nD PRINTING

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Printing as known from antiquity is a process for reproducing text and images, using a master form or template, by the means of printers. The things coming out of those printers are text and images that have been printed on a flat surface, flattish shapes or objects that cannot be picked up like two-dimensional (2D) artworks - drawings, paintings, photographs.
The process is called *2D Printing*.
The earliest examples of printers were *Seals* and *Stamps* used for making impressions.
The oldest seals come from Mesopotamia and Egypt. Back to early Mesopotamian civilization, before the year 3000 BC, the most common works of art to survive and feature complex and beautiful images were done by use of round *Cylinder Seals,* rolling an impress on clay tablets.
Brick Stamps for marking clay bricks, survive from Akkad from around the year 2270 BC.
There are also Roman lead pipe inscriptions of some length that were stamped.
And there is an unique gold foil sheet stamped with an amulet text from the 6th century BC.
Woodblock Printing, originating in antiquity in China, is a method for printing text, images or patterns that was used widely throughout East Asia. It was a way of printing on textiles and later on paper with surviving examples dating before AD 220.
The wood block, the printer, is carefully prepared as a relief pattern, which means the areas to show 'white' are cut away with a knife, chisel or sandpaper leaving the characters or image to show in 'black' at the original surface level. It is necessary only to ink the block by rolling over the surface with an ink-covered roller (brayer), leaving ink on the flat surface but not in the cut areas and bring it into firm, even contact with the paper or cloth to achieve an acceptable print. The content would print "in reverse" or mirror image, a complication when text was involved.
Woodblock Printing remained the most common East Asian method of printing books and other texts, as well as images, until the 19th century. In Japan the woodblock art print is called *Ukiyo-e*.
In Europe, the woodblock method for printing images on paper is covered by the term *Woodcut Printing* occasionally known as *Xylography.*
Intaglio Printing is another method of making prints invented in Germany by the 1430s years.
Intaglio is the family of printing and printmaking techniques in which the image is incised into a surface and the incised line or sunken area holds the ink, direct opposite of a relief print.
As intaglio surface/matrix/printer were used the copper or zinc plates and the incisions were created by *Engraving*.

Block-book Printing is called the technique when both text and images are cut on a single wooden block for a whole page. A block book is a book printed from wooden blocks on which the text and illustration for each page had to be painstakingly cut by hand. The art of Block-book Printing is almost certainly of Chinese origin, probably of the 6th century AD. The method had spread to Europe at least by the 15th century. Allan Henry Stevenson, an American bibliographer specializing in the study of handmade paper and watermarks, who "single-handedly created a new field: the bibliographical analysis of paper", by comparing the watermarks in the paper used in block-books with watermarks in dated documents, concluded that the "heyday" of block-books were the 1460s years. Block-books printed in the 1470s years were often of cheaper quality, as a cheaper alternative to books printed by "printing press".

Printing Press is a printer device for evenly printing ink onto a medium/substrate such as paper or cloth. The device applies pressure to the substrate that rests on its inked surface of *movable type* transferring the ink; *movable type* is the system of *printing* & *typography* using *movable pieces of metal type* allowing much more flexible processes than hand copying or block printing.

Typography is the art and technique of arranging type to make written language most appealing to learning and recognition, involving selecting typefaces, point size, line length, line-spacing (leading), letter-spacing (tracking) and adjusting the space within letters pairs (kerning).

Printing Press is a *movable printer*.

The world's first known movable type printing technology was invented and developed in China by the printer Han Chinese Bi Sheng between the years 1041-1048. Its invention and its spread are widely regarded as among the most influential events in the human history, revolutionizing the way people conceive and describe the world, guiding in the period of modernity.

In Korea, the movable metal type printing technique was invented in the early 13th century during the Goryeo Dynasty.

In Europe the invention of movable type mechanical printing technology is credited to the German printer Johannes Gutenberg in the year 1450. The high quality and relatively low price of the Gutenberg Bible printed in 1455 year established the superiority of movable type for western languages and printing presses rapidly spread across Europe, leading up to the Renaissance and later all around the world.

Further along the years were developed also many other techniques for printing:

etching, drypoint, mezzotint, aquatint, lithography, chromolithography, rotary press, hectograph, offset printing, hot metal typesetting, mimeograph, photostat and rectigraph, screen printing, spirit duplicator.

Today, practically all movable type printing ultimately derives from Gutenberg's innovations for movable type printing which is often regarded as the most important invention of the second millennium. Modern printing is done typically with ink on paper but it is also frequently done on

metals, plastics, cloth and composite materials. On paper it is often carried out as a large-scale industrial process and is an essential part of publishing and transaction printing.
Since the 1960s years, most types of high-volume books and magazines, especially when illustrated in colour, are printed with *offset lithography* (the inked oiled image is transferred or "offset" from a plate to a rubber blanket, then to the printing surface) that has become the most common form of printing technology.
The word *lithography* also denotes *photolithography*, a micro-fabrication technique used in the *microelectronics* industry to make integrated circuits and micro-electromechanical systems.

Computer Printing was done first time by the 19th century mechanically driven apparatus invented by the English mathematician, philosopher, inventor and mechanical engineer Charles Babbage for his *difference engine*, an automatic mechanical calculator designed to tabulate polynomial functions. The most mathematical functions commonly used by engineers, scientists and navigators, including logarithmic and trigonometric functions, can be approximated by polynomials.
The automatic mechanical calculator used a series of metal rods with characters printed on them and a roll of paper stuck against the rods to print the characters.
An ancestor of the modern computer printer is the *stock ticker machine,* one of the first applications of transmitting text over a wire to a printing device based on the printing telegraph. Text typed on the typewriter at one end of the connection was displayed on the ticker machine at the opposite end of the connection. The “universal stock ticker”, invented by the American inventor and businessman Thomas Edison in 1870 year, laid the basics for the *electric typewriter*. Pulses on the telegraph line made a letter wheel turn step by step until the correct symbol was reached and then printed at a very slow printing speed of one character per second.
Newer and more efficient tickers became available in the 1930s years, but these newer and better tickers still had an approximate 15-20 minutes delay. Ticker machines became obsolete in the 1960s years being replaced by computer networks.
A *ticker type electronic device* was produced in the year 1996 that could operate in true real time.

Digital Printing, developed in the second part of the 20th century, is referring to methods of 2D Printing on different materials from a file generated by the digital computer.
It has many advantages over the traditional methods.
Digital printing usually refers to professional printing where jobs from digital sources are printed on 2D, flat surface using different digital printers. Desktop publishing, variable data printing, fine art, print on demand, advertising, photos, architectural design are some of its applications.
Digital Printer is a peripheral in computing, a device used to take text and images from a computer and put them on paper engaging printing technologies as *blueprint, daisy wheel, dot-matrix, line printing, heat transfer, inkjet, electrophotography, laser, solid ink.*

The two most common printer mechanisms are black and white *laser printing* used for common documents and colour *inkjet printing,* used for high-quality output.
Laser Printing is an electrostatic digital printing process, first experimented in 1969 year, that very rapidly produces high-quality text, graphics and moderate-quality photographs.
Laser printers employ a xerographic printing process, alike used in *photocopy machines, multifunction / all-in-one inkjet printers* and *digital presses* which are slowly replacing many traditional offset presses in the printing industry for shorter runs.
The first commercial implementation of a laser printer was the IBM 3800, designed and manufactured by IBM company in the year 1976.
Inkjet Printing is a type of computer printing that recreates a digital image by propelling droplets of ink onto paper, plastic or other substrates. The concept of inkjet printing originated in the 19th century and the technology was extensively developed from 1951 year.
Inkjet printers are the most commonly used type of printer ranging from small inexpensive consumer models to very large expensive professional machines.
Starting in the late 1970s years, inkjet printers that could reproduce digital images generated by computers, were developed mainly by Epson, Hewlett-Packard (HP), Canon companies and later in year 1991 by Lexmark, spin-off from IBM company and by 2005 year, digital printing accounts for approximately 9% of the 45 trillion pages printed annually around the world.

Printed Electronics is the manufacturing of electronic devices using standard printing processes.
It involves a set of 2D printing methods to create electrical devices on various substrates.
Electrically functional electronic or optical inks are deposited on the substrate creating active or passive devices as thin film transistors or resistors. Printed electronics technology can be produced on cheap materials like paper or flexible film, which makes it an extremely cost-effective method of production. Printing typically uses common printing equipment suitable for defining patterns on material such as *screen-printing, flexography, gravure, offset lithography, inkjet*.
Printed electronics is expected to facilitate widespread, very low-cost, low-performance electronics for applications such as *flexible displays, smart labels, decorative and animated posters, monitoring* and *active clothing* that do not require high performance.
Since early 2010 year several large companies are contributing heavily to the advancement of the printed electronics industry.
In a computer workspace the actual dimensions are referred to the two-dimensional space 2D and the three-dimensional space 3D. 2D space is 'flat', using horizontal & vertical axes X&Y, the image has only two dimensions and if turned to the side becomes a line in one-dimensional space 1D. 3D space adds the third dimension Z, allowing for rotation and depth.

The difference between a representation in 2D space and a representation in 3D space is essentially like the difference between a painting and a sculpture: two-dimensional art is called painting and three-dimensional art is called sculpture.

In the year 1983, the American engineering physicist Charles Hull experimented with liquid acrylic-based materials, the photopolymers, which harden when exposed to ultraviolet UV light. *Stereo Lithography* was defined by him as a method for making solid three-dimensional 3D objects by successively "printing" thin layers of the ultraviolet sensitive material one on top of the other. Charles Hull built a machine that stacked layers of material to form a 3D object.

The first object he printed in 3D, a cup about 5 cm tall, took months to produce.

Charles Hull continued to make improvements to the machine and by the mid of 1980s years the machine was ready to print larger and more complex objects such as prototypes of machine parts. *3D Printing* was born by the means of the newly created *3D Printer*.

The new 3D Printer attracted the attention of car manufacturers who wanted a way to create their own prototypes of parts such as door handles and stick-shift knobs.

Charles Hull patented his invention – U.S. Patent 4,575,330 entitled *Apparatus for Production of Three-Dimensional Objects by Stereo lithography* issued on March 11, 1986.

Further, Charles Hull founded the *3D Systems* company, in Valencia California in the 1986 year, whose first 3D Printer appearing on the market in 1988 year and was bought by airplane and medical equipment manufacturers and by several car makers companies including General Motors or Mercedes Benz.

3D Systems company also developed the suitable software. Designers use this software to create *Standard Tessellation Language* STL files; STL is a file format Hull invented that converts Computer Added Design CAD files into directions that printers can read to produce 3D objects.

In the early1990 years *Stratasys*, a 3D printing company in Rehovot Israel, developed a 3D printer that used a process called *Fused Deposition Modelling* FDM (plastic is melted and deposited in super-thin layer by layer through a heated nozzle) yielding durable models in comparison with the earliest method of Stereo lithography limited by the fragility of models and toxic chemicals. With FDM technology, the traditional fabrication process is substantially simplified, for example toolmaking becomes less expensive and time consuming, intricate designs that are impossible to make with conventional tooling are now possible and manufacturers realize immediate improvements in productivity, efficiency and quality.

In the 2005 year the mechanical engineering professor at University of Bath, England, Adrian Bowyer, founded *RepRap*, an open-source project to develop a 3D Printer that could print most of its own components. In February 2008 RepRap launched *Darwin 1.0*, a printer that could produce half of its components.

From 2012 year, some companies such as *Sculpteo* or *Shapeways* are proposing online solutions for 3D Printing.

3D Printing known also as *Additive Manufacturing* AM or *Desktop Manufacturing, Rapid Manufacturing, On-demand Manufacturing, Rapid Prototyping* refers to any of the processes for printing of three-dimensional 3D objects using additive processes (in which successive layers of material are laid down) under computer control.

3D Printing applications now seem endless, beginning with jewellery and toys and continuing with robots, cars and even gourmet desserts that require precise layers of icing or chocolate. 3D Printing has also medical applications as custom prosthetics and scientists in Australia and the United States are now working toward printing artificial organs such as kidneys from patient's own cells.

Over the years were developed over 40 AM technologies.

New unique capabilities of AM technologies like shape complexity, hierarchical complexity, material complexity enable new opportunities for customization, very significant improvements in product performance, multi functionality and lower manufacturing costs; to take advantage of them, new design and CAD methods must be developed. As example of new capabilities are printed flat sheets of ceramic materials which can be rolled or folded into different shapes before firing and fuel cells in concentric circles or interwoven instead on the standard stack, creating more surface area and therefore easier transport of charge.

Objects of almost any shape or geometry can be produced by "3D Modelling" in a 3D Printer.

3D Modelling in 3D computer graphics is the process of developing a mathematical representation of any three-dimensional surface of an object via specialized software.

The product is called *3D Model*. It can be displayed as a two-dimensional image through a process called *3D Rendering* or used in a computer simulation of physical phenomena.

The model can also be physically created using 3D Printers.

The 3D Printer prints shaped layers that build up into a replica of the thing you want to copy or designed. As materials, the industrial printers can use resin, clay, plastics or even powders of materials ranging from wood to metal. The year 2015 brings the first 3D printed car.

The real beauty of 3D Printing is that it removes constrains associated with traditional manufacturing, boosts project efficiency and reduces costs by allowing designs to be tested and adjusted quickly; it helps you think faster, innovate better and broaden horizons by providing a new medium where creative minds can develop new applications for innovative engineering in aerospace, architecture, automotive, commercial products, consumer products, defence, dental, education, entertainment, medical.

4D Printing is printing referring to the four-dimensional 4D space; 4D space adds the fourth dimension, T dimension, allowing for time.

On 27th February 2013, Stratasys company in collaboration with U.S. Massachusetts Institute of Technology MIT developed a 3D Printing with "smart" materials called the 4D Printing. Essentially, a 4D object is a 3D object evolving in time.

It is possible to create objects that have *four dimensions* 4D *characteristics* including a fourth dimension as a *dynamic component* that causes the structure of objects to change over time under the influence of water, heat, light.

This emerging technology will allow us to print objects that then reshape themselves or self-assemble over time: a printed cube that folds before your eyes, or a printed pipe able to sense the need to expand or contract. That means that those objects are made from *programmable materials*.

The American architect, artist and computer scientist Skylar Tibbits, as research scientist at the Massachusetts Institute of Technology, established what is known as the university's *Self-Assembly Lab,* a cross-disciplinary research laboratory for inventing self-assembly and programmable material technologies aimed at reimagining construction, manufacturing, product assembly and performance.

Self-Assembly is a process by which disordered parts build an ordered structure through local interaction. The *concept of self-assembly on a nano-scale* has been around for years.

But now the *challenge is to demonstrate that this phenomenon is scale-independent* and can be utilized for self-constructing and manufacturing systems at nearly every scale and also to identify the key ingredients for self-assembly as a simple set of responsive building blocks, energy and interactions that can be designed within nearly every material and machining process available.

Self-assembly is a daring concept that would promise to enable breakthroughs across every application of biology, material science, software, robotics, manufacturing, transportation, infrastructure, construction, space exploration and the arts.

The courageous designers, scientists, engineers of the MIT Self-Assembly Laboratory have been researching for developing a variety of programmable materials as wood, textiles, flexible carbon fibre that have limitless applications.

5D Printing is built on 3D Printing, adding two more axis to the printing bed to allow a greater control over the printing process with the aim to create very complicated and detailed designs.

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