Digital DIY – Technologies and Tools

Welcome to Digital DIY and Technologies and Tools

This module has the following learning objectives:

1. ***Understanding the general potential of DiDIY technologies;***
2. ***Understanding the nature, general principles, and possibilities of some fundamental DiDIY technologies;***
3. ***Getting introduced to at least one tool for each technology.***

INTRODUCTION

Digital DIY (DiDIY) production of all sorts of objects is enabled by the availability of hardware tools and other machines that are:

- directly controlled by some computer, or more exactly by some software, instead of a human being;
- much cheaper and simpler to use than they were even a few years ago.

The first, immediate consequence of these characteristics is that DiDIY can be really ubiquitous. The second is that it does much more than just giving some people cheaper and faster ways to perform the same DIY activities they were already doing.

DiDIY is ubiquitous, because software is extremely flexible. Any tool that is controllable by electric signals can be controlled by software. Software, in turn, can process designs and instructions of every conceivable sort. This means that, from a purely technical point of view, the only limits to manufacturing something in DiDIY fashion are the costs of the raw materials.

The fact that DiDIY replaces (albeit not completely!) manual dexterity skills with the capability to use software is even more important. It means that DiDIY enables a (much) greater number and variety of people to do the same things. The easiest proof of this is sculptures: today, even people who would never work with clay or handle a chisel can produce them with a 3D printer.

Digital DIY also gives some rights back to consumers, allowing them e.g. to self-produce spare parts of a product they already own, which would otherwise not be available.

if not properly known and practiced, the DiDIY technologies presented here have the same drawbacks as traditional DIY, e.g. safety, plus one that is less known: the microelectronics components at the core of many DiDIY projects are hard to recycle, if recyclable at all. The same applies to certain plastics used in 3D printing.

In this module, we will mostly mention Open Source/Open Hardware tools, even when they are not the state of the art in the field or, in some cases, have not been updated recently. The reason for this choice is to highlight the following point: with the right knowledge, or the right experts assisting you, it is certainly possible for everybody, both technically and legally, to build, use and even customize those tools **"without permission"!** Without, that is, any limitation that may make those tools accessible only to large organisations.

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Fundamental DiDIY Technologies

Besides software, there are some DiDIY technologies that are complete in their own right, that is, sufficient to create useful objects. The most relevant of these technologies are presented first because, due to their nature, they can be, and already are, used as "components" of or building tools for many other DiDIY technologies, which are presented in Module 3 of this same course in a separate module.

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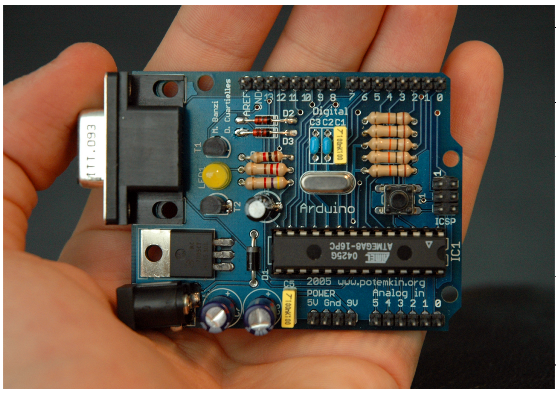
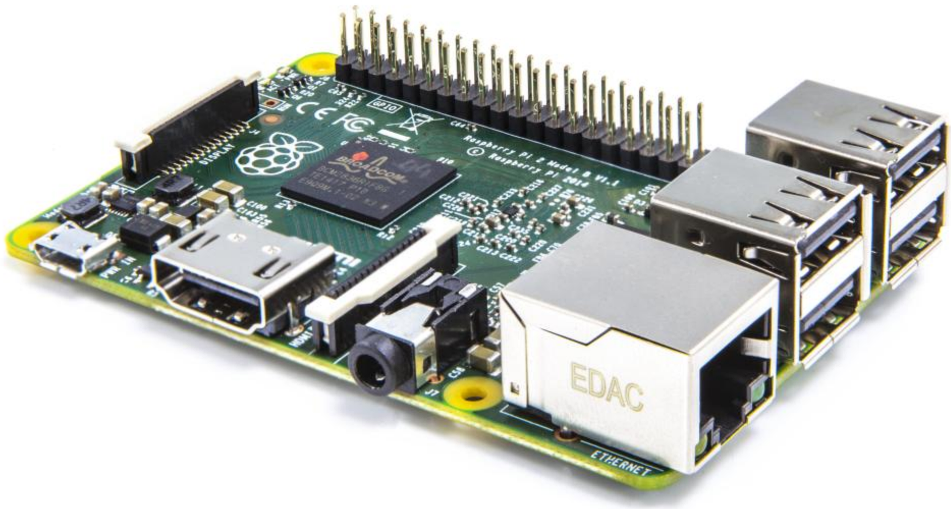
Microelectronics

Software may be generically described as "sequences of instructions for machines". In practice, software programs "run", that is are executed, inside digital integrated circuits called microprocessors or microcontrollers. The word "digital" means that these circuits exchange, process and store information, instructions and raw data as encoded sequences of digits, that is discrete values, conventionally coded as ones and zeroes.



As far as DiDIY is concerned the most popular microelectronics products today are the Arduino/Genuino microcontroller (http://arduino.cc) and the Raspberry Pi "single-board" computer (www.raspberrypi.org). The first usually comes on very small boards that can be connected to the sensors and actuators described in the next section, to monitor the surrounding environment and/or control other physical devices. Arduino is already used to create DiDIY products for all possible purposes, from game joysticks to home alarm systems, music synthesizers and hydroponic controllers. Arduino microcontroller boards are available for as little as 20 Euros plus VAT and shipping (prices correct as of March 2016).



The Rasperry Pi, shown in the picture above, is a credit-card size board with an ARM microprocessor and accessory circuits and ports. While apparently similar to the Arduino, it has a very different purpose: to be a really small and cheap but general purpose computer (the Pi was originally conceived for educational purposes). As such, it is well suited for all situations where it is not only necessary to interact with the physical environment but also to process large amounts of data. As of March 2016, the price for a Raspberry Pi 3 Model B is around 25 GBP plus VAT.

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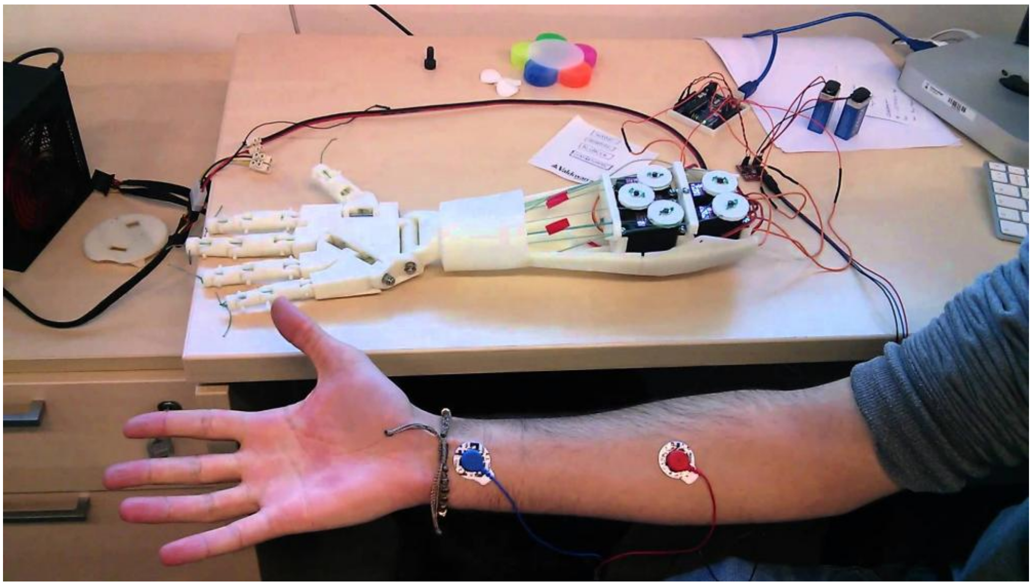
Sensors and Actuators

A sensor is an object that can detect and measure events or changes of some physical parameter of the surrounding environment (motion, temperature, air pressure, speed, geographical position, humidity, levels of electric current...) and then transmit the corresponding data as electric signals. The picture below shows an Arduino-compatible "muscle sensor" used to monitor movements, temperature and other vital parameters from the arm of a developer, in the Roujin project (https://www.youtube.com/watch?v=DZixSyP47aM).



An actuator is a motor that converts the control signals it receives, usually electric ones, into linear or circular motion. Examples of actuators are pistons and stepping motors, which rotate a shaft by a fixed angle every time they receive an electrical impulse. Combining sensors and actuators with a microcontroller like Arduino, it is possible to build robots, and many other objects with mobile parts, that interact with the surrounding environment. The picture below shows a Lego MindStorm project, in which actuators are the small electrical motors that power the wheels and arms of a mini robot.

Online distributors like Adafruit (www.adafruit.com) or SparkFun (www.sparkfun.com) sell many kinds of sensors, actuators and all the other components needed to build complete DiDIY systems.

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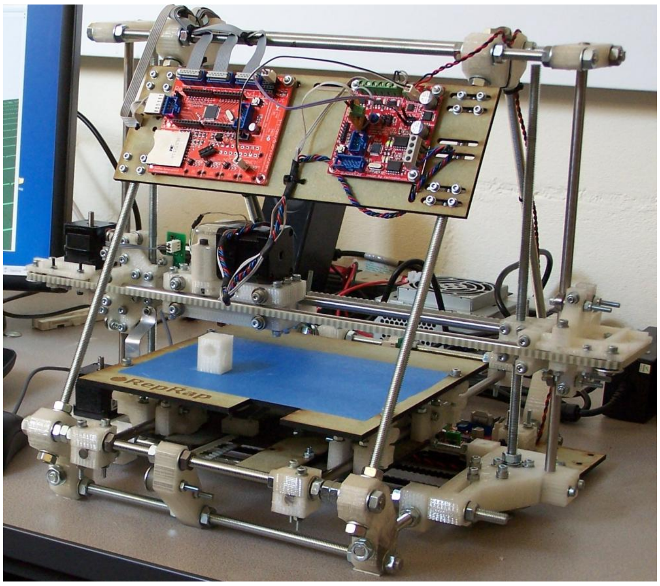
3D Printing

3D printing is the popular name of the technology formally called “additive manufacturing”. It consists of building three-dimensional objects in successive layers by placing one “drop” of material in the right position at a time. This is called “3D printing” by analogy with the way normal inkjet printers work. The material, which is ejected by a moving nozzle, is usually plastic, but there are 3D printers capable of using metal, cement or several composite materials.

The commands to make the nozzle automatically move and deposit drops in the right places, one at a time, are contained in a digital file sent to the 3D printer. This file (called G-Code) is created by specialized software like slic3r (http://slic3r.org), converting the three-dimensional models of the object created with 3D modeling software.

3D printing has endless applications. Everything that can, in theory, be assembled by piling together very small “drops” of some material may, again in theory, be produced with a suitable 3D printer. In practice, DIY 3D printing is already used to produce objects as diverse as sculptures, food (e.g. cakes), toys, furniture, small homes, or spare parts for any other product. The main limits include the physical characteristics of the filament from which the drops are created, the size of the objects, and the number of different colours or materials of which it should be composed.

RepRap (http://reprap.org), shown in the picture below, was the first, really popular low-cost DIY 3D printer (as of March 2016, pre-assembled models cost around 150 USD, while the cost of components alone may be under 100 USD (http//reprap.org/wiki/Cost_Reduction). Besides its simplicity and cost, the popularity of RepRap is also due to the fact that it may be used to build the parts of *other RepRaps.*



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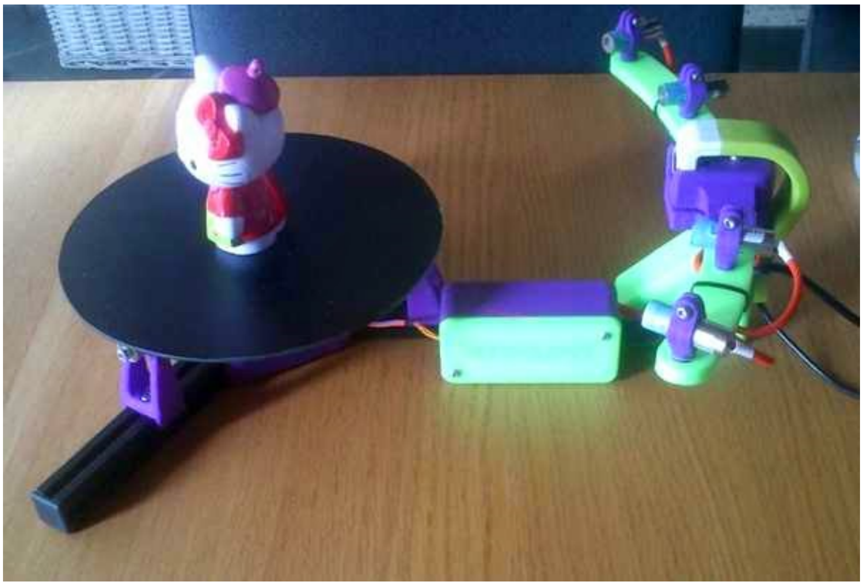
3D Scanning

3D scanning is a way to capture the exact size and shape of some object and save it in a file, as a digital three-dimensional model. Such models are the starting point for many movie special effects (e.g. the dinosaurs in Jurassic Park), but above all are used as input to 3D printers and other DiDIY machines that create copies of the modelled objects. In other words, 3D scanning makes it possible for people to 3D print something even when, for whatever reason, they cannot design it themselves with a computer.

The basic principle of 3D scanning is relatively simple: a low power laser beam scans the entire object, while a digital camera captures how the same beam is reflected by each point of the object's surface. Special software then analyzes the data from the camera to calculate the position of each surface point.



State-of-the-art 3D scanners are very sophisticated and expensive. It is relatively simple, however, to self-build inexpensive ones. Such scanners combine an ordinary USB webcam, a laser pointer of the type that can be purchased in most hardware stores, and some software that decodes the images captured by the webcam. One example of these products is the Open Source SardauScan scanner (www.instructables.com/id/Build-a-30-laser), shown in the picture, which costs around 30 Euros.

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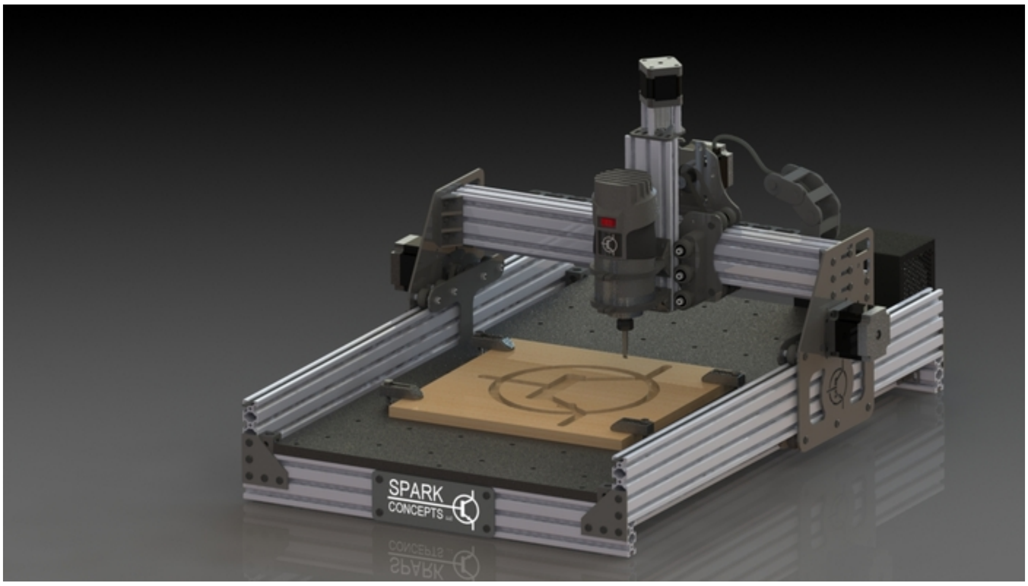
CNC Machines

DIY manufacturing of e.g. wood or metal objects combines basic operations like cutting, carving or perforation. Before digital technologies became a mass phenomenon, the only affordable way to perform these operation in a DIY fashion was the manual operation of power tools like drills, lathes or milling cutters. Besides being relatively dangerous and difficult, this way of working can be very time consuming.

CNC, which stands for *Computer Numerical Control*, solves much of those problems. A CNC drill, lathe or milling cutter is controlled in all its operations by a computer. Once the file with the instructions is ready, the user only has to place the raw piece of wood, metal or other material into the CNC machine and start it. In a sense, CNC is the *opposite* of 3D printing, because it *removes* material instead of adding it. However, just like 3D printing, digital DIY made with CNC machines allows people to:

- produce objects that they would be unable to manufacture with non-digital tools because they lack the skills to operate those tools;
- produce objects that it would be extremely time consuming to do by hand, regardless of their skill level.



An example of simple Open Hardware CNC router is the so-called "OX CNC machine" shown in the picture (www.openbuilds.com/builds/openbuilds-ox-cnc-machine.341), whose cost is around 300 Euros.

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Laser Cutting and Engraving
Laser cutting is a technology that uses a high power laser beam to make cuts of any shape in a sheet of material. The laser beam is emitted by optics mounted on a movable head, which is controlled with CNC techniques as explained in the previous paragraph. Depending on its composition, the material directly hit by the beam either melts or vaporizes. Laser engraving works in the same way. The most common materials suitable for DIY laser cutting or engraving are wood, hard paper, cardboard, leather and acrylic plastic.
Laser cutting has the same advantages seen in traditional CNC machines, plus the following:

- the possibility to cut materials that would break if cut with a metal drill or saw;
- higher precision since the beam can be as thin as 0.1 millimeters;
- less wear on the equipment, because no physical parts touch the material.

The disadvantages of laser cutters are that, besides being dangerous if not assembled and operated carefully, they are more expensive than other DiDIY machines. Laser engraving works in the same way. The most common materials usable for DIY laser cutting or engraving are wood, hard paper, cardboard, leather and acrylic plastic.
The components necessary for building a basic laser cutter like the one at http://www.buildlog.net/blog/2011/02/buildlog-net-2-x-laser/ may cost around 1000 Euros, while those for a cutter with higher performance like the Lasersaur (www.lasersaur.com), which may still be assembled on your own, cost several thousand Euros.

FURTHER RESOURCES

Articles:

- ✓ Ten photos of 3D printed bridges, buildings and other supersized structures - http://www.techrepublic.com/pictures/big-3d-printing/
- ✓ 3D Printing – A Sustainable Solution Near You? - http://www.sustainability.com/blog/3-d-printing-a-sustainable-solution-near-you
- ✓ 3D printing: The trends that will change the game in 2016 - http://www.techrepublic.com/article/3d-printing-the-trends-that-will-change-the-game-in-2016/
- ✓ DIY 3D Scanners to Watch - http://makezine.com/2015/01/15/5-diy-3d-scanners-to-watch/
- ✓ Fishy business makes more sense with sensors - http://www.bbc.com/news/business-34390356
- ✓ The real Sim City: How over 15,000 sensors made Santander smart - http://www.telecomstechnews.com/news/2014/mar/26/real-sim-city-how-over-15000-sensors-made-santander-smart2/
- ✓ Motes_ "small, wireless sensors" - https://www.indiegogo.com/projects/wimotos-tiny-wireless-helpers-for-your-life--47#/
- ✓ When hackers and farmers join forces - http://www.guerrillatranslation.org/2014/04/23/when-hackers-and-farmers-join-forces
- ✓ Get Acquainted with CNC machining - http://www.guerrillatranslation.org/2014/04/23/when-hackers-and-farmers-join-forces
- ✓ When a CNC machine is overkill - http://www.instructables.com/id/3D-Router-When-a-CNC-machine-is-overkill/

LEARNING ACTIVITIES

You may choose the activities that you like the most, although we recommend that you try everything. Please document each of your chosen activities and publish your documentations in the appropriate location, so peers can access them and contribute feedback.

- ✓ Describe two or three objects in your house that are commercial products, for which identical, or very similar equivalents are **already** manufactured also in "DiDIY style"., with at least one of the techniques described in this module. Study and describe (if possible, asking directly to their makers) how those equivalent products are fabricated, how much each copy costs, and which hardware, software and raw materials are used
- ✓ Find and describe at least one application, already used in your country, of the DiDIY techniques described in this module to "LOW-TECH" activities, like crafts, agriculture, fashion...

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