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Claytronics

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Abstract:
Claytronics is a new technology which makes 3D objects with the assembly of nanoscale robots. These robots come together in a synchronized manner to form tangible and interactive objects. This concept is similar to shape shifting, thus this idea came from the folklore and mythology. Shape shifting was omnipresent in ancient stories mostly in the form of therianthropy, which is essentially the phenomenon of a man turning into an animal or vice-versa. Similarly here a group of unorganized nanoscale robots will assemble in such a way that they will form different objects. The assembly of these robots should be in response to a human demand in the form of touch or input and some cases demand may be automatic sensing. Once the stimuli is received it reacts accordingly.

Key Terms:

- **Programmable matter**: The matter which can transform its physical properties like density, shape, moduli, optical properties, conductivity etc.
- **Shape-shifters**: Shape shifters are creatures who can transform themselves into other creatures believed to be due to inherent ability, divine intervention or due to some sort of magic.
- **Nanoscale robotics**: Nanoscale robotics also called nanorobotics is a field of creating functional robots sized as small as nanometer (10^{-9} meters).
- **Human-computer interaction**: Computers working and producing outputs on input from humans in the forms of data, touch, voice etc.

I. INTRODUCTION

CONCEPT

Claytronics is a very big project, and it comprises of characteristics of modular robotics, nanotechnology and computer science to create 3-Dimensional dynamic display of electronic information. The researchers focus on two main sub-tasks: **Catom:** creating the most fundamentally basic building block of claytronics known as the claytronic atom or catom, and **Software:** Designing and writing safe, secure, robust and reliable **s**oftware programs that will manage the shaping of ensembles of millions of catoms into dynamically forming 3-Dimensional objects. Claytronics through is the self-operated, controlled and monitored assembly of millions of catoms into a technology called synthetic reality. This will have a big effect on the user-experience of conveying information in electronic form. This has become possible because of the ever increasing speeds of computer processing and rapidly growing high end technology.

II. HARDWARE REQUIREMENT

In the past, there have been projects in the field of hardware engineering. The scientists found out some of the effects of large scale production of catoms. Based on their findings they modelled concepts around producing the nanoscale modular robotics. Catoms created from this research to populate claytronic ensembles will be less than a millimeter in size, and the challenge in designing and manufacturing them draws the CMU-Intel Research team into a scale of engineering where have never been built. The team of research scientists, engineers, technicians and students who design these devices are testing concepts that cross the frontiers of computer science, modular robotics and systems nanotechnology. These nano systems should be able to arrange themselves which will create objects that can be touched and interacted with. The process of assembling these nano sized robots should be smooth. For testing the effects of natural forces like physical and electrical force the macro sized robotics is being used. Using these, the researchers will have the necessary information about the nanoscale robots that need to be produced and can proceed with their engineering research and project. The binding and releasing of the modular robots was devised to be achieved by electrostatic latching technology. This technology also provided the motion for transfer of data and power while introducing ample amount of force. The catoms combine together in random movement with the information communicated in a simple language understood by computers to arrange the catoms in their ensembles. This uses natural force to create an object which cooperates with the helium catoms to execute the given instructions. The helium catoms are big in size and they provide a platform to study the relationship of different forces when electrostatics affects it more than gravity on the nanoscale robots. This simulated the effect of the modular robots which self-constructed themselves to form the macroscale devices. The electrostatic latches are employed by cube shaped structures which practically show how the device works, a device being used for self-assembly at nanoscale as well as macro scale. The researchers have succeeded with the development plan at millimeter scale model. This model will demonstrate the self-actuating catom. This catom can communicate, compute and move at nanoscale. With this millimeter scale robotic model the scientists and researchers will be able to demonstrate the achievable manufacturing of catoms needed for 3D representation of objects.

III. SOFTWARE REQUIREMENTS

Distributed Computing

There are many challenges faced by computer technologists trying to introduce claytronics. The biggest challenge is the creation of a program that will control all these millions of nanoscale catoms to arrange themselves in the required formation or ensemble to create the desired object. This research program is a based broad and in-depth knowledge of the resources needed in terms of software to create and operate the large sums of distributed network of nanoscale robotic nodes. For this the claytronic matrix was brought into picture. The claytronics matrix has a characteristic of having huge computational power in a small space. To make it more clear, one billion catoms can be accommodated in a space of just 1 cubic meter. Thus, all these billions of catoms when computed in parallel, has the power to provide huge computing capacity whilst not consuming space more than a standard packing container. This tremendous technology pressurizes the software writers with new challenges in creating new programming environments.

Comparison with the internet

The catoms are large numbers of individual computing nodes. Thus it is natural to compare it to the technology that connects large number of different computing nodes from across the globe, the Internet. Internet is a huge reservoir for many computing nodes spread across countries and is connected to each other. This medium distributes data to different places across the globe also allows people to share work from remote locations. This brings us the metaphor, as the billions of computing nodes in a small ensemble of claytronics being in close proximity of each other like the entire internet is assembled in a single location as small as a table. Claytronics is compared to internet as seen earlier, yet it is not very simple as that. Since claytronics ensemble is much more complicated and also achieves totally different objectives than what internet is known to do. To state the obvious, the computing nodes known as catoms do not have unique addresses or identifiers like the computing nodes in the internet have them. Without these unique identifiers there is no way the data can transfer on the internet. Claytronics matrix also doesn't have wires or any kind of physical connection to define the path the information is supposed to take. The atomized catoms in a claytronics matrix are supposed to travel without any wires and work for attaining the flow of the claytronic substance. As of now the network scientists have not worked on the wireless network technology without any address for the nodes involved. Thus the consequences of the same is not known to the network scientists.

For creating the program which will control the catoms demand an abbreviated syntax and commands as opposed to the lengthy and complex instructions which are used when translating data for computers linked to the internet by the popular coding languages like C++ and Java.

These coding languages have lengthy instructions and can be appropriate for data transmission in networks where each computer node can be easily flagged with a unique address. Also because under such networks the computing nodes are under the control of separate operators. These computing nodes function independently and are linked to the network.

It is not the same as programming environment which is tightly linked of machines which operate for different functions simultaneously where languages like Java and C++ have proved themselves useful. Whereas, the software developer required to fulfill the claytronics matrix that needs to have certain qualities. The physically dynamic network should create connections required for the ensemble to form by rotating contacts with the nearest neighboring catoms and essentially it should be well organized, single purpose and densely concentrated. The unstable channels of this programming environment also need the instructions that move differently sized packets of data. The anonymous computing nodes transfer data through the network, while they do that the software matrix must keep a track of actual constant change in their physical location.

Nodes

The claytronic environment demands each and every catom to be completely dedicated to the operational goal of the claytronic matrix. The claytronic matrix will have a higher goal of creating ensembles for forming 3 dimensional objects which humans can interact with or touch. There are very large numbers of catoms present in a single setting which require dedicated global resources. The claytronic matrix is huge and it cannot look into micro-management of each sm. all catom, thus the level of dedication required is not achieved. This is why it is essential that every small catom is self-sufficient to actuate itself in cooperation with its neighboring catom. This modality of cooperation on a local level must be ensured throughout the matrix. In order to universally distribute the instructions, the software language for the matrix has to be consisted of concise statements for the high level commands. This is why it should contain a simple syntax which is different to software languages. The software languages have detailed commands for each and every node, this need to be altered in terms of claytronic matrix. The commands should not be directed to an individual catom but it must state only specific conditions which should help the catoms direct them in their local groups. This how the catoms will organize themselves to achieve their higher level goals of the claytronic ensemble. Software for the claytronic matrix should implement local coordination in groups.

Programming Languages

The new languages are declarative in nature, they provide compact structures. The property of being compact helps in the cooperative management of movement of millions of catoms in a matrix. These catoms are directed towards a target through commands. This is a complex process since the programs have to direct millions of catoms simultaneously, hence the researchers anticipate failure or errors. This process required self directed process for identifying and debugging errors. There is another algorithm required for the conversion of group of catoms into actual primary smooth structures. These structures form building dynamic 3 dimensional representations. In this class of algorithms the matrix is given a template for the representations of the form they will be rendering. This will give a structural strength and fluid movement to dynamic forms.

Localization: The researchers are working on localization as it is a critical part in claytronics ensembles. There are specific algorithms that will help the catoms with localizing their positions among millions of other catoms in their ensemble. knowledge about their relative position will help in creation of fluid and cohesive shapes in the matrix. It is similar to the muscle movement in our body.

Dynamic Simulation
This simulation is used when researchers want to create a world in which catoms have the properties and characteristics the researchers want to observe. The characteristics portrayed in this simulation is essential to understand the real life problems of claytronic ensembles. The movement and activities of catoms are simulated according to the physical laws of nature. Dynamic simulator shows the effects of gravity, electrical and magnetic forces and other such phenomenon which will determine the behaviour of catoms in reality.

IV. APPLICATIONS

Simulating robots
There are various costly robotic technologies proposed. Although there are no simulating environments/technologies available to prototype such robots without really putting in the funds to create the robot. Claytronics can be used as a multi-million ensemble prototype robotic model. This will give an insight of the proposed robots, and also problems with the design can be identified with the simulation of the robot.

3 dimensional fax machine
A large number of submillimeter robots form a group which is called clay. This clay can be restructured with the help of an external application that will manipulate the mechanical forces to form the 3 dimensional shapes. thus this clay acts as an input device and uses localization techniques to form the required 3 dimensional shapes. Such clays are termed as digital clay whereas when these digital clays are equipped with inter modular latches they act as 3 dimensional output devices.

Pario
Claytronics is a form of programmable matter which is a collection of high functioning submillimeter spherical robots. There is a possibility to use claytronics to achieve telepresence. This can create a 3 dimensional form which can imitate the motion, look and feel of a person on the telephone call. This indeed will require new form of media namely pario. This form of media will project 3dimensional moving objects which you can interact, feel, look at or hold it in your hands.

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