Claytronics

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ABSTRACT

Claytronics is an abstract future technology also referred broadly as "Programmable Matter" that uses nanoscale robotics to create claytronics atoms, also known as catoms. Catoms co-operate and interact with each other and configure themselves into palpable 3D objects.

General Terms

Shape-Shifters, Scaffol-based technique, metamodules, Catoms.

Keywords

Catoms; MRRs; Claytronics; Programmable Matter; Shape-Shifters.

1. INTRODUCTION

Claytronics is a type of programmable matter, which makes use of microscopic robotic units that assemble themselves into three-dimensional (3D) entities. Seth Goldstein and Todd Mowry introduced this concept. They got their idea from playing with molding clay. This technology can make a set of tiny beads turn into any other object. Today, we use a cell phone, tomorrow the cell phone can rearrange itself to form a laptop: the technology, sure is mind blowing. The project is undertaken by Carnegie Mellon University and funded by Intel. If the project succeeds, it can be exploited in a number of fields such as the entertainment industry, medical industry, the telecommunications industry.

2. OVERVIEW

The paper aims to present the project "Claytronics" undertaken by the professors at Carnegie-Mellon University and sponsored by Intel in a simplified manner. The aim and the techniques used are presented below. The goal is to develop an environment with which the user can interact and be able to visualize the 3D changes an object undergoes. The first of the two main projects is to design the catom and the second is to develop software that would enable shape-shifting. Claytronics will find its usage in many real-time applications and an example of such is also explained in the last section.

3. THE PROJECT "CLAYTRONICS"

The Claytronics project seeks to show the world how programmable matter can significantly improve computing knowledge and experience. The primary purpose is to recreate moving 3D objects, create 3D Shape Shifters. The main intention of claytronics is not to change any chemical composition of the object; instead to redesign a substantial relic by making use of programmable matter that would ultimately impersonate the primary object's shape, the movements, the sound, the façade and all its physical qualities.

3.1 Synthetic Reality

One function is to enable many robotic units to modify into any random 3D object by programming it. The ultimate goal is to enable physical realization of these entities. As a result users can interact with the objects naturally and sans any additional sensors.

3.2 MRRs and Motion Planning

The challenge of reconfiguration is much more difficult in modular robots (MRRs) as compared to non-modular robots. The planner may be to reconnoiter a huge state space as there is an extremely large number of isolated molecules through which stem a large number of degrees of freedom. Moreover, their movement is restricted. The movement of one molecule will cause the other molecules to also move which may be inappropriate. A reconfiguration path can fundamentally be used to divide two configurations that are analogous in state space. Two new techniques endeavor to solve the problem caused by blocking constraints allow uninhibited planning that can be used even if the number of molecules scale considerably.

A scaffold-based technique - This technique constricts modules to a specific grid structure that permits the remaining modules to route through unimpeded. More current work merges modules into metamodules and gives access to a highlevel set of primitives that are not exposed to blocking constraints. The two techniques allow greedy or stochastic shape planning to flourish. However, the metamodule system is more universal, and this technique can be exploited in a large number of designs.

4. CLAYTRONICS HARDWARE



Fig 1: Controller Canvas

Nano scale robots that are capable of self-assembly are being designed by scientists at CMU who through hardware projects, scrutinize the upshots of scaling micro-electro-mechanical systems.

4.1 Millimeter Scale Catoms



Fig 2: Millimeter Scale Catom



Fig 3: Tube Bending

An important prerequisite for claytronics is that catoms should be in the order of millimetres. They are triggered electrostatically and are self-contained. Millimetre Scale Catoms are built cylindrically and not spherically (Karagozler et al, October 2007).

The stator on which the catom moves contains rails which carry high voltage AC signals. The chip converts the AC power in to DC power which then enables the generation of voltage on the actuator electrodes which push forward the tube.

4.2 Planar Catoms



Fig 4: Planar Catom Version 8

Planar catoms are larger than the millimeter scale catoms by around 45 times in diameter. These catoms assess the notion of motion sans repositioning parts and the outline of force effectors that cause motion among collaborative molecules in the system (Kirby et al, October 2007). The attraction and repulsion of EMF with magnetic rings on neighbouring catoms convert electrical energy into kinetic energy which enables the entity to establish a turning motion to enable spherical rotation of millimetre scale catoms (Funiak et al, October 2007).

4.3 Electrostatic Latches



Fig 5: Electrostatic Latch Faces

These latches model a new system of connection and disconnection between modular robots, a binding that initiates motion and transfers power and data by applying powerful force.

It employs capacitive coupling. The latch holds with a force of 0.6 N/cm^2 and requires almost zero static power for maintaining the force after the formation of the latch (Karagozler et al, October, 2007). In order to maximize the mutual coupling, a specific degree of flexibility is maintained in the electrodes.

4.4 Stochastic Catoms

These catoms form programmed patterns using computers to effect a simple device, one that liaises with helium catoms to achieve certain instructions (Funiak et al, October 2007).

4.5 Giant Helium Catoms

They provide a stupendously large platform to examine the relation of forces (Karagozler et al, 2006). This becomes necessary as we need to explore possibilities when electrostatic forces are stronger than gravitational forces on robotic devices so that they can redesign themselves.

4.6 Cubes



Fig 6: Electrostatic Latches

Cubes exploit the use of electrostatic latches to present the working of a device that could be used in a system of lattice-style self-reconfiguration at both the macro and nano-scale.

5. CLAYTRONICS SOFTWARE

Software research involves distributed computing in claytronics that can effectively handle and assure perfect cooperation among the nodes albeit a huge degree of scalability, a seamless collaboration of form and functionality.

The research deeply entails the programming languages that can be used, integrated debugging, shape sculpting, localization and dynamic simulation.

5.1 Programming Languages

Meld and LDP are two programming languages for claytronics that has been designed by the researchers at CMU.

5.1.1 Meld

Meld is developed for vigorously programming huge composites. It gives the programmers an ensemble-centric perspective, where programs are written for whole rather than individual entities. It is then compiled into discreet programs for the nodes that construct the whole. So the programmer need not have any apprehensions about the intricacies of programming a distributed system and can lay his emphasis on the logic (Michael P. Ashley-Rollman et al, July, 2009), (Daniel Dewey, September, 2008).

5.1.2 LDP

Locally Distributed Predicates (LDP) is used for distributed programming and uses pattern-matching methods (Rosa et al, 2008). With LDP, programmers can state the distributed state configurations. This can be done on the basis of the groupings of the state found on connected subgroups of catoms. The runtime of LDP will perfunctorily perceive incidences of these distributed configurations, and activate actions stipulated by the user in rejoinder to the perceived event (Dewey et al, September 2008).

5.2 Integrated Debugging

As millions of tiny computers understand and implement huge number of instructions parallel using multithreading, huge number of bugs can get generated that cast a spell on the coded instructions making them go cockeyed. This gives rise to new varieties of bugs and more places for bugs to hide (Rister et al, 2007). The effect of bugs can also affect the status to several catoms; and so to detect such bugs "Distributed Watchpoints" have been developed to detect and repair such conditions in order for the ensemble to function effectively and efficiently.

5.3 Shape Sculpting



Fig 7: Planar Catom Magnets

Lifting catoms to the 3rd dimension and creating dynamic motion with them is the ultimate goal of the project "Claytronics". In order to achieve height and volume from the array of a million catoms lying next to each other in a plane, the ensemble must overcome both local inertia as well as gravity. So it becomes necessary for the ensemble to multiply

its catom forces (Padmanabhan et al, 2007). Each catom must restrict its position with respect to the neighboring atoms. Collective Actuation needs to be achieved.

5.4 Localization



Fig 8: Localized ensemble

Algorithms are being developed to restrict a catoms with respect to its neighboring catoms in order to achieve localization (Funiak, et al, 2007). The position of each catom with respect to the whole matrix is very import for the organization and management of catoms group and the generation of consistent shapes.

5.5 Dynamic Simulation of Claytronic Ensembles

Before the matrix of catoms can be realized, they must first be tested in real-world conditions. For this, the Dynamic Physical Rendering Simulator or DPRSim was created at the Intel Pittsburgh Research Lab on the campus of Carnegie Mellon. The DPRSim creates a platform between imagination and reality by helping researchers create matrices that operate in a software environment which duplicates the forces that effect the functioning of these devices in real-time systems. They are developed to run on desktop computers, and the DPRSim must design the communication among billions of catoms as they will be used in real world systems (Rister et al, 2007). The DPRSim will also present a visual display for the user to view the catoms changing states during the test.

6. CURRENT WORK IN PROGRESS

Claytronics will find its usage in many real-time applications. It will provide an accurate long distance mode of communication called "Pario". Just like we have audio and video to provide auditory and visual perception, Pario provides an auditory, optical, chromatic and corporeal sensation. Pario can effectively be used in many industries. The innovations in the field of nanotechnology and advanced computing have progressed a lot in recent years, making the possibility of the success of Claytronics feasible; but there are still many challenges that need to be overcome.

7. CONCLUSION AND THE FUTURE SCOPE

Once this technology reaches the market, a user will be able to walk around freely yet carry a number of devices with him. This would just be a small Claytronics enabled device which would then rearrange itself to form any device that the user wishes to have! Such is the power of this technology- it will bring the world into a common man's pocket!

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