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Future Communication Technology: A Comparison Between Claytronics And 3-D Printing

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Abstract: Man has always dreamt of changing the world around him; this led him to gradual advancement of communication technology that brought into reality the things, which were once termed impossible. It may be possible that in future-a chair can change its shape into a bed; the car could automatically change their shape, colour and size etc. The cell phone could turn into a laptop, and when the work is done it will turn back into a cell phone or any other object we want it to become. The technology that allows this kind of shape shifting is called Claytronics. Claytronics is a collection of programmable matter. It is also known as catoms. These catoms can work together in a vast network to build 3D objects and also capable to change colour and shape etc. Therefore, catoms are the basic building block of Claytronics. The idea behind Claytronics is putting enough of these catoms together, and giving them a command, and they will assemble themselves into anything we want. Claytronics is the technology to improve human to human (H2H) communication. One of the other most exciting innovations in communication technology in recent times is the 3-D printing. This technology offers the realistic possibility that anyone, anywhere in the world can produce any object they need on demand. Using 3-D printing it is possible to create an object by creating a digital file and printing it at home or sending it to one of a growing number of online 3-D print services.

In this paper, the author(s) presents a new approach about comparison of the upcoming future communication technology: Claytronics and 3D printing. It can revolutionize the field of communication in future.

Keywords: Communication, Claytronics, 3-D printing, Hardware, Software, Applications, Comparison

I. INTRODUCTION

The word 'communication' refers to the faithful transfer of information or message from one point to another point in an intelligible form. In ancient times, long distance messages were carried by messengers on foot, horse, cart etc. People also used coded signaling methods through burning fires, beating drums or waving flags, etc. Human involvement is necessary at every stage of communication. In modern communication systems, the information is first converted into electrical signals and then sent electronically. We use many of these systems such as telephone, TV and radio communication, satellite communication etc.

The work of the earlier scientists of 19th century and 20th century like J.C Bose, F.B. Morse, G. Marconi and Alexander Bell has proved to be the backbone of the modern communication. Today the growth of communication sector is much faster than any other industry [1].

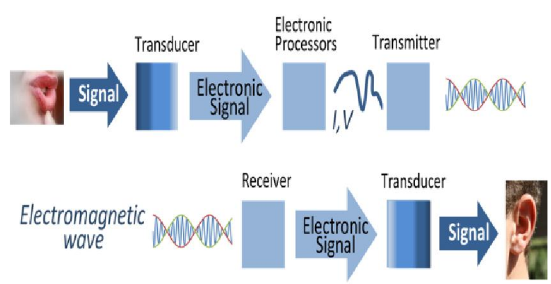

Fig.1 Block diagram of electronic communication system
Source: http://en.wikipedia.org

In the 1990s, the dominant means of communication shifted from the telephone to email as the Internet became commonplace. It was the decade when person-to-person communication was linked via ICT systems. During the first decade of this century, the form of communication developed into communication available at anytime and anywhere as a result of the explosive spread of mobile communication devices such as cell phones and wireless broadband. Furthermore, as smart phones became popular, people became accustomed to touch-based user interfaces. In the 2010s, we assume that optimum communication, in which the means of communication is optimized according to the users' situations, will become the norm [2].

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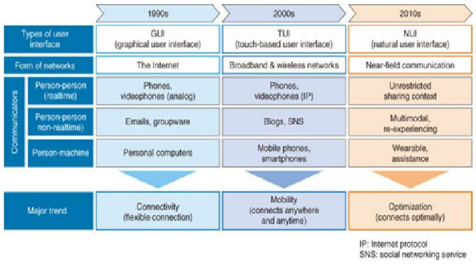

Fig.2 History of communications technologies
Source: https://www.ntt-review.jp/archive/nttechnical.php?contents=ntr2012fa11_s.html

No doubt, in the world of urbanization and modernization, new communication technologies are coming. Communication technologies can play a vital role in the advancement of new technologies such as 4G,, 5G,Artificial Intelligent (AI),Internet of Things (IOT), Claytronics,3D Printing etc.

In this paper, we present a new approach about comparison of the upcoming future communication technology: Claytronics and 3D printing. Both technologies –Claytronics and 3D printing are emerging technologies and both technologies have the potential to revolutionize the field of communication in the coming future In this paper, after the comparison between both of the technologies, we will find that which type of technology is better than other. Claytronics is the field in which one object can transform itself into another object. It might be possible that when we finished using a replica for one purpose, we could transform it into another useful shape. A human replica could morph into a desk, a chair could become a keyboard, and a lamp could be transformed into a ladder .Using Claytronics technology we would be able to talk to someone who lives far away, and yet have the experience of talking to him as if he was in the same room. Using this method we can communicate using not just voice and picture, but also touch. Means, the other person would be made out of Claytronics, this type of experience would be so real that it could not be differentiated from reality. But in 3D printing, though it is possible to make 3D model of an object but we can't feel or touch it which is possible in Claytronics. In 3D printing, there is limited availability of materials and source due to which interaction of the people working on the same model from various parts of world is not possible. But, using claytronics, multiple people at different locations could work on the same model. As a person at one location manipulated the model, it would be modified at every location. It is possible because of Programmable matter called catoms.

II. CLAYTRONICS

The idea is to build an object from molecular level, such that each molecule can be programmed to act according to instructions of the user and together with millions of its kind change the shape, size and even the characteristics of the object. The technique of developing individual micro scale computers, which can interact with each other to form tangible 3-D objects known as 'Claytronics'.

This technology combines ensemble robotics, computer science and nanotechnology to develop individual micro scale computers called computation atoms or catoms, that ensemble in millions to form transformable dynamic and self reconfigurable 3-D objects. Also known as 'Programmable matter', the catoms will be sub-millimetre computers that will have the ability to move around, communicate with each other, change colour, and electro statically connect to other catoms to form different shapes. The shapes made up of catoms can change their forms into nearly any object, even replicas of human beings for virtual meetings. Seth Golstein and Todd Mowry introduced this concept. They got their idea from playing with moulding clay. This technology can make a set of tiny beads into any other object. Today, we use a cell phone, tomorrow the cell phone can rearrange to form a laptop; the technology, sure is amazing and useful. This technology is not only effective in many skilled disciplines from engineering innovativeness, education , healthcare, entertainment and leisure activities but it is a step which can lead the world towards an innovative revolution. The main purpose of this technology is to improve human-to-human communication even when they remain considerably far away [3].

A beautiful example to depict the worth of the technology is the video conferencing which makes the 2-D image to be transferred from one place to another but being impossible to transfer a 3-D image.

Using claytronics, the physical presence of the person sitting beside can be felt continents away. This system could also have a role in telemedicine, allowing a patient and doctors to be miles away examining the patient with claytronics emulations. Thus, this technology is the next unparalleled entity towards a Future world. This technology has become possible because of the ever increasing speeds of computer processing predicted in Moore's law.

II.I. CONCEPT

It is a system designed to implement the concept of programmable matter, that is, material which can be manipulated electronically in three dimensions in the same way that two-dimensional images can be manipulated through computer graphics. Such materials would be composed of "catoms"-claytronics atoms- which would, in analogy with actual atoms, be the smallest indivisible units of the programmable matter. Each catom would be capable of receiving electronic instructions, processing information, and communicating with other catoms. Groups of catoms would be capable of movement, but without the individual

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catoms having any moving parts. The aim is for large numbers of extremely small catoms to be used in nanoscale robotics, allowing a wide range of applications.

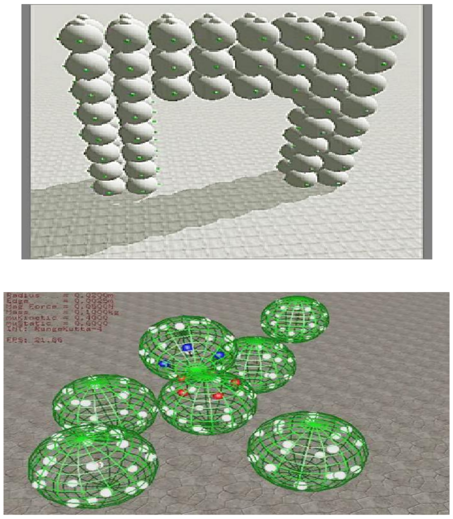

Fig.3 Catom or Claytron
Source: athuls0708.wordpress.com

The basic unit of claytronics, the catom, consists of a self-contained structure that has a receiver or antenna, a central processing unit (CPU), a power supply, one or more sensors, a video display and moving relative to, other catoms.

Ensembles: In claytronics, collections of catoms are referred to as "ensembles". Each catom within an ensemble is able to determine its location and, combining this information with some overall goal prescribed for the ensemble as a whole, can decide whether to bond with neighbouring catoms, or whether to more relative to them. For example, an ensemble might be given the goal of reproducing the three-dimensional object. Initially, the individual catoms may be moving around randomly, but as they use the information they have been provided about the object to be reproduced in combination with information about their states and locations from their internal memory and sensors, the object take shape through their cooperative action. It is a technology to create synthetic reality with which human interaction is possible [3].

The big advantage of designing on a computer is the ease of changing things, like colour and shape. But especially for 3D objects, it has some disadvantages. WE don't really get a feel for the object: What does it look like when I walk around it? How does it feel when I hold it in my hands? The problem can be solved with the help of Claytronics technology.

This technology is different from the 3-D holographic technology where the image is there but cannot be tangible and cannot be moved or morph, it is like the projection of object. Nanotechnology or sometimes called molecular manufacturing is a branch of engineering that deals with the design and manufacturing of extremely small electronic circuits and mechanical devices built at the molecular level of matter.

It can be said that this was the basic need to fulfil before moving advance in claytronics research.

II.II. HISTORY

The term Programmable matter is a term originally coined in 1991 by Toffoli and Margolus to refer to an ensemble of fine- grained computing elements arranged in space. Programmable matter is a matter which has the ability to change its physical properties like shape, density, conductivity etc. in a programmable fashion, based upon user input or autonomous sensing. In 2002, Seth Goldstein and Todd Mowry started the claytronics project at Carnegie Mellon University in Pittsburgh, Pennyslvania and the project is funded by Intel. In 2005, research efforts to develop a hardware concept were successful on the scale of millimetres. Presently collaborative research in Claytronics is directed by Carnegie Mellon University and Intel [4].

II.III. THE ROLE OF MOORE'S LAW

The promise of Claytronics technology has become possible because of ever increasing speeds of computer processing predicted in Moore's Law. It is a rule of thumb in the history of computing hardware whereby the number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years. This technology has become possible because of the ever increasing speeds of computer processing predicted in Moore's law. The law is now used in the semiconductor industry to guide long-term planning and to set targets for research and development.

MOORE'S LAW: It is the observation that the number of transistors in a dense integrated circuit doubles approximately every two years. The observation is named after Gordon Moore, the co-founder of Intel. It is an observation and not a physical or natural law. Moore's law describes a driving force of technological and social change, productivity and economic growth. It forms the basis of Claytronics [5].

II.IV. COMPONENTS OF CLAYTRONICS

The components of Claytronics are majorly hardware and software part to make an object move and morph. The major component of claytronics is Catom, a Catom is a single unit which is having all the equipments necessary to communicate along with the sensors for working. A Catom or Claytronic atom would be similar to the look of an atom

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and is preferred to be spherical in shape. It would have no moving parts and each of the Catoms will act as an individual and would be covered by electromagnets to attach itself to other Catoms. A large moving object such as a human replica might have billions of Catoms. A moving shape will make the Catoms to constantly and quickly change the positions, breaking connections with one set of Catoms and establishing new connections with others. They are attached to other catoms through electrostatic force each catom's negative charge side is attached to the positive side of the other catom so that the movement and torque is maintained in a circular motion. All components of electronics are working together in making the impossible possible.

II.V. HARDWARE

The driving force behind programmable matter is the actual hardware that is manipulating itself into whatever form is desired. Claytronics hardware operates from macro scale design with devices that are much larger than the tiny modular robots. Catoms created from the present research to populate Claytronics ensembles will be less than a millimetre in size, and the challenge is designing and manufacturing them draws the CMU-Intel Research team into a scale of engineering where have never been built. The team of scientists, students and engineers who design these devices are testing concepts that cross the frontiers of computer science, modular robotics and system nanotechnology.

1. Millimeter Scale Catoms

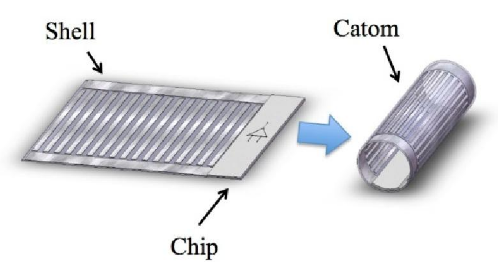

Fig.4. Millimeter Scale Catoms
Source:http://www.cs.cmu.edu/~claytronics/hardware/milliscale.html

In Millimeter Scale Catoms the catoms that are in the order of millimeters.

Fig.5
http://www.cs.cmu.edu/~claytronics/hardware/milliscale.html

The catoms consists of a cylindrical shell and a High voltage CMOS die that attached inside the tube. The tubes are fabricated as double-layer planar structures in 2D using standard photolithography. The difference in thermal stress created in the layers during the fabrication processes causes the 2D structures to bend into 3D tubes upon release from the substrate. The tubes have electrodes for power transfer and actuation on the perimeter. The high voltage CMOS die is fabricated separately and is manually flip-chip bonded to the tube before release. The chip consists of a rectifier, a charge pump for creating high voltages, a storage capacitor, a simple logic unit, and high voltage drivers [6].

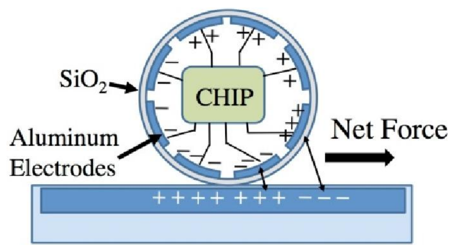

Fig.6. showing that catom moves on the stator
http://www.cs.cmu.edu/~claytronics/hardware/milliscale.html

The catom moves on the stator that contains rails which carry high voltage AC signals. An AC signals are generated on the coupling electrodes of the tube, with the help of capacitive coupling. An AC signals are then converted to DC power by the chip. The chip then generates voltage on the actuation electrodes sequentially, creating electric fields that push the tube forward.

2. Planar Catoms: It tests the concept of motion without moving parts and the design of force effectors that create cooperative motion within ensembles of modular robots. The self-actuating, cylinder-shaped planar Catom tests concepts of motion, power distribution, data transfer and communication that will be eventually incorporated into ensembles of nano-scale robots. The planar catoms operates on a two-dimensional plane in small groups of two to seven modules in order to allow researchers to understand how micro-electro-mechanical devices can move and communicate at a scale that humans cannot imagine. These are approximately 45 times larger in diameter than the

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millimetre scale Catom for which its work is a bigger-than-life prototype.

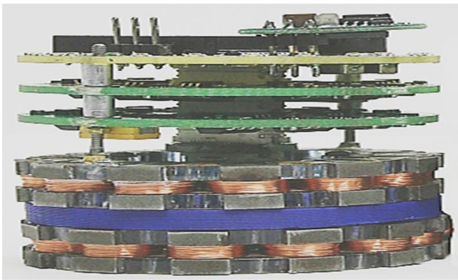

Fig.7 Planar Catom Version 8
Source: www.cs.cmu.edu

The view of stack of control and magent-sensor rings of the Planar Catom V8 is shown above. Its solid state electronic controls ride at the top of the stack. An individual ring is dedicated to each of the two rings of magnet sensors, which ride at the base of the module. Two thin threaded rods extend from top to bottom through the outside edge to brace the rings. At the base of the planar catom, the two heavier electro-magnet rings, which compromise the motor for the device, also add stability. To create motion, the magnet rings exchange the attraction and repulsion of electromagnetic force with magnet rings on adjacent catoms. Due to conversion of electrical to kinetic, the module achieves a turning motion to model the spherical rotation of millimetre-scale catoms[7].

2.1. Planar Catoms with LED

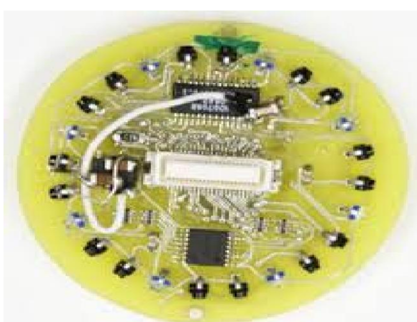

Fig.8 Planar Catoms with LED
Source: http://www.cs.cmu.edu/~claytronnics/hardware/planar-stuff/catomelelectromagneticmodules.pdf

The picture above displays a planar catom controller ring with Light emitting diode(LED's) arranged around its perimeter. This board directs the two magnet driver boards embeeded in the magnet rings. Built with the smallest componets availabe, each controller board contains 5 layers of embedded microcircuits on 45mm diameter acrylic boards. The resulting capacity of its boards enables the module to carry on board all devices needed to manage its firmware, drivers and magnets.

3. Electrostatic latches model: A new system of binding and releasing the connection between molecular robots, a connection that creates motion and transfers power and data while employing a small factor of a powerful force. It incorporates many innovative features into a simple, robust device for attaching adjacent modules to each other in a lattice-style robotic system. These features include a parallel plate capacitor constructed from flexible genderless electrodes of aluminium foil. Currently, the electrostatic latch is being tested on a modular Cube that is 28 cm on a side. Each star-shaped face supports passive self-alignment of the link with a 45-degree blade angle at the top of each comb on the face. The design also supports easy disengagement with a five-degree release angle along the vertical lines of faces. The electrodes that form the latch fit into "genderless" faces constructed as star-shaped plastic frames carried by each module. In the design of the circuits, each electrode functions as one-half of a complete capacitor. A latch forms when the faces of two adjacent modules come together and create an electrostatic field between the flexible electrodes [8].

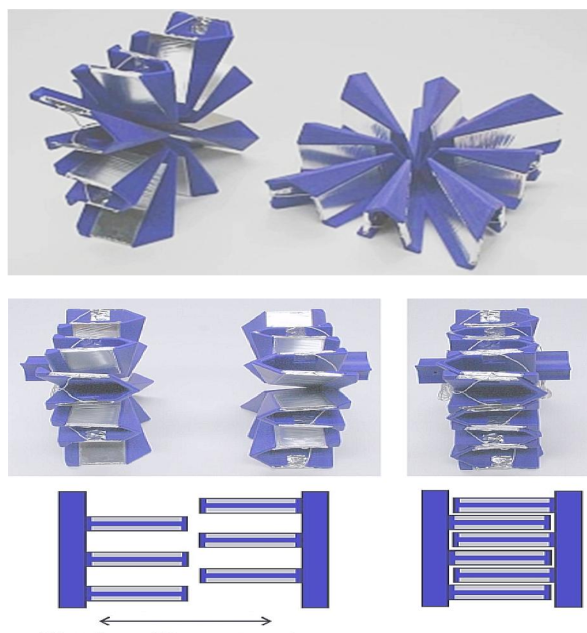

Fig.9 Showing the Locking Pattern
Source: http:/www.cs.cmu.edu/~claytronics/hardware/electrostatic-notes.html

4.Stochastic Catoms: It integrate random motion with global objectives communicated in simple computer language to form predetermined patterns, using a natural force to actuate a simple device, one that cooperates with other small helium

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Catoms to fulfil a set of unique instructions. The module makes its decision by evaluating the relation of its form in the instance of the contact location to the ensemble's overall goal for a predetermined shape. Based on this evaluation, the module either forms a bond or continues in motion [9].

Fig.10 Showing Helium Balloon
Source: http://www.cs.emu.edu/~claytronics/hardware/electrostatic-notes.html

5. Giant Helium Catoms**:** It provides a larger-than-life, lighter-than-air platform to explore the relation of forces when electrostatics has a greater effect than gravity on a robotic device, an effect stimulated with a modular robot designed for self-construction of macro-scale structures. The GHC provides researchers a macro scale instrument to investigate physical forces that affect micro scale devices. It measures eight cubic meters when its light Mylar skin fills with helium to acquire a lifting force of approximately 5.6 kilograms. This lift is required to elevate a frame of carbon fibre rods and plastic joints, which contains the balloon and carries communication package to actuate the catom's motion and engage it with other GHCs [10].

Fig.11 Showing Giant Helium Balloon-A Giant Helium Catoms(GHC)
Source: http://www.cs.emu.edu/~claytronics/hardware/helium.html

6. Cubes: A lattice –style modular robot, the 22-cubic-centimeter Cube provides a base of actuation for the electrostatic latch that has also been engineered as part of this program. The Cube also models the primary building block in a hypothetical system for robotic self-assembly that could be used for modular construction and employ Cubes that are larger or smaller in scale than the picture device. The design of the cube resembles a box with starbursts flowering from six sides, emphasizes several performance criteria; accurate and fast engagement, facile release and firm, strong adhesion while Cube latches clasps one molecule to another. Its geometry enables reliable coupling of modules, a strong binding electrostatic force and close spacing of modules within an ensemble to create structural stability [11].

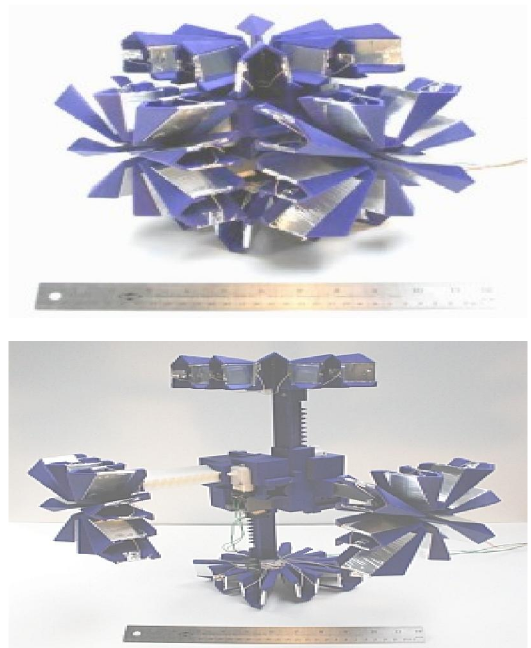

Fig. 12 Showing Electrostatic Latches and Cube with extended Worm-drivers
Source: http://www.cs.cmu.edu/~claytronics/hardware/cubes.html

II.VI. SOFTWARE

The researchers and engineers of Carnegie Mellon-Intel Claytronics Research Lab launched a wide range of projects to develop the necessary software to facilitate the communication between catoms. The most important projects are developing new programming languages which work more efficiently for claytronics. In a domain of research defined by many of the greatest challenges facing computer scientists today is perhaps the creation of algorithms and programming language to organize the actions of millions of sub-millimetre scale Catoms in a claytronics. As a consequence, the research scientists and engineers have formulated a very broad-based and in-depth research program to develop a complete structure of software resources for the creation and operation of the densely distributed network of robotic nodes in Claytronics matrix. Software language for the matrix operation must convey concise statements of high-level commands in order to be universally distributed. A large, moving shape such as a human replica might contain a billion Catoms. A system with a billion computer nodes is something on the scale of the entire Internet. Unlike the real Internet, our real thing is moving. Internet is a medium that not only distributes data around the globe but also enables nodes on the network to share work from remote locations.

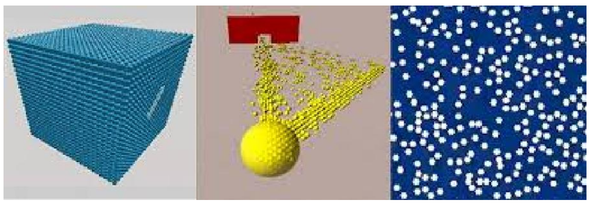

Fig.13 Software- Carnegie Mellon University

Source: www.cs.emu.edu

II.VI.I. PROGRAMMING LANGUAGES

Researchers in the Claytronics project have also created Meld and LDP (Locally Distributed Predicates). These new languages for declarative programming provide compact linguistic structures for cooperative management of the motion millions of modules in a matrix.

1. Meld: Meld is a programming language designed for robustly programming massive ensembles. Meld was designed to give the programmer an ensemble-centric viewpoint, where they write a program for an ensemble rather than the modules that make it up. A program is then compiled into individual programs for the nodes that make up the ensemble. In this way the programmer need not worry about the details of programming a distributed system and can focus on the logic of their program. Because Meld is a declarative language or a logic programming language, the programs written in meld are concise. The implementations are so concise; we have found it practical to prove them wrong. Meld programs are robust. They have been demonstrated on ensembles containing millions of modules. Meld addresses the need to write computer code for an ensemble of robots from a global perspective. This form of logical programming represents a heuristic solution (to produce a solution in a reasonable time frame that is good enough for solving the problem at hand) to the challenge of controlling the action of such a great number of individual computing nodes [4].

2. Locally Distributed Predicates (LDP): LDP approaches the distributed programming problem using pattern-matching techniques. LDP provides programmers the ability to specify distributed state configurations, based on combinations of the state found on connected subgroups of Catoms. The runtime of LDP automatically detects occurrences of these distributed configurations. It allows for the expression of distributed event sequences as well as the expression of particular shapes. As with Meld, LDP produces shorter code than traditional high-level languages (C++, Java, etc.). It is used to implement several motions planning algorithms, as well as a variety of low-level utilities such as gradient fields and distributed aggregation. This language enables the programmer to address a larger set of variables with Boolean logic that matches paired conditions and enables the program to search for larger patterns of activity and behaviour among groups of modules in the matrix [12].

II.VI.II. INTEGRATED DUBBING

In directing the work of the thousands to millions of individual computing devices in an ensemble, Claytronics research also anticipates the inevitability of performance errors and system malfunctioning. Such an intense computational environment requires a comparably dynamic and self-directed process for identifying and debugging errors in the execution of programs. IN programming modular robots to create dynamic, 3-D representations, the Carnegie Mellon-Intel Claytronics Research Project also anticipates a less enchanting probability for software programmers whose coded instructions will shape the actions of metamorphic robots. Claytronics will open the gates to greater number of bugs that can add a hex to coded instructions, multiplying opportunities for coded devices to go away. Claytronics also create operations where new types of bugs develop. One result is a program known as Distributed Watch Points.

1. Distributed Watchpoints: A more challenging error can arise when modules in a group properly execute their individual processes yet do not place the group in an intended global state. In this outcome, the error may be said to be distributed because it is not clear that any individual module has failed to properly execute its commands. The group has failed to achieve the desired configuration. The result is a condition that cannot be observed in the local state of one robot.

Traditional debugging tools would not detect the new species of bug. Thus, to find bugs whose effects are distributed across the status of several catoms, claytronics researchers have developed Distributed Watch points, an algorithm-level approach to detecting and fixing conditions that need to be resolved in order for the ensemble to engage properly the related status of multiple catoms in appropriate sequences. This approach provides a simple and highly descriptive set of rules to evaluate distributed conditions and proves effective in the detection of errors missed by more conventional debugging techniques [13].

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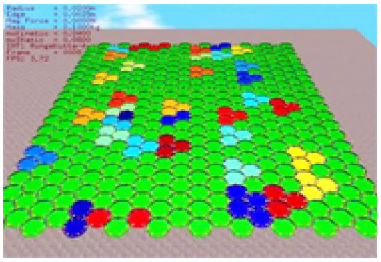

Fig.14 Showing Integrated Debugging-watch points

Source:

http://www.cs.cmu.edu/~claytronic/software/debugging.html

II.VI.III. SHAPE SCULPTING IN CLAYTRONICS

1. Lifting Catoms into the 3-D Dimension: Creating dynamic motion in 3-D poses the ultimate goal of the Carnegie Mellon-Intel Claytronics research Project. A Claytronics designer might demonstrate the complexity of this challenge of forming 3 –dimensional objects from millions of robotic catoms, each less than a millimeter in diameter, by presenting an ensemble of these tiny spherical devices laid side-by-side on a flat surface. This arrangement would present a 2-D square, approximately a meter on each side. This is the organized position that an ensemble could assume before the application of any external forces.

2. How then to give it a 3D shape?: With a flow of power into the ensemble, the sensors of adjacent catoms induce an electrostatic alignment to increase the hold of one catom to another across this million-member network of distributed computing devices. Each Catom would possess sufficient micro processing capacity to implement algorithms that instruct the device to localize its position in relation to other catoms. Thus, ensemble would reshape as it creates a new contour in a boundary line or opens a void inside its boundary while still lying flat [14].

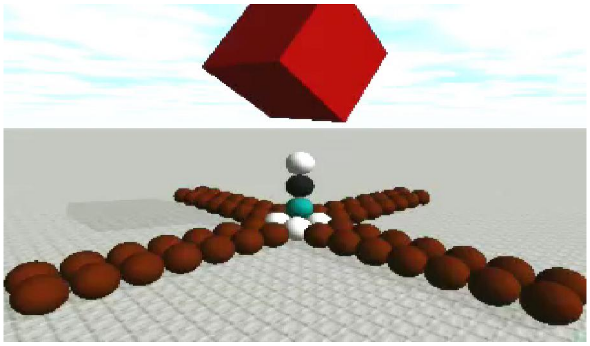

Fig.15 showing 3-d shape of Assembled Catoms
Source:
http//www.cs.cmu.edu/~claytronics/software/shapesculpting.html

II.VI.III. LOCALIZATION: DETERMINING MODULE LOCATIONS FROM NOISY OBSERVATIONS

The team's software researchers are also creating algorithms that enable Catoms to localize their positions among thousand to millions of other Catoms in an ensemble. One of the first tasks for a modular robot is to understand where its modules are located relative of one another. For example, motion planning and control will often shift many modules from one location to another, and knowing the module locations helps robot properly allocate the resources. In order to determine their locations, the modules need to rely on noisy observations of their immediate neighbors. These observations are obtained from sensors onboard the modules, such as short-range IR sensors. The robot's modules will often form irregular, non-lattice structures. The algorithm has a number of attractive properties: It can handle errors that arise from uncertain observations. The algorithm is sufficiently simple that it permits a distributed implementation. Hence, the communication complexity of our algorithm scales logarithmically with the size of the ensemble [15].

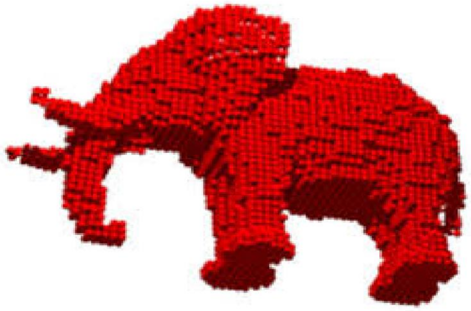

Fig. 16 Showing Localization Process
Source:http://www.cmu.edu/~claytronics/software/localization.htm
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II.VI.IV. DYNAMIC SIMULATION OF CLAYTRONICS ENSEMBLES

VISUALIZING THE INVISIBLE WHILE REALIZING THE UNREAL

Long before the first ensemble of a million catoms can be created, the designing of these never-before constructed robotic modules and testing of their performance in real-world conditions must occur. For this purpose, the research team assembled by Carnegie Mellon and Intel to create Claytronics technology, created the Dynamic physical Rendering simulator at the Intel Pittsburgh research Lab on the Carnegie Mellon campus.

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Fig .17 Showing DPRSim(Dynamic Physical Rendering Simulator)

Demonstrating the validity of claytronics requires extensive observation of cooperative behaviors among Nanoscale modular robots. The research task is made uniquely challenging by the absence of physical prototypes that can serve as demonstration platforms for these tiny devices, which are no larger than a grain of sand. It provides the bridge between imagination and reality by enabling researchers to create models of claytronic ensembles that operate in a software environment that fully replicates the forces that will affect the behavior of these devices during real world operations. It enables researchers to observe and track the performance of algorithms and software programs to control the actions of otherwise unobservable catoms in a claytronics ensemble. DPR Sim has become the essential tool for translating the visionary concept of dynamic. Moreover, a tool that operates with a real-time perspective on the operating state of every individual unit in the claytronics ensemble, it offers a version of the dynamic dashboard tools that will integrate the operations of hardware and software in real-life versions of claytronics ensembles [16].

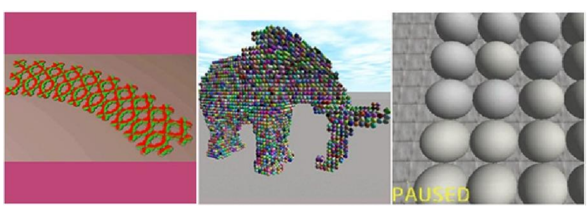

Fig.18 Showing DPR Sim [Dynamic Physical Rendering Simulator]

II.V. APPLICATIONS OF CLAYTRONICS

The Claytronics is newly developed branch of engineering that has the ability to change our thinking about future; it could be helpful in many ways to mankind. From the creation of wheel to the space technology mankind has done miracle to help people all over the world, the discovery of panacea drugs and computer aided technology, this technology can play the role of missing link in generating the full potential to the current and forthcoming technology.

Claytronics is actually beyond our imagination with the combination of Nanotech, computer science, electronics and communication, internet and artificial intelligence and forthcoming new technology. It can prove to be beneficial in every field whether science and technology, medical, pharmacy, tourism, education, business sector and so on, which has the potential of transforming the world in future. Let's hope for the best, and like every developed technology or thing it has pros and cons.

1. One likely application for claytronics is a 3-D fax machine that would enable the reproduction of three-dimensional objects from transmitted information. While a number of other options have been suggested to achieve this, it is probable that claytronics technology would result in much faster reproduction. The object to be reproduced could simply be buried under a layer of catoms that would obtain and transmit information about the object's themselves to create an accurate reproduction [17].

2. Another possibility is "pario"that allows the manipulation of moving three-dimensional objects, with many possible uses in research, modeling, design and education as well as entertainment. The idea behind pario is to reproduce moving, physical 3D objects. Similar to audio and video, we are neither transporting the original phenomenon nor recreating an exact replica; instead, the idea is to create a physical artifact than can do a good enough job of reproducing the shape, appearance, motion, etc., of the original object that our senses will accept it as being close enough. This featured application of claytronics is a new mode of communication. Claytronics will offer a more realistic sense to communication over long distance called pario. A user will be able to hear, see and touch the one communicating with them in a realistic manner. Pario could be used effectively in many professional disciplines from engineering design, education and healthcare to entertainment and leisure activities such as video games [18].

3. Surgeons to perform intricate surgery on enlarged claytronic replicas of organs, whilst the actual organs are being worked upon by a claytronic replica of the surgeon.

4. 3D TV'S and movies may also possible using this claytronics.

5. It might be useful for producing 3D shapes in the computer-aided design processes.

6. Claytronics cell phone might grow a full-size keyboard, or expand its video display as needed.

7. Using Claytronics, multiple people at different locations could work on the same model. As a person at one location manipulated the model, it would be modified at every location.

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8. In 3D physical modeling, physical replicas could replace 3D computer models, which can only be viewed in two dimensions and must be accessed through a keyboard and mouse. Using Claytronics, you could reshape or resize a model car or home with your hands, as if you were working with modeling clay. As you manipulated the model directly, aided by embedded software that's similar to the drawing tools found in office software programs, the appropriate computations would be carried out automatically. You would not have to work at a computer at all; you would simply work with the model. Using Claytronics, multiple people at different locations could work on the same model. As a person at one location manipulated the model, it would be modified at every location [19].

9. In the field of medicine, it may become possible that a replica of your physician appear in your living room and perform an exam. The virtual doctor would precisely mimic the shape, appearance and movements of your "real" doctor, who is performing the actual work from a remote office.

III. 3-D PRINTING

3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layer of material. It is also known as rapid prototyping. It is a mechanized method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing blueprints for the object. This revolutionary method for creating 3-d models save time and cost by eliminating the need to design, print and glue together separate model parts. We can create a complete model in a single process using 3-d printing. The basic principles include materials cartridges, flexibility of output, and transmission of code into a visible pattern. It is possible to 3D print in a wide range of materials that include thermoplastics, pure metals, ceramics, metal alloys and various form of food. In combination with synthetic biology and nanotechnology, it has the potential to radically transform may design, production and logistic processes.

3D printing is not a science fiction. It is a tool, like many others used in business. It has factual evidence of its benefits, and one can easily establish its worth to your business.

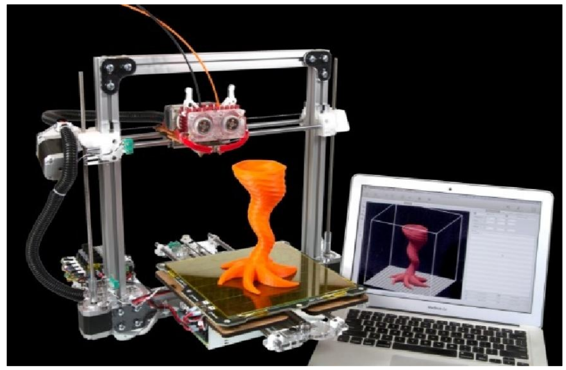

Fig.19 An example of 3-D printer
Source: manufacturingunlimited.com

3D Printers are machines that produce 3D models from digital data by building objects in successive layers that are typically about 0.1 mm thin. It can create 3D printable models with a computer aided design (CAD) package, via a 3D scanner, or by a plain digital camera. 3D printed models created with CAD result in reduced errors and can be corrected before printing which can allow the verification in the design. It encompasses a wide range of additive manufacturing technologies. This is then processed by 'slicing software' that divides the object into thin cross sections that are printed out one on top of the other. It is used in a variety of industries including engineering and construction, automotive, aerospace, dental and medical industries, education, consumer products etc.

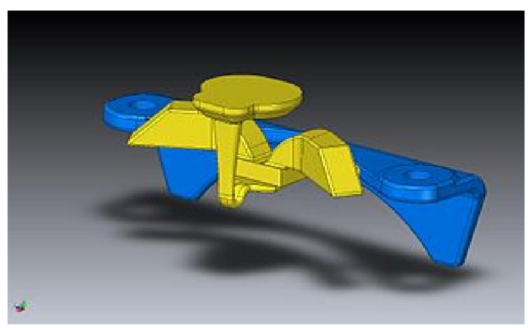

Fig.20 CAD model used for 3 D printing

Source: en.wikipedia.com

The manual modelling process of preparing geometric data for 3 D computer graphics is similar to plastic arts such as sculpting. 3 D scanning is a process of collecting digital data on the shape and appearance of a real object, creating a digital model based on it.

3D printing can speed development and delivery for customized products and bring increased flexibility through better inventory management and real-time production of

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products with variable demand. Other advantages include manufacturing advantages for small batches, cost advantages based on efficiencies for certain applications and unprecedented flexibility in new markets. 3D printing also can improve quality through lighter parts, better ergonomics and more design freedom [20].

III.I. HISTORY OF 3-D PRINTING

The technology for printing physical 3 D objects from digital data was first developed by Charles Hull in 1984. He named the technique as Stereo lithography and obtained a patent for the technique in 1986. While stereo lithography systems had become popular by the end of 1980's, other similar technologies such as Fused Deposition Modelling (FDM) and Selective Laser Sintering (SLS) were introduced. In 1993, Massachusetts Institute of Technology (MIT) patented another technology named "3 Dimensional Printing techniques", which is similar to the inkjet technology used in 2-d printers. In 1996, three major products, "Genisys" from Stratasys," Actua 2100" from 3D Systems and " Z402" from Z Corporation, were introduced. In 2005, Z Corp. launched a breakthrough product, named Spectrum Z510, which was the first high definition colour 3D Printer in the market. Another breakthrough in 3D Printing occurred in 2006 with the initiation of an open source project, named Reprap, which was aimed at developing a self- replicating 3 D printer.

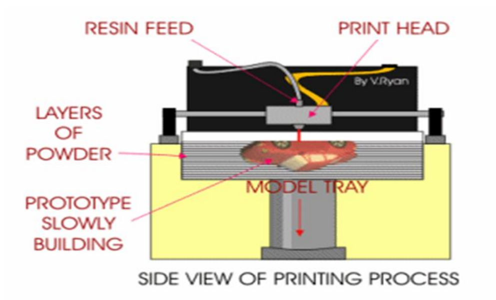

Fig.21 manufacturing a model with the 3D printer
Source: www.technologystudent.com

The model to be manufactured is built up a layer at a time. A layer of powder is automatically deposited in the model tray. The model tray then moves down the distance of a layer and another layer of power is deposited in position, in the model tray. The print head applies resin in the shape of the model. The model trays then move down the distance of a layer and another layer of power is deposited in position, in the model tray. The print head again applies resin in the shape of the model, binding it to the first layer.

Very recently, Engineers at the University of Southampton in the UK have designed the world's first aircraft manufactured with the help of 3D printing technology. Created on an EOS EOSINT P730 sintering machine, its wings hatches and control surfaces basically everything that makes up its structure and aerodynamic controls was custom printed to snap together. It requires no fasteners and no tools to assemble [21].

Fig.22 World's First 3D Printed Plane Takes Flight
Source: www.dailymail.co.uk

III.II. CURRENT 3D PRINTING TECHNOLOGIES

1. Stereolithiography: Stereolithography (SL) is one of several methods used to create 3D-printed objects. It's the process by which a uniquely designed 3D printing machine, called a stereolithograph apparatus (SLA) converts liquid plastic into solid objects. This technology uses an ultraviolet beam to harden liquid photopolymer resin, bonding each successive layer. It is process for creating 3 D objects, in which a computer- controlled moving laser beam is used to build up the required structure, layer by layer, from a liquid polymer that hardens on contact with laser light. The term was coined by Charles W. Hull in 1986. With the help of CAD software, the UV laser is used to draw a pre-programmed design on to the surface of photopolymer resin. It requires the use of supporting structures which attach to the elevator platform to prevent deflection due to gravity. Supports are created automatically during the preparation of 3d CAD models and can be made manually. Its speed is good; parts can be manufactured within a delay. But it is often costly [22].

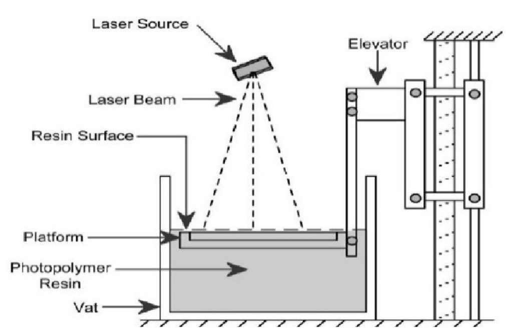

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Fig.23 Stereolithography
Source: www.whiteclouds.com

2. Fused deposition modeling: This technology uses a thermoplastic filament, which is heated to its melting point and then force out, layer by layer, to create a 3D object. The technology was invented in 1980's by Scott Crump. Objects created with an FDM printer start out as CAD files. Before an object can be oriented, its CAD file must be converted to a format that a 3d printer can understand. They use two kinds of materials- finished object and a support material. During printing, these materials take the form of plastic threads which are unwound from a coil and fed through an extrusion nozzle. Both the nozzle and the base are controlled by a computer that translate the dimensions of an object into X, Y and Z coordinates for the nozzle and base to follow during printing. Most common printing materials are acrylonitrile butadiene styrene (AbS) and polydactyl acid polymers. The technology is basically used to produce end-use parts- particularly small parts and specialized manufacturing tools [23].

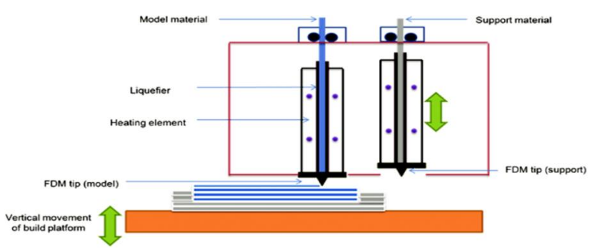

Fig.24 Process of fused deposition modelling
Source: manufacturingscience.asmedigitalcollection.asme.org

3. Selective Laser Sintering: It is a technique that uses a laser as the power source to sinter powdered material aiming the laser automatically at points in space defined by a 3D model, binding the material together to create a solid structure. Sintering is the process of compacting and forming a solid mass of material by heat and pressure without melting it to the point of liquefaction. The technique was developed by Dr. Carl Deckard. During SLS, tiny particles of plastic, ceramic or glass are fused together by heat from a high-power laser to form a solid, 3D object. This technique builds objects by using a laser to selectively fuse together successive layers of a cocktail of powdered wax, ceramic, metal, nylon or one of a range of other materials. For example, SLS is used to build prototypes for airplane parts. SLS requires the use of high-powered lasers. It is often more expensive and dangerous for use at home [24].

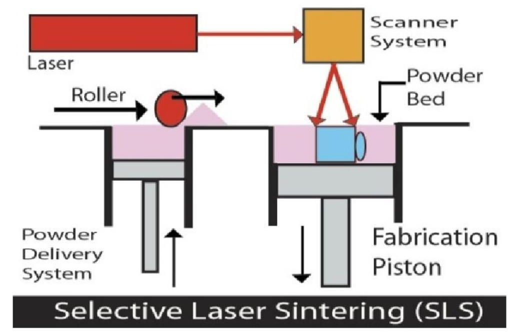

Fig.25 Selective Laser Sintering (SLS)
Source: en.topmaxtech.net

4. Selective Laser Melting: It is similar to SLS, but rather than fusing the powered material, the powder is melted at very high temperature. A laser is used to melt successive layers of metallic powder. The laser will heat particles in specified places on a bed of metallic powder until completely melted. The CAD 3D file dictates where melting will occur. Then, the machine will successively add another bed of powder above the melted layer, until the object is completely finished. The most common applications for this technology are in aerospace industry, as complex parts can be made with additive manufacturing. It can also result in the reduction of parts needed. Also used in the medical field where some prosthetics are created with this technology [25].

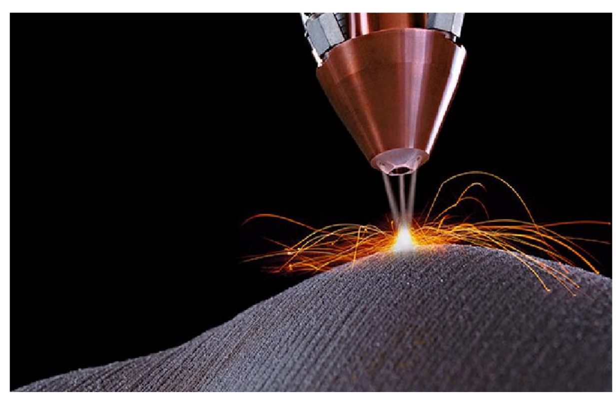

Fig.26 Selective Laser Melting
Source: www.extremetech.com

5. Electron Beam Melting: It is a rapid manufacturing process in which fully dense parts with properties equal to those of wrought materials are built on layer-by-layer basis. After melting and solidifying one layer of titanium powder, the process is repeated for subsequent layers until the part is complete. For industries such as aerospace, this creates new opportunities for both prototyping and low-volume

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production for titanium parts. When the high-speed electrons strike the metal powder, the kinetic energy is instantly converted into thermal energy. Raising the temperature above the melting point, the electron beam rapidly liquefies the titanium powder. It is similar to laser melting, but working with an electron beam instead of a laser. EBM requires support structures, which anchor parts and overhanging structures to the build platform. This allows the heat transfer away from where the powder is melted. Therefore, it reduces thermal stresses and prevents wrapping. Parts can be manufactured in some standard metals with high density by electron beam melting. However, the availability of materials is limited and the process is rather slow and expensive.

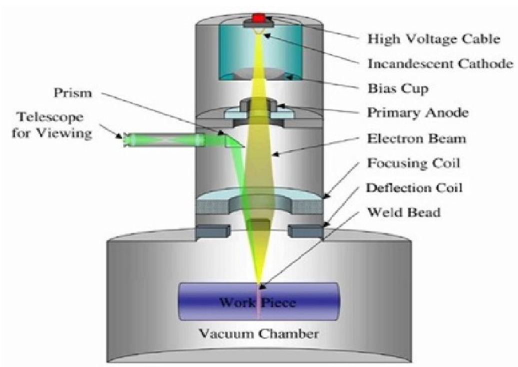

Fig.27 Electron Beam Melting
Source: www.popular3Dprinters.com

6. Multi-jet modeling (MJM): It is one of the high-end solutions in the 3D printing market. This technology is unique because one large print head is used, which covers the full width of the building platform. Users of this technology are virtually independent of the build-speed, because no matter whether just one part or 10 to be produced, the build-time is almost identical. MJM is using an acrylic photopolymer, which offers a very high surface quality, accuracy, and precision. The material is then heated and "trickled" out of Nano-Jets on the build platform. Support structures are generated automatically. The support material is a wax which has a lower melting temperature than the component material and thus easily could melt out. Depending on the choice of material, this technology is used in applications where high precision, strength and series-like prototypes are needed [26].

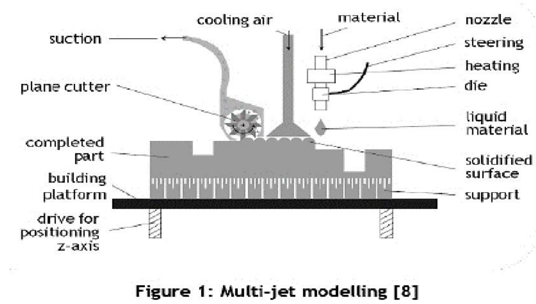

Fig.28 Multi-jet modeling
Source: www.scielo.org.za

III.III. APPLICATIONS OF 3D PRINTING

3D printing has the potential to shake up supply chains by positively impacting parts manufacturing, inventory costs and lead times. For example, 3D printing can help companies meet demand in real time in situations when long lead times are a problem. It also can help lower inventory costs by enabling companies to maintain a virtual inventory and print parts as they need them. 3D printing can be used in centralized and decentralized networks; however, research has shown that using 3D printing in decentralized networks has a measurable impact on the supply chain.

1. Consumer Electronics: 3D printing has generated positive results for the consumer electronics industry through prototype development, new product and concept designs, and parts prototyping. For example, a large consumer electronics company reduced design validation times from one week to one day, significantly improved fit and finish, and created better products through 3D printing. A large computer accessories company saw a return on its initial investment in just eight months of 3D printing use. A small consumer audio company experienced improved processes and workflow by using 3D printing for customized assembly components.

The next big 3D printing opportunity for the consumer electronics industry is in smart phones, which comprise an estimated 35% of total consumer electronics sales. Smartphone manufacturers are slowly moving beyond prototyping applications for 3D printing with more growth projected in the near future after advancements in materials [27].

Fig.29 Consumer electronic products created by Germany
Source: www.3ders.org

2. Automotive: The automotive industry invested early once 3D printing became commercially available. Today, automotive manufacturers primarily use the technology for prototyping rather than parts manufacturing. This is likely because automotive production volumes are usually too high for 3D printing to be a viable manufacturing method for most finished parts. 3D printing users in the industry have experienced measurable benefits. A medium-sized automotive engine control company used 3D-printed sand cores for the casting of prototypes and saw prototyping time diminish from 16 weeks to one week or less. A large automotive supplier used 3D printing for product concept prototypes, pre-production prototypes and show models. Automotive company's also experienced improved product cycle times by experimenting with 3D printing for assembly fixture, test fixtures and robotic arm tooling. 3D printers in automotive design empower companies to try multiple options in the development stages leading to optimum and efficient automobile design.

Making parts cheaper, lighter and faster is often a key goal of the automotive industry, indicating future opportunities for 3D printing in parts manufacturing [28].

Fig.30 3D printed car
Source: www.foxnews.com

3. Research: The ultimate goal of any researcher is to advance their field of study. With the help of 3D printing it allows printing fully functioning assemblies in a single piece to reduce extra steps. Researchers can save time by making lab more efficient and responsive. They can use 3D print custom fixtures and lab instruments that improve accuracy, repeatability and safety. The Researchers can test more scenarios in less time by simulating a wide range of material properties.

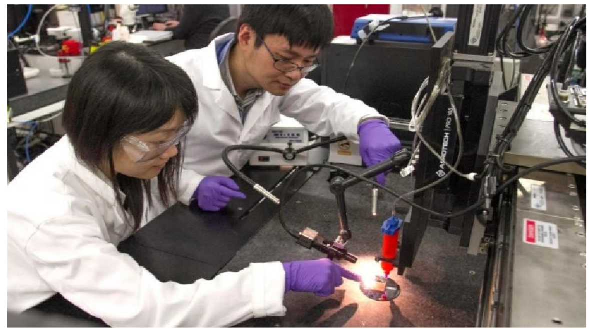

Fig.31 3D printing in research
Source: www.llnl.gov

4. Fashion industry: 3D printers are capable of fabricating anything from toys to body parts to entire houses. More common 3D printing use a biodegradable plastic to build item layer by layer with a technique called additive manufacturing and one field where this has potential is the fashion industry. Traditionally, sustainable fashion meant recyclable materials, fair wages for those making the clothes, etc. But a powerful 3D printer and an innovative mind could change all that. Designers have begun experimenting with 3D printed pieces of clothing. The fashion industry is the third largest consumer of water. Unsustainable cotton farming practices and irrigation requirements are a serious environmental threat. The problem can be solved by using 3D printing. It eliminates waste. Items are created one layer at a time with extreme specificity. Fabric for clothing does not need to be rolled out by the meter, then cut and stitched; instead it's printed and ready to wear. The ability to 3D print clothing equals a huge reduction in shipping and transportation needs. Van Herpen, known for pushing haute couture boundaries, was the first designer to sent 3D catwalk in 2010, forcing industry to rethink the deign process. Big name brands like Adidas plans on realizing 3D printed running shoe that can be customized with individualized support for every foot [29].

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Fig.32 3D printing in fashion industry
Source: modeconnect.com

5. Food: 3D printing is a way of preparing a meal in an automated additive manner. For this 3D printed pizza, the dough was applied with a food 3D printer. Afterwards, tomato sauce was 3D printed by the same machine. Cheese and oregano were applied by hand. 3D printing food works much like a non-food 3D printer in the sense that material is extruded through a print head onto a surface. A dish can be printed in any shape the designer wants as long as it does not extend past the spacial limitations of the printer and the laws of physics. Ideally, 3D printed food is nothing more than fresh, natural ingredients processed in such a way, that it can be extruded through a nozzle onto a food-safe surface [30].

Fig.33 Food 3D Printing
Source: https://all3dp.com/3d-printed-food-3d-printing

6. Medical Field: Medical practitioners have now begun using 3-D printers to produce medical devices. Examples of medical 3-D printing successes include the creation of plastic tracheal splints and limb prosthetics as well as titanium replacements for jaws and hips. 3-D printing has created a remarkable change in medical manufacturing industry because of the relatively low cost and small size of printers that help in making the technology widely accessible, allowing doctors and researchers to create personalized devices for patients. A physician whose patient experiences pain or has developed an infection from a non-customized prosthetic can now use imaging technology and a 3-D printer to customize a new prosthetic that conforms to the specific shape and movements of the patient's body. A related area of 3-D printing called bio printing, involves printing human tissue and organs by layering living cells instead of plastic or titanium. While bio printing remains in the experimental phase, the ability to print human tissue could have a huge impact on such things as pharmaceutical research, transplants, surgical operations and reconstructive surgery.

The greatest advantage that 3D printers provide in medical applications is the freedom to produce custom-made medical products and equipment .For example, the use of 3D printing to customize prosthetics and implants can provide great value for both patients and physicians. In addition, 3D printing can produce made-to-order jigs and fixtures for use in operating rooms. Custom-made implants, fixtures, and surgical tools can have a positive impact in terms of the time required for surgery, patient recovery time, and the success of the surgery or implant.It is also anticipated that 3D printing technologies will eventually allow drug dosage forms, release profiles, and dispensing to be customized for each patient. Another important benefit offered by 3D printing is the ability to produce items cheaply. Traditional manufacturing methods remain less expensive for large-scale production; however, the cost of 3D printing is becoming more and more competitive for small production runs. This is especially true for small-sized standard implants or prosthetics, such as those used for spinal, dental, or craniofacial disorders. The cost to custom-print a 3D object is minimal, with the first item being as inexpensive as the last. The current medical uses of 3D printing can be organized into several broad categories: tissue and organ fabrication; creating prosthetics, implants, and anatomical models; and pharmaceutical research concerning drug discovery, delivery, and dosage forms [31].

Fig.34 3-D printed prosthetic hand
Source: inhabitat.com

III.IV. ADVANTAGES OF 3D PRINTING

1. Save money: Prototyping injection mould tools and production runs are expensive instruments. The 3D printing process allows the creation of parts through additive manufacturing at rates much lower than traditional

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machining.3D printing is increasingly being used by large companies such as Converse or Alessi to replace some of their traditional manufacturing methods with cost savings of up to 70%. This is achieved through lower shipping and packaging costs related to overseas parts suppliers, less human resource involved and cheaper and sometimes more reliable raw materials.

2. Mitigate Risk: Being able to verify a design before investing in an expensive molding tool is worth its weight in 3D printed plastic. Printing a production-ready prototype builds confidence before making these large investments. It is far cheaper to 3D print a test prototype then to redesign or alter an existing mould.

3. Clear Communication: Describing the product you are going to deliver is often misinterpreted since it leaves construction up to imagination. A conceptual picture of the product is better than the description since it is worth 1,000 words, but getting to hold the tangible product-to-be, in hand, clears all lines of communication.

4. Feedback: With a prototype you can test the market by unveiling it at a trade-show, showing it to potential buyers or raising capitals. Getting buyer's response to the product before it actually goes into production is a valuable way to verify the product has market potential.

Personalize it: With standard mass- production, all parts come off the assembly line or out of the mould the same. With 3D printing, on can personalize and customize a part to uniquely fit their needs, which allows for custom fits in the medical and dental industries. It also helps in set people apart in the fashion and jewellery world.

5. Build your imagination: One can now 3D print almost anything they imagine after drawing it up virtually. In a relatively short time, an idea, concept, dream or invention can go from a simple thought to a produced part that you can hold [32].

6. Sustainability: Less waste compared to traditional manufacturing methods is not only a cost saving feature of 3D printing but also a possible eco-friendly attribute. Add to this them multi-purpose characteristic of a 3D printer (can build different objects without the need of using specialized machines for each part) and their digital ecosystem (all 3D models are transmitted electronically so in theory they can be printed out where they are needed, minimizing therefore transport costs) and you get a sustainable manufacturing process .

Fig.35 3D printed fabrics
Source: www.ecouterre.com

7. Warehousing: With traditional manufacturing technologies, it is much faster and cheaper to manufacture additional products that you probably know that you will eventually need. With 3D printing only products that are sold need to be manufactured, thus warehousing of excess inventory is significantly less needed.

8. 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 artist would be able deliver their products to the market.

9. Waste reduction: With unused powder being reused for successive printing, much less material is wasted with the help 3D printing technology. The finished 3D printed product can be up to 60% lighter compared to the machined part but still as study according to the Economist. Significant cost savings can be achieved in this way and less waste also means a lower impact on the environment.

10. New shapes and structures: Complete 3D models can be manufactured including those with hollow parts that could not possibly be made by hand in one piece, even by the most skilled engineer or craftsperson. Parts such as bearings, engineering parts and complex working models can be manufactured. Models can be electroplated to give the look and feel of a range of metals. The 3D printer's nozzle can build an infinite number of complex figures, being limited only by human imagination. This method gives them more durability and higher structural integrity. From medical implants that resemble bone to aerodynamic parts for the space industry and from unique-shaped furniture to 3D printed jewellery, the opportunities are endless.

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Fig.36 3D printed geometric shape
Source: augmentedtomorrow.com

11. Quick production: The speed of 3D printing compared to traditional methods is similar to comparing a sports car's top speed to a horse carts. They both take you where you want to go but the journey time differs considerably. With industrial 3D printers being able to 'manufacture' most objects in a matter of hours, the classical manufacturing methods, taking up to several days or even weeks (from prototype to end product), are slowly becoming obsolete.

12. New combination of materials: Mixing different raw materials is not always possible with mass-manufacturing methods due to the sometimes high costs involved and to their physical & chemical properties that make them difficult to combine through traditional methods. 3D printing has removed many of these boundaries not only because of the initial dependency on plastic (being one of the few raw materials that melt at lower temperatures) but also because of a continuous innovation fed by enthusiasts believing that additive manufacturing's potential has not been reached yet. As a result, many companies now offer tens of different materials with different finishes giving the look and feel of metal, ceramics or glass with various strengths and temperature resistance [33].

13. New business models: With 3D printing gaining popularity fast, entrepreneurs have not lost any opportunity to get their foot into an industry deemed by many as potentially very lucrative. This is how 3D printing 'shops' were born. Imagine going shopping in a supermarket where you decide how your products will look and feel, and where everything can be personalized to fit your demanding tastes.

Fig.37 3D Printed metal art for your home
Source: www.pinterest .com

The best thing that can happen for 3D printing would be the invention of 3D scanners. It would make it possible for people to create replacements for a broken accessory of an object in their possession. Take for example an office desk chair, imagine you break one of the wheels, if you could scan the wheel (temporarily glued together) than you can replace it with a 3D print.

14. Eco-friendly: 3D printing is also considered environment friendly since it produces less waste compared to other techniques.

III.V. DISADVANTAGES OF 3D PRINTING

1. Size: Parts printable by a 3D printer are limited by the size of the printer itself. The chamber sizes of commercially available 3D printers, which are commonly small in size enough to be transportable and fit on your desktop, are proportionally small. The larger models, capable of printing larger shapes and parts, are expensive. Also large parts can take a long time to print on current technology.

2. Manufacturing limitations: 3D printing is perfect for creating prototype parts because it's an economical, inexpensive way of creating one-run parts for which you don't have to create tooling. Parts typically are created in hours and changes to the design and engineering of the part can be made in a CAD (computer-aided design) file after the part is analyzed. But in terms of a manufacturing process, 3D printing is not a realistic option as of the date of publication. In manufacturing processes such as thermoforming and stamping, several parts are typically made in one minute, not hours.

3. Questionable accuracy: 3D printing is primarily a prototyping technology, meaning that parts created via the technology are mainly test parts. As with any viable test part, the dimensions have to be precise in order for engineers to get an accurate read on whether or not a part is feasible. While 3D printers have made advances in accuracy in recent years, many of the plastic materials still come with an accuracy disclaimer. For instance, many materials print to either +/- 0.1 mm in accuracy, meaning there is room for error.

4. Limited materials: The 3D printing material of choice is plastic, as it can be deposited down in melted layers to form the final part. The kinds of plastic vary among the likes of high-strength and high temperature materials, so part strength can't accurately be tested in many cases. Some developers are offering metal as a material, but final parts often are not fully dense. There are several more specialized materials that companies are printing in, such as glass and gold, but such technologies have yet to be commercialized.

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5. 3D Printed Objects May Require Heavy Duty Post Processing: One of the disadvantages of 3D printing isthe poor finishing quality of the object printed. The quality of the finish can leave a lot to be desired in a 3D printed object. Moreover, it isn't only the lack of polish that is the problem but also the possible dimensional inaccuracy.

6. Unchecked production of dangerous items: With 3D printers, plastic knives, guns and any other hazardous objects can be created. It makes easier for terrorists and criminals bring a weapon without being detected.

7. Cost of printers: The cost of buying a 3D printer is very high. It is beyond the reach of a average man. Different 3D printers are required in order to print different types of objects. Printers that can manufacture in colour are costlier than those monochrome objects.

8. Violation of copyrights: Technology such as this can be misused resulting in the rise of many ethical concerns. As any desired object can be printed, an owner of a 3D printer can print objects that are protected by copyrights. By cutting off the availability of 3D printer design of the protected work can help to protect the copyrights. However, it is nearly impossible to remove the availability of all the existing design files on the internet.

9. Fewer manufacturing jobs: As with all new technologies, manufacturing jobs will decrease. This disadvantage will have a large impact to the economies of countries which are over populated especially China, that depend on a large number of low skill jobs.

10. Limited Raw Materials – Traditional manufacturing of products has an enormous range of raw materials that can be used. Presently 3d printers can work up to approximately 100 different raw materials and creating products that uses more raw materials are still under development [34].

IV. COMPARISON BETWEEN CLAYTRONICS AND 3D PRINTING

3D PRINTING	CLAYTRONICS
In 3-D printing, it is possible to create an object by creating a digital file and printing it at home or sending it to one of a growing number of online 3-D print services.	Claytronics is the technology which combines nano-robotics and large-scale computing to create synthetic reality, a revolutionary, 3-dimensional display of information.
One problem with the 3D printing technology is the size of the 3D printers. Laser scanners and 3D printers remain bulkier than the object being scanned/ reproduced despite years of commercial development.	Similar results could be achieved with a smaller volume of programmable matter in Claytronics.
The display of things, information and other objects in 3-D is not much better in 3D printing.	The display of things, information and other objects in 3D is much better in Claytronics as compared to 3D printing.
In 3D printing, we can create a complete model in a single process but we can't feel or experience its presence around us.	In Claytronics, we can create a complete model in a single process and we can feel or experience its presence around us. Researchers are trying to make moving, physical, three-dimensional replicas of people or objects, so lifelike that human senses would accept them as real. This would eliminate the need for virtual reality gear and overcome the viewing angle limitations of 3D printing technology. The replicas would mimic the shape and appearance of a person or object being imaged in real time, and as the originals moved, so would their replicas. These 3D models would be physical entities, not holograms. You could touch them and interact with them, just as if the originals were in the room with you.
In 3D printing, it is not possible to transform one thing to another in less amount of time.	In Claytronics, it might be possible that when you finished using a replica for one purpose, you could transform it into another useful shape. A human replica could morph into a desk, a chair could become a keyboard, and a lamp could be transformed into a ladder.
In 3D printing, there is limited availability of materials and source due to which interaction of the people working on the same model from various	Using Claytronics, multiple people at different locations could work on the same model. As a person at one location manipulated the model, it

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parts of world is not possible.	would be modified at every location. It is possible because of Programmable matter called catoms. The catoms will be sub-millimetre computers that will have the ability to move around, communicate with each other, change colour, and electro statically connect to other catoms to form different shapes.
In 3D printing, software development and capabilities are not well advanced. Physical replicas could replace 3D computer models, which can only be viewed in two dimensions and must be accessed through a keyboard and mouse.	Using Claytronics, we could reshape or resize a model car or home with our hands, as if we were working with modeling clay. As we manipulated the model directly, aided by embedded software that's similar to the drawing tools found in office software programs, the appropriate computations would be carried out automatically. We would not have to work at a computer at all; we would simply work with the model.
In 3D printing, the quality of the finished product is poor. There is less availability of equipments and source required for communication.	Claytronics will offer a more realistic sense to communication over long distance called Pario. A user will be able to hear, see and touch the one communicating with them in a realistic manner. Pario could be used effectively in many professional disciplines from engineering design, education and healthcare to entertainment and leisure activities such as video games.
In 3D printing due to lack of advanced technologies, the interaction between different people is not possible.	Claytronics is a combination of new emerging technologies mainly nanotechnology and robotics which can help in the advancement of various field like cloud computing, Internet of thinking (IOT) that can play an important role in the advancement of communication.

V. FUTURE ASPECT OF THE CLAYTRONICS AND 3D PRINTING

3D printing has absolutely nothing to do with printing - it has everything to do with manufacturing.
3D printing uses "reductive" or "additive" modeling which is useful, but not all that sophisticated. Once a model is "carved out" or "glued together", it remains just that, a model. Using 3D printing more complex models can be assembled in future like: shoes, jewelry, gears, and machinery etc. [35].

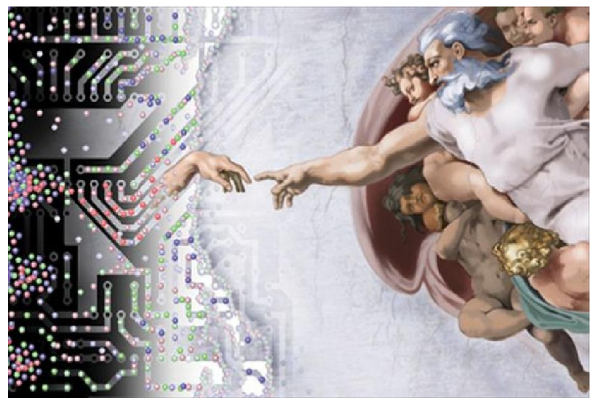

Fig.38 Communication in future
Source: http://www.thedeathofthecopier.com/2015/07/claytronics-programmable-matter-forget.html

Similarly the future results of Claytronics will be amazing. Our furniture will be able to do double duty, the art on our wall will change itself according to your mood, our cell phone could turn into a laptop, and when the work is done it will turn back into a cell phone. A bracelet or watch will change into something else when we take it off. Perhaps it becomes a cell phone, tablet, or computer. Basically, this technology will revolutionize the way we live, and communicate .The main aim of using this technology is to improve human to human (H2H) communication. So that we would be able to talk to someone who lives far away, and yet have the experience of talking to him as if he was in the same room with us. In future using this technology we can communicate using not just voice and picture, but also touch. The other person would be made out of Claytronics, but the experience would be so real that it could not be differentiated from reality.

In future the Programming of catoms can be stored on the cloud for better coding as it can be explored by the whole world. Some of the basic programs from performing utility action like Turing into big LED T.V. screen or multifunctional smart phone or 3-D fax machine or 3- D personal assistance of your choice can be stored on the cloud these program instructions can be accessible to the masses and other customized program instruction can be tailor made according to the usage of corporate world or industry [36].

VII. CONCLUSION

In this paper we concluded that with the help of both technologies, it can be said that, it is a new beginning of era which is full of possibilities, imagination and creativity. The innovation and advancement in the communication can be seen very prominently from the old days to the modern ways of communicating there is a remarkable change. In this paper after studying the two technologies Claytronics and 3 D Printing and their comparison we concluded that using 3D printing, more complex models can be assembled in future like: Jewelry, Gears, and Machinery etc.

Claytronics, the technology seems to be from the science fiction and yet here we are discussing the possibilities of programming matter in its full capacity. The concept came from ‘clay’ modeling, which can be shaped in any form and size. The basic programmable unit called as ‘catoms’ is the derived from Nano tech and it can interact with other atoms and also send signals to communicate there is no moving part inside whole catoms moves altogether.

3D printing has become a useful and potentially transformative tool in a number of different fields, including medicine. As printer performance, resolution, and available materials have increased, so have the applications. Researchers continue to improve existing medical applications that use 3D printing technology and to explore new ones. The medical advancements that have been made using 3D printing are already significant, exciting and encouraging, but some of the more revolutionary applications, such as organ printing etc. it will need time to evolve and develop. 3D printing technology could revolutionize and re-shape the world. Advances in 3D printing technology can significantly change and improve the way you manufacture products. It is an expanding technology and can offer lot of benefits to society.

No doubt, both the technologies are amazing emerging technologies and both technologies have the potential to revolutionize the field of communication in the coming future. But after comparing both the technologies, we can conclude that Claytronics is better than 3d printing. Claytronics is the field in which one object can transform itself into another object. A human replica could morph into a desk, and a chair could become a keyboard. But in 3d printing, though it is possible to make 3d model of an object, that is not to be further modified or take command to do extra function, but in Claytronics we can’t feel or touch it.

It is possible that in future, this technology will open the new door of perception, thinking, vision and opportunities. The field of communication can be revolutionized with the help of Claytronics. The way we live today will get completely changed after few years. Everything will appear in new transformed form. Just wait and watch the magic impact of this technology which completely change our vision and transform the whole world in future. With all the future possibilities and limitation of the technologies in current scenario we can say that both of these are promising technologies and having a great future ahead it is our effort to explore the two technologies in a comparative way.

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