WOMEN

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(Module 1: 3D Printing and Module 2: Internet of Things)

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Content

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1 Module 1: 3D Printing

1.1 Unit 1: Introduction to 3D printing

Imagine a very complex object, did you know you can create that in 3D by printing it? Nowadays, almost anything that can be modelled on a computer can be printed in three dimensions with the use of 3D printing technologies. 3D printing - also known as additive manufacturing - is a process that allows building three dimensional objects typically by laying down many successive thin layers of a material to create objects that are practical and complex.

Applications of 3D printing are emerging almost every day, and, this technology continues to be used more widely across industries, maker and consumer sectors and this is only set to grow. Experts in this technology sector agree that, with the current resources and knowledges, we are only just beginning to see the true potential of 3D printing. Some of them even consider it to become more popular than the Internet.

This unit presents an overview of 3D printing basics, how 3D printing is creating a revolution in the manufacturing industry and beyond, and how it has the power to make a change in the business environment and - as these technologies become more and more available - how it can be used in our day-to-day life, by looking at a few practical applications.

Learning aims:

- understanding the basics of what 3D printing technology is;
- learning about the global effects of this technology on manufacturing in a wide range of sectors;
- getting information about practical applications and the benefits of the 3D technology in business and in the private sphere;

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Content:

1.1. What is 3D printing?

1.2. The effects of 3D printing on manufacturing and beyond

1.3. Applications of 3D printing

1.4. Women in 3D printing

Duration:

- 3 hours

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1.1.1 What is 3D printing?

The earliest 3D printing technologies can be dated back to the late 1980's and they were called Rapid Prototyping (RP) technologies. This is because the processes were originally conceived as a fast and more cost-effective method for creating prototypes for product development within industry.

Throughout the 1990's and early 2000's, a wide range of new technologies continued to be introduced, still focusing entirely on industrial applications and, while they were still largely processed for prototyping applications, Research and Development (R&D) was also being conducted by the more advanced technology providers for specific tooling, casting and direct manufacturing applications. This saw the emergence of new terminology, namely Rapid Tooling (RT), Rapid Casting and Rapid Manufacturing (RM) respectively.

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The world's first 3D Printer designed by Charles Hall in 1984 on display at the National Inventors Hall of Fame[1]

During the mid-90's, the different technologies emerging in the sector started to show signs of distinct diversification with two specific areas of emphasis. First, there was the high end of 3D printing, still very expensive systems, which were geared towards part production for high value, highly engineered, complex parts. This is still ongoing — and growing — but the results are only now starting to become visible in production applications across the aerospace, automotive, medical and fine jewellery sectors, as years of R&D are now paying off. At the other end of the spectrum, some of the 3D printing system manufacturers were developing and advancing 'concept modellers', as they were called at the time. Specifically, these were 3D printers that kept the focus on improving concept development and functional

[1] Image source: www.3Dprint.com

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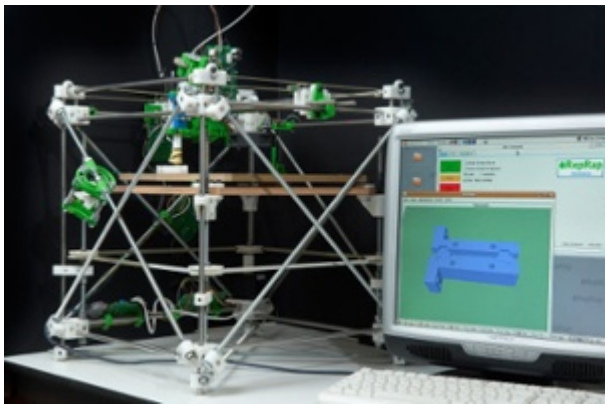
prototyping, developed specifically as office- and user-friendly, cost-effective systems. However, these systems were all still widely used for industrial applications.

Throughout the 2000's different technologies were developed for accessible 3D printing with the most notable innovation being the open source 3D printing, which proved difficult to sustain due to high R&D investments.

The Darwin printer - A professor in England named Dr. Adrian Bowyer made it his mission to create a low-cost 3D printer. By 2008, his "Darwin" printer had successfully 3D printed over 18% of its own components, and the device cost less than $650.



The Darwin printer[2]

As a result of the market divergence, significant advances at the industrial level with capabilities and applications, dramatic increase in awareness and uptake across a growing maker movement, 2012 was the year that many different mainstream media channels picked up on the technology.

Today, the term 3D printing is used to refer to the spectrum of processes and technologies that offer a wide range of capabilities for the production of parts and products in different materials carried out layer by layer in an additive process. This is substantially different from traditional methods of production involving subtractive methods or moulding/casting processes.

The starting point for any 3D printing process is a 3D digital model, which can be created using a variety of 3D software programmes — in industry this is 3D Computer-Aided Design (CAD).

[2] Image source: blog.thomasnet.com

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For Makers and Consumers there are simpler, more accessible programmes available — or scanning the object with a 3D scanner. The model is then 'sliced' into layers, thereby converting the design into a file readable by the 3D printer. The material processed by the 3D printer is then layered according to the design and the process. The most basic, differentiating principle behind 3D printing is that it is an additive manufacturing process, based on advanced technology that builds up parts, additively, in layers at the sub mm scale. It is completely different from any other existing traditional manufacturing techniques. There are different types of 3D printing technologies, which process different materials in different ways to create the final object. Functional plastics, metals, ceramics and sand are, now, all routinely used for industrial prototyping and production applications. Research is also being conducted for 3D printing bio materials and different types of food. Generally speaking though, at the entry level of the market, materials are much more limited. Plastic is currently the only widely used material — usually ABS (Acrylonitrile Butadiene Styrene) or PLA (Polylactic Acid), but there are a growing number of alternatives, including Nylon.

Selection of materials that can be used for 3D printing. While other materials such as metal, sand, chocolate, salt and a variety of other unusual choices can be used as well, the most common ones are the ones above. [3]

[3] Image source: www.3Dprint.com

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Advantages and Limitations:

For many applications, traditional design and production processes impose a number of constraints, including expensive tooling, fixtures, and the need for assembly for complex parts. In addition, the subtractive manufacturing processes, can result in up to 90% of the original block of material being wasted. In contrast, 3D printing is a process for creating objects directly, by adding material layer by layer in a variety of ways, depending on the technology used.

3D printing is an enabling technology that encourages and drives innovation with unprecedented design freedom while being a tool-less process that reduces production costs and time. Components can be designed specifically to avoid assembly requirements with intricate geometry and complex features created at no extra cost. 3D printing is also emerging as an energy-efficient technology that can provide environmental efficiencies in terms of both the manufacturing process itself, utilising up to 90% of standard materials, and throughout the product's operating life, through lighter and stronger design.

Layer by layer production allows for much greater flexibility and creativity in the design process. No longer do designers have to design for manufacture, but instead they can create a part that is lighter and stronger by means of better design. Parts can be completely re-designed so that they are stronger in the areas that they need to be and lighter overall. 3D printing significantly speeds up the design and prototyping process. There is no problem with creating one part at a time and changing the design each time it is produced. Parts can be created within hours, bringing the design cycle down to a matter of days or weeks compared to months. Also, since the price of 3D printers has decreased over the years, some 3D printers are now within financial reach of the ordinary consumer or small companies.

In recent years, 3D printing has gone beyond being an industrial prototyping and manufacturing process as the technology has become more accessible to small companies and even individuals. This has opened up the technology to a much wider audience, and as the

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exponential adoption rate continues on all fronts, more and more systems, materials, applications, services and ancillaries are emerging.

The **limitations of 3D printing** in general include expensive hardware and expensive materials. This leads to expensive parts, thus making it hard if you were to compete with mass production. It also requires a CAD designer to create what the customer has in mind, and can be expensive if the part is very intricate.

While 3D printing is not applicable to every type of production method, its advancement is helping accelerate design and engineering more than ever before, the technology being recognized as having the potential to impact all industries, by offering a means of production that is within reach for the designer or the consumer.

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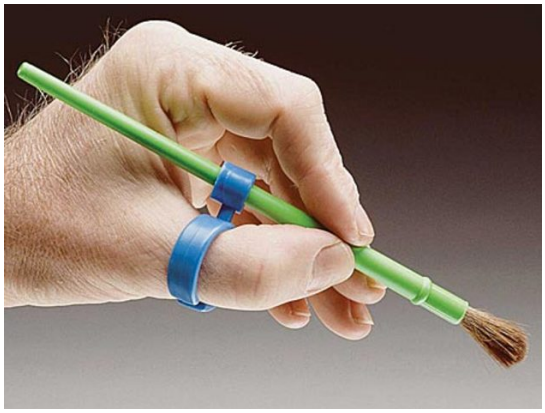
1.1.2 The effects of 3D printing on manufacturing and beyond

Compared to traditional methods of manufacturing, 3D printing - whether at an industrial, local or personal level – provides for a wide range of benefits such as:

- **Customisation:** 3D printing processes allow the personalization of products according to individual needs and requirements



Ring Write/Painter clip assistant device by Ion Gurguta[4]

Highly customisable products are the 3D printed assistive devices for people with motor impairments.

In this image, the Ring Write/Painter clip assistant device by Ion Gurguta from Thingiverse was designed to assist people who have gripping problems or arthritis.

- **Complexity:** the emergence of 3D printing has seen a proliferation of products (designed in digital environments), which involve levels of complexity that simply could not be produced physically in any other way. While this advantage has been taken up by designers and artists to impressive visual effect, it has also made a significant impact on industrial applications, whereby applications are being developed to materialize complex components that are proving to be both lighter and stronger than their predecessors. Notable uses are emerging in the aerospace sector where these issues are of primary importance.

[4] Image source: https://www.thingiverse.com/

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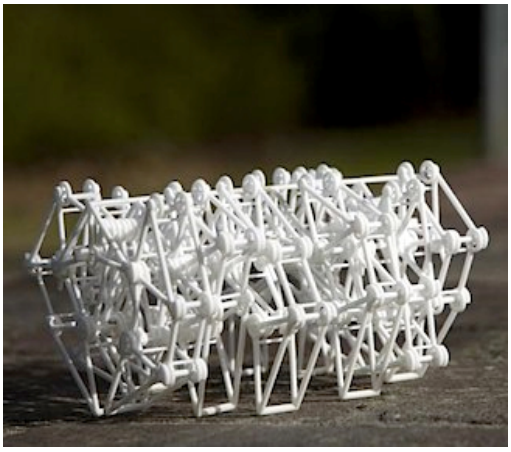
An example of complex 3D printed objects is called the *Animaris Geneticus Parvus*, by kinetic sculptor and artist Theo Jansen. It has 70 moving parts and it was printed in one single process, not in multiple processes.



Example of a complex 3D printed object [5]

- **Tool-less**: for industrial manufacturing, one of the most cost-, time- and labour-intensive stages of the product development process is the production of the tools. For low to medium volume applications, industrial 3D printing — or additive manufacturing — can eliminate the need for tool production and, therefore, the costs, reduce times and labour associated with it.

TinkerCAD modelling software [6]

One of the main "tools" used for 3D printing is the 3D software used to design the characteristics of the final object. There is a variety of software available on the market, including open source software used to create both simple and complex designs and architecture. TinkerCAD is considered to be one of the easiest 3D software to use when starting with CAD modelling.

[5] Image source: www.3dprinter.net
[6] Image source: http://www.i.ytimg.com

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- **Sustainable/environmentally friendly**: 3D printing also proves to be an energy-efficient technology that can provide environmental efficiencies in terms of both the manufacturing process itself, utilising up to 90% of standard materials, and, therefore, creating less waste, but also throughout an additively manufactured product's operating life, by way of lighter and stronger design that imposes a reduced carbon footprint compared with traditionally manufactured products. Furthermore, 3D printing is showing great promise in terms of fulfilling a local manufacturing model, whereby products are produced on demand in the place where they are needed — eliminating huge inventories and unsustainable logistics for shipping high volumes of products around the world.

A study from *Cuboyo* looking at the environmental impact of 3D printing shows that, on the one hand, classic manufacturing is not adapted for low-volume production of different objects in terms of environmental impact, while, on the other hand, 3D printing cannot compete with injection moulding for high-volume production. According to their research, 3D printing technology tends to be ecologically interesting for low-volume production (<1000 parts) compared to traditional manufacturing. Therefore, 3D printing shows lower environmental impact in low volume over many different variants.

The study states: "3D printing is being promoted as the technology that will lead us into the next industrial revolution. Clothing, electronics, replacement body parts, biological components and even entire functional organs will be able to be built in the near future. Consumers should be aware of and prepared to enter the third industrial revolution governed by mass customisation and a lower environmental impact."[7]

[7] Source: http://www.cuboyo.com/

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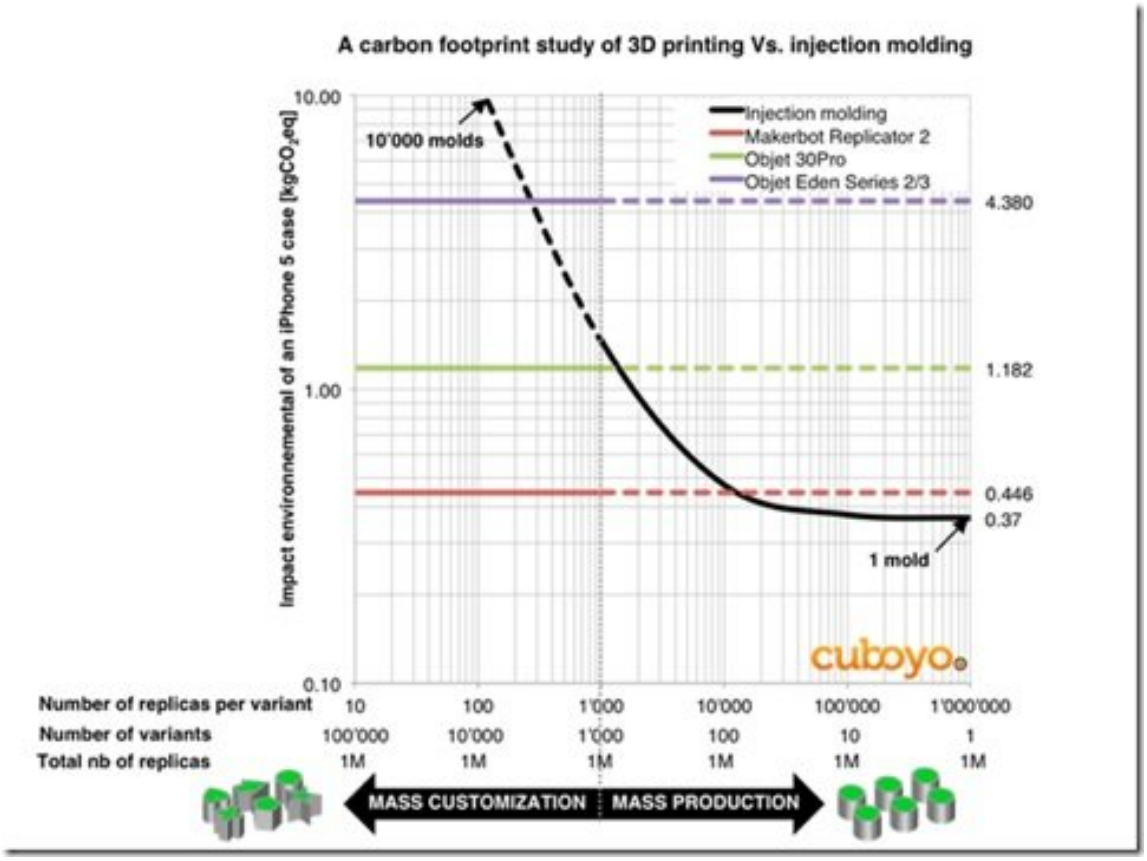

A carbon footprint study of 3D printing Vs. Injection molding [8]

These characteristics of the 3D technology leads to new ways of thinking in terms of the social, economic, environmental and security implications of the manufacturing process.

One of the key considerations on 3D printing is that it has the potential to bring production closer to the end user and/or the consumer, thereby reducing the current supply chain restrictions. This could have a major impact on how businesses, large and small, and consumers operate and interact on a global scale in the future. The wider adoption of 3D printing would likely cause re-invention of a number of already invented products, and, of course, an even bigger number of completely new products.

[8] Image source: tctmagazine.com

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3D printing has the potential to create new industries and completely new professions. There is an opportunity for professional services around 3D printing, ranging from new forms of product designers, printer operators, material suppliers all the way to intellectual property legal disputes and settlements. An entry level position in 3D printing jobs is the 3D Printer Technician. They make 3D prints on commission, manage machines at rapid prototyping outsourcing services or operate them on a production line. Their responsibilities often include servicing and maintenance of the machines too. 3D printing would not be possible without designers, who can take a product idea and translate it into a feasible product, and CAD experts, who have the skills and expertise to convert product designs into digital blueprints. Interdependently, jobs will also open up for forward-thinking R&D professionals who understand the intersection of tech and consumer products, but also in an array of scientific fields. Job offers in the education sector will increase as well, teachers with 3D modelling and fabrication experience will have a range of opportunities open to them within educational programs looking to incorporate this new technology. Lastly, 3D printing offers opportunities for innovation — not only in creating products, but also for entrepreneurship. As 3D printing technologies advance and become more readily accessible, this will lead to new business opportunities for individuals and companies offering on-site and remote 3D printing services.

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1.1.3 Applications and leading women in 3D printing

The developments and improvements of the process and materials used in 3D printing for prototyping, resulted in this technology being taken up for applications further down the product development process chain.

Various markets are greatly benefiting today from industrial 3D printing, the examples below giving a broad overview of these markets:

- **Biomedical Engineering**

In recent years scientists and engineers have already been able to use 3D printing technology to create body parts and parts of organs. The first entire organ created through 3D printing is expected to be done in the coming years. The process of creating the organ or body part is exactly the same as if you were to create a plastic or metal part, however, instead the raw material used are biological cells created in a lab. By creating the cells specifically for a particular patient, one can be certain that the patient's body will not reject the organ.

Another application of 3D printing in the biomedical field is that of creating limbs and other body parts out of metal or other materials to replace lost or damaged limbs. Prosthetic limbs are required in many parts of the world due to injuries sustained during war or by disease. Currently prosthetic limbs are very expensive and generally are not customized for the patient's needs. 3D printing is being used to design and produce custom prosthetic limbs to meet the patient's exact requirements.

The medical sector is viewed as being one that was an early adopter of 3D printing, but also a sector with huge potential for growth, due to the customization and personalization capabilities of the technologies and the ability to improve people's lives as the processes improve and materials are developed that meet medical grade standards.

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Prosthetics was one of the first biomedical areas to be revolutionized by 3D printing and continues to grow as the technology becomes more democratized, making replacing limbs easier and cheaper. "The impact of 3D printed prosthetics on the developing world is immeasurable," says Elliot Kotek, co-founder of the non-profit organization Not Impossible, LLC, which uses 3D printing for building low-cost prosthetics for populations with no access to an alternative.

Children in Sudan fitted with 3D printed prosthetic arms as part of Project Daniel. Image: Not Impossible, LLC

"3D printed options are providing tools for those who've previously lacked access to workable, affordable, timely solutions," says Kotek, adding that "The 3D printed mechanical hands and arms are not, of course, anywhere near the standards of bionics being offered in higher socio-economic environs, but in places where lives are on the line, daily, having rapid prototyping options is a game changer."[9]

[9] Source: www.notimpossible.com

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Leading women in 3D Printing

Hui Jenny Chen – Neuroradiologist & Founder of 3DHEALS

Hui Jenny Chen – Neuroradiologist & Founder of 3DHEALS

As a neuroradiologist, Jenny Chen has played a major role in integrating 3D printing technology into the medical sector. Her company 3DHEALS is focused on curating and improving the healthcare 3D printing ecosystem. Chen and her team aim to facilitate global collaborative innovations in medical 3D printing, and also promote greater quality control and standardization. She is also a current adjunct clinical faculty in the radiology department at Stanford Healthcare, as well as a mentor with the Women in 3D Printing group. [10]

More information can be found here.

- **Aerospace**

Like the medical sector, the aerospace sector was an early adopter of 3D printing technologies in their earliest forms for product development and prototyping. These companies, typically working in partnership with academic and research institutes, have been at the sharp end in terms or pushing the boundaries of the technologies for manufacturing applications.

Because of the critical nature of aircraft development, the R&D is demanding and strenuous, standards are critical and industrial grade 3D printing systems are put through their paces. Process and materials development have seen a number of key applications developed for the aerospace sector — and some non-critical parts are all-ready flying on aircraft.

[10] Image source: www.all3dp.com

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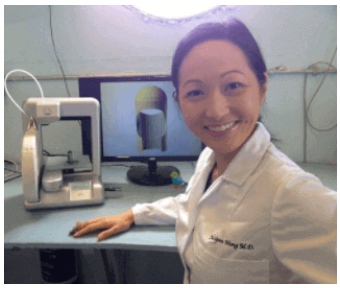
According to Apex, one of the aviation industry's top leader, Airbus, now has a record number of 3D printed parts on their new A350 XWB aircraft, with 1,000+ parts. Partnering with Stratasys helped them produce these parts quickly and efficiently using high-performance FDM materials like ULTEM 9085. This production-grade thermoplastic is a strong and FST (flame smoke and toxicity) compliant material with excellent strength-to-weight ratio, certified to Airbus's specifications. [11]

Leading women in 3D Printing

Dr. Julielynn Wong - Founder of 3D4MD

Dr. Wong is Harvard-educated public health physician, innovator, educator lecturer and pioneer in 3D printing medical devices in austere environments. She carried out several experiments involving 3D printing and space exploration with NASA and launched the first 3D printing learning activity for students and teachers at Canada's only Challenger Learning Centre. [12]



Dr. Julielynn Wong - Founder of 3D4MD

More information can be found here.

- **Automotive**

Among the early adopters of Rapid Prototyping technologies - the earliest form of 3D printing - was the automotive sector. Many automotive companies - particularly at the cutting edge of

[11] Image source: BBC Technology, Airbus had 1,000 parts 3D printed to meet deadline
[12] Image source: www.all3dp.com

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motor sport and F1 — have followed a similar trajectory to the aerospace companies. First (and still) using the technologies for prototyping applications but developing and adapting their manufacturing processes to incorporate the benefits of improved materials and end results for automotive parts.

Automotive companies are now also exploring the potential of 3D printing to fulfil after sales functions in terms of production of spare/replacement parts, on demand, rather than holding huge inventories.

Being able to rapidly manufacture a complex, lightweight bracket overnight is a trademark of the additive manufacturing industry. Not only does 3D printing allow for organic shapes and designs to be manufactured, but it also requires very little input from an operator meaning that engineers are able to quickly take a design from a computer to assembly in a very short amount of time. This is not possible with traditional manufacturing techniques, where a highly skilled machine operator is needed to produce parts. [13]

A functional alternator bracket printed using SLS nylon. Image souce: Chevy Hardcore

[13] Image source: Chevy Hardcore

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Leading women in 3D Printing

Livia Cevolini - CRP Group, CEO Energica Motor Company S.p.A.

Image source: all3dp.com

Engineer Livia Cevolini has served in multiple roles at CRP Group, an Italian family run business based in Modena since 2002. The company provides engineering services, including industrial 3D printing, largely for the automotive industry. CRP also developed and commercialized the proprietary WindForm material product line for 3D printing. Since 2013, Livia has served as Chief Executive Officer of Energica Motor Company S.p.A. while retaining a directorship at CRP. [14]

More information on CRP can be found here.

- **Jewellery**

Traditionally, the design and manufacturing process for jewellery has always required high levels of expertise and knowledge involving specific disciplines that include fabrication, mould-making, casting, electroplating, forging, silver/gold smithing, stone-cutting, engraving and polishing. Each of these disciplines has evolved over many years and each requires technical knowledge when applied to jewellery manufacture.

For the jewellery sector, 3D printing has proved to be particularly disruptive. There is a great deal of interest — and uptake — based on how 3D printing can, and will, contribute to the further development of this industry. From new design freedoms enabled by 3D CAD and 3D

[14] Image source: all3dp.com

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printing, through improving traditional processes for jewellery production all the way to direct 3D printed production, eliminating many of the traditional steps, 3D printing has had — and continues to have — a tremendous impact in this sector.

Using 3D printing to create a wax model. The wax is then used to create the 18 karat white gold and diamond pendant, the final piece of jewellery. [15]

Leading women in 3D Printing

Bathsheba Grossman - Sculptor and Jewelry Designer

Image source: all3dp.com

Bathsheba Grossman is one of the very first artists to explore the possibilities of direct metal 3D printing in jewelry, creating amazing products like the Klein Bottle Opener, the Ora Pendant, and the Cuttlefish Pendant. These items are some of the most recognizable and popular in the entire landscape of 3D printed things. [16]

You can find more of her work here .

[15] Image source: qualitygem.com
[16] Image source: all3dp.com

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- **Art / Design / Sculpture**

Artists and sculptors are engaging with 3D printing in myriad of different ways to explore, form and function in ways previously impossible. Whether purely to find new original expression or to learn from old masters, this is a highly charged sector that is increasingly finding new ways of working with 3D printing and introducing the results to the world. There are numerous artists that have now made a name for themselves by working specifically with 3D modelling, 3D scanning and 3D printing technologies.

Artists Rob and Nick Carter have 3D printed a sculptural replica of Vincent van Gogh's renowned *Sunflowers*, pushing the boundaries of the technological medium by translating a two-dimensional painting into a tangible form. The structure was realized through a collaboration with MPC, an international visual experience and effects studio, who generated a digital adaptation of a flat artwork, rendered in 360° perspective. The team of artists and designers began by creating a base mesh - a computerized model - which typically lacks a great deal of fine detail, but is the first step in understanding the volume of a painting. The printing process was done following extensive testing of methods and printers. The final digital file was printed to a resin material called 'visijet-x' using the high-end project 3500, which prints to a tolerance of 16 microns. finally, the sculpture was cast in silicon bronze. [17]

Image source: designboom.com

[17] Image source: *designboom.com*

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Banksy printed in 3D

The British street artist Banksy has an extremely unique style, and now his 2D artwork has been turned into 3D sculptures by the *render3dart* company. Printed in high-quality multi-color sandstone, some of Banksy's most well-known works have been recreated as 2- to 3-inch-tall figurines.[18]

In 2015, the most famous Spanish museum organized an exhibition for a few days featuring paintings by Greco, Gentileschi and also José de Ribera printed in 3D. This operation aimed to allow visually impaired people to feel these works that were previously inaccessible. Certain aspects of each painting, including textures, were selected for showcasing in the 3D reproductions. A chemical process involving ultraviolet light and special ink resulted in a few millimetres of added volume. The reproductions retained the originals' colour, for visually impaired visitors with the ability to perceive it. The works were created by start-up Estudios Durero.

[18] Image source: *all3dp.com*

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Spanish museum exhibition printed in 3D [19]

Leading women in 3D Printing

Anouk Wipprecht - Designer and Artist

Who is she? Wipprecht is an artist, designer, curator and lecturer in electronic couture. Many of her creations make intensive use of 3D printing, often in collaboration with 3D printing service Materialise. She has worked with the Black-Eyed Peas, Super Bowl, Eurovision, as well as Audi, Volkswagen and more. Famous 3D printed incarnations include the Smoke Dress and Spider Dress. She is also curator of the TECHNOSENSUAL 'Where Fashion meets Technology' exhibition. [20]

More information on Anouk Wipprecht on her website.

[19] Image source: 3dnatives.com
[20] Image source: audi-city.com

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- **Architecture**

Architectural models have long been a staple application of 3D printing processes, for producing accurate demonstration models of an architect's vision. 3D printing offers a relatively fast, easy and economically viable method of producing detailed models directly from 3D CAD, BIM or other digital data that architects use. Many successful architectural firms, now commonly use 3D printing (in house or as a service) as a critical part of their workflow for increased innovation and improved communication. The digital construction economy will develop on its own, with hardly any insight from current professionals. That means workers in the construction, engineering and design industries will need to redefine their roles and find new uses for their skills. We can expect construction to evolve, especially once organizations and teams realize how efficient and cost-effective 3D printing can be. New business opportunities will arise and need to be assessed, and what we know of the average contractor could change radically over time.

A 3D-printed house by WATG Urban [21]

[21] Image source: *watg.com*

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A 3D-printed house by WATG Urban. WATG's innovative Urban Architecture Studio has won First Prize in the Freeform Home Design Challenge, a competition to design the world's first freeform 3D printed house. The challenge was to design a 600-800 square-foot single-family home that would rethink traditional architectural aesthetics, ergonomics, construction, building systems, and structure from the ground up.

Leading women in 3D Printing

Anielle Guedes - Founder & CEO of Urban3D

Anielle Guedes is the founder and CEO of Urban3D, a Brazilian start up that aims to reduce the cost of materials and construction time by up to 80 percent with 3D printing. Urban3D isn't just your typical construction start up. Using high-tech materials, 3D printing, and robotics, Guedes' company wants to create sustainable housing at one-tenth the cost and ten times the speed as traditional construction. Her ultimate goal is to eliminate homelessness over the next 15 years by creating adequate housing for the 3 billion people in the world without a roof over their heads. [22]

More information can be found here.

- **Fashion**

As 3D printing processes have improved in terms of resolution and more flexible materials, one industry, renowned for experimentation and outrageous statements, has come to the forefront, the fashion industry. 3D printed accessories including shoes, head-pieces, hats and

[22] Image source: *womenseday.org*

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bags have all made their way on to global catwalks. And some even more visionary fashion designers have demonstrated the capabilities of the tech for haute couture — dresses, capes, full-length gowns and even some under wear have debuted at different fashion venues around the world.

3D printing permits fashion designers to expand beyond the traditional boundaries of design, allowing them to turn some of the most challenging design concepts into reality. We are seeing an evolution from traditional textile production methods, such as pattern-cutting and sewing textiles together, towards a textile being totally 3-dimensionally grown.

Digitally-created materials are offering up vast possibilities in terms of enabling sophisticated physical properties to be embedded in specifically defined areas of a textile. For example, you can create a specific textile that is waterproof, opaque, flexible or rigid and then combine these elements together, meaning that these properties can all be present in a single garment. Without the need for a specific mould, designers are free to create intricate geometries and structures, which are not only aesthetically pleasing, but can add smart functionality.

The immense opportunities for customization that 3D printing offers is another important benefit for the industry. Apparels can now be created to perfectly fit the size and curvature of each part of the body, allowing for true personalization. This capability will also enable 3D printing to branch into other areas of fashion, such as leisure and sportswear, and potentially in cases of medical care.

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Leading women in 3D printing

Iris van Herpen – Fashion designer

Iris van Herpen should get a special mention as the leading pioneer in the fa. She has produced a number of collections — modelled on the catwalks of Paris and Milan — that incorporate 3D printing to blow up the 'normal rules' that no longer apply to fashion design. Many have followed, and continue to follow, in her footsteps, often with wholly original results. [23]

More information can be found here.

Dutch designer Iris van Herpen has created a line emphasising graceful, florid shapes thanks to 3D printing technology. Introduced at the 2018 Paris Fashion Week, her Spring/Summer 2018 collection of 21 pieces resorts to advanced digital technology such as laser-cutting, parametric design, and 3D printing.

[23] Image source: *all3dp.com*

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The 2018 Ludi Nature collection[24]

- **Food**

Food is one emerging application (and/or 3D printing material) that has the potential to truly take the technology into the mainstream.

Initial forays into 3D printing food were with chocolate and sugar, and these developments have continued apace with specific 3D printers hitting the market. Some other early experiments with food including the 3D printing of "meat" at the cellular protein level. More recently pasta is another food group that is being researched for 3D printing food. Looking to the future 3D printing is also being considered as a complete food preparation method and a way of balancing nutrients in a comprehensive and healthy way.

[24] Image source: *3dprintingindustry.com*

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Natural Machines is a Barcelona-based company that has developed one of the first food 3D printers in 2015, the Foodini. The company's goal was to create safe and quality food more easily through Foodini. The printer has different types of nozzles that allow you to print with almost any food material possible. In addition, the start-up shares recipes and examples of how to use the machine.

Foodini, the 3D printer for healthy foods [25]

The famous Italian company Barilla, who specializes in pasta, worked with the Dutch research institute TNO in 2016 to make its first fresh pasta 3D printer. The machine uses a mixture of water and flour to create, layer-by-layer, pasta with unique shapes while maintaining the flavour as we know it today.

[25] Image source: *3dnatives.com*

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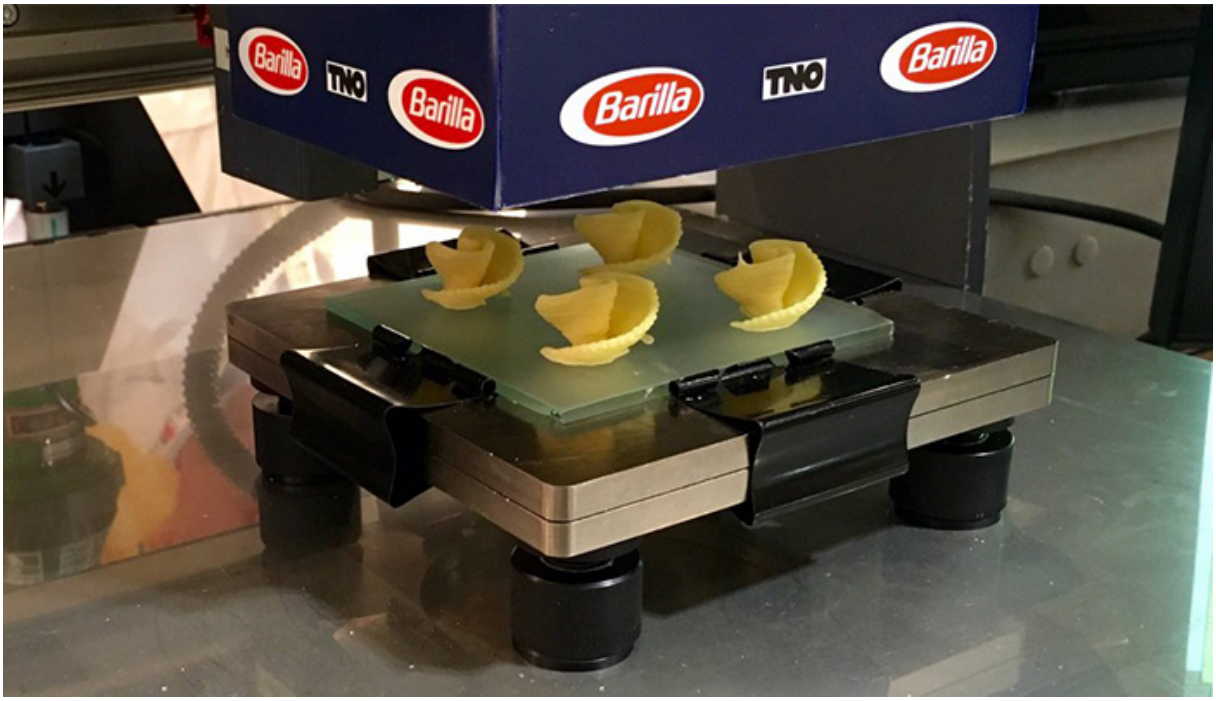

A fresh pasta 3D printer [26]

Leading women in 3D printing

Dinara Kasko - Pastry chef

Dinara Kasko is a Ukrainian pastry chef who could even be called an artist. She uses 3D printing to offer her desserts a unique design and an impressive aesthetic. Her pastries are not 3Dprinted, instead, Dinara uses 3D technologies to design the plastic mould, allowing her to create increasingly extravagant shapes. [27]

More information can be found here.

[26] Image source: 3dnatives.com
[27] Image source: 3dnatives.com

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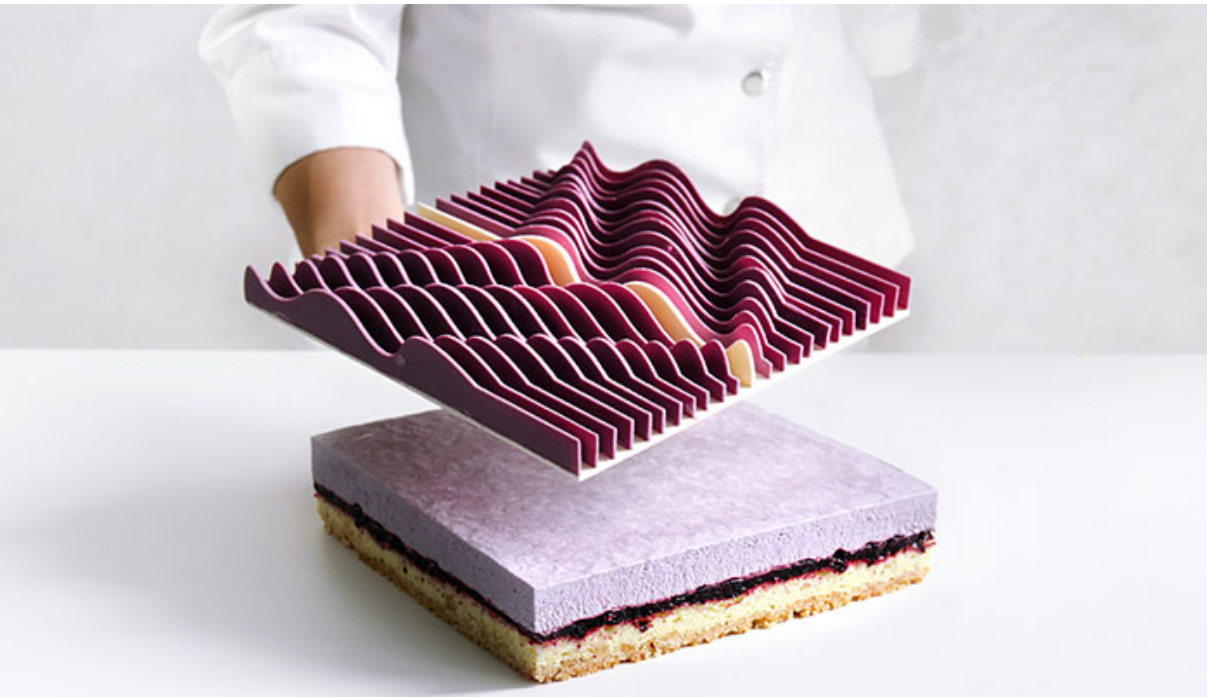

3D printing in gastronomy [28]

- **Education and research**

3D printing, and open source 3D printers in particular, are the latest technologies to make their way into the classroom. 3D printing allows students to create prototypes of items without the use of expensive tooling required in subtractive methods. Students design and produce actual models they can hold. The classroom environment allows students to learn and employ new applications for 3D printing.

3D printers have the potential to create an unprecedented "revolution" in STEM education mainly due to the low cost ability for rapid prototyping in the classroom by students, but also the fabrication of low-cost high-quality scientific equipment from open hardware. Engineering

[28] Image source: *3dnatives.com*

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and design principles are explored as well as architectural planning. Students recreate duplicates of museum items such as fossils and historical artefacts for study in the classroom without possibly damaging sensitive collections. Other students interested in graphic designing can construct models with complex working parts easily. 3D printing gives students a new perspective with topographic maps. Science students can study cross-sections of internal organs of the human body and other biological specimens. And chemistry students can explore 3D models of molecules and the relationship within chemical compounds.

3Doodler has developed an interface for children to learn to use 3D pens. They have created a range of resources for educators such as lesson plans, learning packs, curriculums, but also tips and tutorials that can be said beyond the classroom.

3D pen for educational purposes [29]

[29] Image source: *the3doodler.com*

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- **Consumers**

Currently, consumer uptake of 3D printing is low due to the accessibility issues that exist with entry level consumer machines. There are currently three main ways that individuals can interact with 3D printing tech for consumer products:

- design + print
- choose + print
- choose + 3D printing service fulfilment

One of the foremost benefits of this technology is the concept of mass customization, the ability to personalize products that are being mass produced, as per the needs of every individual. 3D printing is the future of the retail market – customized products based upon specifications provided by the consumer. 3D printing is enabling makers to quickly bring their ideas to life, while making failure affordable and acceptable rather than a negative outcome to be feared. As this technology becomes more and more accessible, innovations and advancements will continue to pick up pace.

Accessibility and a variety of options are the keys for success: shape, size, fonts, and texts need to be easily customizable by the users, allowing for truly unique and personal products.

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Leading women in 3D printing

Limor "LadyAda" Fried - Founder of Adafruit

One of the women that best represents a new generation of makers and designers, Limor Fried was the first female engineer on the cover of WIRED magazine and has received countless awards for her entrepreneurial achievements.

Fried founded Adafruit as a place for learning electronics and making the best-designed products for makers. Adafruit has since grown into the leading online retailer for maker projects, with over 50 employees in the heart of NYC with a 15,000+ sq ft. factory. It has also expanded its offerings to include tools, equipment, and electronics. [30]

More information on Limor Fried on Adafruit's website.

Raspberry Pi and 3D printing[31]

[30] Image source: all3dp.com
[31] Image source: adafruit.com

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A mainstay in the world of makers and electronics, The Raspberry Pi® is a single-board, low-cost, high-performance computer first developed in the UK by the Raspberry Pi Foundation. Not only has it helped bring the joy of electronics and computer programming to people around the world, but it has also become a staple of the maker community.

Since the release of the first Raspberry Pi, manifold products have been created to accompany, modify, and enhance the Pi's capabilities. From touchscreens and displays to HATs, Bonnets, cameras and plates, the possibilities are endless when it comes to project ideas.

Glossary

Additive manufacturing is the official industry standard term (ASTM F2792) for all applications of the technology. It is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.

An **open source 3D printer** is one for which the hardware designs, the firmware and the software designs are all available under an open source license.

Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology.

Subtractive manufacturing is a process by which 3D objects are constructed by successively cutting material away from a solid block of material.

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1.2 Unit 2: 3D printers

The word "3D printer" implies that it is a printer and therefore we expect when you click the "print" command on your computer, we will get at least a satisfactory print. However, such a name is misunderstood when connected to so-called 3D printing. A more appropriate name for such a device would be a special CNC machine, suggesting that it takes a lot of knowledge about software and materials and a lot of preparation work before the first project can be "printed".

There is a great future in combining IoT technology (computers, sensors and motors) with 3D invented objects that can only be achieved by mastering several technologies: IoT construction, computerized modelling and 3D printing.

3D printers are able to materialize objects in three dimensions - length, width and height/depth.

A 3D printer is a device, invented for the first time in the 80's, that allows the creation of physical objects composed either of a single material or a variety of materials such as plastic, metal, glass, ceramics, resin, digitally-defined three-dimensional geometry - after a virtual 3D modelling sketch. In other words, a 3D printer is an industrial robot capable of creating physical objects under computerized control.

3D printing of an object is accomplished by the controlled layer-added layer overlay process until the object has been completely created as it has been digitally defined. Each such layer can be seen as a horizontal section of the object, more precisely a 2D slice, all layers being gradually joined together to form the final shape of the object.

All current 3D printers use this layer-layer overlay process, as well as several types of available technologies, the difference between them being the way the layers are created and merged. Some of them are based on melting or increasing the degree of malleability of the material on which they work, others on different processes including the use of laser beams or ultraviolet radiation on materials receptive to them.

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Learning aims:

After completing this chapter, the learners will be able to:

- know and understand the main 3D modelling applications associated with the main 3D printers available;
- know examples and case-studies of best practices in 3D printing
- conduct deep research to get acquainted with the most up-to-date technologies and advancement in 3D printing.

Content:

- Types of 3D printers: filament/laser
- Pros/cons
- What software is available
- STL format (export standard)
- Two Options: Buy your own 3D printer or Design your model and outsource the printing
- Best free 3D software
- Designing vs. reproducing object AGISOFT (simplest/cheapest effective software to build models from photos)

Duration: 5 hours

1.2.1 Types of 3D printers: filament/laser

Although there are many different printers available, only **nine basic types of 3D printing technology** currently exist: Fused Deposition Modelling (FDM), Stereolithography (SLA), Digital Light Processing (DLP), Selective Laser Sintering (SLS), Selective Laser Melting (SLM), Electron Beam Melting (EMB), Laminated Object Manufacturing (LOM), Binder Jetting (BJ), and Material Jetting/Wax Casting. **The three most common are SLA, FDM and SLS.** These

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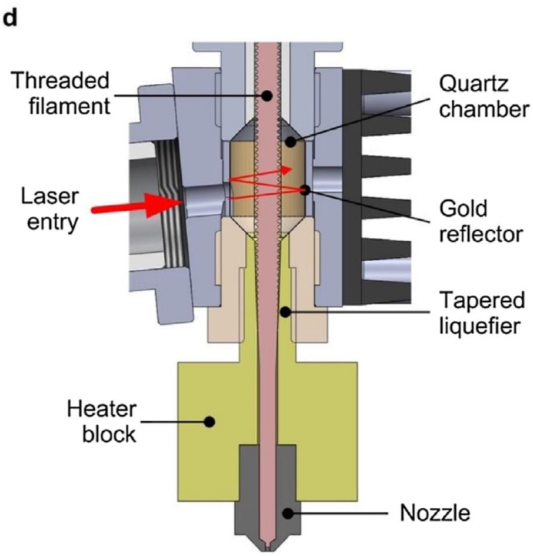
technologies have significantly impacted the way businesses, professionals, consumers and educational institutions function due to their adoption of 3D printing.



Fused Deposition Modelling (FDM)

Fused Deposition Modelling is the most widely used form of 3D printing at the consumer level, fuelled by the emergence of hobbyist 3D printers. FDM 3D printers build parts by melting and extruding thermoplastic filament, which a print nozzle deposits layer by layer in the build area.

FDM works with a range of standard thermoplastics, such as ABS, PLA, and their various blends. The technique is well-suited for basic proof-of-concept models, as well as quick and low-cost prototyping of simple parts, such as parts that might typically be machined.

FDM has the lowest resolution and accuracy when compared to SLA or SLS and is not the best option for printing complex designs or parts with intricate features. Higher-quality finishes may be obtained through chemical and mechanical polishing processes. Industrial FDM 3D printers use soluble supports to mitigate some of these issues and offer a wider range of engineering thermoplastics, but they also come at a steep price.

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Stereolithography (SLA)

Stereolithography was the world's first 3D printing technology, invented in the 1980s, and is still one of the most popular technologies for professionals. SLA uses a laser to cure liquid resin into hardened plastic in a process called photopolymerization.

SLA parts have the highest resolution and accuracy, the clearest details, and the smoothest surface finish of all plastic 3D printing technologies, but the main benefit of SLA lies in its versatility. Material manufacturers have created innovative SLA resin formulations with a wide range of optical, mechanical, and thermal properties to match those of standard, engineering, and industrial thermoplastics.

SLA is a great option for highly detailed prototypes requiring tight tolerances and smooth surfaces, such as moulds, patterns, and functional parts. SLA is widely used in a range of industries from engineering and product design to manufacturing, dentistry, jewellery, model making, and education.

See how stereolithography works: How SLA works

Selective Laser Sintering (SLS)

Selective laser sintering is the most common additive manufacturing technology for industrial applications.

SLS 3D printers use a high-powered laser to fuse small particles of polymer powder. The unfused powder supports the part during printing and eliminates the need for dedicated support structures. This makes SLS ideal for complex geometries, including interior features, undercuts, thin walls, and negative features. Parts produced with SLS printing have excellent mechanical characteristics, with strength resembling that of injection-moulded parts.

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The most common material for selective laser sintering is nylon, a popular engineering thermoplastic with excellent mechanical properties. Nylon is lightweight, strong, and flexible, as well as stable against impact, chemicals, heat, UV light, water, and dirt.

The combination of low cost per part, high productivity, and established materials make SLS a popular choice among engineers for functional prototyping, and a cost-effective alternative to injection moulding for limited-run or bridge manufacturing.

The first thing to understand is that 3D printing is actually an umbrella term that encompasses a group of 3D printing processes.

In total, **seven different categories of additive manufacturing processes have been identified and established.** These seven 3D printing processes brought forth ten different types of 3D printing technology that 3D printers use today.

Fused filament fabrication (**FFF**) is a 3D printing process that uses a continuous filament of a thermoplastic material. This is fed from a large coil, through a moving, heated **printer extruder head**. Molten material is forced out of the print head's nozzle and is deposited on the growing workpiece. The head is moved, under computer control, to define the printed shape. Usually the head moves in layers, moving in two dimensions to deposit one horizontal plane at a time, before moving slightly upwards to begin a new slice. The speed of the extruder head may also be controlled, to stop and start deposition and form an interrupted plane without stringing or dribbling between sections. **Fused filament fabrication** was coined by the members of the RepRap project to give a phrase that would be legally unconstrained in its use, given patents covering **Fused Deposition Modelling** (**FDM**). RepRap was the first of the low-cost 3D printers, and the RepRap Project started the open-source 3D printer revolution. It has become the most widely-used 3D printer.

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Fused filament printing is now the most popular process (by number of machines) for hobbyist-grade 3D printing. Other techniques such as photopolymerization and powder sintering may offer better results, however their costs are greatly increased.

Fused Deposition Modelling (FDM) was developed by S. Scott Crump in the late 1980s and was commercialized in 1990 by Stratasys.

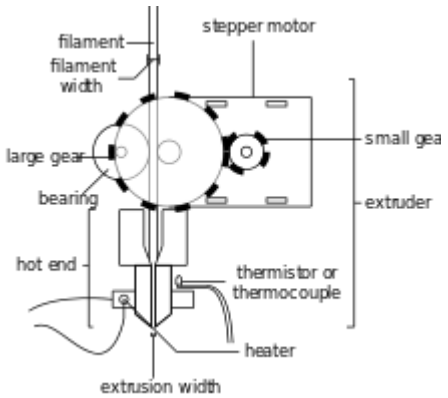

Illustration of an extruder, that shows how all parts are named.

The **3D printer head** or **3D printer extruder** is a part in material extrusion-type printing responsible for raw material melting and forming it into a continuous profile. A wide variety of materials are extruded, including thermoplastics such as *acrylonitrile butadiene styrene* (ABS), *polylactic acid* (PLA), *high-impact polystyrene* (HIPS), *thermoplastic polyurethane* (TPU), *aliphatic polyamides* (nylon). Paste-like materials such as ceramics and chocolate can be extruded using the fused filament process and a paste extruder.

Extruder – The mechanism that moves the filament in a FDM/FFF 3D Printer. It consists of several parts, including a drive gear, stepper motor and a construction to apply pressure between the drive gear(s) and filament.

Direct Drive Extruder – An extrusion system where the stepper motor and drive gear pushes filament directly into the hot end. Direct Drive Extruders sits in the print head and moves with the 3D Printer in either X or Y axis, sometimes both depending on machine type.

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Bowden Extruder – An extrusion system where the stepper motor and drive gear is separated from the print head, allowing weight saving in X/Y axis. Bowden extruders push filament through a guide tube between the drive gear and hot end.

Print Head – The Print head assembly is the collective name of the parts that make up the moving head, where plastic is extruded in FDM/FFF machines, and where material is jetted in Material jetting machines.

Hot-End – Hot end Assembly – The Hot end is an assembly of parts that handle hot or molten filament. This usually consists of Nozzle, Heater, Thermocouple and Heater block.

Heat break – The separation between hot parts and cold parts in the Hot End. Usually consists of a thermal tube or gap between metals. Can also be a PEEK isolator. For many PLA-specific 3D printers, this break is made with a PTFE-tube inside the thermal tube.

Heater block – The metal part that's central in a hot end. This part connects the nozzle, Thermal tube, thermocouple and heater cartridge together.

Nozzle – The nozzle where filament goes from 1.75 or 2.85 mm into a smaller hole. This is where the molten filament leaves your 3D printer to build your object. Nozzles are often 0.4mm in diameter, which is the exit hole's diameter of the nozzle. The incoming hole's diameter is often the same as the filament the machine is made for, or to fit the Thermal Tube + filament diameter.

Hardened Nozzle – A nozzle that's hardened to allow more abrasive filaments before the exit hole's diameter is worn out.

Ruby Nozzle – A nozzle with a ruby mounted at the exit hole, that is extremely hard and will not wear close to the rate of a traditional nozzle.

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Thermal Tube – A tube (often threaded) where you connect the Heater Block and Heat break to the rest of the Print head assembly. This often includes a PTFE-tube inside.

Thermocouple – The temperature sensor for your 3D Printer, reading a specific resistance depending on the temperature. This translates to a temperature in either Hot end or Build Plate.

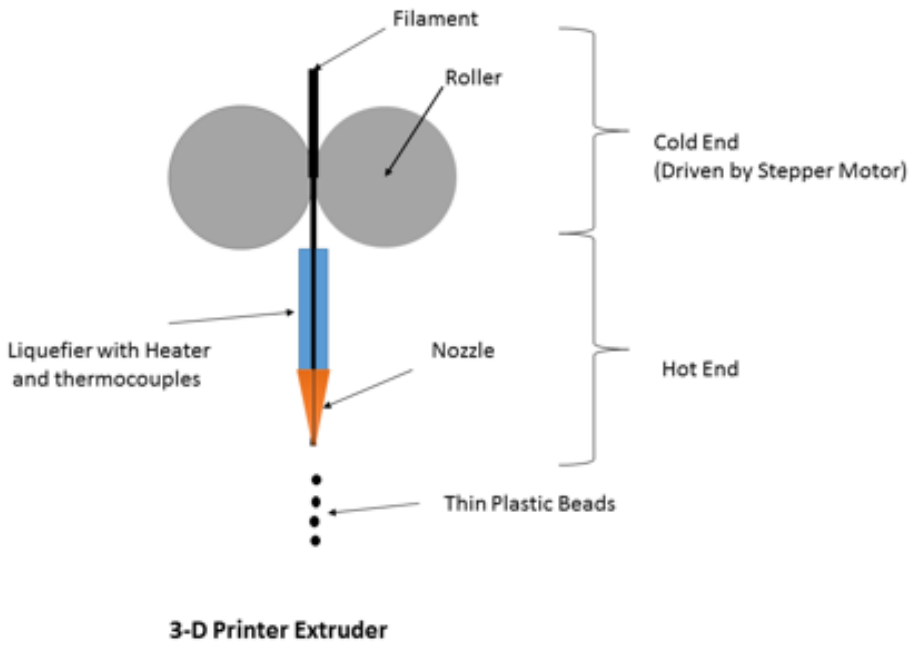

Illustration of a 3D printer extruder, that shows how all parts are named.

The plastic nurdles are always white or clear. Pigments or other additives are added to the material before it is melted to create coloured filament or filament with special properties, for instance, increased strength or magnetic properties. Before the filament is extruded the nurdles are heated to 80°C to reduce water content. From there the nurdles are fed into a single screw extruder where it is heated and extruded into a filament. The diameter is often measured by a laser as part of a quality control mechanism to ensure correct diameter of the filament. The filament is then fed through a warm water tank which cools the filament that

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gives the filament its round shape. The filament is then fed through a cold water tank to cool it down to room temperature. It is then wound onto a spool to create a finished product.

Laser technology and 3D printing

3D printing and laser technology go hand in hand. SLS, also known as selective laser sintering is a special method that employs a process called powder bed fusion to create 3D objects. The material used is often nylon, which is transferred from bins containing fresh powder into the processing chamber using a recoating tool. Afterwards, a laser is used to scan the powder layers, sintering together with the particles thus making the first 3D layer of an object.

The laser scanning procedure generates current and adjoining layers simultaneously, thus crafting the solid part. As opposite to additional manufacturing processes, like FDM – Fused Deposition Modelling and SLA – stereolithography, SLS – selective laser sintering doesn't need support structures considering that the powder serves as a supporting material. This is excellent because it allows the construction of more complicated geometric pieces.

Applications for 3D printing with SLS result in designs with prototypes, moving parts, architectural models, consumer products, electronics housing, hardware, promotional items, sculptures, and more. As for SLS and FDM printing technologies, these are commonly used for similar printing processes.

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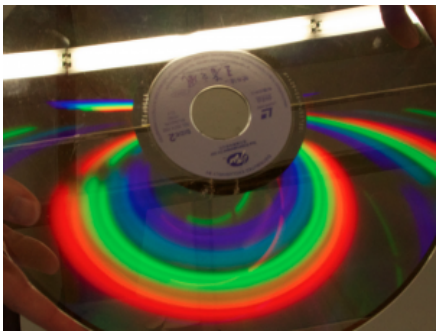
SLM – selective laser melting

Selective laser melting (SLM) is yet another form of additive manufacturing technique used to print metal objects in 3D. The metallic powder is melted with a laser in specific areas. SLM makes use of lasers to soften successive metallic powder layers. The laser heats the particles in certain areas until it is completely melted. The melting process is dictated by the CAD 3D file in the machine; another bed of powder is added on top of the melted layer until the piece is completed.

The most widespread applications for SLM technology occurs in the aerospace industry. That's because intricate parts are made using additive manufacturing; this surpasses limitations in conventional manufacturing. SLM can also be used in medicine. Certain prosthetics are made using this method of 3D printing because it permits the pieces to be customized adapting to the anatomy of the patient. Manufacturing metallic pieces with 3D printing can additionally be done using direct metal laser sintering (DMLS). However, there is a difference between the two (the degree at which the powder particles are melted; with DMLS, the melting is only done partially). This technique also uses other materials than metal. Some other common materials are aluminium, steel, nickel, cobalt-chromium and titanium.



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3D printing with lasers and paper

There's another type of technology that uses lasers for printing materials, namely SLD – selective deposition lamination. The technology resembles LOM – laminated object manufacturing. It involves using various layers of plastic, coated or metal laminates/paper that are glued together successively using a heated roller. These are cut and shaped using a laser cutter, and the process is done layer by layer.

Laser technology can be used in all sorts of industries. It certainly plays a key role in 3D printing, but it has become vital in other industries too. Commercial metal engraving uses lasers to mark all sorts of metallic pieces, from auto parts to metallic tags and medical utensils.

It's a process that allows prototypes to be produced much more quickly than machining, and it allows very complex shapes to be made in a single unit instead of being built up from several simpler units. However, such printing can still take hours or even days, and while the object is being printed it may be necessary to include ridging or temporary structures to support it until it's complete.

Additive manufacturing, better known as 3D printing, promises to revolutionize prototyping and manufacturing, but it's a process that has its limitations. Conventional 3D printing works by printing an object in layers. Plastic objects can be built up by squirting molten plastic in a three-dimensional pattern and metal objects by laying down layers of fine metallic dust, which is fused into a pattern using a laser or electron beam.

Developed by LLNL (Lawrence Livermore National Laboratory) in collaboration with UC Berkeley, the University of Rochester, and MIT (Massachusetts Institute of Technology), volumetric printing replaces layering with a process that creates the entire object simultaneously. It does this by using three overlapping lasers beamed in a hologram-like pattern into a transparent tank filled with photosetting plastic resin. A short exposure by a single beam isn't enough to cure the resin in a short time, but combining three lasers can

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induce curing in about ten seconds. After the object is formed, the excess resin is then drained off to reveal the complete unit.

Filaments and temperature of 3D printing

When we print with a plastic filament, it is pushed through the nozzle, heated and in liquid form extruded onto the growing 3D print model. The crucial parameters here are the chemical type of the filament, the diameter of the nozzle hole (typically 0.2 1.4 or 2 mm) the speed of the filament applied to the model and of course the temperature of the nozzle. The fluid plastics has to be just enough viscous to be nicely applied to the model, the plastics must not have absorbed moisture since this can lead to the bubbles in the model. If the temperature is too high, the bubbles also appear in the model. On the other hand, if the temperature is too low, the filament does not stick enough to the model and can also break.

Chemically we can use lots of substances, also the chocolate. However, for 3d printing chocolate one needs a special nozzle with large opening and low temperature 30-40 degrees. The process is slow so that I would recommend to 3D print moulds instead chocolate objects.

We recommend the use of PLA, PETG and nylon filaments. ABS more difficult to 3d print. For nylon you will find in literature that it is difficult to print, but we use nozzle with 0.25mm diameter and temperature about 250 degrees and get very nice and strong 3d printed objects. All the protective cases for my cameras I made this way and they survived my travels through Europe and Asia. For PLA they say that it is biologically degradable, but forget this in praxis. Our partners have 3d printed cages for feeding birds for three years in the garden – subtune, rain and snow do not harm them.

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1.3.1 Advantages and Disadvantages of 3D Printing

Advantages of 3D Printing

In order to make a successful 3D printed product, understand the 3D printing marketplace, or just use 3D printing effectively, it's vitally important to have a general understanding of why 3D printing should be used. There are plenty of ways to make objects, so why would you want to choose to 3D printing something over another production method? To answer this question, we'll dive into a few reasons why 3D printing is great, a few ways in which 3D printing has significant constraints, and a series of pros and cons that will enable you to make an informed decision of whether to 3D print something.

Oftentimes, 3D printing offers an excellent opportunity, and other times it may be too costly, or it may be possible to make something with 3D printing, but another option may be better or easier.

Complex Geometry

One of the main advantages to 3D printing is that it allows the production of extremely complex geometry – that could not be made by any other production method. In my opinion, this is the most significant advantage to 3D printing. With other conventional manufacturing methods, typically, the more complex an object or part, the more expensive it is to produce. This is because the more complex an object, the more steps that would be required of a manufacturing process. Because of this, people often say that 3D printing is free of complexity. Meaning that adding significant complexity to an object does not proportionately increase costs. In fact, a more complex or porous object can actually make its production cheaper.

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Lighter Stronger Part

In the aerospace industry, efficiency improvements of small parts can save millions of dollars.

Faster Design Cycle Iteration

Ask almost any industrial design or product design consultant today, and they will tell you the same thing. 3D printing has changed the way products are designed, developed, and produced. Even inexpensive desktop 3D printers that lack the resolution or material capabilities of some higher end models are able to very quickly produce sometime rough prototypes that will accelerate the design iteration process. These initial prototypes can be extremely valuable even if they answer simple questions about the design of a product: "What does it feel like?" "What does it look like?" "How does it feel when I hold it in my hand?" Once you can collect feedback based on a 3D printed design, you can not only iterate quicker, but also help to design better products.

For example, Brooklyn based company, Spuni, came up with a product idea to solve a problem. When babies transition to solid food, many current spoon designs were just miniature versions of adult spoons – either too wide or too deep for a baby to eat without creating a mess. Spuni founder Marcel Brotha used a BPA-free plastic material and printed dozens of iterations of a spoon design until finding the final form.

One gigantic advantage to 3D printing – when it comes to a technology that has the potential to upend how consumer goods are manufactured – is that there you can produce an object on-demand. Let's compare this to the way many of our current consumer goods are produced. First, they are mass manufactured, typically overseas. Next, they are packed up and freighted across the ocean. This is a big problem – because shipping emissions account for almost 20% of global CO2 emissions. After this, products typically arrive in mass at a port. Then the products are driven to a distribution warehouse. Then products are

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distributed to a retailer. On top of this, there is huge waste in inventory. Holding inventory of products costs money and many products have surpluses of inventoried products that end up going to waste.

Consider an alternative with 3D printing – given that 3D printing could produce a given end-use product: when you want a product, it can be produced geographically close to the point of consumption, on demand. This relieves the need for wasted inventory and wasteful travel of a product around the globe.

Waste Reduction

Although 3D printing materials and processes vary (especially in terms of their environmental friendliness), 3D printing is inherently green. Building on the last point about on-demand manufacturing, 3D printing is also inherently sustainable because it is an additive process. This means that in many cases, you can eliminate much of the material waste because many 3D printing processes will only add as much material as necessary.

Price and Economies of Scale

The reason why mass manufacturing works in many instances is because of economies of scale. The higher the mass quantity of a product that is produced via a conventional mass manufacturing process like injection moulding the less that each unit will cost.

Let's say you are tasked with manufacturing a plastic duck figurine. If you wanted to use injection moulding, there would be significant upfront production costs. You'd have to create tooling and front other associated costs that could easily be tens of thousands of dollars. So if you were to use injection moulding to make 10 ducks, each unit would be incredibly expensive. In the case of a small run like this, 3D printing would be a great alternative.

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More Jobs

More engineers are needed to design and build 3D printers, and more technicians are needed to maintain, use, and fix 3D printers too. Additionally, with the lower cost of manufacturing, more designers and artists would be able deliver their products to the market. Even more domestic jobs for shipping these products should be created too.

Disadvantages of 3D printing

Material Property Limitations

Although the 3D printing industry is making improvements to material capabilities, there are still significant limitations. We have more and more options of what materials we can use for 3D printing, but sometimes the available materials may not work.

Firstly, 3D printing materials may be too costly. Material costs can be significant and can be one of the main limitations for using 3D printing for a project.

Also, you may need a very specific trait for a material. Maybe you need a material that is water-tight, food safe, or a material that has certain properties for strength, flexibility, or opacity. There are more and more options, but sometimes the materials available to use for 3D printing may not have all the right characteristics that you need.

Currently, 3D printers only manufacture products out of plastic, resin, certain metals, and ceramics. 3D printing of products in mixed materials and technology, such as circuit boards, are still under development.

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Size Constraints

With today's commercial and desktop 3D printers, there are limitations to the biggest part that you can print. Also, because 3D printing is most often charged by volume of material used, an increase in size can lead to an exponential increase in cost.

Most often, you will be limited to objects about the size of a shoebox or smaller. Some 3d printers specifically address this issue, like the BigRepOne which has a build volume of 1 cubic meter.

One workaround is to print an object in parts and manually assemble, however this does not always lead to ideal results.

Fewer Manufacturing Jobs

As with all new technologies, manufacturing jobs will decrease. This disadvantage can and will have a large impact on the economies of third world countries, especially China, that depend on a large number of low skill jobs.

Copyright

With 3D printing becoming more common, the printing of copyrighted products to create counterfeit items will become more common and nearly impossible to determine.

Dangerous Items

3D printers can create dangerous items, such as guns and knives, with very little or no oversight.

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More Useless Stuff

One of the dangers of 3D printers is that they will be used to create more useless stuff that is bad for the environment and wallets. Fortunately, there are new methods of automatically recycling objects made by 3D printers that hold promise of better recycling in the future.

Size

Currently, 3D printers are limited with the size of the products that they can create. Ultimately, large items, such as houses and building, could be created using 3D printers.

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1.3 Unit 3: Software

1.3.1 What software is available

3D Slash - www.3dslash.net

3D Slash focuses on providing design software with a uniquely fun user interface and enough advanced features to work with a high level of precision. You can also make logos and 3D text with this software. 3D Slash is free to use and ideal for beginners, however there a range of price packages that add in features for cooperative use or commercial use depending on the needs of the consumer. Additionally, the free versions have limitations in terms of functions, higher resolutions and colours you can apply. It's intuitive interface with a block cutting style to create shapes makes it simple enough for anyone to use.

Even if you can't find the creative spark to start a design from scratch, there are a multitude of files available for download that you can import and then cut apart into something new. Novel features like the cursor mode that makes interior designing much easier are great additions. Aside from its ability to run on standard mode, it can also be used with VR headsets. While the blockish style can be limiting in terms of range of shapes one can make and less pleasing to the eyes, it is nonetheless efficient and practical. There is some other software that are as quick from concept to finish as 3D Slash.

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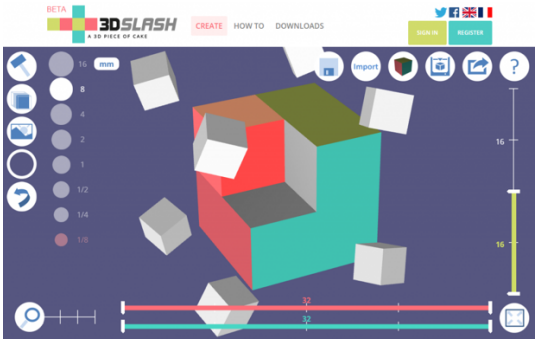
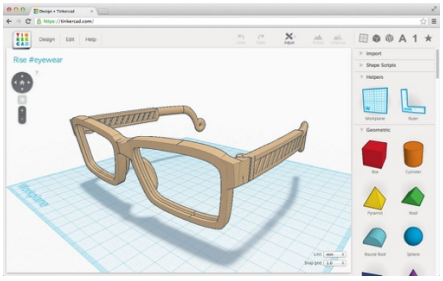


TinkerCAD - tinkercad.com

This is an online 3D design app geared towards beginners. The software features an intuitive block-building concept, allowing you to develop models from a set of basic shapes. TinkerCAD is full of tutorials and guides to aid any aspiring novices get the designs they're looking for. It even allows you to share and export files with ease.

With a library of literally millions of files, users can find shapes that suit them best and manipulate them as they wish. It also has a direct integration with 3rd party printing services, allowing you to print and have your print at your door-step at the press of a button. Even though it can be a bit too simple to the point of limitation, it serves as a great way to learn about 3D modelling.



FreeCAD - freecadweb.org

A parametric 3D modelling tool that is open-source and enables you to design real-life objects of any size. The parametric component makes editing your design a piece of cake. Simply go

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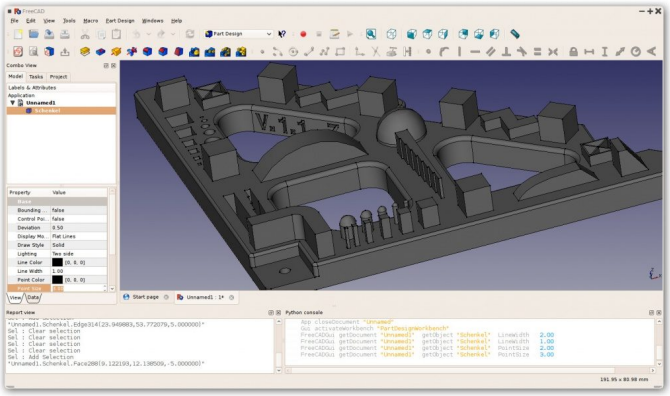
to your model history and change the parameters, and you'll have a different model. As the name suggests, it is in fact totally free. The upside of this is that none of the tools are blocked behind a pay wall, so you can tweak your models to your heart's desire.



SketchUp - sketchup.com

SketchUp is another good modelling software because it maintains that balance between usability and functionality, making it ideal for most skill levels. The software has an easy learning curve and there are advanced features available for professionals at an extra cost. It is especially good for designing interior and exterior architectural projects but also has tools for a diverse range of other purposes.

Anything complex can take quite a while, but simpler designs aren't too time-consuming. A freeware version, SketchUp Make, and a paid version with additional functionality, SketchUp Pro, are also available.

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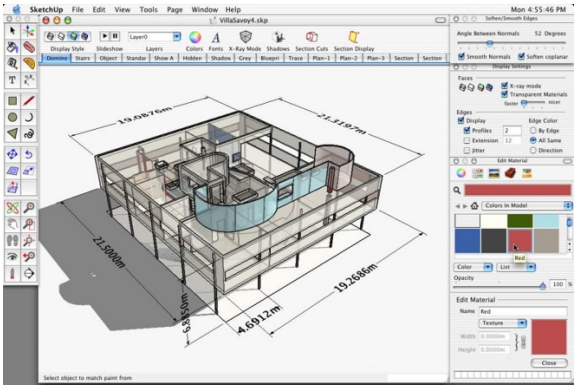
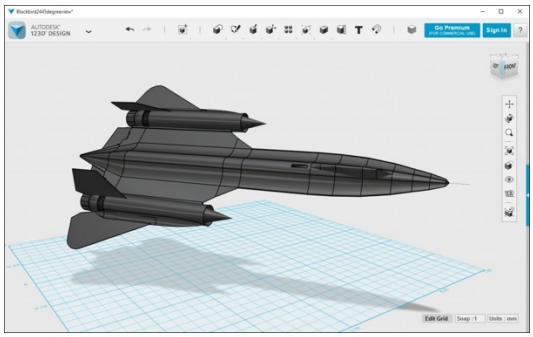


123Design

This is a powerful yet accessible piece of software to help create and edit 3D designs. You can take photos of objects and make 3D models from these photos, and the software is also available on smartphones. Many newer printer models are supported.

It runs on a payment model and is great for those just starting out with their models. While the download file is quite large, once it is up and running it is smooth and operates with simplicity in mind. The software allows you to do mark-ups, leave comments, make changes and put up red lines, making it ideal for collaborative efforts.



Blender - blender.org

In essence, Blender covers many facets of 3D creation, including modelling, animation, and simulation amongst others. This open-source software has a steep learning curve and is ideal

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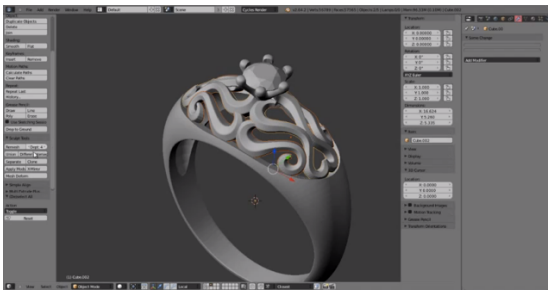
for users who feel ready to transition of designing complex 3D models. Check out the Blender tutorials for 3D Printing page.

Blender is actually a free 3D modelling software which was originally for 3D animation and rendering using polygonal modelling techniques. Despite its origins as a software for artists, it is considered quite accessible. One of the software's interesting features is the photorealistic rendering option. This gives the models an air of realism that few free software can achieve.



SolidWorks - solidworks.com

Now we move on to SolidWorks. This is a CAD program often used by professional 3D designers. There is a plethora of advanced features included, such as design validation tools and reverse engineering. SolidWorks comes in three distinct packages, depending on the exact features you need.

SolidWorks tends towards the industrial side of things. It is practical and detailed. While most software, mimic curves through gently inclining flat structures, SolidWorks uses a system of nurbs (Non-Uniform Rational B-Spline (mathematical algorithm used in computer graphics especially CAD) that create averages of the edges to produce fantastically detailed curvatures. It only does away with polygonal modelling, opting instead for dimensional sketching. As a result, resizing becomes far less of a hassle.

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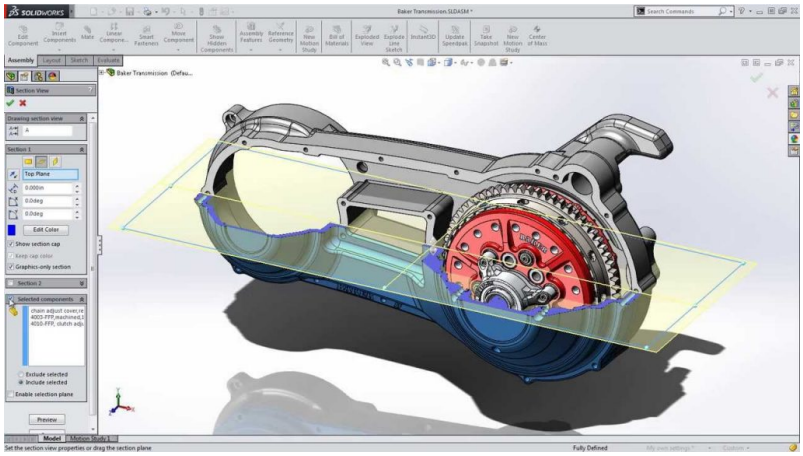

Rhino3D - rhino3d.com

The company behind this software markets it as the world's most versatile 3D-modeler. The software is available for download in a variety of bundles on their website at various prices. The program uses a precise and mathematical model known as NURB, allowing you to manipulate points, curves, meshes, surfaces, solids, and more in all sorts of ways. Ultimately, given the range of design features available with Rhino3D, it's hard to argue against its claims about unrivalled versatility in creating complex 3D models.

Users have commented on how the software can be very difficult to learn. This is a natural trade-off between capabilities and user friendliness many designers have to make when creating a detailed software. While it is not the most accurate software at capturing user intent, it is one of the best on the market.

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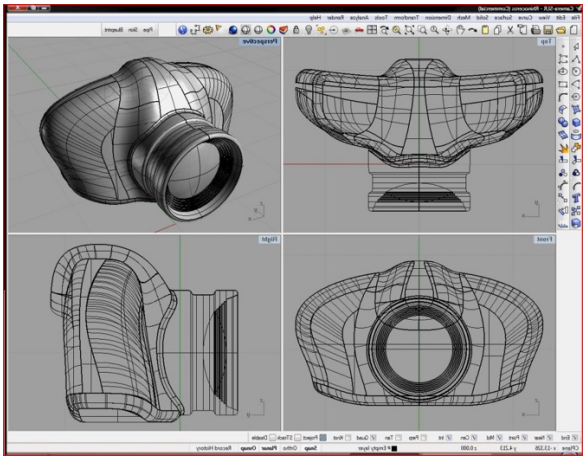
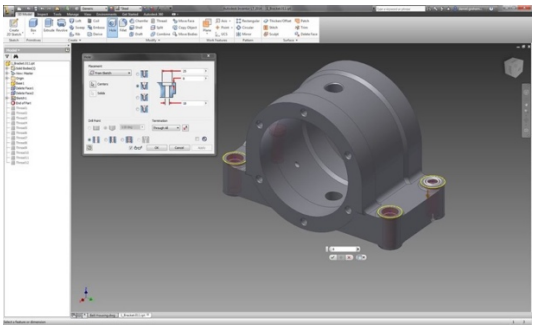


Inventor - autodesk.com/products/inventor/overview

Inventor 3D CAD software offers professional-level 3D mechanical design. The program comes with freeform, direct, and parametric modelling choices. Furthermore, you also get automation and simulation tools.

Developed by Autodesk, Inventor comes in different packages depending on level of proficiency (student, professional etc.). One of the great things about Inventor is how they improve the software with user feedback. New versions include improvements to visual data representation and the ability to easily reference 3rd party designs without the need to convert file formats.



DesignSpark - www.rs-online.com/designspark/home

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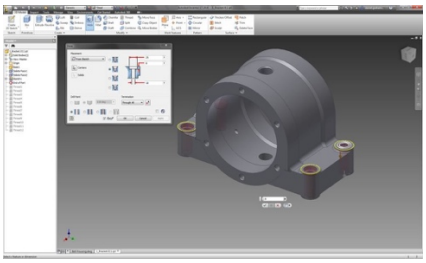
This nifty and free CAD software is ideal for professionals and advanced hobbyists alike. The user interface is relatively straightforward, and the software runs quickly, meaning efficient designing. You also have the capability to generate a bill-of-materials that calculates the cost of printing potential 3D design projects.

DesignSpark Mechanical allows users to utilise an in-built library to mix with own drawings. Another feature that new users might find useful is the pull feature that allows users to create 3D models from only a surface. It is feature-rich for a free software and quite beginner-friendly.



Maya - www.autodesk.com/products/maya/overview

Primarily marketed at animation professionals, Maya is useful for many aspects of 3D modelling, especially in terms of mathematically smooth surfaces and shapes. Maya was originally slated as a 3D animation software but is very useful in 3D printing as well. Thus, a lot of the interface options are more reminiscent of sculpting and animation.

Maya is more applicable to artistic printing requirements. It has a fast rendering engine and is best for highly detailed models with many intricacies. The downside is that it is very expensive (it is, after all, the same software used for high-budget movie CGI|). Nonetheless, it allows for realistic representations of reflection and colour on a software with smooth operation.

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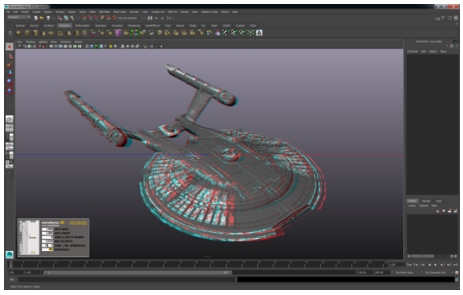
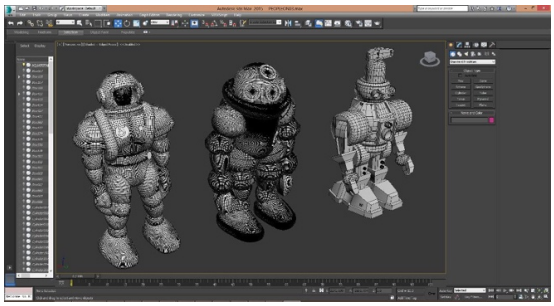


3DS Max - www.autodesk.com/education/free-software/3ds-max

Another program that focuses on animation, 3DS Max offers some great 3D modelling features such as shading tools, parametric mesh modelling, and polygon modelling. This Windows only software is a favourite among video game developers, many TV commercial studios and architectural visualization studios.



Cinema 4D - www.maxon.net/en/products/cinema-4d/overview/

This is an extremely powerful 3D modelling tool that lets you create complex 3D designs. Cinema 4D's quite flat learning curve makes it approachable for beginners intimidated by software with advanced features. The program is regularly updated with free service packs, which help to optimize how it runs on various operating systems.

The user-friendly options present the prints in very accessible ways. Scaling and shading options make modelling far easier. Its sculpting tool is a great example of why this software is ideal for editing models and pre-existing files.

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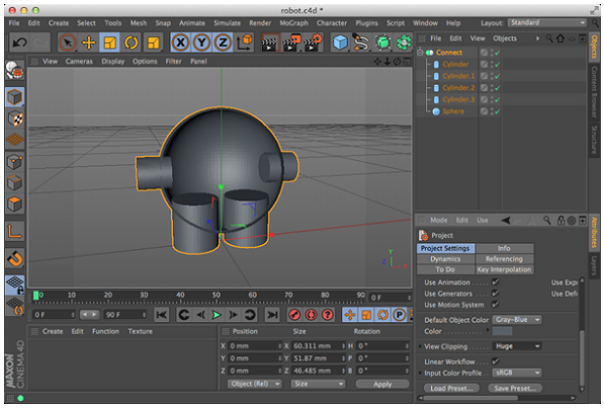

OpenSCAD - www.openscad.org/

OpenSCAD is a free software with a ton of features and a unique way of creating models. This software takes a programming approach to 3D modelling, making it a unique addition to this list of 3Dprinting software tools. Instead of the traditional interactive modelling interface, users write code in a script file that describes the parameters of the 3D object. Once you've entered your code, you can view the shapes you've created by clicking a "compile" button.

Another great feature that OpenSCAD has, is the ability to import 2D drawings and extrude them as 3-dimensional. It uses a part profile from drawings made in a standard sketching software. Il also uses the SXF file to do this. With its stronger focus on programming, OpenSCAD may appeal to some while alienating others. Regardless, it is still a powerful tool.

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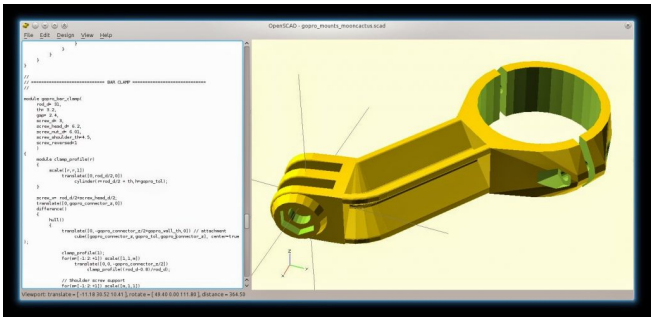
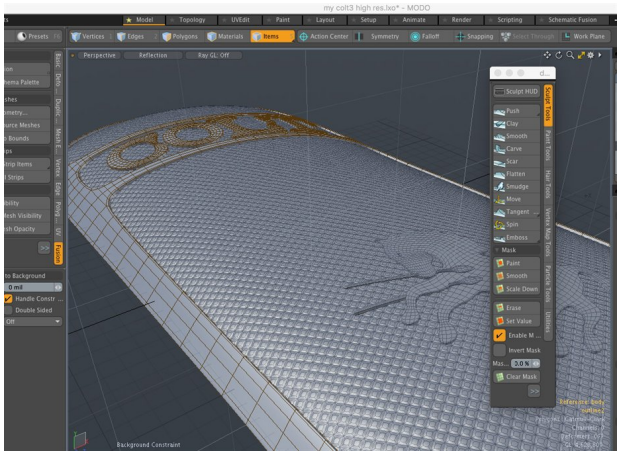


Modo - www.foundry.com/products/modo

Modo provides creative 3D polygon and subdivision surface modelling tools with a lot of flexibility, allowing you to create both freeform organic models and precision meshes using the same software. This is a professional-grade program with a range of features designed for advanced 3D designers, and the price reflects this.

Even though it isn't the most user-friendly software, it hosts a large set of features while running smoothly. The speed of the software is particularly evident in terms of baking textures. It also works with partner software and extensions as additional customisations.



Fusion 360 - www.autodesk.com/products/fusion-360/overview

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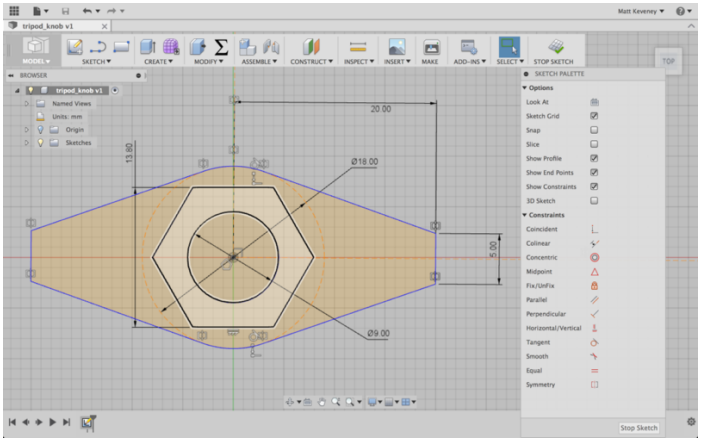
This is a unique addition to the list of 3Dprinting software tools. Fusion 360 is a cloud-based 3D CAD program that utilizes the power of the cloud to bring design teams together and collaborate on complex projects. Another advantage of the cloud platform is that Fusion stores the entire history of the model including the changes to it. Numerous design options are available, including freeform, solid, and mesh modelling.

Fusion 360 operates on a monthly payment subscription basis. The developers also regularly update the features, making it better as new instalments come along. It runs on multiple platforms and allows users to access their information wherever they want.



MoI 3D - moi3d.com/

Short for Moment of Inspiration, MoI offers a sleek UI and powerful range of CAD tools for users specializing in polygonal modelling. The program comes with advanced Boolean functions (any logical operation in which each of the operands and the result take one of two values, as “true” and “false” or “circuit on” and “circuit off.”) that enable quick design of “hard surface” models. It is a user-friendly software that uses the NURBS (Non-Uniform Rational B-Spline (mathematical algorithm used in computer graphics especially CAD) modelling system.

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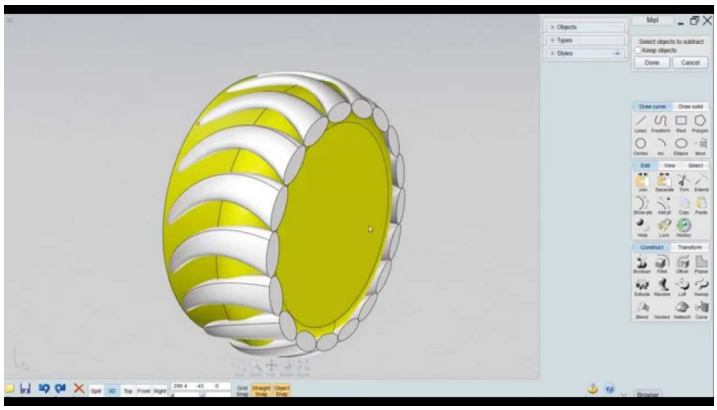
While it isn't free, it is cheaper than some of its competitors. It has a good amount of functions in it yet avoids being too cluttered with pointless features. The system which uses curves and Booleans makes workflow quicker as well.



Wings3D - wings3d.com

Wings3D is another open-source polygon model tool. Despite being freeware, it comes with a wide range of mesh and selection tools. Tools like mirror make symmetrical modelling a breeze. Seeing as it is a program for beginners, it is very user-friendly, and the learning curve is quite steady. Features like the customisable hotkeys and easy to use interface are indicative of its status as an ideal tool for starters.

Despite the ease of use, it has no shortage of useful features such as plane cut, intersect, inset, bend, sweep, circularize, and sheer, making it capable of some very impressive models. It also supports a very wide range of file formats for both import and export. Despite its simple and plain looks, it is definitely worth checking out if you're just starting out.

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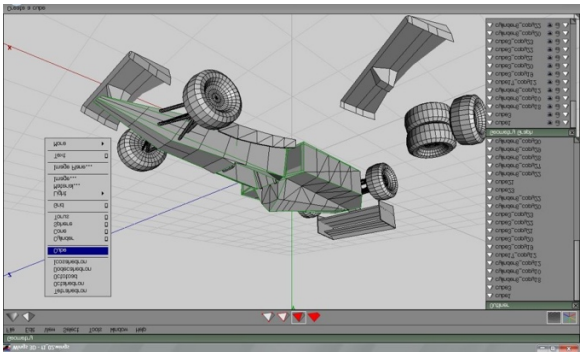
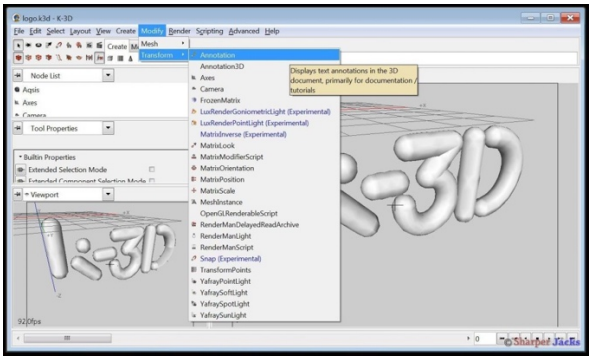


K-3D - k-3d.org

K-3D is a completely free 3D modelling and animation software. The program is extremely versatile and powerful, especially when it comes to polygon modelling. The software uses a node-based visualization pipeline that gives it great visualisation. As a result, it is a great tool for artists.

One of its most widely praised features is its undo/redo function. Users can access a whole undo tree that outlines each change the user has made. Thanks to its open-source coding and general public license, there is a wealth of features and detailed guides on its operations.



BRL-CAD - brlcad.org

This open-source software is an advanced solid modelling system with interactive geometry editing. It is apparently used by the U.S. military to model weapons systems, showing that it

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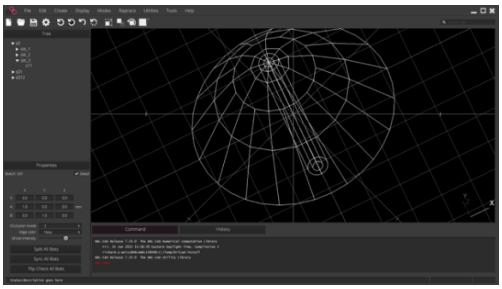
is quite dependable but also very advanced. BRL-CAD offers a high level of precision due to its use of specific coordinates to arrange geometric shapes.

It offers a large library of simple and complex shapes users can implement into their own designs. They can take multiple shapes and combine them at their leisure, as well. The software used to be quite costly, however it was converted to open source a few years ago. It includes over 400 tools in its arsenal. It also runs at great speeds, especially considering how dense its features are.



Slicers & 3D Printer Hosts

The second section of this list of the best 3D printing software tools focuses on programs that help you to execute a 3D print. Slicers are the easiest way to go from a 3D model to a printed part because they take a CAD model, slice it into layers and turn the model into G-code. The slicer software also includes 3D printer settings like temperature, layer height, print speed, etc. to the G-code. The 3D printer can read this G-code and make the model layer by layer following the instructions set in the G-code.

NetFabb - www.netfabb.com/blog/netfabb-basic-now-just-netfabb

Quite apart from being just a slicer program, NetFabb allows you to identify any last issues with your STL files before they get to the slicing stage. In a nutshell, an STL file stores information about 3D models. This format describes only the surface geometry of a three-dimensional object without any representation of colour, texture or other common model

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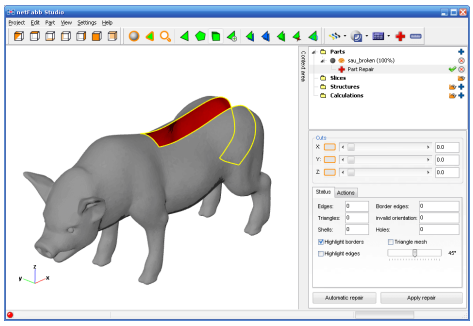
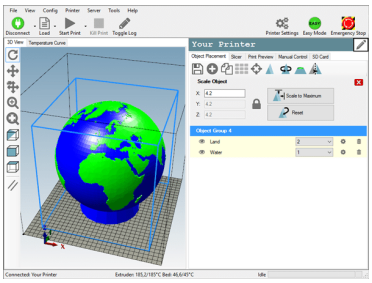
attributes. These files are usually generated by a computer-aided design (CAD) program, as an end product of the 3D modelling process. ".STL" is the file extension of the STL file format. This powerful software is available in a professional edition, which users need to now download as a free trial, even if they only require the basic slicing features.



Repetier - repetier.com

This open-source slicer software supports three different slicing engines; Slic3r, CuraEngine, and Skeinforge. Repetier can also handle up to 16 extruders with different filament types and colours simultaneously, and you can visualize your end result before printing. There is a lot of customization and a lot of tinkering involved, making Repetier ideal for more advanced users. You also get remote access to your printers with Repetier host.



Simplify3D - simplify3d.com

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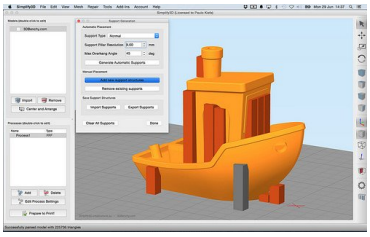
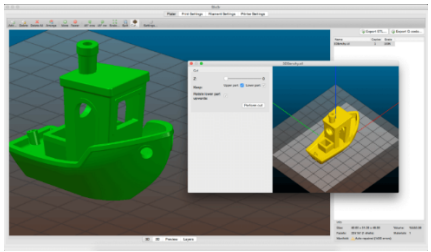
Simplify3D is an extremely powerful premium slicing tool that helps you drastically improve the quality of 3D prints. Not only does Simplify3D slice your CAD into layers, it also corrects any problems with your models and allows you to preview the end result, helping to further identify any other issues. Advanced users will need to decide if the premium features are worth paying for compared to open-source slicers.



Slic3r - slic3r.org

This open-source software includes real-time incremental slicing, 3D preview, and more. It is one of the most widely used 3D printing software tools. The incremental real-time slicing ensures that when you change a setting, the slicing doesn't need to start from scratch. Only the G-code for affected parts is recalculated. The end result is a fast, flexible, and precise slicing program.



Ultimaker Cura - ultimaker.com

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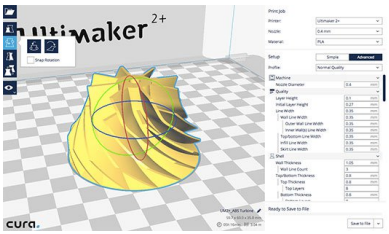
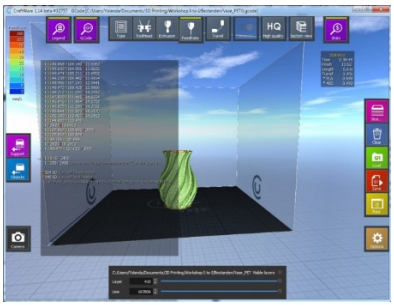
Despite its name, Cura can be used with almost any 3D printer because it is an open-source slicer. The program is ideal for beginners because it is intuitive and fast. Most of all, it's easy to use. More advanced users can access a further 200 settings to refine their prints.



CraftWare - craftbot.com/craftware

CraftWare is another hassle-free slicer suitable for beginners. The free software efficiently converts your 3D digital model into the G-code for 3D printing. There is also a really good visualizer with this software that enables you to identify any possible areas of the model that need modifying.



KISSlicer - kisslicer.com

This slicing software does its job well, although the user interface is somewhat basic. Still, if you just need a slicer that delivers great results, use KISSlicer. Note that the basic version is for single-head machines only. You'll need a PRO version for multi-head machines.

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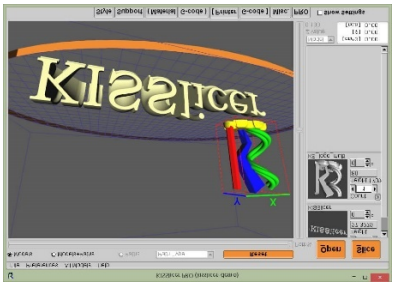
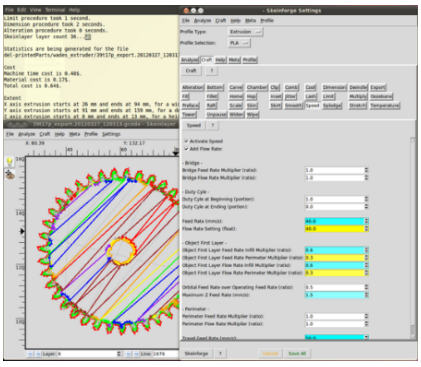


Skeinforge

This chain of Python programming scripts converts 3D STL CAD files to G-code. It is rather outdated now and has been replaced by much faster slicing software but deserves an honourable mention.



ReplicatorG - replicat.org

ReplicatorG is another unpretentious slicing program. It uses Skeinforge as its slicing system, though, meaning it's a bit dated. On the other hand, it's still perfectly adequate at what it does. This software works on the MakerBot Replicator, Thing-O-Matic, CupCake CNC, RepRap machines, or generic CNC machines.

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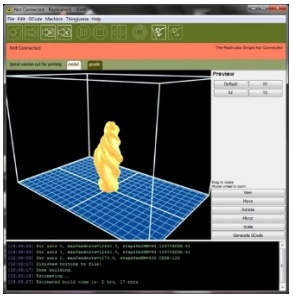
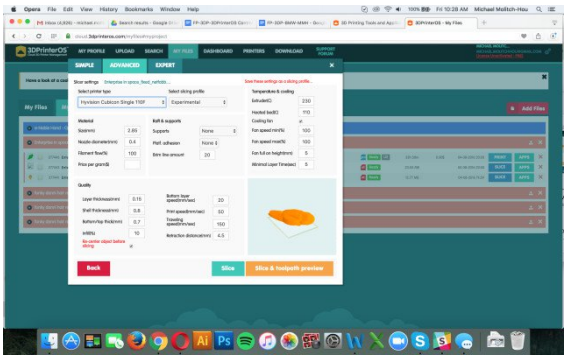


3DPrinterOS - 3dprinteros.com

This nifty cloud 3D printer management software comes at a cost. The essential idea is the management of the entire 3D printing process with one platform. Users can edit and repair designs, slice STL files from the cloud, and even send files for printing from anywhere in the world. The software also features the capability to share CAD files.



STL format (export standard)

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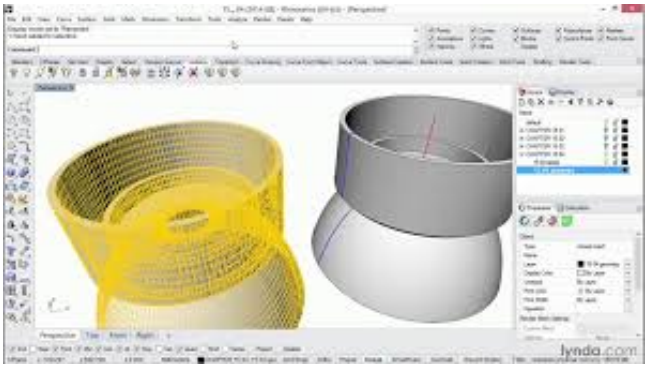

STL is a type of standardized computer file which contains a 3D model. The representation of the surface of the object is in the form of one or more polygon meshes. The meshes in an STL file are entirely composed of triangular facets. The name “STL” is taken from its extension, stl, originally because the files were intended for a rapid prototyping process called Stereolithography. STL also stands for Standard Triangle Language. The file format quickly became a world standard for exchanging 3D mesh type objects between programs, and. stl’s are now used as input for virtually all rapid prototyping processes, as well as some 3D machining. Virtually all 3D programs can export an STL and most can import them.

The triangulation (or poly count) of a surface will cause faceting of the 3D model. The parameters used for outputting a STL will affect how much faceting occurs (Figures 2 and 3). You cannot build the model smoother than the STL file. If the STL is coarse and faceted the physical 3D printed model will be coarse and faceted as well. However, the smoother/ less faceted your surface is, (the higher the poly count or triangulation) the larger your file. 3D printing can only accept a certain file size; therefore, it’s important to find a balance between your model, its desired surface, and the 3D printing process of your choice.

TinkerCAD is great for 3D printing simple geometrical objects. Its interface was created with 3D printing in mind.

1. Design > Download for 3D Printing > .STL

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SketchUp does not offer STL creation directly within the program. Download the extension for .STL here (note: this plugin is open-source and updated frequently).

1. Download and install the plugin
2. Select Tools > Export to DXF or STL and select the units for your model (millimetres is recommended)

Tip: SketchUp isn't inherently built for model production therefore it's useful to check your SketchUp file for additional feature accuracies once it's exported from the interface. We recommend uploading your SketchUp file into Meshmixer (a free program from Autodesk) to check your file for faceting and fix any surface flaws.

Note: We don't recommend SketchUp for use with 3D printing as it does not export well and is best for early design sketches rather than producing physical models.

Inventor (Autodesk)

1. Select IPro > Print > 3D Print Preview
2. Select Options and choose desired resolution and click OK
3. Within the preview window, select Save Copy As or Send to 3D Print Service
4. Save As type to STL File (*.stl)

Note: The "High" setting will also produce the largest file size. From Low, Medium to High, the hairdryer sample file in Inventor went from about 6.7MB to 17.6MB to 50MB.

Tip: Before finalizing your export, select the Options tab. Within this window, you can select the resolution (faceting) for your model (High, Medium, Low and Custom) and check that your units are correct. The "High" setting will produce a large file size. Autodesk's Inventor allows you to save both individual parts and assemblies in STL format, at all design levels. To check your modifiers have been applied before exporting:

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1. Tools > Rebuild All (this ensures that the design data contains recent changes, and that it is not corrupt)
2. File > Save Copy As > STL (.stl)
3. Select High and click OK

Note: To change the values associated with each of the resolution settings (High/Medium/Low) you need to edit the Windows registry.

CATIA

1. Select STL command (we recommend setting maximum segmentation to 0.015 mm)
2. Select the model > Yes > Export

Note: CATIA V5 is capable of creating STL files from CATPart files, but not from assemblies (CATProduct files) or geometrical representations (car files). Therefore, source files, including those saved in a neutral format (i.e. STEP or IGES), must be saved as CATParts. If the source design was saved as an assembly, it is imported to CATIA as a CATProduct. To create an STL file from it, you must first convert it to a multi-bodied part. The procedure described below is one of several methods for doing this.

Saving CATProduct files as CATPart Files for 3D printing:

1. File Menu > Open > select your source file (assemblies import as CATProduct)
2. Save the imported CATProduct file
3. Select File > New > Part > Name the new part
4. Select one component from your master CATProduct File and copy it
5. Paste the component in a new part window
6. Repeat steps and until you have copied all of the components and pasted them as individual parts

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7. Once you have the assembly completely separate into individual components, select File > New Part
8. Copy each of the individual components from the working files and paste them into the new combined model file (the geometries of all of the parts should retain and align correctly in the combined part)
9. The new part is now ready to be exported as an STL file
10. Select Tools > Generate CATPart from Product
11. Finally, Select File > Salve As > Save as type: STL

Tip: Occasionally some of the components may not align correctly in the combined part because of the way the original assembly was designed. To align parts, select Insert Menu > Constraints Feature.

Before saving the file, it is advisable to review the settings that determine model accuracy and file size. To see these parameters:

1. Tools > Options
2. In the Options dialog box, display the Performance tab
3. Under the General category (on the left), select Display
4. Review 3D Accuracy settings

Tip: Curves' accuracy ratio: The higher the setting, the smoother the surface will be when dealing with complex geometries, especially if surfaces contain sudden small changes with small radii (like the bumps on a golf ball).

MAYA

Maya is a free-form design space not specifically tailored for production, therefore it is especially crucial to check the dimensions of your design (are the wall thicknesses defined? Are all vertices connected?

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Features to check:

1. Window > Settings > Preferences >Settings
2. Change measurement units to millimetres
3. Review dimensions and scale within the Chanel Box
4. Finally, open Create > Scene Assembly
5. Access measurement tools to check all feature sizes and thicknesses

Once you've checked your features, open the Rebuild Surface Options and define the surface density of your part. This will determine the resolution of the final 3D print. Check the design guidelines of your preferred technology to ensure the 3D print process can handle your desired resolution.

Now you're ready to export.

1. Select File > Export Selection > Export as STL_DCE.

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1.3.2 Buy your own 3D printer or Design your model and outsource the printing?

3D printing is becoming increasingly integral in the workplace. It helps companies validate designs, perform functional tests, and bring products to market more quickly. 3D printed prototypes are useful for communicating concepts with stakeholders, resulting in faster iterations and better-quality products. Executives seldom need to be convinced of the benefits – yet many continue to outsource their 3D printing tasks; especially when it comes to final part production.

Why companies outsource

Outsourcing means no investment in machinery or training. It also eliminates uncertainty about in-house manufacturing of functional prototypes or final parts. SMEs can't afford expensive industrial additive manufacturing equipment – outsourcing gives them access to this, and to the right level of expertise, which improves their pipeline efficiency. Even engineering teams in large enterprises haven't always got the budget to invest in expensive training and equipment.

An alternative solution

Models and prototypes are crucial at the design stage, and companies want quicker, more effective ways to develop their product concepts. Outsourcing lets them use 3D printing technology without a large initial investment; but the throughput times can still be significant, undercutting the short iterations usually associated with 3D printing.

Desktop 3D printers offer a great alternative, without requiring a significant financial investment. They deliver professional results and other benefits; lower costs, quicker lead times, more customer interactions and higher scalability. They're also easy to operate,

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resulting in more capacity, more teams, and more departments making use of them. In short, they make 3D printing accessible to more professional users, regardless of industry.

What are your options?

This depends both on purpose and application. Businesses have three options when it comes to 3D printing: outsource the tasks, print in-house with industrial machines, or invest in cost-effective, accessible desktop 3D printers.

The following sections examine the pros and cons of each.

- 3D printed tools
- A collection of tools 3D printed in-house and outsourced

Outsourcing to third parties

Outsourcing is a good option if you're looking for exceptional quality, low quantities, and high complexity. It's the right choice if you need five parts or fewer per month, especially if the parts are large or require non-standard materials. It's also useful for final parts that require unusual materials or applications.

However, be warned – this is the slowest, priciest option. Yes, you'll have an expert performing the task without the associated risks of long-term commitment. But the hourly or project rate is often substantially higher than hiring an employee, and you'll be waiting longer for them to complete the job.

Pros:

- Several technologies available in-house, such as SLA, FFF, and SLS
- More materials than an in-house system
- Expert knowledge about materials (and their limitations)

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- No long-term commitment
- No initial investment

Cons:

- Cost per part is far higher than in-house printing
- Slower process - weeks instead of days
- More paperwork and more workflow steps. You'll need to contact suppliers, review quotes, put in a purchase request, pass over specifications, develop ideas, evaluate functionality, and more
- Small amendments are expensive
- Multiple iterations take longer to create
- Customer locked in with software, add-ons, or filaments
- Structural underutilization
- Inaccessibility. An operator is needed, engineers can't use it directly, and maintenance means no availability
- Not scalable
- Industrial 3D printer
- Parts inside the build chamber of a large industrial 3D printer
-

In-house industrial 3D printers

Industrial printers are ideal if you're producing large batches of parts. You'll need to use the printers frequently to justify the considerable investment and training involved.

Pros:

- Wide range of high-performance materials available
- When implemented, it's quicker than using third-party service bureaus
- Cost-effective option (when printing in large batches)

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Cons:

- Significant up-front investment. Expect to pay between $250,000 and $1 million for a comprehensive manufacturing system
- Lots of space required. True manufacturing systems require over 30m2 of floor space, industrial HVAC, finishing stations, cleaning stations, and more
- Accounting for all costs, a single build would cost more than a desktop 3D printer (approximately $3,000, plus usage and labor)
- Unsuitable for short batches – costs a lot more per printed product
-

Utimaker 3D printers

Desktop 3D printers provide a cost-effective and versatile solution

In-house desktop 3D printers

Desktop 3D printers are perfect for rapid prototyping. If you're doing a lot of printing, a print farm of multiple desktop machines is far cheaper and easier-to-scale than industrial printing. Multiple printers and 3D print clusters also offer more flexibility and control (e.g. printing one part per machine).

Pros:

- Most cost-effective option. An outsourced prototype can cost thousands of dollars (for complex models). On average, printing in-house costs a tenth of the price
- Quicker turnaround time. Outsourcing 3D printed parts takes about a week. An in-house 3D printer produces a prototype in a matter of hours, shaving weeks off the development cycle. Products can be brought to market in a fraction of the time
- Greater flexibility – tweak designs at a far lower cost
- No risk of designs being leaked – it's all done in the safety of your business premises

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- Total design control – print fine details, smooth surfaces, and even moving parts in a single build
- Less room required
- Relatively inexpensive and scalable

Cons:

- Most desktop 3D printers are technically limited to printing high-performance materials
- More suited for smaller-size parts
- Not as suitable for mass customization
- Employee training is required (but less intense and complicated compared to industrial machines)

Questions to ask

Before committing to a 3D printing solution, ask yourself the following:

- What do you need the parts for? Functional prototyping? Visual display? Casting into end products?
- What materials will you be using?
- How many parts will you need per week? How many parts can you fit into one build volume on a desktop, or on an industrial machine?
- How familiar are your employees with additive manufacturing processes? Is additional training required?
- What is the timeline for implementing 3D printing into your workflow?
- What best suits your working environment?

In most cases, investing in several in-house desktop printers is the best option, then outsourcing final parts with specific requirements to a service bureau. It's the cost-effective

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choice, not only for knowledge workers and design or engi2.6neering teams, but also for multinational companies. Industrial machines are often underutilized and not worth the investment, unless your business model involves mass customization or low-volume, high-profit activities. If you're confident that you'll need large batches of parts with high compliance (e.g. aerospace), then this may be a viable option for you.

Consider not only your current requirements as a company, but what you're looking to achieve in the future. Cost and practicality should always be a priority, but so too should scalability and creative potential.

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1.3.3 Best 3D Design/3D Modelling Software

Used in industries like 3D printing, animation, gaming, architecture, and industrial design, 3D models are crucial components of digital production. That's why choosing the right 3D modelling software is important; it helps to realize your creative ideas with a minimum of fuss.

But finding the right 3D modelling software is often difficult. That's because of various aspects and the wide range of features available in these applications. To help you with making the right choice, we have included 3D modelling software suites pitched at every stage of learning, whether you're a complete 3D modelling beginner or an experienced professional.

However, to keep our list nice and short, we have excluded some 3D modelling software that is usually employed mainly for 3D animation and gaming. So don't be alarmed if you don't find Lightwave, Maya and the like on this list. Also, the ranking of the tools is from Beginner to Industrial.

Name	Level	OS	Price	Formats
LibreCAD	Beginner	Windows, macOS and Linux	Free	dxf, dwg
SculptGL	Beginner	Browser	Free	Free obj, ply, sgl, stl
TinkerCAD	Beginner	Browser	Free	123dx, 3ds, c4d, mb, obj, svg, stl
3D Slash	Beginner	Windows, Mac, Linux, Raspberry Pi or Browser	Free, 24 €/ year Premium	3dslash, obj, stl

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SelfCAD	Beginner	Browser	Free 30-day trial, $9.99/month	stl, mtl, ply, dae, svg
Photoshop CC	Beginner	Windows and Mac	142 €/year	3ds, dae, kmz, obj, psd, stl, u3d
FreeCAD	Intermediate	Windows, Mac and Linux	Free	step, iges, obj, stl, dxf, svg, dae, ifc, off, nastran, Fcstd
MakeHuman	Intermediate	Windows, Mac and Linux	Free	dae, fbx, obj, STL
OpenSCAD	Intermediate	Windows, Mac and Linux	Free	dxf, off, stl
Meshmixer	Intermediate	Windows, Mac and Linux	Free	amf, mix, obj, off, stl
Clara.io	Intermediate	Browser	Free, Premium features from $100/year	3dm, 3ds, cd, dae, dgn, dwg, emf, fbx, gf, gdf, gts, igs, kmz, lwo, rws, obj, off, ply, pm, sat, scn, skp, slc, sldprt, stp, stl, x3dv, xaml, vda, vrml, x_t, x, xgl, zpr

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SketchUp	Intermediate	Windows and Mac	Free, 657€ Pro	dwg, dxf, 3ds, dae, dem, def, ifc, kmz, stl
DesignSpark	Intermediate	Windows	Freemium (basic services are provided free of charge while more advanced features must be paid for), $835 (All Addons)	rsdoc, dxf, ecad, idf, idb, emn, obj, skp, STL, iges, step
nanoCAD	Intermediate	Windows	Freemium, $180/year	sat, step, igs, iges, sldprt, STL, 3dm, dae, dfx, dwg, dwt, pdf, x_t, x_b, xxm_txt, ssm_bin
3ds Max	Professional	Windows	2.141,70 €/ year, Educational licenses available	stl, 3ds, ai, abc, ase, asm, catproduct, catpart, dem, dwg, dxf, ipt, jt, nx, obj, prj, prt, rvt, sat, skp, sldprt, sldasm, stp, vrml, w3d xmldwf, flt, iges
AutoCAD	Professional	Windows and Mac	1400 €/ year	dwg, dxf, pdf
Blender	Professional	Windows, Mac and Linux	Free	3ds, dae, fbx, dxf, obj, x, lwo, svg, ply, stl, vrml, vrml97, x3d

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Cinema 4D	Professional	Windows, macOS	$3,695	3ds, dae, dem, dxf, dwg, x, fbx, iges, lwf, rib, skp, stl, wrl, obj
Modo	Professional	Windows, macOS and Linux	$1799	lwo, abc, obj, pdb, 3dm, dae, fbx, dxf, x3d, geo, stl
Mudbox	Professional	Windows and Mac	85 € / year	fbx, mud, obj
Onshape	Professional	Windows, Mac, Linux, iOS, Android	2.400 €/year, free and price reduced business version available	available sat, step, igs, iges, sldprt, stl, 3dm, dae, dfx, dwg, dwt, pdf, x_t, x_b, xxm_txt, ssm_bin
Poser	Professionals	Windows, Mac	Standard $129.99, Pro $349.99	cr2, obj, pz2
Rhino3D	Professional	Windows and Mac	495€ Educational, 1695€ Commercial	3dm, 3ds, cd, dae, dgn, dwg, emf, fbx, gf, gdf, gts, igs, kmz, lwo, rws, obj, off, ply, pm, sat, scn, skp, slc, sldprt, stp, stl, x3dv, xaml, vda, vrml, x_t, x, xgl, zpr
ZBrush	Professional	Windows and Mac	400€ Educational License,	dxf, goz, ma, obj, stl, vrml, x3d

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			720€ Single User License	
CATIA	Industrial	Windows	7.180 €; Educational licenses available	3dxml, catpart, igs, pdf, stp, stl, vrml
Fusion 360	Industrial	Windows and Mac	499.80 €/year, Educational licenses available	catpart, dwg, dxf, f3d, igs, obj, pdf, sat, sldprt, stp
Inventor	Industrial	Windows and Mac	2,060 €/year	3dm, igs, ipt, nx, obj, prt, rvt, sldprt, stl, stp, x_b, xgl
SolidWorks	Industrial	Windows	9.950 €, Educational licenses available	3dxml, 3dm, 3ds, 3mf, amf, dwg, dxf, idf, ifc, obj, pdf, sldprt, stp, stl, vrml

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3D Printing Practical applications

There are a lot of practical applications related to 3D printing in your home. For example, my mixer for producing smoothies broke. The reason was that the plastic wheel that connected the motor and the mixer bowl “melted” because of use. So, I measured its dimensions, made a 3D model and in less than an hour my 3D printer started to produce the spare part of nylon that worked well. Also, if it breaks it does not bother me, since I just press the button and I get another piece from the 3D printer. There is a lot of objects in your everyday life that you can design or fix in a short time this way. It is only imagination that is your limit and of course the laws of physics that govern the 3D printing process. The main thing to consider here is the support that your object needs during the 3D printing. In order to get best results and use as little material as possible, you would place the object on the printer bed so that it requires as little support as necessary.

Learning Aims:

If you want to be efficient and happy with your final result, it is fine to learn some fundamental things. First a little of photography but this is typically not a big deal since we all are now taking pictures all the time with our mobile phones and cameras. You need photography in order to make a lot of photos for the 3D reconstructions from which you then produce your 3D model. So the next step of learning is 3D reconstruction from the photos. The computer program like the affordable Agisoft (http://www.agisoft.com/) produce the so-called point cloud from which they calculate the 3D object coordinates. Afterwards you export the 3D model directly to the 3D printer or make some fine tuning with a 3D modelling tool. Finally, you need to choose the right filament for the 3D printing process and place the 3D object so that the 3D printer can print it in the most economic and physically feasible way.

Content/Topics:

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We shall cover the design and manufacturing of your own jewellery. We shall start with object that we find around us and try to turn them into the jewellery.

Duration:

In practice it will last one day for your first product to be produced, but then when you have learned the process it will last only several hours.

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Area: Jewellery

Approach 1:

We find objects in our home or in the nature (forest, riverbed etc.) which are beautiful and could be the substrate for our new piece of jewellery. For example, you find an interesting root or an old tree branch or some fruit or seed. The objects can be small or even big like a meter or more in diameter. In case of big objects, you walk around them with your photo camera or mobile phone and take a lot of overlapping pictures. We recommend setting the camera to slow continuous shooting so that it makes around 3 pictures per second. Of course, you can also manually release the shutter or take the pictures with the mobile phone. So, first point the camera to the starting point of the photography process, press the shutter so that it starts to photograph continuously and move camera slowly (about 30 centimetres per second) as if you have spray brush and would like to "paint" the object.

The most important part is to move the camera around, not just to change the angle of the camera at a fixed point. If you start to feel pain in your arm, you can have a rest so that both you and your camera cool down. Also, the change of camera battery is a good suggestion because though the battery is still not completely exhausted, replacing with a fresh full and cool battery makes also the camera cooler. At the end both you and the camera get warm and you have "painted" the whole object thus obtaining typically 200-800 photos. At home you move these photos to your computer which will then be one or several nights busy with the computations related to the 3D reconstruction.

If you have a drone you can let it fly around some building, some hill or some rock and so get the pictures from which you can make your own small pendant of the interesting hill beside your house, for example. For this purpose you set the camera of the drone not to video, but to shooting photographs in a continuous mode and then cover the area like the planes which take photos for production of the maps (https://www.topoflight.com/products/topoflight-mission-planner/)

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In case of smaller objects, you can bring them home and put the object a turntable. You take pictures while rotating the turntable and so get many photos from which the 3D reconstruction software will construct the 3D object. Typically, you rotate the turntable for about 20 degrees, take a photo and so on. You do one sequence with the camera pointing straight, one sequence with the camera pointing downwards and one sequence with the camera pointing upwards. Finally, you photograph the top and bottom of the object.

Alternatively, you can photograph the face of your friend or somebody takes photos of you and you produce the 3D model of the face that can be used to make a piece of jewellery.

In the next step you import the 3D object that is the result of the photo scanning into your 3D modelling software tool. You refine it there and make it beautiful and feasible for the 3D printing process. Finally, you 3D print it or give it to a service for 3D printing.

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Approach 2:

You are 3D printing not the final objects, but the moulds or 3D object that will dissolve during the moulding process. This is called cire perdue method (Lost-wax casting, https://en.wikipedia.org/wiki/Lost-wax_casting). This link describes how it is possible also to retain the original model, but this is not necessary in our case. It is very old and typically the object is done in wax. Around this wax model you put a coat of gypsum and after it dries you pour on the wax model (through a small hole that you left) for example the molten bronze. Hot liquid bronze immediately melts and evaporates the wax and replaces the cavities where there was wax before. So you get a bronze statue instead of the wax statue that you originally sculpted. In older times this was obviously the problem since the sculptor used a lot of time to produce a wax figure that was the lost for ever. However, now with 3D printing we just smile and let our wax 3D model melt since we can immediately 3D print another one. One needs to mention here that classical affordable 3D printers that use filaments cannot print with wax. However, they can print with water soluble filaments. So you can make your temperature resistant coat around the object made with the water soluble filament, then soak everything in water, the filament dissolves and you get the empty cavity where you pour the molten metal. By the way, water soluble filament is much more expensive than the ordinary filament for 3D printing.

3D printing in chocolate was very attractive for me and I thought this is a great opportunity. I checked on youtube about this – you should try yourself, too because it is very funny and interesting – and came to the conclusion that there holds the old saying that the mushrooms often grow faster than our 3D object on the 3D printer bed. So printing chocolate objects directly is simply too slow. In addition, you have the temperature problems so you need a dedicated 3D printer for chocolate or a modified standard printer with heating and cooling etc. In short, I do not suggest to 3D print with chocolate, but instead make moulds of e.g. silicone and so you produce 3D printed chocolate objects indirectly by moulding. This holds also for other kinds of food like biscuits.

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3D printing can be used to produce high detail, custom jewellery. 3D printing can be used to make moulds for jewellery or actual jewellery. Customisable jewellery can be created in many shapes: metal or plastic or even in consumable forms by using for example chocolate.

How to get started:

Our suggestion is to start in one of two ways. If you are a passionate 3D modeller then you start with modelling from scratch. Your imagination is the limit here! We suggest the software tool that our partners use: Zbrush and it has also a free simplified version now. Check www.pixologic.com. On the other hand, if you are more comfortable with your mobile phone or your photo camera than with your computer, you can made 3D objects from your photographs and bring this to your 3D printer or send to a service which does 3D printing. But it makes more fun and you learn more if you 3D print yourself!

The proposed approach is to start by creating the 3D file holding the information about the object to be printed and use an online 3D printing service. This way it will not be necessary to get into the details of the different printing technologies before establishing that jewellery creation is something in which we would like to invest time and money. Use your creativity to make designs and order them online using a 3D printing service like i.materiliase. Using an online service means you only have to deal with the creative part of the process, the actual design and there is no need to worry about production.

Here is how to get started:

- Browse through jewellery images from jewellery makers using 3D printing to see what they have designed and get inspiration [e.g.: https://www.vectary.com/3d-modeling-inspiration/12-jewelry-designers-using-3d-printing-you-should-follow-20e703adfcaa]
- Learn about 3D printing materials mostly used for creating jewellery and consult the design rules for each material. All online printing services should provide such information and rules and through consulting it will be possible to understand which material will give the best result for your design.

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- Learn to use a 3D modelling software. There are numerous options available. Especially for beginners, among the best choices are:
    - TinkerCAD
    - Morphi
    - SelfCAD
    - 3D Slash
    - Sketch Up
    - Leopoly
    - Sculptris
- Find an online service which is easy for you to use and upload and print your design to get a quote

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2. Module 2: Internet of Things:

2.1 Unit 1: Introduction to IoT world

In this unit you will have the opportunity to learn everything that today is there to know about the Internet of things (IoT).

It may seem a very abstract concept and not relevant to someone who is looking for new job opportunities. However, you will discover that the IoT is used by us daily and offers many advantages in truth and the expertise is increasingly requested, even in the female world.

You will deepen:

- the basic concepts of the IoT
- the general application of IoT
- the daily use of IoT (business – farming – smart home – smart cities – public health – in the future)
- the future applications
- the safety and security sector and the use of IoT
- the most relevant workplaces and professional profiles for women

Learning aims

- to learn what does IoT mean generally speaking
- to understand the current application of IoT in our world, daily
- to deepen the current working opportunities especially for women
- to illustrate by examples the definition of the IoT, and how it links the offline with the online world
- to describe in detail how IoT can create value into people's daily lives, therefore providing reasons why it should be implemented
- to identify challenges and opportunities related to the application of IoT into different business fields

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- to learn how to use IoT key concepts to formulate potential models of application for business or daily life
- to instruct and advice about a safe and secure implementation of IoT tools and solutions.
- to know how to apply the IoT approach/perspective to identify a new potential solution for a practical/business problem.

Content/Topics

At the end of this unit you will know more about the main concepts related to the Internet of Things (IoT) and understands how it can bring a change in people's daily lives, capitalizing on its practical applications. The origin of the IoT (history and background), along with the current stock of the situation about its application and the future trends.

Duration

3 hours

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2.1.1 What is IoT?

Definition

According to the Oxford Dictionary, that has recently introduced it, the IoT is "the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data"[32].

The term IoT (Internet of Things) is now part of the current vocabulary; not many people, however, could provide a correct definition of it.

Smart thermostats, smart appliances and connected heating, lighting and electronic devices that can be controlled remotely via computers, smartphones or other mobile devices are now part of our life insofar that soon it will be hard to remember the times we used to live without them.

However, the term was first used only in 1999 by Kevin Ashton, while trying to draw the Procter & Gamble management's attention on his presentation on the Radio Frequency ID (RFID) by adding in it the new buzz word: Internet[33].

If the definition could seem hard to understand and memorise, identifying IoT devices in our daily life is much easier: we constantly make use of devices interacting with each other while collecting data on our habits or health conditions.

The idea of adding sensor and intelligence to basic objects can be traced back to the early '80s, when programmers of the Carnegie Mellon University created the first appliance which allowed to check the status of the Coke machine through the web and assess the availability of a cold drink.

32 Source: Oxford's Dictionary definition of Iot, http://en.oxforddictionaries.com/definition/internet_of_things
33 Source: Web article by Kevin Ashton, available at https://www.rfidjournal.com/articles/view?4986

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2.1.2 Examples of IoT Devices

Internet of Things can be tough to wrap your head around without seeing examples, so here are the top ten IoT gadgets on the market.

Canary Smart Security System

Previously a motion detector was the closest we would get to being informed if there was an intrusion at your house. However, with IoT, home security technology is now much more advanced.

The Canary Smart Security system combines video, audio, motion detection, night vision, a siren, and air quality, temperature, and humidity sensors into a single device that you can control from your phone. If something is detected, you will be alerted on your phone and can check the camera. The system can also act as a speaker. Once the system alerts you that there is someone at the door, you can use the speaker to tell that person to come back later.

https://www.youtube.com/watch?v=PAEQMiAGKJE

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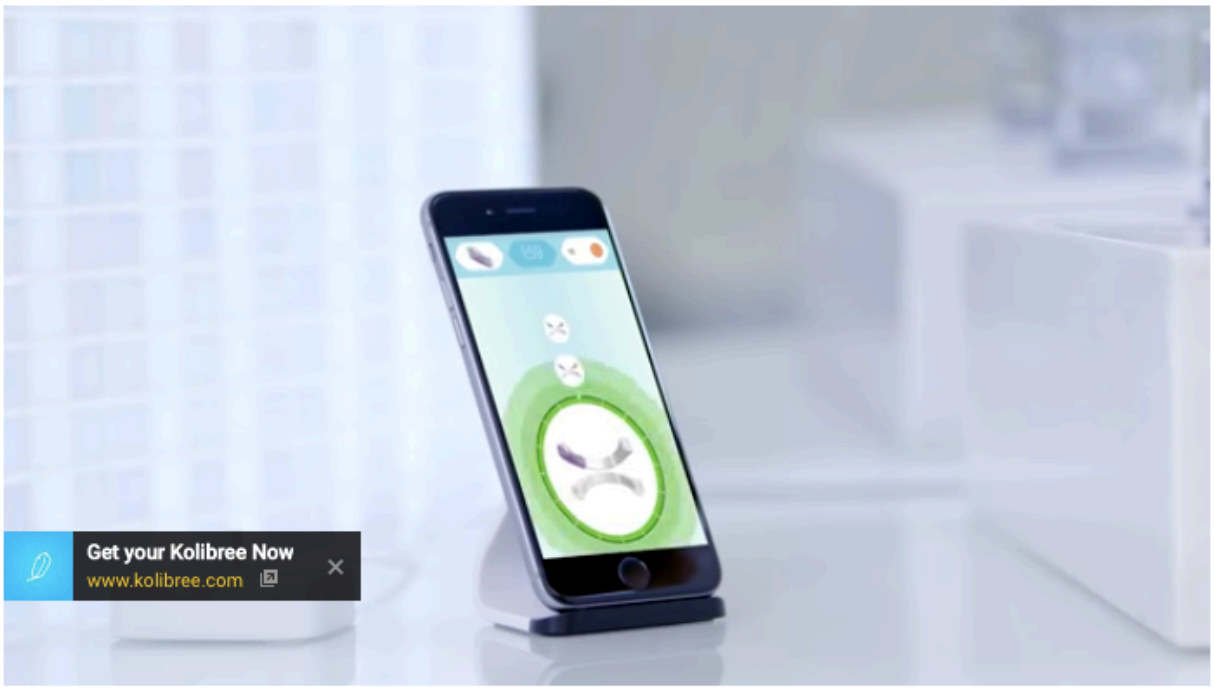
Kolibree Smart Toothbrush

Kolibree is a smart toothbrush which was developed with the intention of encouraging good teeth brushing habits amongst kids and adults. It works by turning brushing your teeth into a game which can particularly help parents with the challenge of getting kids to brush their teeth every morning and night. It also saves data on your phone about your brushing habits.



https://www.youtube.com/watch?time_continue=49&v=XFw6ra4yPWI

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Tile

Tile is a visible 'Tile' that you can hook onto your keys, purse, wallet etc., which links to an application on your mobile. If you lose or can't find your belongings, the app allows you to call your tile, and if you can't hear it, find its location on the map.

https://www.youtube.com/watch?time_continue=31&v=WG7BdW7iFzo

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Petnet Smart Pet Feeder

Why should humans be the only ones to benefit from the Internet of Things?

Petnet's smart feeder helps you calculate the best type of food for your dog or cat, how much they should be eating, and even sets up delivery of pet food for when you run out. You control the smart feeder via your smartphone and can monitor your pet's food consumption even if you're away from home.

Furbo Dog Camera

The Furbo Dog Camera allows you to see your dog at home from wherever you are from your phone. It also allows you to take to them and dispense a treat on demand.

https://www.youtube.com/watch?v=TjOwycbkJDM

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Automatic Car Tracking Adapter

You may have noticed that the previous examples of Internet of Things devices have focused on the home. However, the IoT goes far beyond your home. The Automatic Car app, for example, tracks information about your car by using an in-car adapter.

It keeps track of things like how many miles/hours you have driven, fuel cost, efficiency of the fuel, the location of your car and its ignition status. Many fleet vehicles are now getting IoT capabilities, so they can be monitored and made more efficient, as well.

https://www.youtube.com/watch?time_continue=2&v=_AyXNeRbpRk

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Kisi Smart Lock

Kisi Smart Lock provides a keyless office entry system, since after all, most people could forget their office keys but never their mobile phone. Kisi also provide residential keyless entry systems, although they discovered their niche market was offices and they still push predominantly in that direction.

https://www.youtube.com/watch?time_continue=1&v=8XDPctHkhCk

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Lively Personal Emergency Response System

This product is aimed at those with medical problems. Particularly the residential market where many live alone. The Lively system consists of a watch that the person with medical problems will wear, and if they feel unwell, they can alert their family/friends of this.

It also enables the wearer to alert their family or an ambulance that they require assistance in case of a fall or another mishap. Passive sensors placed around the home can also track activity, enable medication reminders, and send out alerts for things like missed meals or decreased physical activity.

Lively Personal Emergency Response System [34]

[34] Image source: *http://www.getmylively.com/*

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Kohler Verdera Smart Mirror

This IoT example seems like a luxury item for now, but in the future we may all have one of these on the bathroom wall.

The Kohler Verdera Smart Mirror is a new step in technology. Coupled with Amazon Alexa, the Verdera can answer questions, tell you about the weather, and show you notifications from your phone on the mirror. With the popularity of voice already dominating the market, this makes sense as a next step. So, you won't touch the mirror, you will simply talk to it.

The Kohler Verdera Smart Mirror [35]

[35] Image source: *https://www.snyxius.com/7-internet-of-things-examples-show-power-iot/*

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Google Glass

Google Glass, although it is only in Enterprise edition, is one of the most popular technologies to enter and change the world.

Google Glass is essentially a pair of glasses that you wear (without the normal lense) with an optical-head display and it transformed the very understanding of the functionality limits of eyeglasses. In particular, Google Glass was the first product to make it possible to use voice command to search the Internet, find pictures, and interact with the digital world in a number of different ways.

Exactly like a smartphone - but without the necessity of using your hands. And the opportunities to use the innovation in real life are tremendous. For example, you can check the weather or see your flight information right at the moment of entering the airport. Or you could scan the barcode of a product to view all the information about it. Or you could use the navigation system to direct you to a café in a new city - and behave like a local.

https://www.youtube.com/watch?v=4EvNxWhskf8

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2.1.3 Evolution of IoT

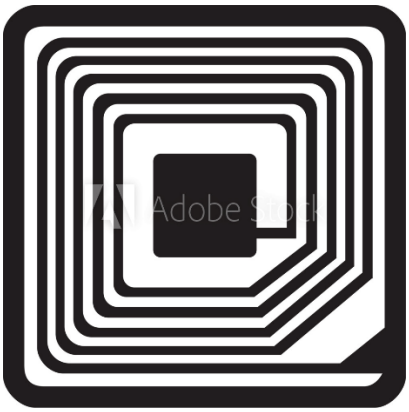
RFID methods utilise radio waves to identify objects, collect data about them, and enter those data directly into computer systems without human intervention.

At a simple level, RFID systems are made of three components:

1. RFID-tag or smart label,
2. RFID-reader,
3. And an antenna.

RFID tags contain an integrated circuit and an antenna, which are used to transmit data to the RFID reader that converts the radio waves to a more usable form of data. These data are then transferred through a communications interface to a host computer system, where they can be stored in a database and analysed at a later time[36] .

You will surely have seen one of these square tags attached on some products like perfumes and liquors and asked yourself what their use was (See Figure);



RFID tag example[37]

[36] Source: Content referred to the website https://www.epc-rfid.info/rfid
[37] Image source: https://stock.adobe.com

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Well, these tags are used for inventory reasons in order to reduce operational costs, track products within the supply chain and prevent tampering as well as thefts.

The addition of RFID tags to expensive pieces of equipment to help track their location was, in fact, one of the first IoT applications.

Since then IoT has evolved from the convergence of wireless technologies, microelectromechanical systems (MEMS), microservices and the internet. The convergence has eliminated the distinction between Operational Technology (OT) and Information Technology (IT), enabling unstructured machine-generated data to be analysed for insights to drive improvements.

This process has been encouraged by the quick drop of costs of adding sensors and an internet connection to objects.

Today the term IoT is mainly used for devices that aren't originally designed for having an internet connection (for this reason, PCs, smartphones or tablets cannot be considered IoT) and that can communicate with the network independently of human action. Now pretty much any physical object can be transformed into an IoT device if it can be connected to the internet and controlled that way.

In the broadest sense, the term IoT encompasses everything connected to the internet, but it is increasingly being used to define objects that "talk" to each other.

IoT APPLICATIONS

The IoT was initially most interesting to business and manufacturing, where its application is sometimes known as machine-to-machine (M2M), but the emphasis is now on filling our homes and offices with smart devices, transforming it into something that's relevant to almost everyone.

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IoT is more than smart homes and connected appliances, however. It scales up to include smart cities and industry, with connected sensors for everything from tracking parts to monitoring crops.

There are numerous real-world applications of the internet of things, ranging from consumer IoT and enterprise IoT to manufacturing and industrial IoT (IIoT). IoT applications span numerous verticals, including automotive, telecommunications, energy and more.

An IoT ecosystem is made of web-enabled smart devices that use embedded processors, sensors and communication hardware to collect, send and act on data they acquire from their environments. IoT devices share the sensor data they collect by connecting to an IoT gateway or other edge device where data is either sent to the cloud to be analysed or analysed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another. The devices do most of the work without human intervention, although people can interact with the devices.

HOW DOES IoT WORK?

A complete IoT system integrates four distinct components:

1. sensors/devices,
2. connectivity,
3. data processing,
4. a user interface.

Sensors or devices collect data from their environment, whether simple as temperature reading or complex as a full video feed.

Multiple sensors can be bundled together, or they can be integrated in a device like a smartphone, which has multiple sensors (camera, accelerometer, GPS, etc.), but is not just a sensor.

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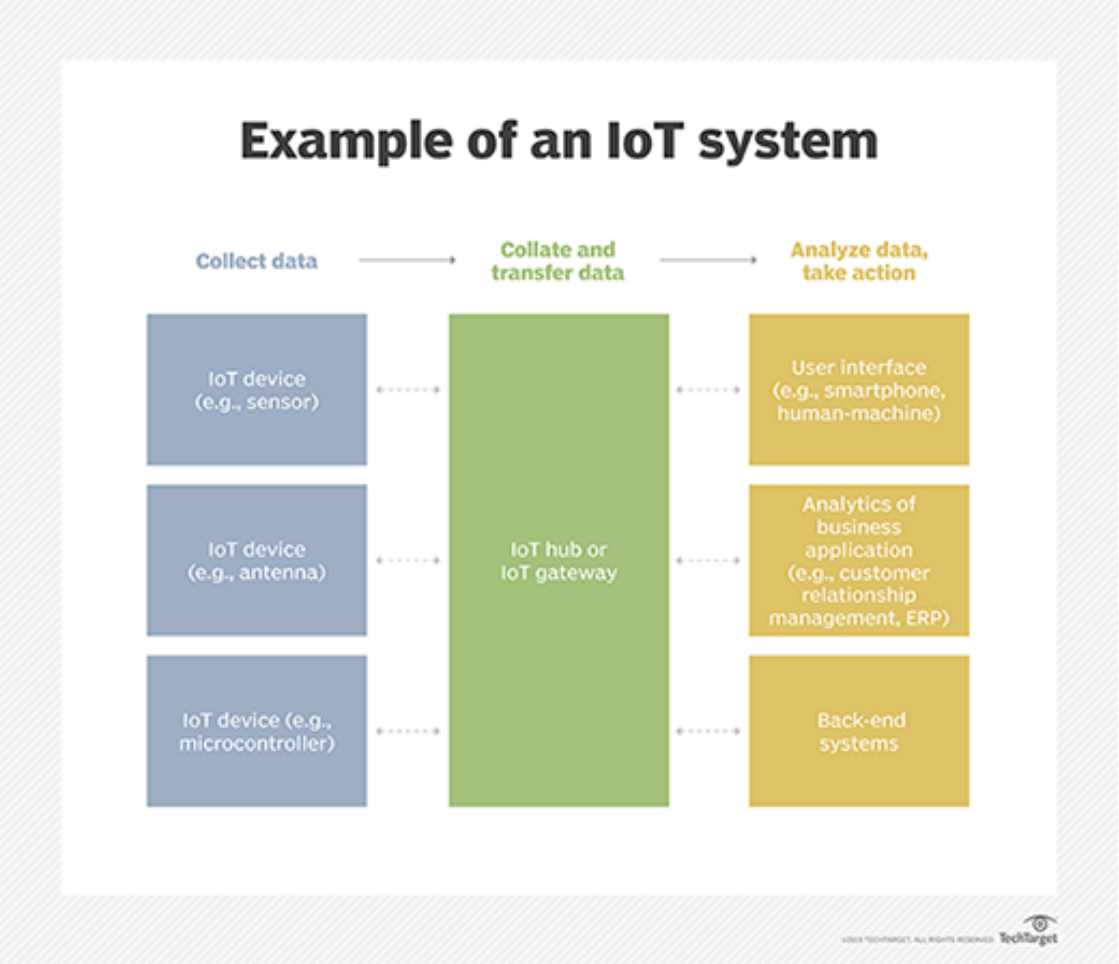
Next, that data is sent to the cloud through a variety of methods including: cellular, satellite, WiFi, Bluetooth, low-power wide-area networks (LPWAN, that is a type of wireless telecommunication wide area network designed to allow long range communications at a low bit rate among things (connected objects), such as sensors operated on a battery), or connecting directly to the internet via Ethernet[38].



Example of an IoT system functioning [39]

[38] Source: Web article, https://medium.com/iotforall/iot-explained-how-does-an-iot-system-actually-work-e90e2c435fe7
[39] Image source: https://www.techtarget.com

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The choice of the best connectivity option to get data to the cloud depends on the specific IoT application, but they all accomplish the same task.

Once the data gets to the cloud, they are processed by a software that could check, for example, whether the temperature reading is within an acceptable range, but that could also implement more sophisticated activities, such as using computer vision on video to identify objects (such as intruders in your house).

Next, the information is made useful to the end-user, through, for instance, a temperature alert on the company's cold storage sent by email.

The user interface, finally, enables him/her to proactively check in on the system.

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2.1.4 How is it changing our daily lives?

BUSINESS

IoT is now portable, wearable, and implantable, creating a ubiquitous and connected universe, where physical objects that surround us are transformed into an ecosystem of information. This dramatically impacts the way we live. Almost every industry has working processes that are affected by IoT technology.

This effect is not surprising if we consider that, as described in the first paragraph of Unit 1, the IoT was initially conceived mainly for business and manufacturing, where its application is sometimes known as machine-to-machine (M2M).

The Internet of Things offers a number of benefits to organisations, enabling them to:

- monitor their overall business processes;
- improve the customer experience;
- save time and money;
- enhance employee productivity;
- integrate and adapt business models;
- make better business decisions;
- generate more revenues.

IoT encourages companies to rethink the ways they approach their businesses, industries and markets and gives them the tools to improve their business strategies, insofar that companies are already moving a step forward, towards the Internet of Everything (IoE), a network connection that encompasses machines, individuals, processes and data that can have a huge impact in our daily lives.

More precisely, the term IoE is described as "the intelligent connection of people, process, data and things. " Because in the Internet of Things, all communications are between machines, IoT and M2M are sometimes considered synonymous. The more expansive IoE

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concept includes, besides M2M communications, machine-to-people (M2P) and technology-assisted people-to-people (P2P) interactions.

A three folds growth has made logistics and supply chain management the most receptive industry towards IoT. This is enabling companies to monitor products throughout the supply chain (asset tracking), collect real-time data to monitor and analyse vehicle performance, driver conduct and track vehicles and the load (fleet management) or track inventory[40] .

The supply chain process [41]

By the way, the revolution brought by the IoT isn't limited to business: nowadays its application has invested all sectors, from business to farming and city management[42].

[40] Source: Web article, http://dataflog.com/read/how-iot-will-transform-logistics-industry/5230
[41] Image source: : http://supplychaintechnews.com/index.php/articles1/119-technology/12164-supply-chain-visibility-with-iot
[42] Source: Maciej Kranz, "*6 ways the Internet of Things is improving our lives*", available at https://www.weforum.org/agenda/2018/01/6-ways-the-internet-of-things-is-improving-our-lives/

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FARMING

In agriculture IoT applications include farm vehicle tracking, livestock monitoring, storage monitoring and other farm operations. IoT is applied in agriculture in general, in arable farming, in fisheries and aquaculture, in animal food consumption, in agri-food supply chain, in green house horticulture and livestock farming.

Applying the IoT, farmers can optimize the use of inputs and decrease production costs. Other benefits include: saving costs by effectively using inputs, better monitoring of crops and avoiding crop losses through disease or adverse weather, optimization of water use and better planning of farm activities[43].

The most popular smart agriculture gadgets are probably weather stations, which combine various smart farming sensors. Located across the field, they collect various data from the environment and send it to the cloud. The provided measurements can be used to map the climate conditions, choose the appropriate crops, and take the required measures to improve their capacity.

Like FarmBot, humanity's first robot farmers for home, educational, and commercial use, 100% Open-Source and a very great example in the field.

[43] Source: Web article available at http://www.fao.org/e-agriculture/news/possibilities-internet-things-iot-agriculture

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SMART HOME

Any device at home that uses electricity can be put in the home network at the user's command, enabling the home to "react" to orders given by voice, remote control, tablet or smartphone.

The diffusion of smartphones with their constant Internet connections implies the possibility of controlling myriad of online devices.

Most IoT home applications relate to lighting, home security, home theatre and entertainment and thermostat regulation.

Smart buildings can, for instance, reduce energy costs using sensors that detect how many occupants are in a room. The temperature can adjust automatically – switching the air conditioner on or the heating down depending on the number of the room's occupants.

Another concrete example are smart home security systems. The basic options are usually just cameras that can access remotely and an alarm that can be set from the phone. Users can then upgrade the tool by adding smart locks, allowing, for example, kids leaving earlier or a repairman to enter home.

SMART CITIES

Nowadays cities are great incubators for IoT-based systems that increase the urban quality of life providing fast, efficient and cost-saving transportation systems, smart and safe street lighting and energy-efficient buildings.

The IoT has proved to be tremendously effective in time and energy consumption reduction (namely money), insofar that it is gaining increasing attention by governments and public administrators.

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With budget getting lower every year, inefficiencies and money waste, solutions like energy management technologies or smart security applications allow municipalities to save money while providing better services to their citizens.

In a smart city, IoT sensors and deployments, such as smart streetlights and smart meters, can help save energy, reduce traffic, address environmental concerns and improve sanitation.

The Barcelona municipality is able to provide smart water technology, automated street lighting, irrigation for parks and fountains and smart transport solutions. This results in the reduction of traffic jams and pollution, as well as water, light and energy usage.

All of this is thanks to a citywide Wi-Fi and information network linked to sensors, software and a data analytics platform.

There is also with the action taken for improvement of public health which aims to address the 9 million deaths caused by polluted air and water only in 2015. Cities like Delhi and Beijing have put in place sensor networks designed to alert residents when levels of pollution are dangerously high.

In London, Drayson Technologies has been testing sensors that are distributed to bicycle couriers and a fleet of fuel-cell cars within a strategy to tackle the 9,000 deaths per pollution registered every year.

PUBLIC HEALTH

Healthcare is another promising field for IoT: a simple wearable device, like a smart watch, can monitor blood pressure and heart frequency and alert its owner when detecting anomalies.

This will eventually save lives. More sophisticated devices enable closer monitoring of patients and the possibility to analyse the collected data.

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Nonetheless, IoT devices are effective also in health management tasks, such as inventorying, a crucial activity in hospitals.

Healthcare workers are finding new solutions for profound challenges thanks to the development of mobile solutions. In response to the 2015 Ebola outbreak in West Africa, various medical device companies joined together to test a patch with integrated sensors to track vital signs.

The device reduces physical interaction with people who may be infected, transmitting data only via Bluetooth.

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2.1.5 What can we expect from IoT in the future?

While IoT is considered in its infancy there are significant security issues that need to be addressed.

A report from Samsung says the need to secure every connected device by 2020 is "critical". The firm's Open Economy document says, "there is a very clear danger that technology is running ahead of the game[44] ". The firm said more than 7.3 billion devices will need to be made secure by 2020.

Another downside of integrated internet connection is hacking: everything that is connected can be exposed to cyber-attacks and IoT products are no exception to this rule. This possibility is anything but science fiction: insecure IoT systems already led toy manufacturer Vtech and this causes harm done to the privacy of children that used Vtech's connected devices, by leaked videos and pictures of them.

Despite worrying scenarios, nowadays IoTs is mainly used for the purpose it was conceived for: business. Indeed, the three industries which are expected to spend the most on IoT in 2018 are manufacturing (€ 169 billion), transportation (€ 74 billion), and utilities (€ 64 billion). Manufacturers will largely focus on improving the efficiency of their processes and asset tracking, while two-thirds of IoT spending by transport will go toward freight monitoring, followed by fleet management.

[44] Source: Samsung's "Open Economy" report 2017, https://samsungatwork.com/files/Samsung_OpenEconomy_Report.pdf

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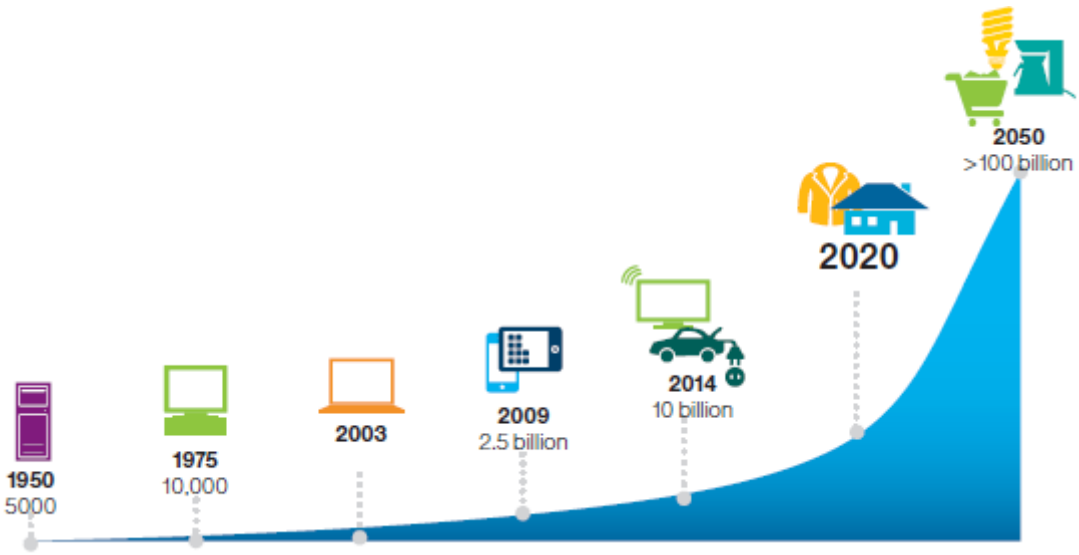
2.1.6 What to expect in the future / future applications

IoT represents an entirely **new approach to the computing world**, whose expansion has inevitably overcome the analogic and non-digital world. Computing is already widespread in many devices from kitchens to cars, but soon even apparently "minor" objects like doorknobs or light bulbs will get as much of computing power and capacity as our smartphones. The growth of inexpensive general computing devices is going hand in hand with the growing availability of sensors and actuators, that are today cheap enough to be embedded in a device even if not strictly necessary. Huge advances in cloud computing, enable storage and analytics of vast data amounts generated by these sensors. As a consequence, fuelled by ubiquitous connectivity and the availability of billions of IP (*Internet Protocols*) addresses, the number of connected devices is expected to surpass 25 billion in 2020 and 100 billion in 2050[45] (see figure).



Number of inter-connected devices worldwide over a century

[45] Source: IBM Institute for Business Value, *Device Democracy – Saving the future of the IoT*, available at https://www-01.ibm.com/common/ssi/cgi-bin/ssialias?htmlfid=GBE03620USEN

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According to a European Commission study[46], the market value of the IoT in the EU is expected to exceed one trillion euros in 2020. As such, the definition of ad-hoc EU policies and strategic plans on this field has been extensive and attentive. 2015 has been a crucial year in this sense, as two significant initiatives were triggered:

- In March 2015, the **Alliance for Internet of Things Innovation** was launched by the European Commission to support the creation of an innovative and industry driven European Internet of Things ecosystem. This highlights the intention of the EC to work closely with all Internet of Things stakeholders and actors towards the establishment of a competitive European IoT market and the creation of new business models. Today the Alliance for Internet of Things Innovation is the largest European IoT Association.

- In May 2015, the **Digital Single Market Strategy** was adopted. The Digital Single Market strategy includes elements which lead Europe a step further in accelerating developments on Internet of Things. In particular, the strategy underlines the need to avoid fragmentation and to foster interoperability for IoT to reach its potential[47].

IoT will be disruptive in its application to business processes within and across industrial sectors. The convergence within the traditional *Information Technology* (IT) and *Operation Technology* (OT) will be empowered with the real-time monitoring capabilities bestowed by Big Data. This will give birth to **Smart Environments**, where data intelligence and hyper-connectivity are set to generate multiple new services (also with other technologies like, for example, Cloud Computing, Robotics and AI).

The desired IoT ecosystem envisaged by the EU should produce a significant shift from the strong vertical market component of today's implementations (often strictly industry-specific) towards the development of horizontal IoT platforms, ensuring open standards and high

[46] Source: web article available at https://ec.europa.eu/digital-single-market/en/news/definition-research-and-innovation-policy-leveraging-cloud-computing-and-iot-combination
[47] Source: Web article available at https://ec.europa.eu/commission/priorities/digital-single-market/

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interoperability. There are several forces pushing from the demand side, driving the evolution of IoT ecosystems, such as:

Demographic trends: IoT solutions like remote monitoring, telemedicine practices and other mobile applications are emerging to cope with the ageing population of Europe and the Western World in general, accompanied by the raising costs of health services and hospital care.

Environmental consciousness: appropriate IoT applications can give remarkable results in terms of energy costs saving such as the minimization of power costs, carbon output and hazardous waste, thus catering for the raising eco-consciousness of a growing number of social actors.

Public sector driving role: the public sector as a whole is playing a major role in the IoT market around smart cities initiatives, public transportation and transport, tourism, public safety, and military programmes, helping to make better and timelier public management decisions.

Business demand: IoT offers the potential to both increase efficiency (for example, through the automation of support to remote equipment) and create new business opportunities (by capturing data that was previously lost or unavailable).

Consumers demand: IoT also opens up the potential for businesses to develop new relationships with consumers, establishing innovative and efficient B2C (Business-to-Consumer) plays.

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In the near future, penetration of smartphones, tablets, and other mobile devices will be almost universal, enabling citizens and workers to access a range of applications and complete a wide variety of actions that are today not possible in all areas. Enabling this will imply a wide range of things connected to networks, with sensors that allow data to be collected and analysed, insight to be gained, and action triggered either in conjunction with people or autonomously. The hyper-connected society is set to be an established reality, and most of the "things" that can be connected, will be within the upcoming years.

As the number of connected devices grows from billions to hundreds of billions, and as governments and corporations strive to take control of devices and data, the giant "IoT machine" will need to be protected from abuses and improper implementation. This "rescue" will require business and technology leaders to fundamentally rethink technology strategy by building solutions for radically lower cost, safeguarding privacy and autonomy of the users. Business models that guide these solutions must embrace highly efficient digital economies and create collaborative value, all while delivering improved products and user experiences.

As we are set to shift from a billion smartphones toward hundreds of billions of smart devices, the scale of opportunity from the IoT becomes more and more evident. After over 50 years of gradually growing penetration, most of the global economy is still considered to rely in industries that are not "IT-intensive." Many of these (like agriculture, transportation and logistics) have not historically fit well with personal computers requiring desks and offices. Here is where the IoT holds the truly potential to be a game-changer.

A good explanation of what above mentioned is perfectly resumed here in the following picture. (see figure).

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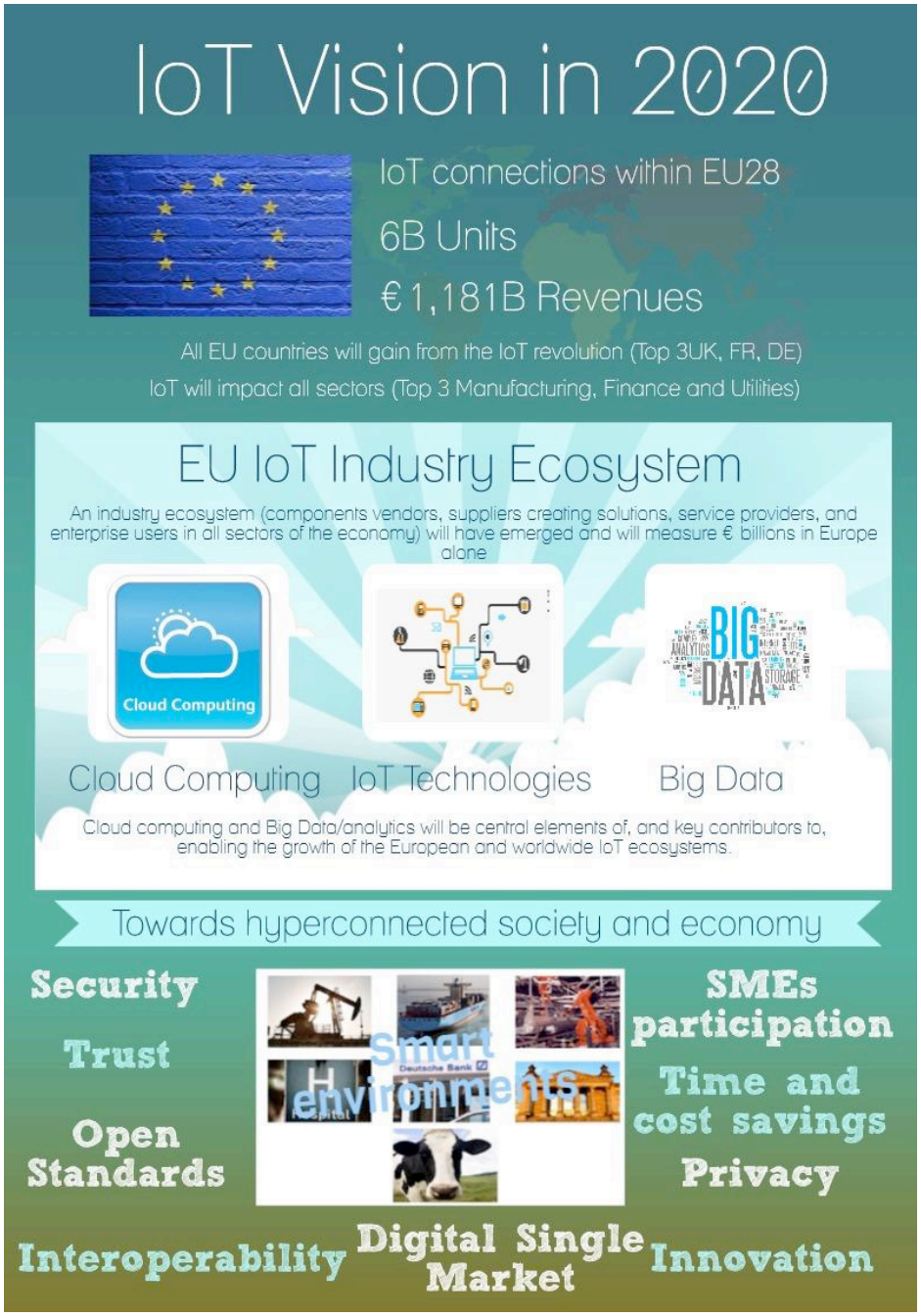

IoT Vision in 2020 [48]

[48] Image source: Source: "Definition of a Research and Innovation Policy Leveraging Cloud Computing and IoT Combination", IDC, 2009

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2.2 Unit 2: IoT in Practice

2.2.1 Using IoT safely

A safe and secure world enabled by the Internet of Things envisages the development of a truly connected environment, where an effective interaction between things and people is put in place to improve the overall quality of life. The predicted pervasive introduction of sensors and devices into currently intimate spaces (such as the home, the car, and with wearables and ingestible, even the body) poses particular challenges. As physical objects in our everyday lives increasingly detect and share observations about us, consumers will likely demand for **enhanced privacy frameworks**.

While IoT might bestow considerable financial benefits to IT manufacturers and meet the increasing 'hunger' of consumers for cutting-edge devices, it might at the same time broaden the potential attack surface for hackers and other cyber criminals. Indeed, more devices online means more devices that will require protection, and the IoT systems are not always designed for particular cyber-attacks, as the sophistication of their activities is constantly increasing and adapting to the latest technological advancements. **Data breaches** are a tangible risk that will have to be faced (see figure).

Data breach [49]

[49] Image source: https://revisionlegal.com/data-breach/2018-statistics

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What is necessary to make IoT more reliable is to anticipate potential threats and hazards that may arise when IoT devices and systems are connected and then introduce countermeasures for them. As every part of an IoT system must be secured to provide security to its users and other users of the Internet, a layered and continuous approach to security is required.

Security should be enforced in IoT throughout the development and operational lifecycle of all IoT devices and hubs. The security challenges of IoT can be broadly divided into two classes:

1. *Technological challenges*, which arise due to the heterogeneous and ubiquitous nature of IoT devices, typically related to wireless technologies, scalability, energy, and distributed nature.
2. *Security challenges*, related to the principles and functionalities that should be enforced to ensure a secure network, namely authentication, confidentiality, end-to-end security and integrity of the system.[50]

Software running on IoT devices should always be authorized, and, when turned on, the device should first authenticate into the network before starting sending/collecting data. It is crucial to guarantee that the data is secure and only available to authorized users. Users in IoT can be human, machines and services, categorized as internal objects (devices that are part of the network) and external objects (devices that are not part of the network). It is important for the users of IoT to be aware of the **data management mechanisms** applied, the process or person responsible for the management, and to ensure that the data is protected throughout the whole process.

It is of the utmost importance to safeguard the accuracy of the data exchanged, since it comes and goes across a considerable number of devices and intended/unintended interference might tamper the information load. Therefore, the **integrity** feature can be imposed by

[50] Source: Web article available at https://www.riverpublishers.com/journal/journal_articles/RP_Journal_2245-1439_142.pdf

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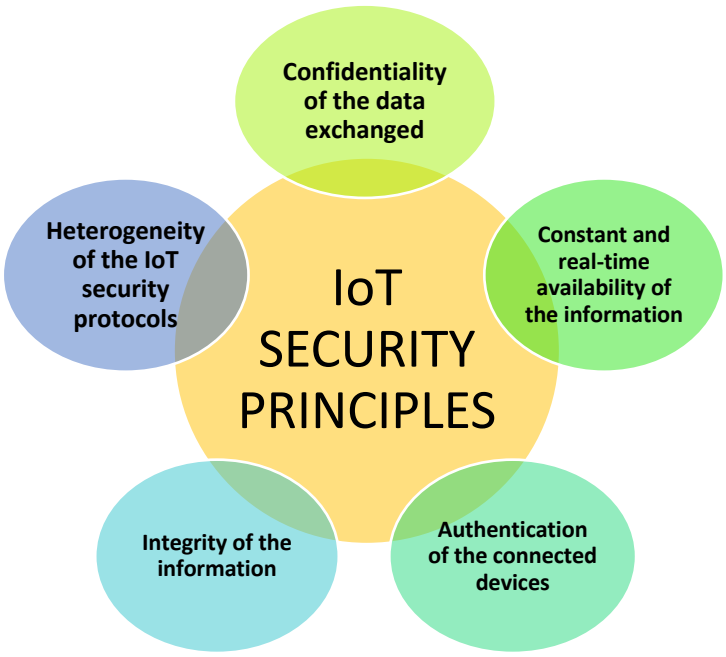
maintaining end-to-end security in IoT communication, and the data traffic can be managed by setting up particular firewalls and protocols.

IoT protocols, by the way, have to be designed in order to be effective in different devices and situations. Devices connected to a same network, in fact, may easily have different dates and release versions, use different interfaces and bitrates. In sum, they might be developed with totally different functions, which the protocol should be good enough to mix together without major conflicts.



As above mentioned in the diagram, security provisions foreseen since the design stage is essential and cannot be thought as an add-on of the IoT system. It has to be carried out all the way through to implementation and support. To this end, five different but consecutive steps can be outlined when dealing with the security issue of IoT systems:

1. **Secure booting**: When the device is started, the authenticity and integrity of the software on is verified through digital signatures cryptographically generated. Largely

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as a person signs a check or a legal document, a digital signature embedded into the software and verified by the device ensures that only the software that has been authorized to run on that device, and signed by the entity that authorized it, will be loaded. Thus, the foundation of trust has been established, but the device still needs protection from other threats and menaces which can appear while running.

2. **Access control**: Next, different forms of resource and access control are applied. Mandatory access controls built into the operating system limit the privileges of device components and applications, so they can only access the device's resources they need to do their jobs. If any component is compromised, access control encloses the threat into a 'security area' preventing it to spread.

3. **Device authentication**: Before receiving or sending data, the device has to authenticate itself when connected into a network. Some devices work automatically and with no human intervention, and this implies the requirement to guarantee that they identify correctly before being authorized. This is called 'machine authentication', still working with a set of credentials stored in a safe storage area.

4. **Firewalling and IPS**: Firewalls and IPS (*Intrusion Prevention Systems*) are security/threat prevention technologies that examine network traffic flows to detect and prevent vulnerability exploits. Attackers can disable the target application (resulting in a denial-of-service state) or can potentially access to all the rights and permissions available to the compromised application. Deeply embedded devices have unique protocols, distinct from enterprise IT protocols. The network appliances take care of filtering the Internet traffic, while the device needs to filter the specific data entering itself in a way that makes optimal use of the limited computational resources available.

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5. **Updates and patches**: Working devices constantly receive patches and software updates. As developers release patches, devices will need to authenticate them. Software updates and security patches must be delivered in a way that preserve the limited bandwidth and irregular connectivity of an embedded device and significantly cleans out the possibility of compromising functional safety.[51]

The security of a system is only as good as its weakest link.

From this overview, it seems clear that security in IoT requires particular expertise to be implemented. Furthermore, many of the recent IoT players may have scarce or no previous experience with internet security, which is complex and requires additional competences when applied to IoT systems. Competitive pressures for shorter times to market and cheaper products drive many designers and manufacturers of IoT systems to devote less time and resources to security. Strong security can be expensive to design and implement, and it might extend the time it takes to get a product to market. The commercial value of user data also means that there is an incentive to store as much data for as long as possible, not exactly what you call a good data security practice. Additionally, there is currently a shortage of credible and well-known ways for suppliers to signal their level of security to consumers. This makes it difficult for consumers to compare the security of competing IoT systems, which results in lower consumer pressures for strong security and makes it challenging for suppliers to use security as a competitive differentiator. Further, the cost and impact of poor security tend to fall on the consumer and other Internet users, rather than on the producers of the vulnerable IoT system.

[51] Source: *Security in the Internet of Things*, Wind River Systems Inc., 2015, Lessons from the Past for the Connected Future
https://www.windriver.com/whitepapers/security-in-the-internet-of-things/wr_security-in-the-internet-of-things.pdf

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The world-renowned IT company IBM has created a model for the IoT that is useful for understanding the security threats existing at various data flow and control transition points. As it is showed in the figure below, the model displays the various layers where security issues have to be monitored, starting from the actual user until the action reaches the "things".

IBM's security model argues that the following items will be needed for IoT implementations:

1. A secure OS with firmware guarantees
2. Unique identifiers
3. Authentication and access control
4. Data privacy protection
5. Strong application security.[52]

These security items will need to be stretched across the whole IoT implementation, involving users, controlling device, cloud service, global network, local network and finally things.

[52] Source: Web article, https://www.zdnet.com/article/internet-of-things-poised-to-be-a-security-headache/

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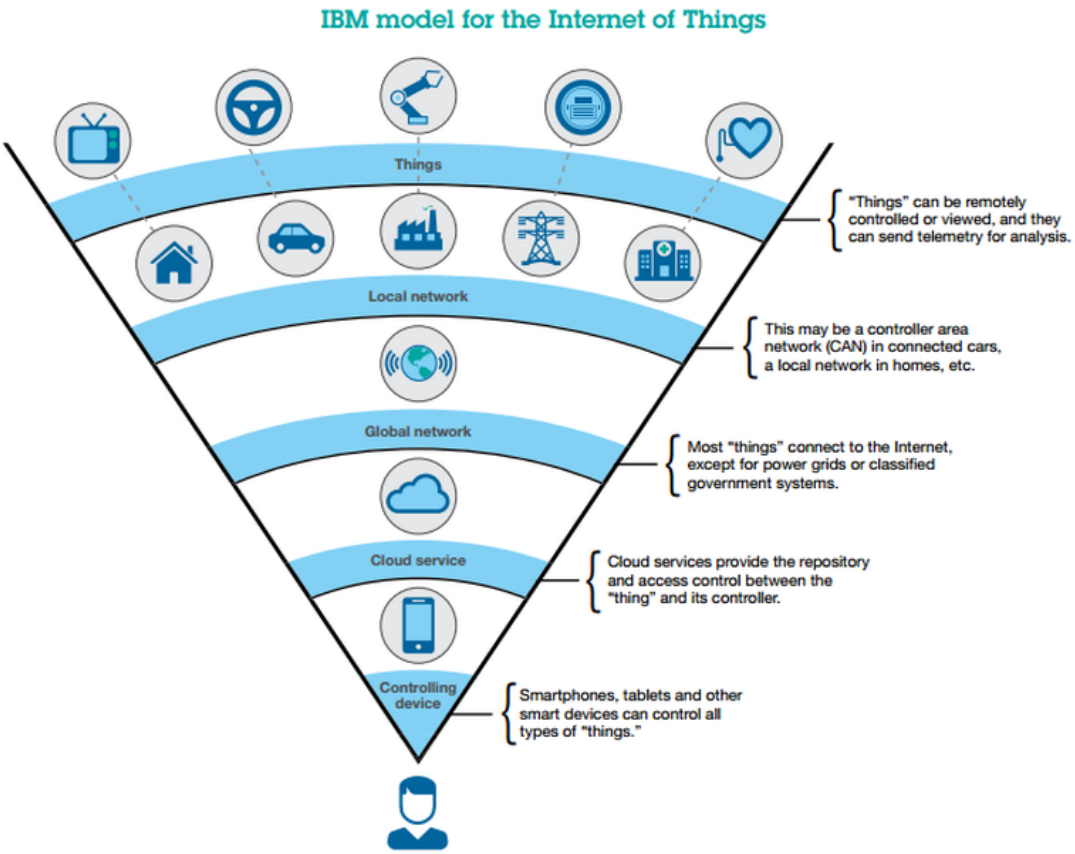

IBM IoT model [53]

The IBM model (web article, https://www.ibm.com/internet-of-things) demonstrates how security should not be seen as a one-off single activity, but rather as an evolving part of the IoT ecosystem. In this respect, managing the lifecycle of security components across device and cloud spectrum is paramount for a strong and long-term digital security strategy. Add new devices, integrate them into a new cloud system, disconnect old devices at the end of their life, manage secure firmware downloads and updates are all activities that need a thorough security monitoring events.

[53] Source: https://www.ibm.com/internet-of-things

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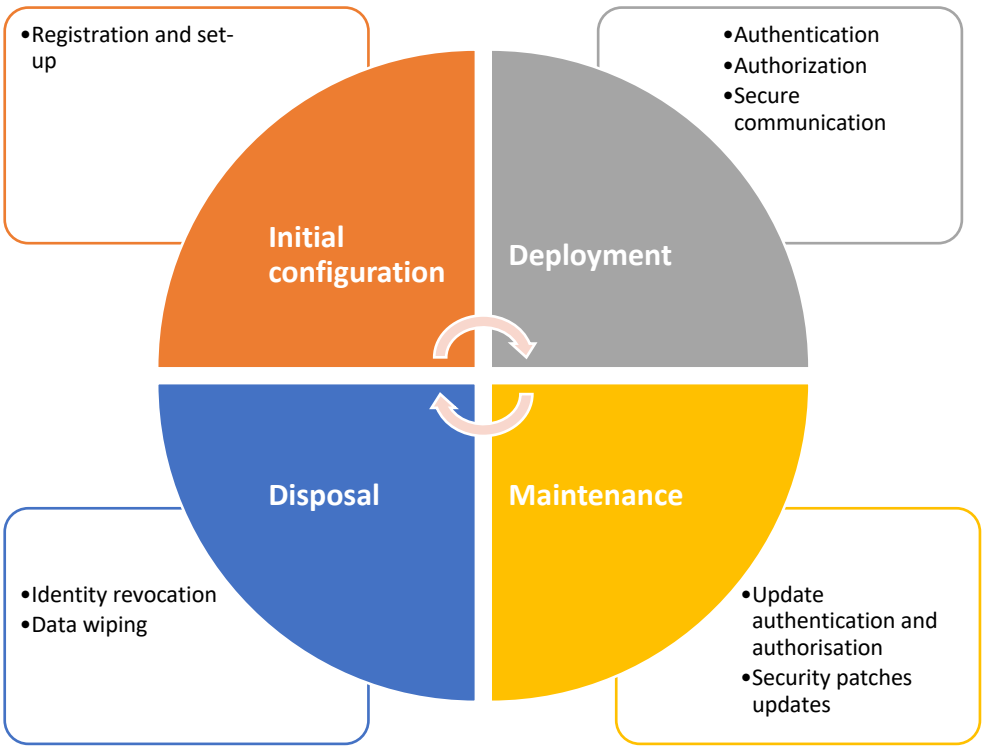
2.2.2 IoT devices Security Lifecycle Management



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2.2.3 Relevant workplaces and professional profiles

The digital evolution of our society has involved many sectors, which take advantage of new technologies to increase their possibilities for interaction and control.

The Internet of Things (shortened IoT) is the result of this transformation, because it made sure to give an intelligence to things thanks to the use of the internet.

Due to the internet connection, the latest generation objects can communicate data to a human being who, in this way, has more and better possibilities of interaction with smart objects. This creates a relation between objects, the outside world and people. Practical examples include, some refrigerators can send an alert to your smartphone in case you miss a product on your weekly shop or are running low on milk. The sneakers memorize the training time, the car detects the traffic and suggests an alternative route, the watch identifies the heartbeat and sends it to a server for medical storage and medical instruments report the exact time of administration and inform if this has not occurred, and so on.

When speaking of smart objects, it is easy to understand how new businesses, related to them, are appearing on the labour market.

According to an analysis conducted by the McKinsey Global Agency[54] 60% of the total jobs can be automated and for them at least 30% of the functions. Worldwide there are 1.2 billion jobs replaceable - in whole or in part - with the technologies available today on a commercial level. The overall total of the salaries involved is 14.6 trillion dollars. In five examined European countries - France, Germany, Italy, Spain and the UK - there are 54 million full-time jobs that have to be renovated due to this technological revolution, equal to a total salary of 1,700

[54] Source: Web article appeared in June 2015 on the McKinsey&Company blog, a global management consulting https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world

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billion. However, these classifications do not include already existing but still experimental technologies, such as unmanned cars or drones for human transport.

Still, the McKinsey Global Institute states that "in 2065 a number of additional jobs will have been reached between 1.1 and 2.3 billion, the important thing is that governments become aware of the extent of change and collaborate with companies in reprogramming of workers' training ".

Regarding furthermore the most relevant workplaces, it has to say that the major research companies, such as Accenture among others, argue that more than 25 billion IoT devices will arrive by 2020. Many industry actors believe that the number will be greatly exceeded. Everyone generally speaking, states that IoT is already, and will increasingly be, a significant opportunity for business and job creation[55].

In a somewhat risky way, however, can we say that whoever more than women can be suitable for change and flexibility? Multitasking in private life and flexible in working life. Always trying to combine family commitments with work.

A myth that needs to be debunked is that the Internet of Things is a complete masculine domain, in which men control the roles of power and direction. Also, in this sense, the IoT has partly changed the perception of the engineering and technological sector, because the number of women who hold positions of control, management and responsibility in this field are constantly increasing. On the other hand, it is undeniable that, even in the university context, women are increasingly choosing faculties that were once predominantly frequented (in some cases exclusively) by men only. All classes of engineering, mathematics, physics and, in general, the scientific disciplines, are today full of women. They are, in fact, ready to carve out their role, with results often better than men, even if their number still remains in a clear minority compared to that of male colleagues. Scientific and engineering studies are often the

[55] Source: Content referred to the website www.internet4things.it

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basis of the career in the Internet of Things, where many projects are now followed and developed in first person by women.

Which Country Has the Largest Proportion of Female Developers?

Share of HackerRank Tests

Rank	Country	Female	Rank	Country	Female
1	India	22.9%	26	France	9.4%
2	United Arab Emirates	21.0%	27	Switzerland	9.0%
3	Romania	20.6%	28	Egypt	8.9%
4	China	19.6%	29	Netherlands	8.3%
5	Sri Lanka	19.0%	30	Greece	8.3%
6	Italy	16.7%	31	Belarus	7.8%
7	Bulgaria	16.5%	32	Russia	7.8%
8	Singapore	15.2%	33	Spain	7.4%
9	Philippines	15.1%	34	Germany	7.4%
10	Indonesia	15.0%	35	Portugal	7.2%
11	United States	14.8%	36	Turkey	6.7%
12	New Zealand	14.6%	37	Colombia	6.5%
13	Malaysia	14.4%	38	Pakistan	6.5%
14	Hong Kong	13.8%	39	Mexico	6.3%
15	South Korea	13.6%	40	Venezuela	6.3%
16	Israel	12.9%	41	Belgium	6.0%
17	Japan	12.8%	42	South Africa	5.9%
18	Ukraine	12.6%	43	Brazil	5.8%
19	Bangladesh	11.9%	44	Sweden	5.7%
20	Canada	11.4%	45	Austria	5.4%
21	Vietnam	11.3%	46	Hungary	5.0%
22	Australia	10.7%	47	Argentina	4.5%
23	United Kingdom	10.3%	48	Czech Republic	4.5%
24	Poland	10.2%	49	Denmark	3.3%
25	Ireland	9.7%	50	Chile	2.9%

HackerRank

This is a breakdown of the share of female developers from each of the top 50 countries with the most developers on HackerRank [56]

[56] Source: https://blog.hackerrank.com/which-countries-have-the-most-skilled-female-developers

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Based on latest figures collected by a study of I-COM (Institute for Competitiveness), in three years the value of the European market of the IoT devices will raise up and will achieve around 80 billion euro by 2020[57].

This means that, surely, new job opportunities are overbearing in the field of digital and hi-tech innovation and could lead all jobs seeker towards this way.

In Italy, along with France, Germany and UK, the market of IoT objects will be one of the most active in 2019.

[57] Source: Web article on the the blog Libero/Tecnologia based on the Report "The impact of digitalization on business-to-consumer relationship", I-com (2017) https://tecnologia.libero.it/iot-mercato-in-forte-crescita-nel-prossimo-triennio-13170,

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2.2.4 Successful Women in Tech

This market is not a barrier anymore to women: as stated by the Top 50 Women in Tech in 2018[58]. Many business women are facing the high-tech world and there are many female success stories which also inspire the next generation of female technology pioneers.

For example, Diva Tommei, Italian, 34 years, founder and CEO of Solenica[59], a hi-tech project very innovative: she invented Caia, the lamp that reproduces sunlight in homes and offices simply by following the sun. Thanks to crowdfunding, the project has been launched and spread in a very short time. She also has been "Inspiring Girls"[60] acting as a Role Model in Italy, developing a communication platform dedicated to raising the aspirations of young girls around the world by connecting them with other female role models.

Diva Tommei, Italian, 34 years, founder and CEO of Solenica[61]

[58] Source: Web article with a list gathering all the best 50 Women influencers between entrepreneurs, managers and engineers https://www.forbes.com/top-tech-women/#15bcc214df03,.
[59] Source: content drafted from a website with the showing up the the domestic tool invented by the Italian woman https://solenica.com/
[60] Source: content drafted from a communication platform dedicated to raising the aspirations of young girls around the world by connecting them with female role models https://inspiring-girls.com
[61] Image source: http://www.lastampa.it/2017/01/23/tecnologia/questa-ragazza-accender-il-sole-in-casa-vostra-mZO1by20f8noXDX3luXcFM/pagina.html

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Limor Fried, founder of Adafruit

Limor Fried is another successful woman in the IoT sector. She founded her company called, Adafruit, back in 2005 when she was at university and has now grown the business into a successful hardware company.

Limor Freid, founder of Adafruit [62]

Adafruit aims to help individuals learn about engineering so that they can build their skills to enter jobs in the STEM sector (Science, technology, engineering and mathematics). It does this by providing DIY kits including IoT starter kits and showing you how to make your own phone charger.

Fried is an accomplished engineer and has been given many awards during her career, including the White House Champion of Change in 2016, receiving Entrepreneur's "Entrepreneur of the Year" award, and being the first female engineer to be on the cover of WIRED magazine.

[62] Image source: https://www.youtube.com/watch?v=D6_aXNY4AcU

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Limor Fried on the cover of WIRED magazine [63]

Her DIY kits are interesting and simple and Fried believe this is all that is needed to create education and build careers in IoT and tech. She also believe that this way opens up access to learning to a more diverse group of people.

Fried's goal is very similar to the goal of the Women Power Code project. We want to get women inspired in all things digital and close that gender gap! We want to spark that interest and prove that women can get a job in the STEM sector just as easily as men if we put our minds to it.

[63] Image source: https://www.wired.com/2011/03/wired-magazines-cover-features-its-first-lady-engineer/

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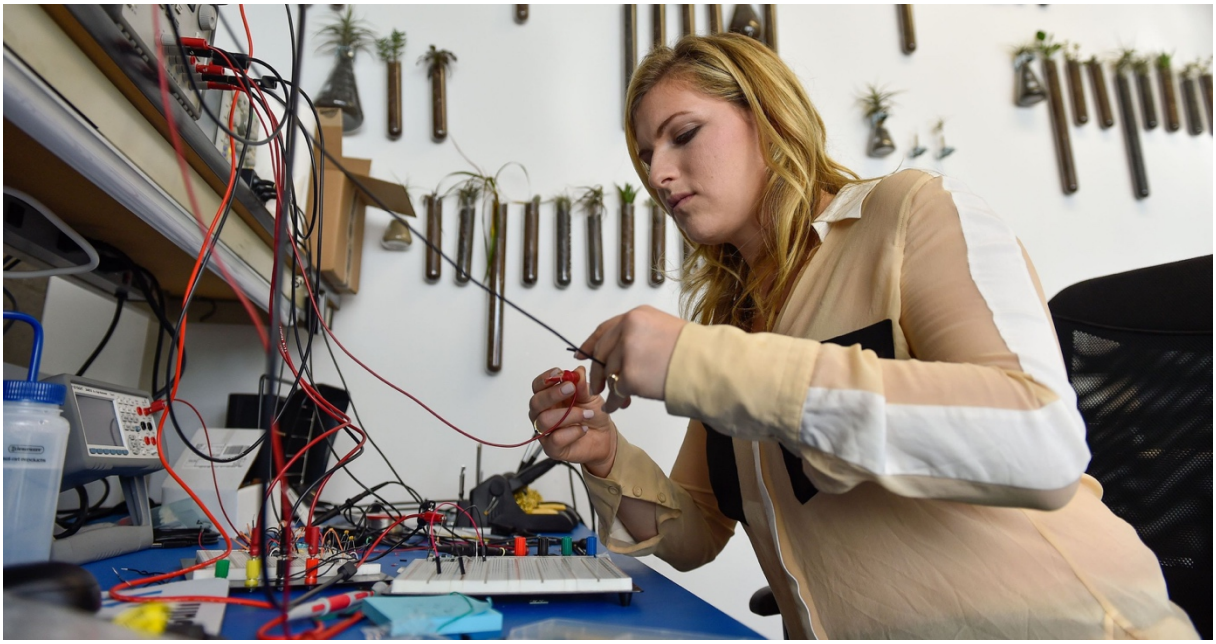
Meredith Perry, Founder and CEO of uBeam

Meredith Perry is another leading woman in tech. She is the Founder and CEO of the innovative tech company, uBeam which transmits power through the air to charge electronic devices.



Meredith Perry, Founder and CEO of uBeam [64]

Similar to Fried, Perry founded the business as a student and has received numerous prestigious awards for her work, including being named to Fortune's "40 Under 40" Mobilizers and Forbe's "30 Under 30" list.

uBeam aims to become the energy source of the future becoming the main wireless power provider to all connected devices which are constantly increasing thanks to the continuous expansion of IoT.

[64] Image source: https://eu.usatoday.com/story/tech/2015/02/23/ubeam-founder-meredith-perry-replaces-cords-with-wireless-charging/23699083/

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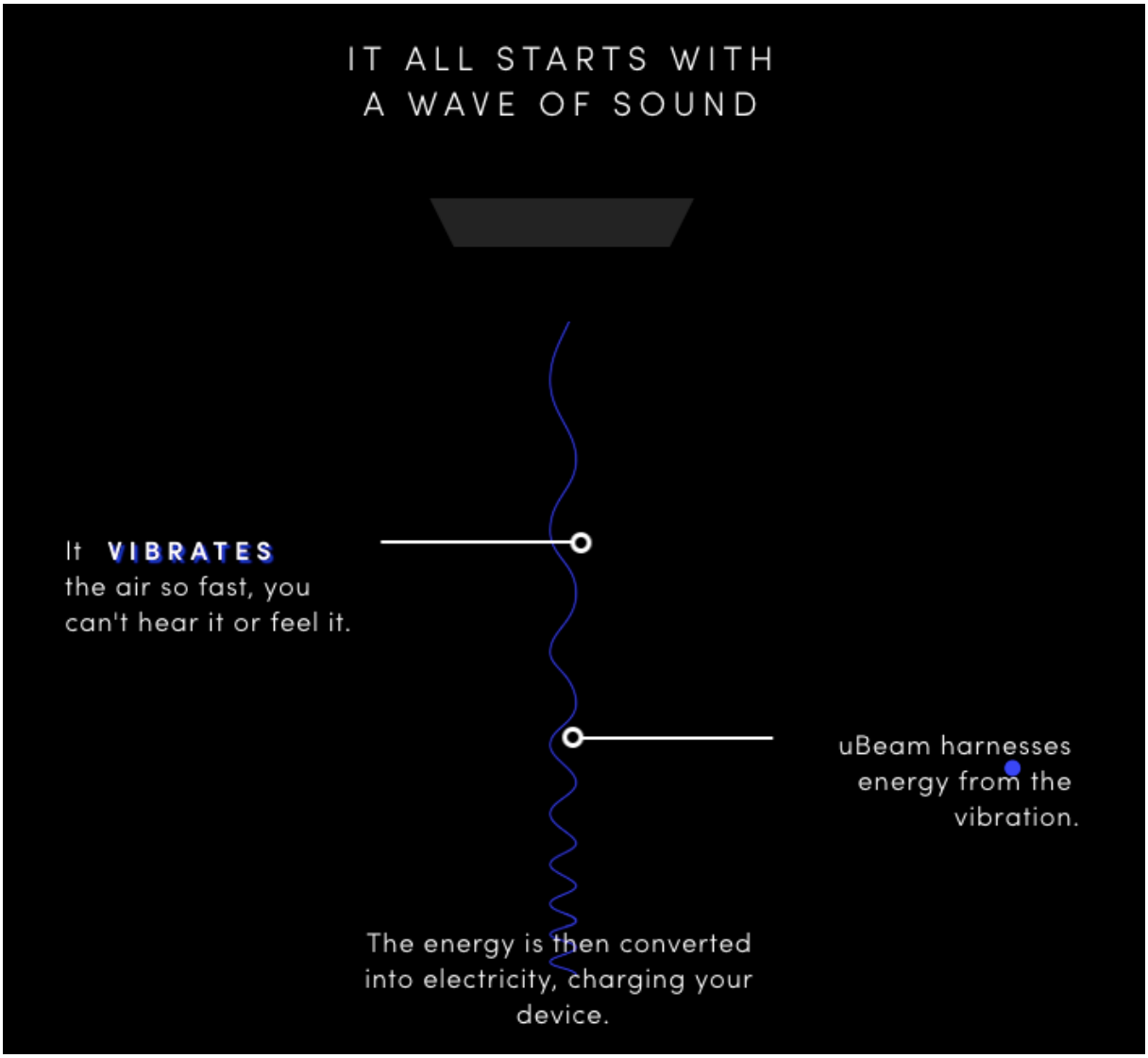
This is how they describe how their product works [65]:



Meredith is a prime example of a women who can drive change and innovation in the technology sector.

[65] Image source: https://ubeam.com/

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Anne Lauvergeon, Chairman of SIGFOX

Another powerful and inspiring female leader in the tech industry is Anne Lauvergeon, who has been ranked one of the most powerful international female leaders. She disrupts gender stereotypes with her success and work ethic.

Anne Lauvergeon, Chairman of SIGFOX [66]

SIGFOX is one of the world's leading IoT service providers, providing cellular connectivity for the IoT and Machine-to-Machine (M2M) communications. They cover 1 billion people across the globe and are in 60 countries. Without an IoT network framework in place, IoT devices couldn't be connected and thus wouldn't be introduced to the commercial market.

Anne Lauvergeon said that her first husband used to say, "'The problem with Anne: she has no ambition." And while Anne claims to agree with him, the ambitions of her company tell a different story: http://fortune.com/2015/05/27/anne-lauvergeon-internet-of-things/.

[66] Image source: https://www.europe1.fr/economie/Anne-Lauvergeon-debarquee-d-Areva-321574

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Technology today is a fundamental and indispensable component of our lives, regardless of whether we are engineers or not. There are still those who think that the developer is forced to be closed in a dislocated laboratory who knows where, and only in very rare cases there are those who know the value of training courses when it comes to choosing high school or the University. It is a matter that transcends the female gender and that also concerns boys. But it is a fact: when you think of a girl's future, it is easier to imagine her as a teacher than as an ICT specialist.

Today there are many cases of women at the head of technological multinationals. From IBM to HP, via Yahoo! the examples are not lacking. They are professionals who have worked hard to reach those positions. To make such a career we still have to go down too many compromises. While it is above all the tech companies to put in place solutions that help to balance private life and professional activity.

But the women inclusion in the ICT world is not just a matter of equal opportunity. Their contribution is fundamental also for the development of the sector.

Examples about design, ergonomics, product features, especially now that the Internet of Things is starting to get serious about wearable. Intel, for example, has shown its great interest in this market by announcing, among other things, the collaboration with Tag Heuer and Google for the creation of a smart watch: fashion will be increasingly relevant to all other technology producers. But in these areas, more than in others, men and women evaluate objects with different criteria. Being able to count on the contribution of women, or more generally on diversity, even in the design phase has strategic value to intercept the widest possible market shares[67].

Generally speaking it is not news that the female gender is under represented in the labour market linked to ICT. As previously mentioned about the gender divide in the Scientific and

[67] Source: Web article on https://www.corrierecomunicazioni.it/digital-economy/andrietti-l-internet-delle-cose-e-donna/

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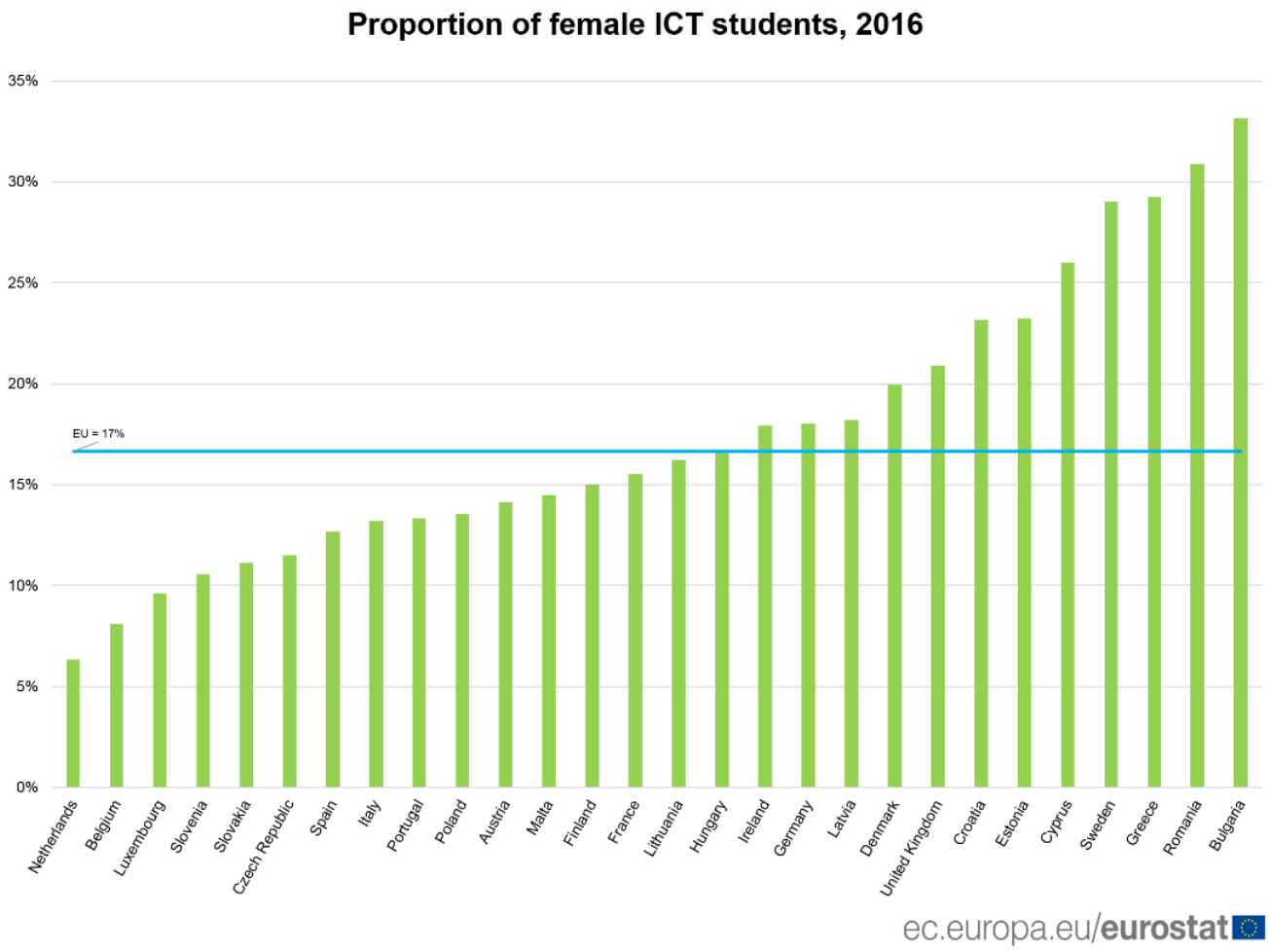
Technological Faculties registrations, stated by Eurostat, in 2016 at the university in Technological Faculties a small minority of girls was enrolled, namely one for every six students.[68]



Pupils and students enrolled by education level, sex and the field of education[69]

With great surprise, on top there are some of the most in difficulty countries belonging to the EU, Bulgaria (33%), Romania (31%) and Greece (29%).

[68]Source: web article available at https://ec.europa.eu/eurostat/web/products-eurostat-news/-/EDN-20180425-1?inheritRedirect=true
[69] Source: web article on the EC website: https://bit.ly/2Wjv0NS

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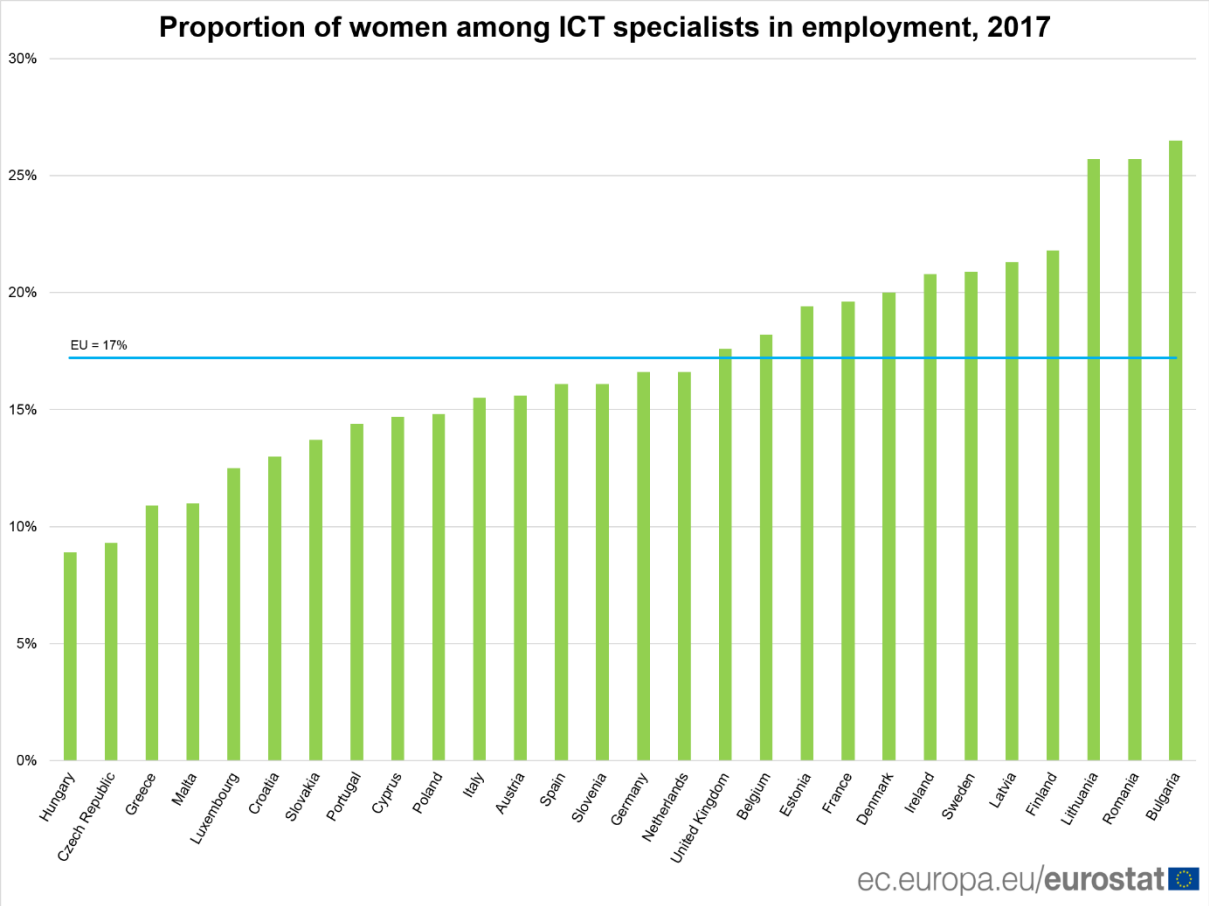
However, in 2017, there was only 17,2% employed as female ICT professionals in Europe. A lot has to be done in this sense.



Employed ICT specialists by sex[70]

In conclusion, the world of IoT is rapidly evolving, much has been discovered and much remains to be done. With no doubts, Europe, with this great drive towards a highly technologically and digitally inclusive society, opens up new job opportunities. These have a great mission to eliminate the gender imbalance in the IT, ICT and IoT sector.

[70] Source web article of the EC website on https://bit.ly/2WlTOVl

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Thus, women are encouraged to study scientific and technological subjects and launch new businesses related to these subjects.

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2.3 Unit 3: Raspberry Pi platform

In this unit you will learn about one of the main tools used in IoT – the tiny credit-card sized computer Raspberry Pi. This unique device for the basic price of 35 EUR is the core for the most IoT solutions. Initially designed for educational purposes nowadays it is one of the most popular technology items in the world. Knowing Raspberry Pi and the first steps in coding will help you understand the existing opportunities to make your everyday life better and easier using the new technologies. And why not to take the next step – a career change towards a new profession in the field of STEM. What is STEM? It is Science, Technology, Engineering, and Mathematics.

It is never too late for new knowledge, new skills and new career.

Learning aims:

The aims of this unit are to give the trainee new knowledge:

- a good knowledge of the Raspberry PI single-board computer and an understanding why it has become one of the most widely diffused device in the field;

- the ability to define why the Raspberry PI should be used, to classify potential benefits and setbacks;

- the ability to recognise the available hardware additions and software to interact with the Raspberry PI device;

- the ability to list practical examples of the Raspberry PI use in both business and daily lives.

New skills:

- to be able to outline with details the main features and characteristics of the Raspberry PI device;

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- to analyse possible strengths and weaknesses of the Raspberry PI;

- to develop a plan for the adoption of the Raspberry PI into own business/daily life;

- to select the most suitable hardware additions and software to interact with the Raspberry PI, measuring them against her/his needs.

- to investigate and identify the scopes for application of the Raspberry PI in her/his business/daily life.

New competences

- to be able to instruct about the Raspberry PI and its main features and characteristics.

- to be able to advise on the Raspberry PI using examples, case studies and best practices.

- to be able to autonomously build a plan of activities which can be carried out with the adoption of the Raspberry PI.

- can autonomously set to work the Raspberry PI device.

Content/Topics:

Following topics will be covered in this unit:

- What is the Raspberry PI

- Why it is called Raspberry Pi?

- Why use Raspberry PI

- Raspberry Pi hardware

- The Raspberry Pi computer

- Set up the Raspberry Pi

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- Raspberry Pi software

- Connecting Raspberry Pi to the internet

- Raspberry Pi applications

Duration: 3 hours

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2.3.1 What is the Raspberry PI

The Raspberry Pi is a very small computer (the size is like a credit card). It can be plugged into a computer monitor or a TV and uses standard keyboard and mouse. It is also very cheap (the core module costs around 35 EUR).

"It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

What's more, the Raspberry Pi has the ability to interact with the outside world and has been used in a wide array of digital maker projects, from music machines and parent detectors to weather stations and tweeting birdhouses with infra-red cameras." [71]

The Raspberry Pi Foundation`s (UK) goal is to advance the education of adults and children, particularly in the field of computers, computer science and related subjects.

Raspberry PI computer inside the box[72]

[71] Source: https://www.raspberrypi.org
[72] Image source: https://www.raspberrypi.org

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Raspberry PI computer with box[73]

The founder of the Raspberry Pi computer is Eben Upton, one "of the tech industry's brightest minds, leaders, and visionaries"[74]. He founded a couple of startups over the last 20 years, worked also as Director of Studies in Computer Science at the University of Cambridge. The initial idea was to "reignite programming in schools with a cheap ($25-$35), compact computing platform that kids could buy themselves" [75]. Nowadays besides it educational purposes Raspberry PI is implemented worldwide in all kind of industries and divices.

Raspberry Pi was first released in 2013 as an educational tool and until 2015 over 5 Million have been sold. Nowadays it is one of the most popular technology items in the world.

[73] Image source: https://www.raspberrypi.org
[74] Source: https://www.techspot.com
[75] Source: https://www.techspot.com

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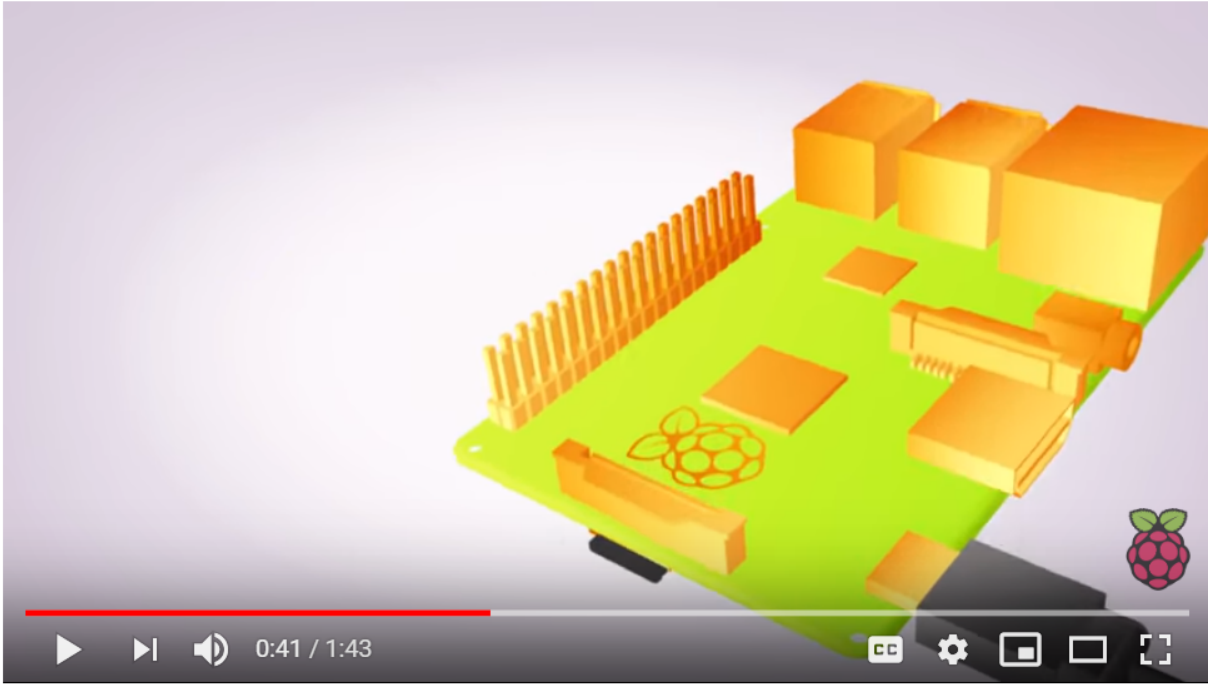

https://www.youtube.com/watch?v=uXUjwk2-qx4

2.3.2 Why it is called Raspberry Pi?

Here is what the founder Eben Upton explains in an interview for *TECHSPOT*:

"Raspberry is a reference to a fruit naming tradition in the old days of microcomputers. A lot of computer companies were named after fruit. There's Tangerine Computer Systems, Apricot Computers, and the old British company Acorn, which is a family of fruit.

Pi is because originally we were going to produce a computer that could only really run Python (a coding language). So the Pi in there is for Python. Now you can run Python on the Raspberry Pi but the design we ended up going with is much more capable than the original we thought of, so it's kind of outlived its name a little bit."

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Raspberry PI logo[76]

2.3.3 Why use Raspberry PI

There are several reasons to choose Raspberry Pi:

- It is cheap
- It is extendable with different hardware parts
- Very low power consuming
- You can run different OS (Operating Systems)
- The best tool for teaching kids and adults how to code

2.3.4 Raspberry Pi hardware

In order to begin learning how to use Raspberry Pi one don't need to know the hardware in detail. It is exactly the same as you don`t need to know all parts of your car in detail in order to drive it. However, it is mandatory to know that your car has an engine and what type it is, what is the purpose of the different parts and how you can use them in the best way, how and who should maintain your car. Here you should know the different components of the computer, their function and the main additional hardware parts that you will need in order to build a real and working device. Also, it is needed to know how they get connected to your Raspberry Pi computer.

[76] Image source: https://www.raspberrypi.org

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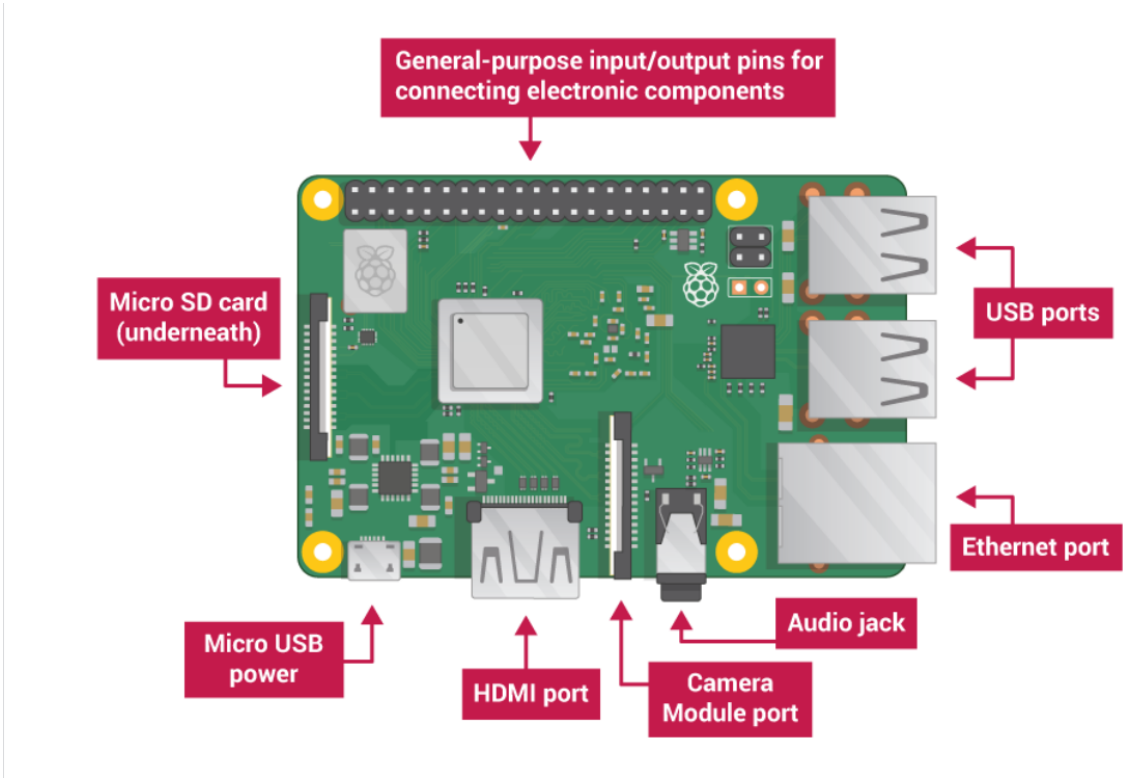
The next step is to gain and practice basic coding skills in order to force your device to do the work you want. Exactly the same as your driving skills and license – the car is a car but without a skilled driver it is just an object.

2.3.5 The Raspberry Pi computer

Here is how the Raspberry Pi computer looks inside:



Raspberry PI computer components[77]

The Raspberry Pi computer has several ports and slots (see figure):

1. **USB ports** - you can use them to connect a mouse and keyboard or other devices

[77] Image source: https://www.raspberrypi.org

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2. **Micro SD card slot** - you can slot the SD card in here. The SD card is where the operating system software and your files are stored. It plays the role of the hard disc of your computer. The SD card is not included in the Raspberry Pi. It is sold separately.
3. **Ethernet port** - you can connect the Raspberry Pi to a network with a cable or via wireless LAN.
4. **Audio jack** - you can connect headphones or speakers here.
5. **HDMI port** - the port where you connect the monitor (or projector) that you are using to display the output from the Raspberry Pi. If your monitor has speakers, you can also use them to hear sound.
6. **Micro USB power connector** - this is where you connect a power supply. You should always do this last, after you have connected all your other components. The power supply is also sold separately.
7. **GPIO (general-purpose input/output pins for connecting electronic components) -** these allow you to connect electronic components such as LEDs and buttons to the Raspberry Pi.
8. **Camera Module port** - here you can connect your camera.

Now that you know all the ports you can set up and connect all your devices like mouse, keyboard, monitor, camera to your Raspberry Pi and connect it to the network.

2.3.6 Set up the Raspberry Pi

In order to set up the Raspberry Pi you will need:

- A monitor or TV with HDMI in. If you have an older model with a DVI or VGA port you will need a HDMI-to-DVI/VGA adapter to attach to an HDMI cable, or a one-piece HDMI-to-DVI cable (see figure below).
- HDMI cable to connect Raspberry Pi to a Monitor or TV (see figure below).
- USB keyboard (see figure below)
- USB mouse (see figure below)
- Power supply (see figure below)
- 8 GB (or larger) micro SD card (better it has a pre-loaded OS) (see figure below)

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Monitor or TV with HDMI in [78]

HDMI cable [79]

[78] Image source: https://www.raspberrypi.org/learning/teachers-guide/
[79] Image source: https://www.raspberrypi.org/learning/teachers-guide/

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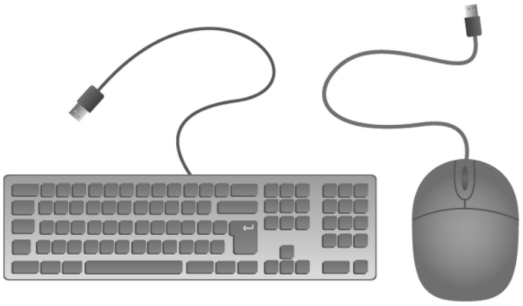
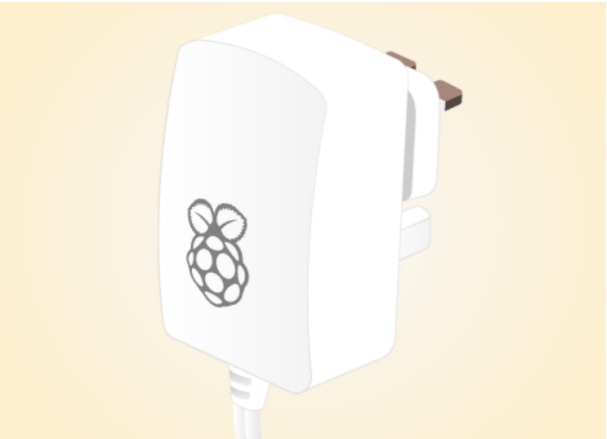


USB keyboard and mouse [80]



Power supply [81]

[80] Source: https://www.raspberrypi.org/learning/teachers-guide/
[81] Source: https://www.raspberrypi.org/learning/teachers-guide/

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Micro SD card [82]

How to set up the Raspberry Pi step by step:

1. The first step is to place your SD card into the SD card slot on the Raspberry Pi. It will only fit one way.
2. Plug your keyboard and mouse into the USB ports on the Raspberry Pi.
3. Connect your HDMI cable from your Raspberry Pi to your monitor or TV (be careful which port of your TV/monitor you use).
4. Connect the micro USB power supply. This action will turn on and boot your Raspberry Pi.
5. You can also connect headphones or speakers to the audio port (or Bluetooth for Raspberry PI 3)
6. In order to enhance your memory/disc space you can plug in any kind of USB storage or external hard disc.

You can check if you have plugged everything correctly here.

[82] Image source: https://www.raspberrypi.org/learning/teachers-guide/

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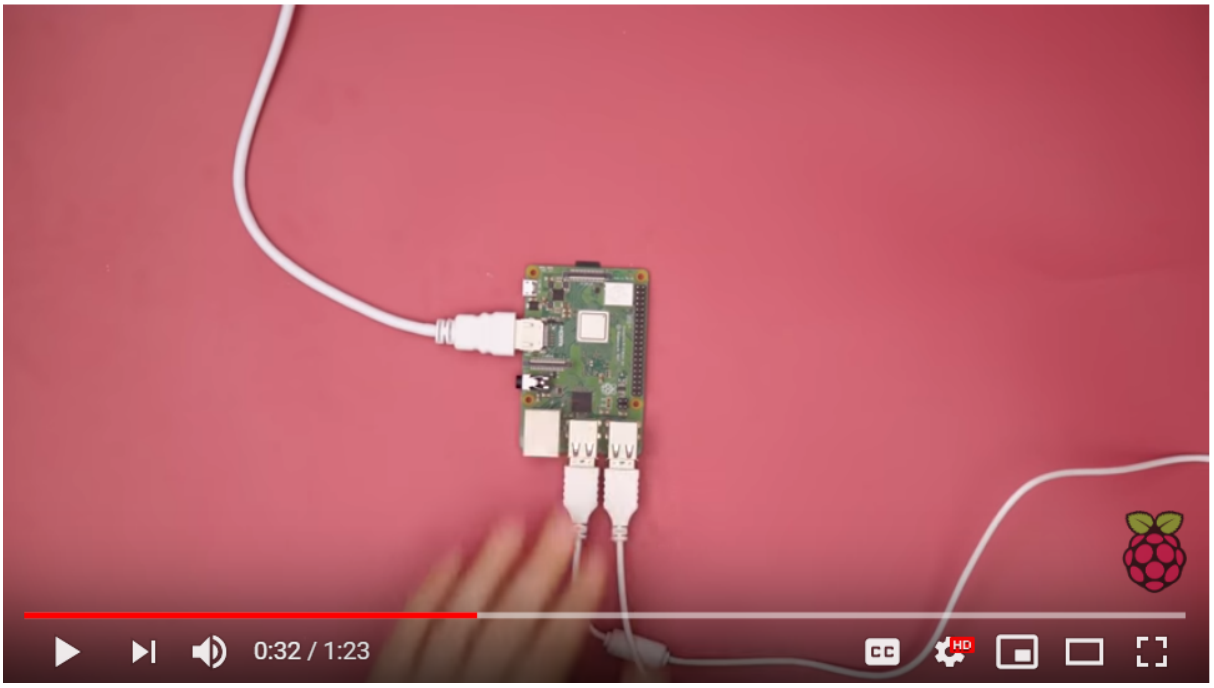

https://www.youtube.com/watch?time_continue=5&v=wjWZhV1v3Pk

2.3.7 Raspberry Pi software

The Operating System (OS)

When you start your Raspberry Pi for the first time, the **Welcome to Raspberry Pi** application will pop up and guide you through the initial setup (in case you have bought a SD card with a pre-loaded OS).

If you don`t use a SD card with a pre-loaded OS you should install your OS first (how to do this – see below).

What is an Operating system (OS)?

The operating system is interface between your computer hardware and the programs which run on it. It is software which manages all the processes that run in your computer and its memory. It allows you to communicate with the computer even when having no knowledge

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on any programming/coding language. Without an operating system you can`t use your computer. That`s why OS usually come pre-loaded on any computer you buy. Most people use the operating system that comes with their computer, but it's possible to upgrade or even change operating systems. The three most common operating systems for personal computers are Microsoft Windows, Mac OS X and Linux.

The Raspberry Pi runs a version of the operating system **Linux**. Linux is a free open-source operating system. Open-source means that the copyright holder grants users the rights to use, change and distribute the software to anyone and for any purpose. The fact that it is free and everyone has the right to modify it for their own purpose (as opposed to MS Windows and MacOS) makes Linux the best choice for the Raspberry Pi computer. The version of Linux used in Raspberry Pi is called Raspbian. It is designed specifically to work well with the Raspberry Pi.

Installing your OS

Installing your OS using NOOBS

The easiest way to install your operating system is with NOOBS. NOOBS stands for **N**ew **O**ut **O**f **B**ox **S**oftware. This software is designed especially to help people without experience to install the Raspbian OS. To begin with, it's always a good idea to make sure you have formatted your SD card. You can do this on your desktop or laptop. You'll need to make sure your computer has a built-in SD card reader, or you can use a USB SD card reader.

- Visit the SD Association's website and download SD Formatter 4.0 for either Windows or Mac.
- Follow the instructions to install the software.
- Insert your SD card into the computer or laptop's SD card reader and make a note of the drive letter allocated to it, e.g. F:/.
- In SD Formatter, select the drive letter for your SD card and format it.

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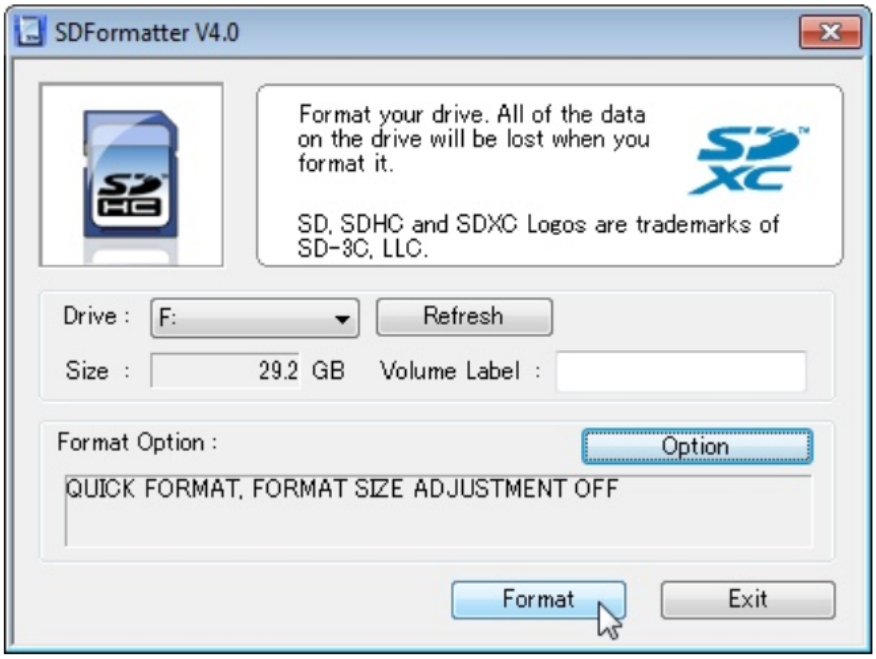

SD Formatter screen [83]

Note: If your SD card has 64GB or more, it will automatically be formatted as exFAT, which is not compatible with NOOBS. Follow these instructions to force your SD card to format as FAT32 so that you can use NOOBS.

Download NOOBS files then drag and drop

1. Visit the official Raspberry Pi Downloads page.

[83] Image source: https://www.raspberrypi.org/learning/software-guide/quickstart/

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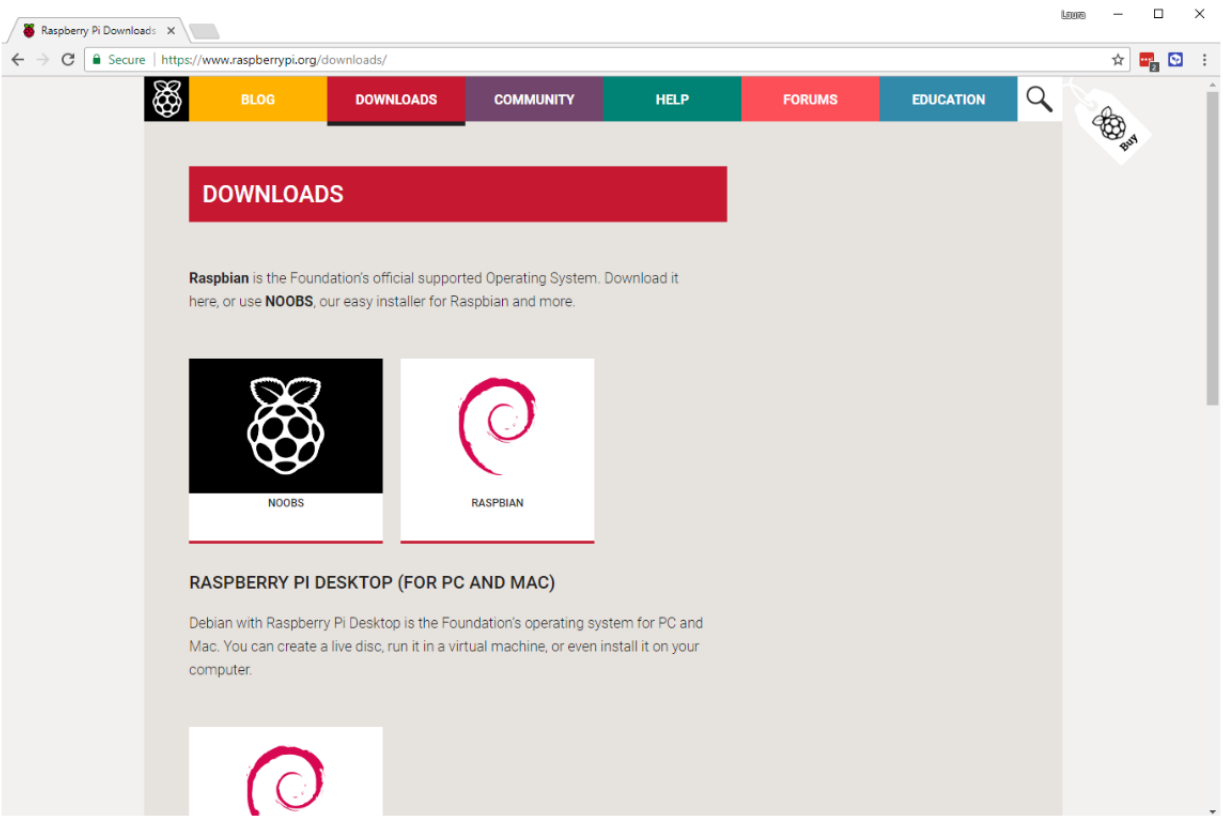

Raspberry Pi Downloads page[84]

2. Click on **NOOBS**.

[84] Image source: https://www.raspberrypi.org/downloads/

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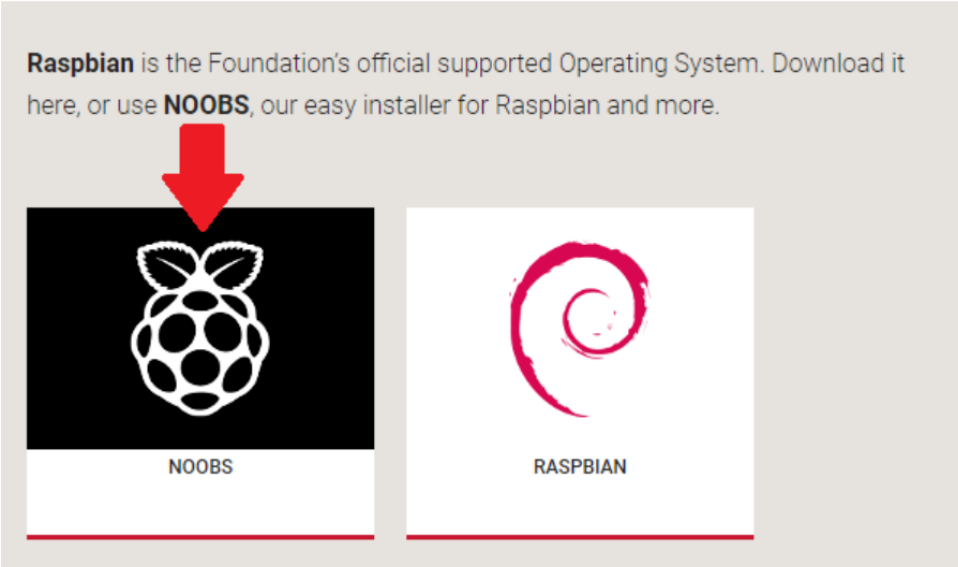
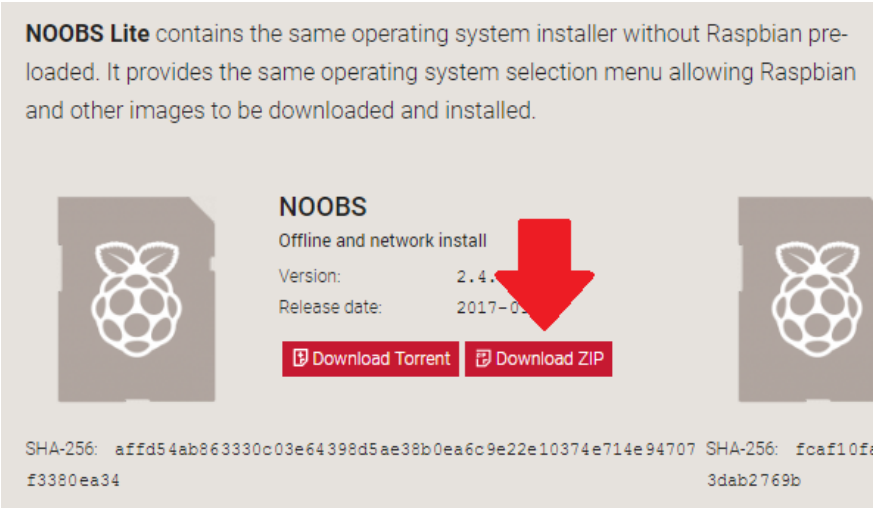


Raspberry Pi Downloads page[85]

3. Click on the **Download ZIP** button under 'NOOBS (offline and network install)', and select a folder to save it to.



Raspberry Pi Downloads page[86]

4. Extract the files from the zip.

[85] Image source: https://www.raspberrypi.org/downloads/
[86] Image source: https://www.raspberrypi.org/downloads/

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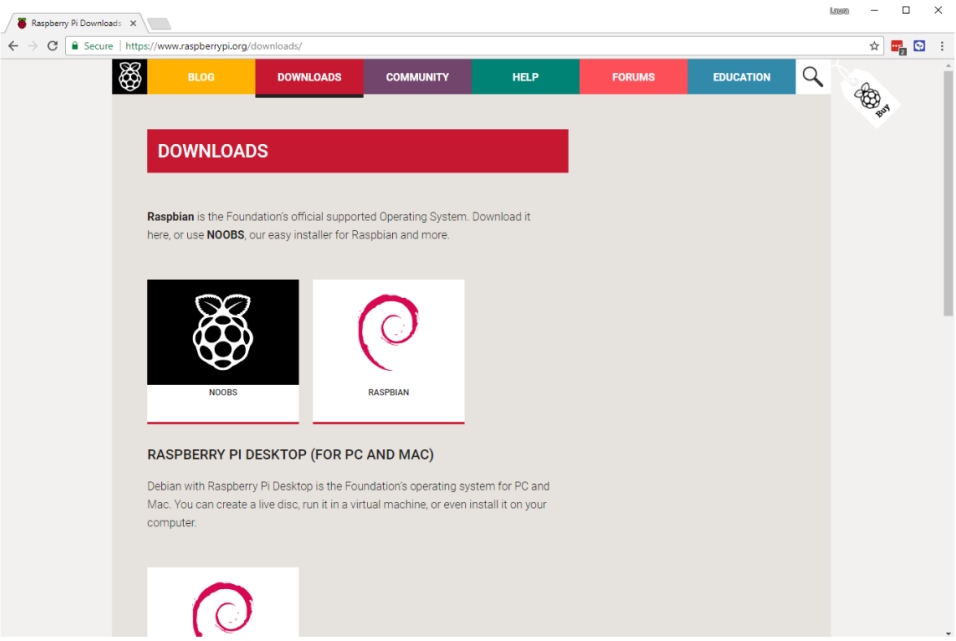
5. Once your SD card has been formatted, drag all the files in the extracted NOOBS folder and drop them onto the SD card drive.
6. The necessary files will then be transferred to your SD card.
7. When this process has finished, safely remove the SD card and insert it into your Raspberry Pi.

Download and image Raspbian directly

An alternative to using NOOBS to install Raspbian is to download and install the image directly. This is a faster process, and is great if you need to image multiple cards for a workshop or class.

1. Using a computer with an SD card reader, visit the official Raspberry Pi Downloads page.
2. Click on **Raspbian**.



Raspberry Pi Downloads page[87]

[87] Image source: https://www.raspberrypi.org/downloads/

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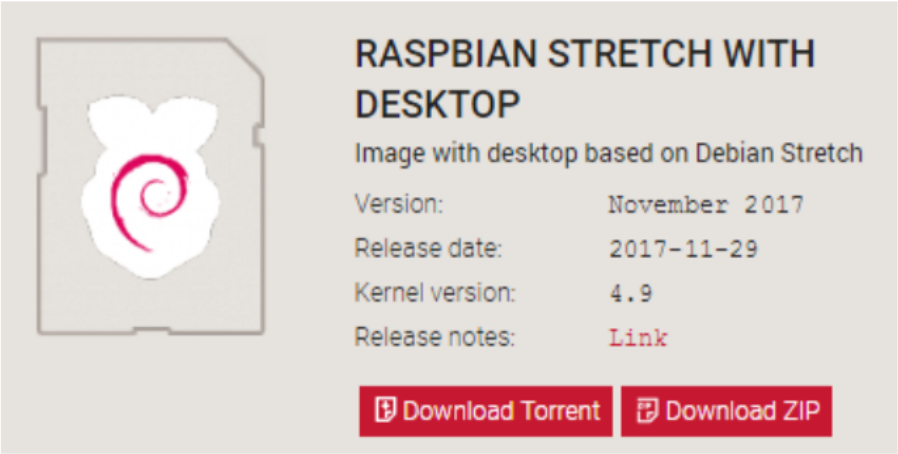
3. Click on the **Download ZIP** button under 'Raspbian Stretch with desktop', and select a folder to save it to.



Raspberry Pi Downloads page[88]

4. Extract the files from the zip.
5. Visit balenaEtcher and download and install the Etcher SD card image utility.
6. Run Etcher and select the Raspbian image you unzipped on your computer or laptop.
7. Select the SD card drive. Note that the software may have already selected the right drive.
8. Finally, click **Burn** to transfer Raspbian to the SD card. You'll see a progress bar that tells you how much is left to do. Once complete, the utility will automatically eject/unmount the SD card so it's safe to remove it from the computer.

[88] Source: https://www.raspberrypi.org/downloads/

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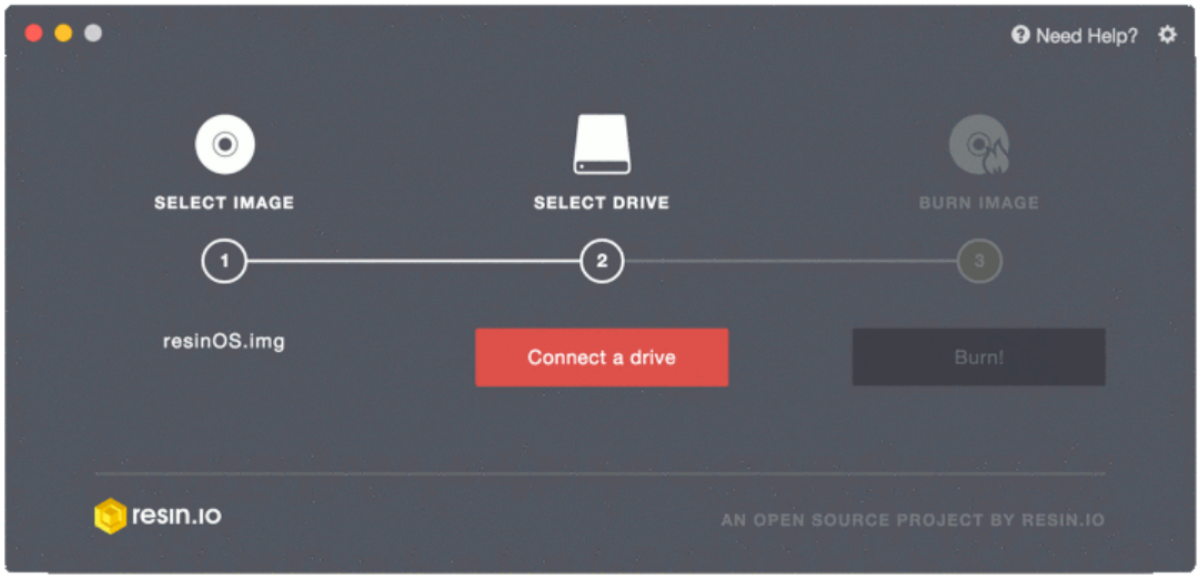

Burning Raspbian to an SD card screen[89]

Now that you have an operating system, you can slot your SD card into your Raspberry Pi and connect the power.

1. If you are using NOOBS and this is the first time your Raspberry Pi and SD card have been used, then you'll have to select an operating system and let it install.
2. If you downloaded Raspbian and imaged it using Etcher rather than NOOBS, then you will boot directly to the desktop environment of Raspbian and won't need to wait.

The initial setup process for Raspberry Pi is like the initial setup process for every computer or laptop – you have to set up your country, language, timezone; set a password; select a network.

After you finish the setup of your Raspberry Pi you will see the home screen and all installed applications:

[89] Image source: https://www.raspberrypi.org/learning/software-guide/quickstart/

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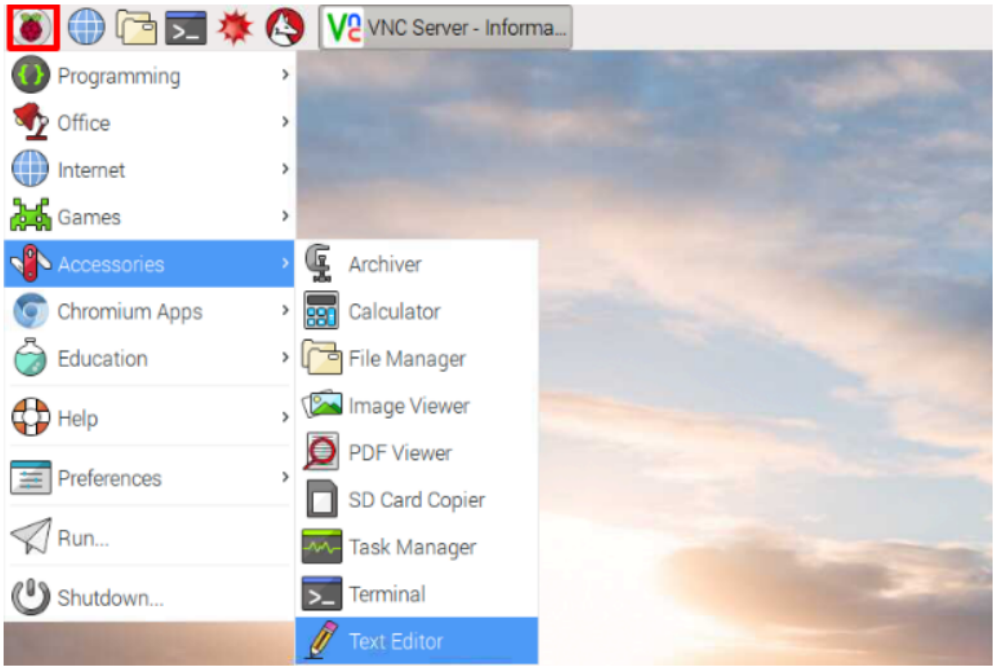

Raspberry PI home screen[90]

You can create text files, save them and organize them in folders and subfolders.

It looks similar to all other operating systems like Windows and macOS.

The Linux OS allows the user to run different programs and applications by typing commands instead of clicking on menu options This has also been the case for the DOS operating system (the one who are familiar with that system, will remember). In order to understand it, click on the **Terminal** icon at the top of your screen.

[90] Image source: https://www.raspberrypi.org

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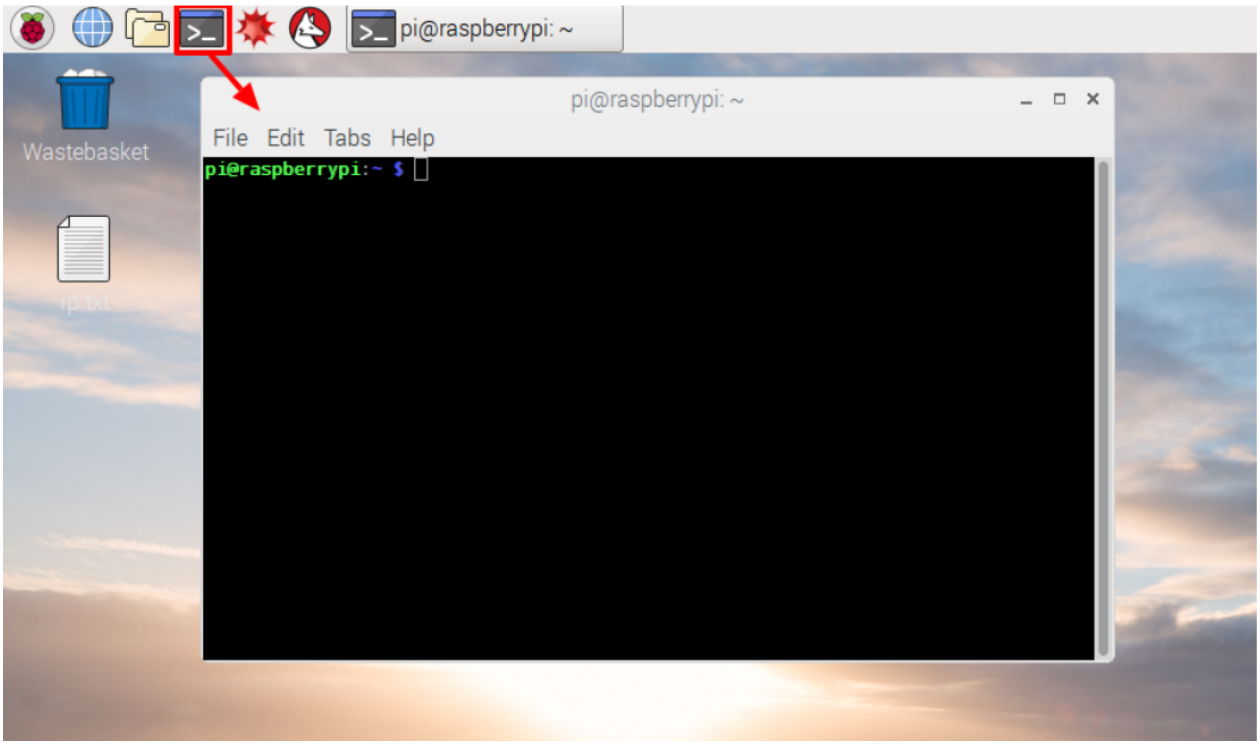

Raspberry PI Terminal screen[91]

Type **1s** in the window that appears. Then press Enter on the keyboard. This will list the files in your home directory when you create them.

Coding languages

PHYTON

Phyton is the main coding language used with Raspberry Pi. The "Pi" in the name comes from Phyton. Any kind of device can be programmed and controlled using Phyton. Examples can be found here.

SCRATCH

SCRATCH is a simple programming language that comes as standard with the Raspberry Pi distribution, Raspbian. Scratch was originally created by the Lifelong Kindergarten Group at

[91] Image source: https://www.raspberrypi.org

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the MIT Media Lab in Boston, U.S. to help young people learn coding and solve mathematical problems while having fun making things.

HTML

HTML is the standard markup language for creating Web pages. HTML stands for Hyper Text Markup Language.

JAVASCRIPT

JavaScript is a scripting language that works alongside HTML to add interactivity to websites. JavaScript was invented, and is maintained by, the World Wide Web Consortium, which also looks after HTML and CSS.

JQUERY

JQuery is the most popular JavaScript library. It runs on any browser, and it makes the scripting of HTML considerably simpler. With jQuery, you can create rich web interfaces and interactive components with just a small amount of JavaScript knowledge.

JAVA

Java is one of the most popular programming languages in the world. It is easy to learn and simple to use. It is open-source and free.

It is secure, fast and powerful. More than 3 billion devices run Java. It is used for: Mobile applications (specially Android apps); Desktop applications; Web applications; Web servers and application servers; Games; Database connection etc. Java works on different platforms (Windows, Mac, Linux, Raspberry Pi, etc.)

C programming language

C is one of the most widely used languages in the world, utilized in everything from complete operating systems to simple programming languages. Linux, the operating system that runs the Raspberry Pi, is largely written in C and is built into all Linux and Unix systems.

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The design for C influenced a great many other programming languages, including Python, Java, JavaScript, and a programming language called D. It was also extended as Objective C, which is the language used to write apps for iPhones and iPads. [92]

C++

C++ was developed by the Danish developer Bjarne Stroustrup as a way to enhance C. C++ is used in a million different circumstances, including hardware design, embedded software (in mobile phones, for example), graphical applications, and programming video games. C++ adds object-oriented features to C. Other object-oriented languages are Java, Smalltalk, Ruby, and .Net. [93]

PERL

Perl has been called the "duct tape that holds the Internet together" and the "Swiss Army chainsaw of scripting languages." It was given these names because of its flexibility and its adaptability. Before Perl came along, the Internet was but a collection of static pages.

Perl added a dynamic element, which meant that for the first time, websites could be put together on the fly. Among other things, it enabled ecommerce and sites such as Amazon and eBay to come into being. [94]

ERLANG

Erlang is a programming language used when there is no room for failure. You might use Erlang if you were running a nuclear power plant or if you were designing a new air traffic control system: mission-critical situations where the computer breaking down would spell disaster.

[92] Source: https://www.dummies.com/computers/raspberry-pi/top-10-programming-languages-ported-to-the-raspberry-pi/
[93] Source: https://www.dummies.com/computers/raspberry-pi/top-10-programming-languages-ported-to-the-raspberry-pi/
[94] Source: https://www.dummies.com/computers/raspberry-pi/top-10-programming-languages-ported-to-the-raspberry-pi/

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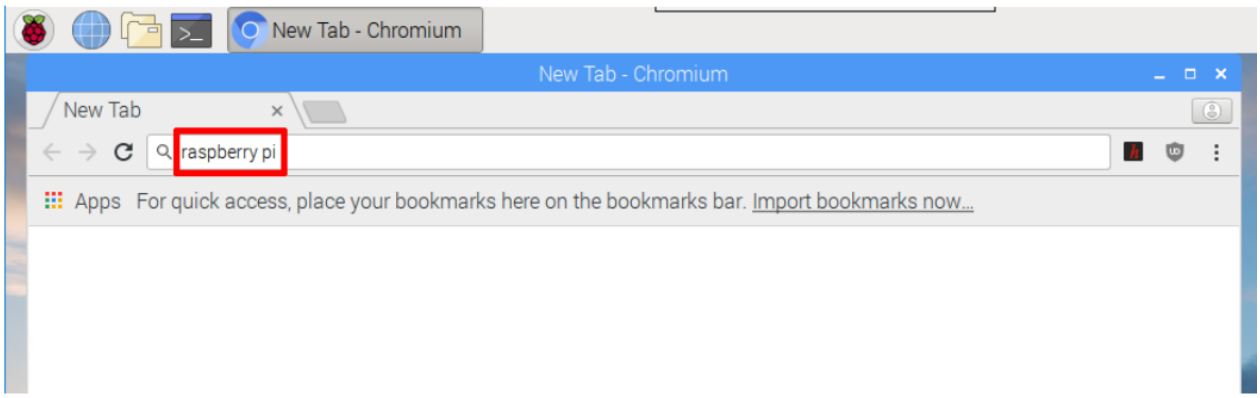
With Erlang, you can create programs that run across several computers. It's designed so that if one computer fails, the others make up for it, which means the system never goes down.

2.3.8 Connecting the Raspberry Pi to the internet

As already said you can use an ethernet cable or WiFi (for Raspberry Pi 3) to connect your Raspberry PI to internet. For wireless connection you need to click the icon with red crosses (figure 29) in the top right-hand corner of the screen and select your network from the drop-down menu.

Connecting Raspberry Pi to the Internet[95]

Then click the web browser icon and search for Raspberry Pi.



Browser screen[96]

2.3.9 Downloading and installing applications on Raspberry Pi

As you already know you can use text commands to download and install extra applications you might need. In the 'What you will need' section of a Raspberry Pi resource, for example, you may see a piece of software listed which you will need in order to complete the activity

[95] Image source: https://www.raspberrypi.org
[96] Image source: https://www.raspberrypi.org

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or project. To download and install extra applications for your Raspberry Pi, you'll need to be connected to the internet via Ethernet or wireless LAN.

From a terminal window or on the command line, type sudo apt-get install <name of software> and press Enter on the keyboard.

After searching for the package and downloading it, you will be asked if you want to continue with the installation. Press Y or Enter on the keyboard to continue.

2.3.10 Use of Raspberry Pi

Raspberry Pi is used widely for educational purposes, in the industry, advertising etc. Below are some examples from www.raspberrypi.org and www.makeuseof.com.

1. Creating computer games for educational purposes - https://projects.raspberrypi.org/en/projects/?interests[]=games
2. Creating a website for educational purposes - https://projects.raspberrypi.org/en/projects/?software[]=html-css-javascript
3. Coding and controlling different kind of devices and robots - https://projects.raspberrypi.org/en/
4. Use as a desktop PC - https://www.makeuseof.com/tag/use-your-raspberry-pi-like-a-desktop-pc/
5. Wireless Print Server - https://www.makeuseof.com/tag/make-wireless-printer-raspberry-pi/
6. Media center - https://www.makeuseof.com/tag/kodi-raspberry-pi-media-center/
7. FM radio station - https://www.makeuseof.com/tag/broadcast-fm-radio-station-raspberry-pi/
8. Motion Capture Security System - https://www.makeuseof.com/tag/build-a-motion-capture-security-system-using-a-raspberry-pi/
9. Digital Photo Frame - https://www.makeuseof.com/tag/showerthoughts-earthporn-make-inspiring-raspberry-pi-photo-frame/
10. Laser-guarded cookies feat. Estefannie Explains It All - https://www.youtube.com/watch?v=cjsk6ZvIxyA&index=10&t=0s&list=PLcd1Q0-YkB1e0x5WuE9tWIKybEarSsYoN

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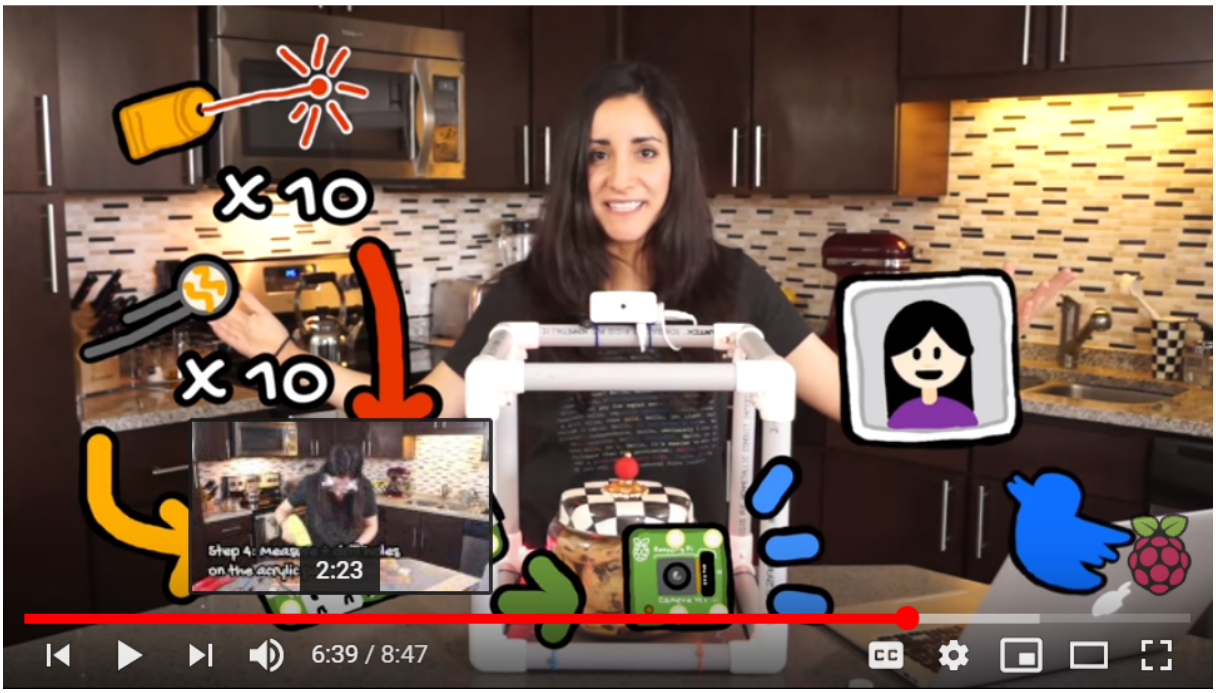

11.

References

https://www.raspberrypi.org/

https://www.techspot.com/

https://www.balena.io/etcher/

https://www.dummies.com/

https://www.w3schools.com

https://www.makeuseof.com

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IoT Practical applications

Practical Application No 1: Smart Doorbell

Area: Household

Context: A smart doorbell is an internet capable doorbell and usually comes with a built-in camera, speakers and microphone. The doorbell connects to a smartphone or tablet and when someone rings the doorbell, the owner will be sent an alert to own device. This will allow the owner to see who is at the door and interact with them, if necessary.

How to get started:

Installing a smart doorbell is relatively easy and hassle-free.

First, you will need to research and purchase the right doorbell for you.

Once you have done this, you will need to install it, according to the specific instructions of the doorbell you purchased. You will likely need to attach wires and disconnect the wiring/turn off power on your manual doorbell.

Then, you will need to connect the smart doorbell to your desired device(s). This will normally be done by installing the app of the doorbell provider, entering your personal details to create an account and you may also be required to input some information from the smart doorbell itself.

Once this is done, you'll be ready to use your doorbell!

There are a number of benefits to using a smart doorbell:

Convenience

You can answer your door from anywhere, and it means you can choose if you wish to interact with the visitor.

Ease of Delivery

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If you frequently shop online and receive parcels, a smart doorbell is an easy way to relay messages to delivery drivers if you are unavailable to accept the delivery.

Safety

If your doorbell rings but you are not expecting any visitors, or if you are suspicious, a smart doorbell means that you can see who's at your door, without giving any indication to the visitor that you are home. This means you can choose whether or not you answer the door or interact with the visitor.

Security

Unfortunately, home break-ins are increasingly common. Many burglars prospect houses, under a false identity, in order to gage if the home-owner is home or not. They may do this over a period of time to track patterns of when homeowners are out, or on holiday, etc. A smart doorbell means that you can answer the door and interact with the visitor, even if you are not home. This may deter them from attempting a break-in on your home as they will be unaware that your property is empty.

References:

https://www.makeuseof.com/tag/what-is-a-smart-doorbell-and-which-should-you-buy/

https://en.wikipedia.org/wiki/Smart_doorbell

https://www.the-ambient.com/reviews/best-smart-doorbells-261

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Practical Application No 2: Automated plant watering

Area: Garden

Context: Automated plant watering is an ever-evolving concept, with many variations which allows you to keep on top of watering your plants, if you are unable to do it manually. The most common automated plant watering system is the implementation of a sensor in the soil of your plants, which measures metrics such as soil moisture levels, temperature and brightness. The sensors then activate irrigation, if necessary. In some instances, you can also set specific watering schedules through your smartphone if you are away from your plants for an extended period of time.

How to get started:

To get started, you must do some research in order to establish which automated watering system will work best for your collection/requirements. There are a rising number on the market and a number of considerations to take into account, such as:

- Is it for indoor or outdoor plants?
- Compatibility with your smartphone/tablet
- Does it require an active internet connection to operate? Will this work outdoors?

Once you have chosen your automated watering system, you will need to install it in all plants that you wish to irrigate remotely.

Each system will have its own specific installation process; however, the majority will require you to insert the sensor into the soil and create an account with the app/internet system you are using to control your irrigation, in order to set it up.

Once you have done this, it should be ready to operate.

Automated plant watering systems offer a number of benefits to gardeners:

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- You can keep on top of plant watering whilst you're away from home for extended periods of time. You'll no longer have to ask your neighbour to pop in and water the plants.
- It's economical! Automated irrigation systems will save you water. They can be set to a specific schedule, meaning plants are only being watered when they really need it and the volume of water delivered to the plant is controlled by the system.
- It prevents water runoff from excess watering. When this water runs off, it takes essential nutrients with it!

References:

https://watermasterirrigation.com/2017/11/21/benefits-irrigation-systems/

https://www.postscapes.com/wireless-plant-sensors/

http://daisy.si/

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