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PROGRESSIVE CONCEPTIONS OF THE FUTURE IN CYBER-MIX MECHATRONICS INDUSTRY AND CLAYTRONICS ENGINEERING (II)

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Abstract: *This scientific work continues the ideas and research from a previous work and presents the progressive conceptions of the future from Mechatronics to Cyber-Mechatronics and from Mechatronics Systems Cyber-Mechatronics Systems, as they are presented at the moment. It also tries to mention the scientific and technological advances in the above mentioned fields, the new and complex innovative concepts of science and Mechatronics and Cyber-Mechatronics. Anticipating the future, the power and flexibility that will flow from the ability to "program" the world around us should influence every aspect of the human experience.*

Keywords: *Progressive concepts, Mechatronics, Cyber-Mixmechatronics, Mechatronic Systems, Cyber-Mechatronics Systems, Claytronics systems.*

1. INTRODUCTION

Claytronics is an example of a “programmable matter”[1] or claytronic system that can be used to create dynamic 3D parts in the real world. This technology not only realizes pario and reduced reality, but also helps as a basis for a macro-scale modular robotic assembly.
The claytronic system is essentially an integrated system, consisting of hardware and software parts, brought together to achieve a special purpose.

The hardware machine is known as cathomi. Each of the cathoms is considered an individual unit with a processor, an energy depot, a network and a video output appliance, one or even more sensors, a resource of locomotion, as well as a mechanism for joining other atoms [1-3].
The software part, on the other hand, is handled by MELD, which is considered a declarative language, which is based on the P2 language, a logic programming language originally considered for programming layers networks. This substantially reduces the "thinking" required for programming large devices. Experiences and primary techniques indicate that they will also lead to a considerable limitation of code size and complexity [2].

Among the new applications of Claytronics are 3D printing and fax machines, which are based on inter-modular communication and computing, without requiring initial self-reconfiguration. Therefore, this application may be feasible sooner than applications that depend on certain displacement modules.
The study summarized the advances made in the field of programmable matter and claytronic system and research on this field of technology to make micro- and nano-scale cathomes and which follows the principles established by the phenomena of programmable matter. The study makes a contribution to the field of programmable matter design [3, 4].

With the advancement in technology, the development of simpler and more intuitive programming language, along with the consolidation and miniaturization of memory and other functional parts of cathomotics, we can see a day in the future when the images we see on television will take physical forms and occupy the space in which we live.

2. CATOMIC SOFTWARE

2.1. Software Functions

It is necessary that the software must organize all the communications and actions between millions of claytronic atoms on a submillimeter scale (ie - chatomies). So, the respective software needs more algorithms and complex programming languages. Researchers and engineers at the Carnegie Mellon-Intel Claytronics Research Laboratory [1, 2] have a wide range of research projects underway to develop the software needed to facilitate communication between atoms. The

purpose of building a claytronic matrix is to dynamically form three-dimensional shapes and models. However - as a first disadvantage - the large number of shared cathomes in this network is noticeable, a fact that leads to the increase in the complexity of network management and the difficulty of organization at the level of each individual cathome. Therefore, each cathome is meant to perceive correct information about positions and help to cooperate with its neighbours. In this situation, the software language for the matrix operation must transmit and process concise information regarding the higher-level commands, to be universally distributed. Therefore, programming languages for an array will need to perceive a more "dedicated" syntax and command style than regular programming languages such as C++ and Java[5].

2.2. MELD

MELD is a language designed "declaratively", a logic programming language originally designed for programming those multilayer networks. With the help of programming logic, the code symbol for assembling robots can be designed from a general perspective, which allows the programmer to focus on the overall performance of the claytronic array with priority, and less on writing individual instructions for each of the millions of cathomies from the base assembly [5].

This concept leads to the reduction and simplification of the process of programming the displacement of a claytronic matrix. MELD is a programming language designed mainly for compact programming of large assemblies. The design of the MELD language provides the programmer with an objective point of view on the general assembly. This helps to write an individual program for each assembly, at the expense of programs addressed to the modules of its composition.

Such a program is then divided into individual programs for each of the subdivisions that make up the whole. In this situation, the programmer does not have to think through the details of programming a distributed system. He can allocate his time to think the logic of the program.

As we have established, MELD is a "declarative" programming language, so programs written in MELD are concise and logical [5, 8].

2.3. LDP

LDP is a "reactive" programming language, used to improve upon previous MELD program research. It focuses more on a module of exact size and less on the assembly itself, thus helping the programmer to work more efficiently with the claytronic matrix.
LDP is intended to be a means of evaluating distributed models that will allow the programmer to work with a larger set of variables with Boolean logic. These variables help the program to use complex patterns of activity and behaviour between groups of modules.

LDP tends towards distributed programming using pattern matching techniques. LDP gives programmers the ability to specify distributed state configurations based on varying combinations of states identified in cathomically connected subgroups.

LDP is a language suitable for troubleshooting and maintenance activities. The major advantages of this language refer to:
- conditions can be easily detected on variable groups of module sizes,
- can easily interface with existing low-level code,
- can easily express a large number of common distributed programming expressions.

LDP has been successfully used to implement many motion and displacement planning algorithms, as well as a wide range of low-level utilities, such as gradient fields and distributed aggregation.

Figure 1 shows the indivisible mechatronic subsystem, structured on several hierarchical levels.

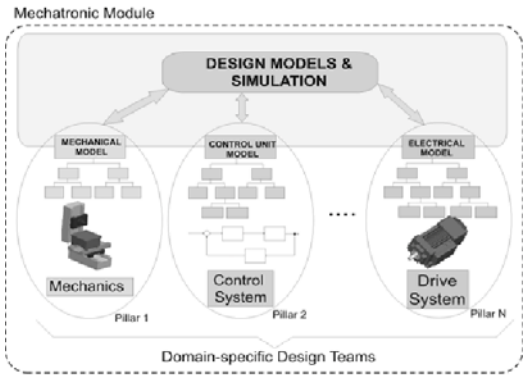


Figure 1. Multilevel cyber-mix mode

3. PRESENTATION OF THE OPERATION OF THE 3D FAX MACHINE

The process of remote reproduction of a facsimile of an object involved three steps: acquisition, transmission, and reproduction. In the first stage, the system detects and analyzes the object and digitally reproduces the visible structure. In the second stage, the obtained information is then transmitted to the remote site. In the last stage, with the help of the transmitted data, a copy of the object is built on the remote site [8, 9].

In the nomenclature of the new claytronic system, the assembly is a connected volume of programmable matter. Cathomies are the individual units.

We propose that, in the process of the operation of this 3D fax machine, we present this operation in stages and sub-stages:

a) Acquisition of the form;

This refers to a variety of light structured approaches and interpretations, mostly based on lasers and scanning technologies. These are able to produce digital representations with medium and high resolutions, for a representation of the external 3D structure of an object. Also, multi-camera stereo systems can catch and capture complex shape information.

b) Contact detection vs. non-contact;

Programmable matter can find the shape of an object by direct contact with its surface. On the other hand, structured light and stereo technique can work at a certain distance and therefore impose limits on the shape of the object.

c) Simplified shapes and geometries. Deciphering information parallel vs. serial;

Resolution varies with the size of the cathom, rather than with the scanning technique.

A claytronic assembly can perform the self-localization function through a peer-to-peer (one to another) multiphase communication and interconnection process between the individual cathomies in each created assembly.

d) Remote transmission or tele-transmission;

This occurs after the 3D structure has been determined by digitally acquiring the shape. Thus, it can be stored and/or transmitted using one of the known functional techniques.

e) Shape reconstruction;

In the final stage of a 3D fax machine, the transmitted data is later used to remotely reconstruct the structure of the object. Another method of digital image conversion/reproduction is the use of a 3D printer based on rapid prototyping techniques, for example, stereolithography. Such equipment can recreate a physical object by building the structure layer by layer, starting from a digital representation.

The cathomies in the ensemble carry out a self-localization process to identify the coordinates in which they are found. Each of the cathomies can then evaluate whether it is a part of the target shape.

Cathomies that are part of the target shape bind themselves together, and cathomies that are not - disconnect themselves. Finally, the user spills or pulls the unbound cathomies to their side to reveal the reconstructed shape (Figure 2).



Figure 2. The reconstructed form of the catome assembly

According to Figure 2, Vona and Rus' crystalline robot (left) has compressible unit-type modules (right), which can change size by a factor of two and locking device for reconfiguration and mobility.

In the following figures, some configuration models of programmable matter are represented.

Figure 3 shows the claytronic realization of an "electrostatic induction motor printed with ink jet".

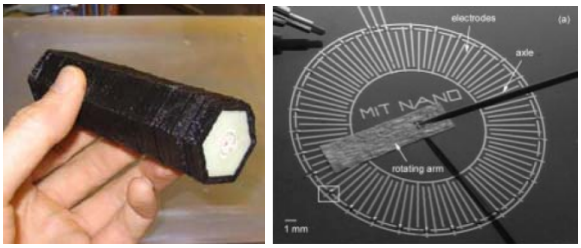


Figure 3. Electrostatic induction motor printed with ink jet

Figure 4 shows the 3D printing of the letter "T", using the technique of folding a piece of magnetic plates.

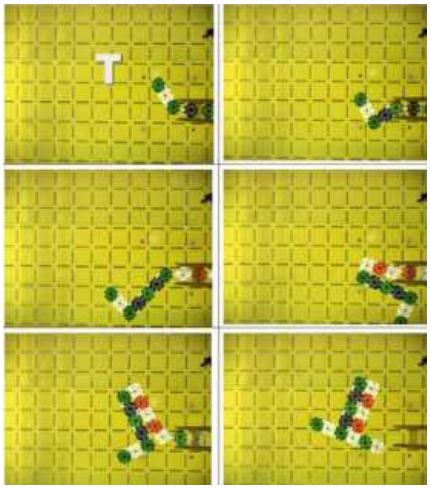


Figure 4. Digital fabrication of the letter "T"

4. CONCLUSIONS

"Programmable matter" is a technology of the future that allows the user to control and manipulate physical 3D models in a similar way to how 2D images are already controlled and manipulated with computer graphics techniques.

In other words, "programmable matter" will allow users to take an important step beyond virtual reality, namely to synthetic reality, in an environment where all objects are made physically.

In sumary, integrated hardware and software systems are becoming the "decisive driving force for inventions, innovations and industry development" in domestic and foreign markets, decisively imposing their advantages, practical benefits, functional role, as well as competitiveness of mechatronic and mix products and systems mechatronics in various industrial environments (automobiles, airplanes, medical equipment, production plants, household appliances, environmental and energy equipment, etc.).

Thus, cyber-mechatronic and cyber-mix-mechatronic systems will represent new challenges for Science (CyberMechatronic and Cyber-MixMechatronic Science) and Research (Cyber-Mechatronic and Cyber-MixMechatronic Research).
As future potential of cyber-mechatronic and cyber-mixmechatronic systems, the following scenarios are identified [9, 10]:

- cyber-mechatronic systems and mixmechatronic systems for smart grid networks;
- cyber-mechatronic systems and mixmechatronic systems for the mobility network;
- cyber-mechatronic systems and mixmechatronic systems for telemedicine and assisted living;
- cyber-mechatronic systems and mixmechatronic systems for mechanical engineering, production enterprises and technology automation;
- cyber-mechatronic systems and mixmechatronic systems for the factory of the future.

Anticipating the future comes "bundled" with the power, control and flexibility that comes from the ability to "program" the world around us. All of these should positively influence every aspect of the human experience.

Seen from this point of view, claytronics is a technology that can serve as a way to implement a new medium of communication, which the researchers are currently calling "Pario". The idea behind the "Pario" phenomenon is to reproduce physical 3D objects in motion.

Advances in nanotechnology and the necessary computing may make claytronic products a reality, but the challenges of overcoming them are daunting and will require great innovation.

In a December 2008 interview, Jason Campbell, a top researcher at Intel Labs Pittsburgh stated the following: "My estimate is that we're going to have 50 years' worth of achievements, but in just a few years" [6, 7].

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**** Note:***
The present work is a tribute to Professor Gheorghe Gheorghe (1946-2022, and is based on his research within the Project aimed at the realization of an Intelligent Integronic and Cyber-Mixmechatronic Multi-application Telecontrol and Telemonitoring System (The Core Program – PN 18 37 02 01).