250[1] 7.2V pack	200 to 300[1] 7.2V pack	200 to 2000[1] 6V pack
Cycle Life (to 80% of initial capacity)	1500[2]	300 to 500[2,3]	200 to 300[2]	500 to 1000[3]	300 to 500	50[3] (to 50%)
Fast Charge Time	1h typical	2-4h	8-16h	2-4h	2-4h	2-3h
Overcharge Tolerance	moderate	low	high	very low	low	moderate
Self-discharge / Month (room temperature)	20%[4]	30%[4]	5%	10%[5]	~10%[5]	0.3%
Cell Voltage (nominal)	1.25V[6]	1.25V[6]	2V	3.6V	3.6V	1.5V
Load Current - peak - best result	 20C 1C	 5C 0.5C or lower	 5C[7] 0.2C	 >2C 1C or lower	 >2C 1C or lower	 0.5C 0.2C or lower
Operating Temperature (discharge only)	-40 to 60°C	-20 to 60°C	-20 to 60°C	-20 to 60°C	0 to 60°C	0 to 65°C
Maintenance Requirement	30 to 60 days	60 to 90 days	3 to 6 months[9]	not req.	not req.	not req.
Typical Battery Cost (US$, reference only)	$50 (7.2V)	$60 (7.2V)	$25 (6V)	$100 (7.2V)	$100 (7.2V)	$5 (9V)
Cost per Cycle (US$)[11]	$0.04	$0.12	$0.10	$0.14	$0.29	$0.10-0.50
Commercial use since	1950	1990	1970	1991	1999	1992

Figure 3: Table comparing different battery technologies

4.4 DC-DC Converter

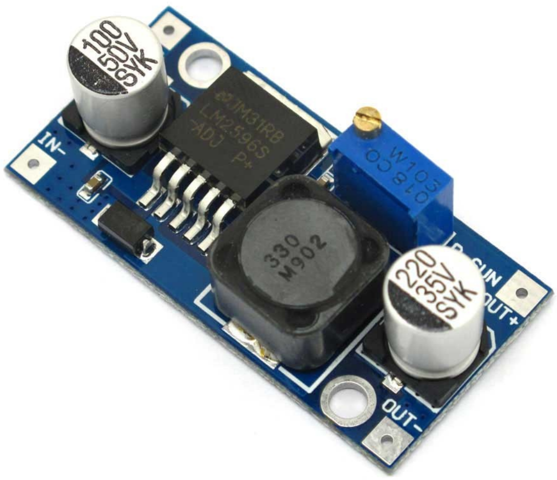

Figure 4: DC-DC Buck converter

4.5 Motors

4.5.1 GA25Y370 DC motor

Figure 5: GA25Y370 motor

4.5.2 GOTECK GS-551MG servomotor

Figure 6: GOTECK GS-551MG servo

4.5.3 TowerPro SG90 servomotor

Figure 7: TowerPro SG90 servo

4.6 Arduino

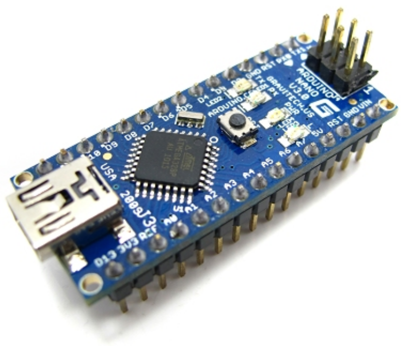

Figure 8: Arduino Nano v3

4.7 Raspberry Pi

From the official website of the homonymous foundation, the Raspberry Pi is a "The Raspberry Pi is a credit-card sized computer that plugs into your TV and a keyboard. It is a capable little computer which can be used in electronics projects."

Figure 9: Raspberry Pi

Available in two models, A and B, the Raspberry has a Broadcom BCM2835 System On a Chip, which includes an ARM1176JZF-S 700MHz processor and a VideoCore IV GPU. It includes as well a 256Mb RAM, upgraded to 512Mb in model B.

The Pi features:

- HDMI, composite and raw DSI video outputs
- 3.5mm audio jack
- SD card socket
- Low-level peripheral connections including:
  - 8 General Purpose Input Output (GPIO) pins
  - Universal Asynchronous Receiver Transmitter (UART) bus
  - Inter-Integrated Circuit (I^2C) bus
  - 2 Serial Peripheral Interface (SPI) buses
  - Power pins: 3.3V, 5V and GND
- Ethernet socket
- USB hub (1 socket in model A, 2 in model B)

The main storage unit is the SD card, and that is where the OS is flashed, normally a Linux distribution. The most popular is Raspbian, an adapted version of Debian Wheezy, although other Linux distros or even other OS like Android or XBMC can be used.

4.8 LCD Screen

Figure 10: LCD screen 16x2

4.9 WiFi USB

Figure 11: WiFi USB dongle

4.10 Camera

Figure 12: PlayStation 2 EyeToy camera

4.11 Android Phone

Figure 13: Android smartphone Haipai Noble H868

5 Assembly

6 Arduino

6.1 Flowchart

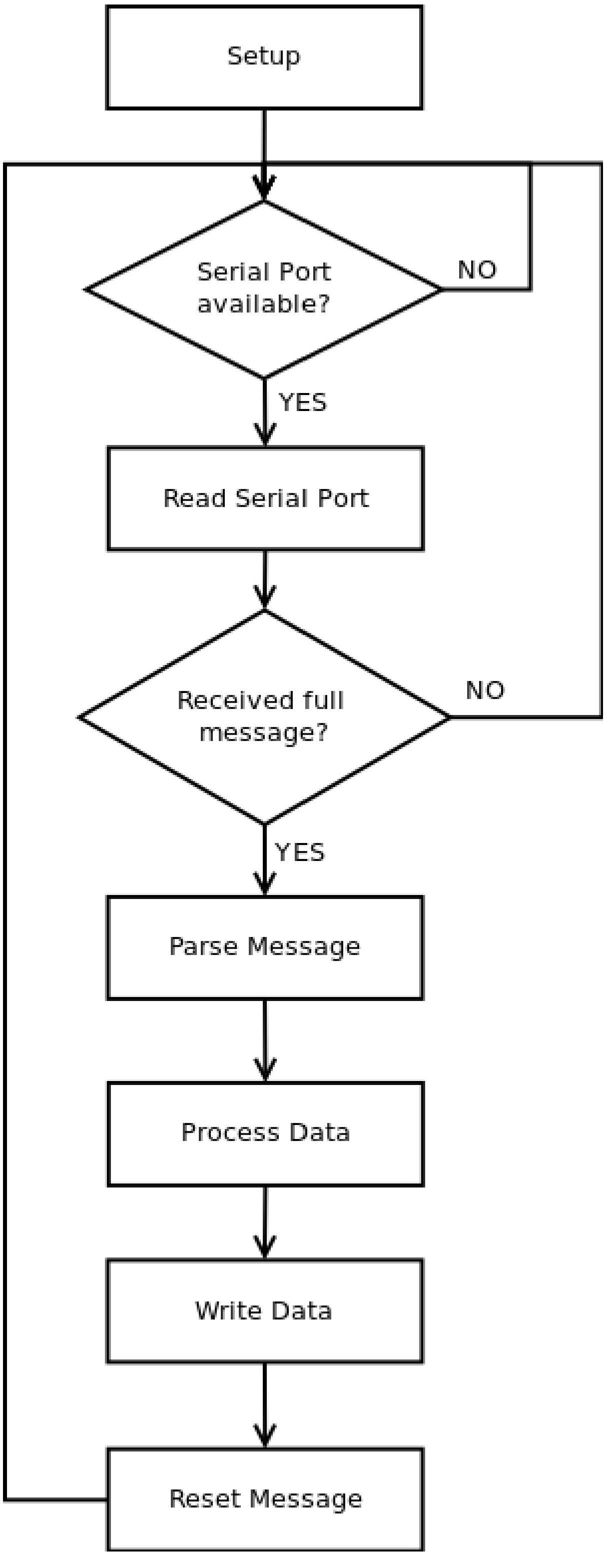

Figure 14: Arduino program flowchart

7 Raspberry Pi

7.0.1 WiFi Acces Point

7.0.2 MJPG Streamer

7.0.3 IP/UART Bridge

8 Android

Part IV
Conclusion