Robotic Atom

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ABSTRACT

We present here a new project in the field of self-reconfigurable system. The built system is able to reorganise itself to adapt its configuration to a particular problem. The particularity of our approach is to build systems that can split into several independent parts and are then able to reassemble in a unique structure. Each atom is able to have simple motion to move from a place to another.

1. Introduction

This paper takes place in the general field of modular robotics research. In this field we can distinguish between two kinds of work.

The first one tries to define elementary modules that can be assembled by an human being to build rapidly of robot that response to a specific problem. For instance, RMMS[1] to build manipulators, Golem project [2] where " robots have been robotically designed and robotically fabricated ", Swarm-bots [3] for the design and implementation of self-organising and self-assembling artifacts.

On an other hand the modular robotics looks for self-reconfigurable systems. In this case the problem is to build components, often identical, that can dynamically reconfigure themselves to adapt their behavior to a task. Molecule Robots [4, 5] are based on a single component with two elementary movements, Conro [9] build serial chain with 2DOF in rotation, I-Cube [8] modules are quite similar but with 3 rotations, Crystalline robot [4, 6] the elementary component is based on a 2D translation movement, Telecube [7] implements a 3D of this Crystalline component, PolyBot/Polypod [7] are very rich structures based on simple component and finally the MEL [10] propose a two rotations element with and universal connecting plate that allows dynamic coupling.

In this paper we will propose a brief description of these different works and then we will present our proposal. We believe that their is still an interest in building an other kind of robotic atom. Then in an other part we will present tour project from different points of view : mechanical design, electronics, computers science. Finally we will propose some conclusions

2. State of the art

In this part we will focus only on modular robotics works.

We can distinguish important criteria to analysis modular systems. The first one is the mechanical design : how many degrees of freedom, what kind of elementary move, what couple can it produce… The second is sensors : do the system have sensors , what kind. The third is the control system : centralised, distributed, communication. Lastly we have to consider the connection mechanism : is it universal (i.e. can be connected independently of the orientation), active or passive, how strong …

2.1 Mechanical design

Different type of elementary movement are usually design.

One single rotation figure 1-1 the rotation perpendicular to the direction of the connections. We did not reference the other solution : the rotation in the direction of the connections figure 1-2 except in the I-cube component where it is used but not as a component (see fig 2-4)

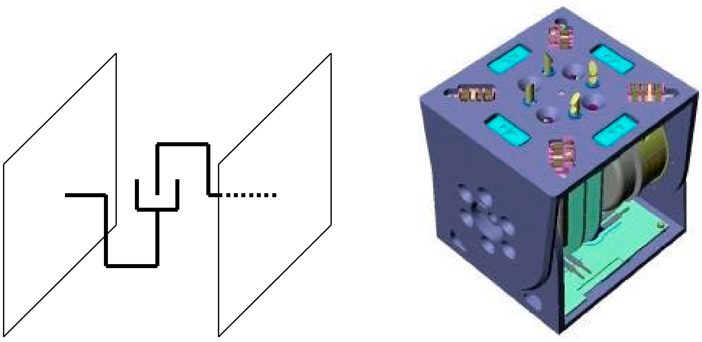


Figure 1-1 : Polypod project [7]

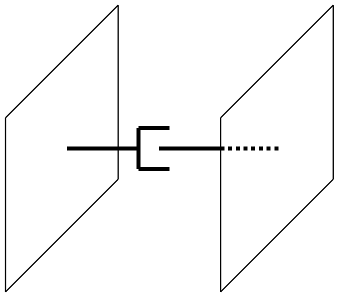


Figure 1-2 : Not built alone

Two rotations on the elementary element:

The figure 3 shows the E. Yoshida proposal [10] with two parallel rotations, the solution proposed by C. McGray [5] is with two perpendicular rotations.

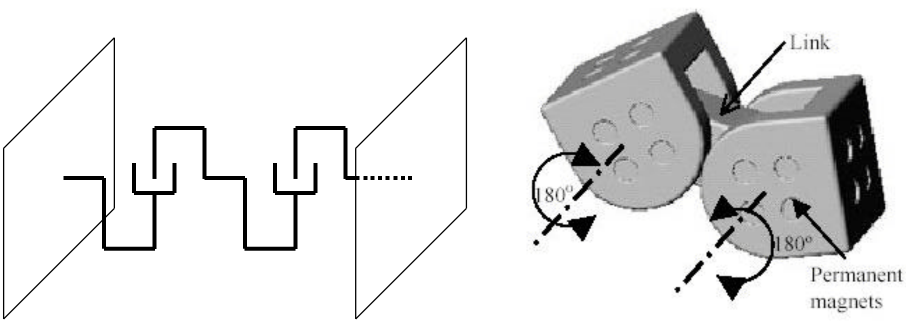


Figure 2-1 : Two parallele rotations E. Yoshida [10]

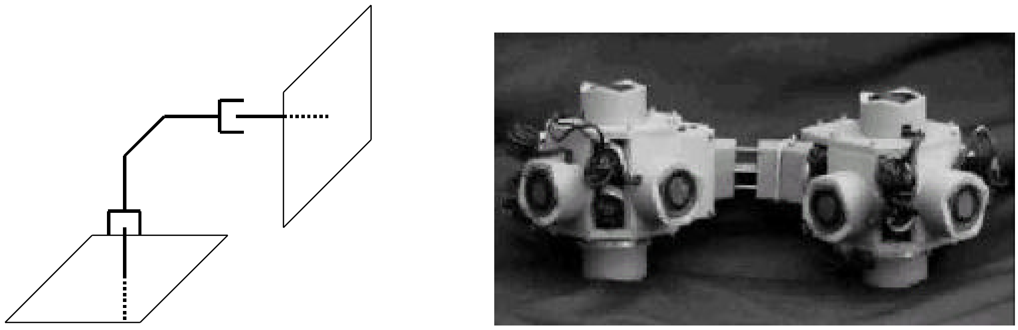


Figure 2-2 : Two perpendicular rotations Mc Graig[5]

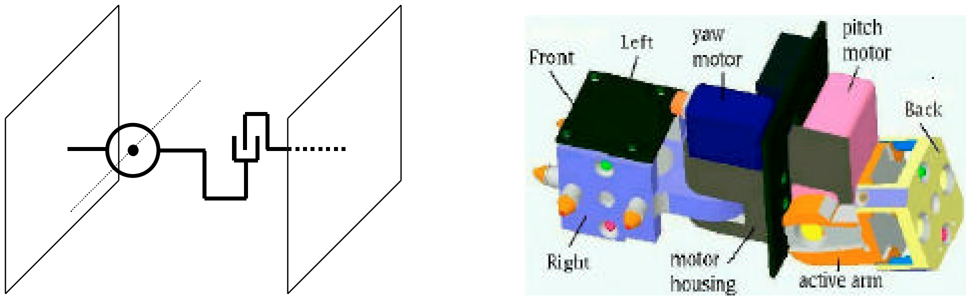


Figure 2-3 : Another solution with two perpendicular rotations by Shen [9]

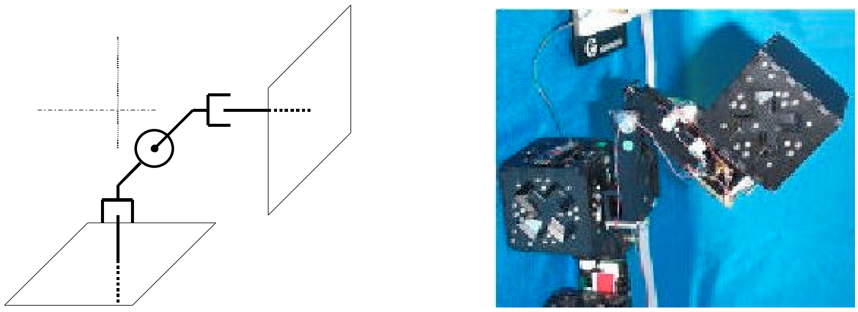
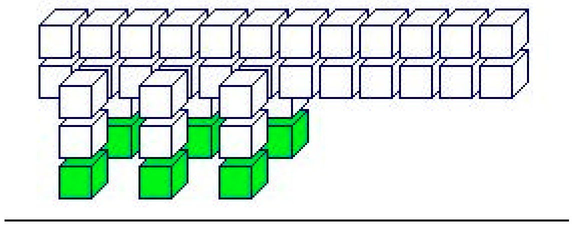


Figure 2-4 : Three rotations are also proposed by C.Unsal in I-Cube [8]. In this case it is a combination of the previous mechanism (fig. 2-2 & 1-1) but integrated in a single component.

__Translation mechanism__ : the unique proposal we know is from the Polypod project done at Stanford University [7] in which the basic component could jointly make a translation and also rotation movement. An other proposal but for two translations is proposed in the Crystalline project.

Figure 3-1 : translation proposition the polypod project [7], Crystalline [6] Telecube [7]

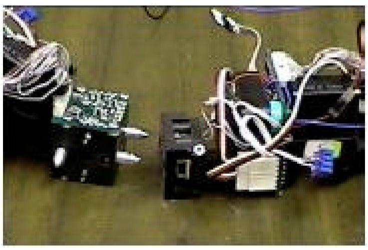
Sliding cube : A solution has been proposed and designed by Joe Michael [11] who proposed elementary cubes sliding on each other. The realization was made with magnetic elements moving inside the cubes. We have no images of the real module, the following is from the simulation software.

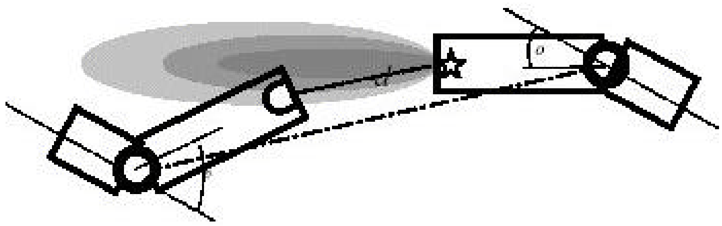


All these design build low-level components. In our project the basic component is a 18 degrees of freedom that could be designed by using this kind of elementary elements (see section 3).

2-2 Sensor and control system

About sensor in the different architecture existing only local information are avaliable. The position of the mechanism is deduced from the information of the potentiometer used to control de motor. Some infrared are used to find the relative position of to component. The position of the elements to assemble is known by the position of open chain. Local infrared information permit the final assembling, the following figure is from the paper [9]





We will describe this in our work. About the control system please refer to the paper [10] in which a comparison between all the existing systems is done. Other Global sensor like accelerometer are proposed in [7] to give the orientation of the module in the space.

2-3 Connection system

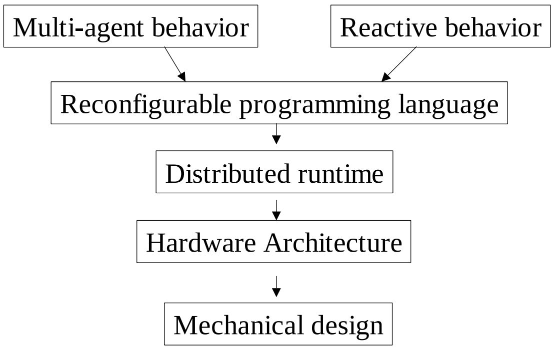
In the definition of modular system, few works try to have dynamic reconfiguration [5, 9 ,10]. The problem of the connection is the orientation that must bring the mechanism at the right position and orientation to plug in. Usually a male/female system is designed to centred the component during the plugging phase.

In principle the elements to be connected are in some suitable position and that the connection process just have small uncertainty to deal with. The latching mechanism is released by using a shape memory alloy or magnetic elements.

On figure 2.3 we can distinguish the male female system, in 2.4 this system is used with a special form of a cross.

3- The Atom project

This project is a joint project with several laboratories working in different areas [12]: computer science, electronics, robotics. For each part of this project we will give the scientific purpose of the work and give the first results after six months of work.



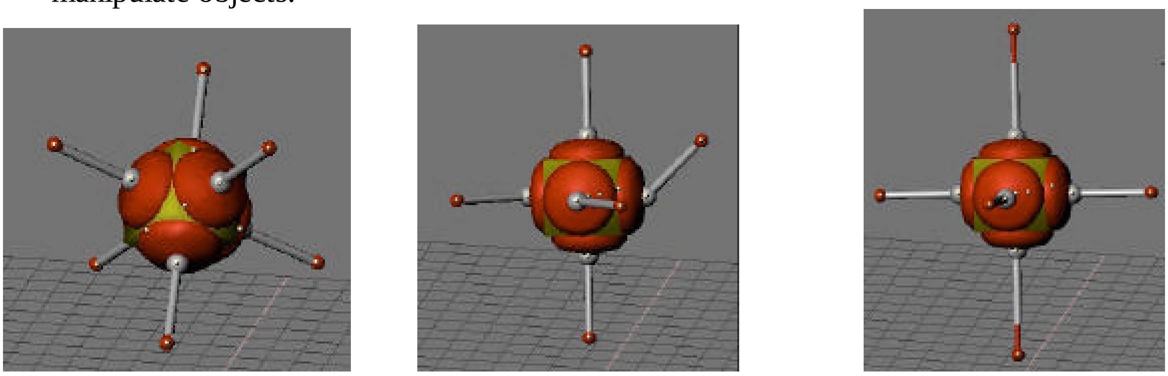
3-1 The mechanical design

A general atom is a 16 degrees of freedom element. The aim of this project is to use this kind of atom to build dynamic reconfigurable structures. Some important expected features are :

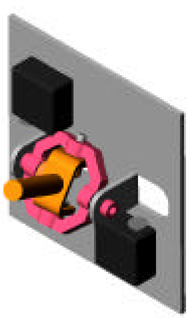
? All atoms are able to move by themselves and, with their sensors on the end of each leg, they can localise other atoms and move to them to connect with

? in 2D we can build active carpet if we assemble the atoms in a array. This carpet can manipulate object, a snake can be design to move into encumbered world …

? in 3D the structure can climb on objects, transform itself in tool, surround objects and manipulate objects.



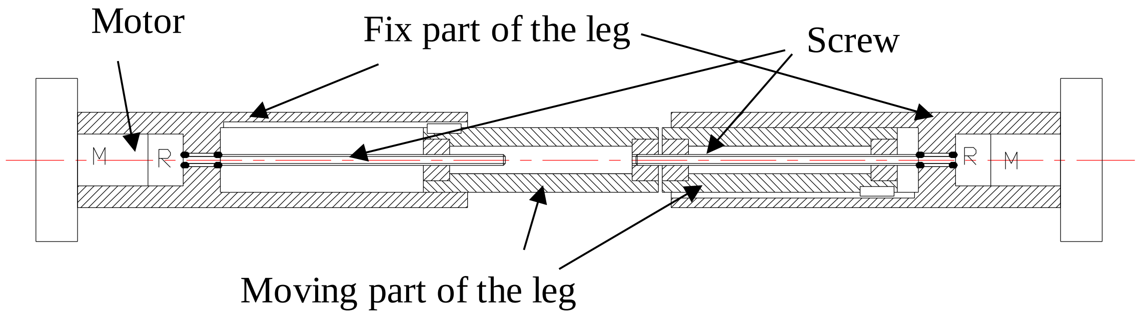
Actually the design proposed for one leg is two perpendicular rotations in the same plan and one translation.



This construction leaves the motors on the platform supporting the leg which is interdependent with the body of the atom : a cube in this case. By this construction the moving part does not include the weight of the motors.

A translation on the leg in a range [1.. 1.6] from the base position will permit the rolling of all the all structure when it is not connected any other

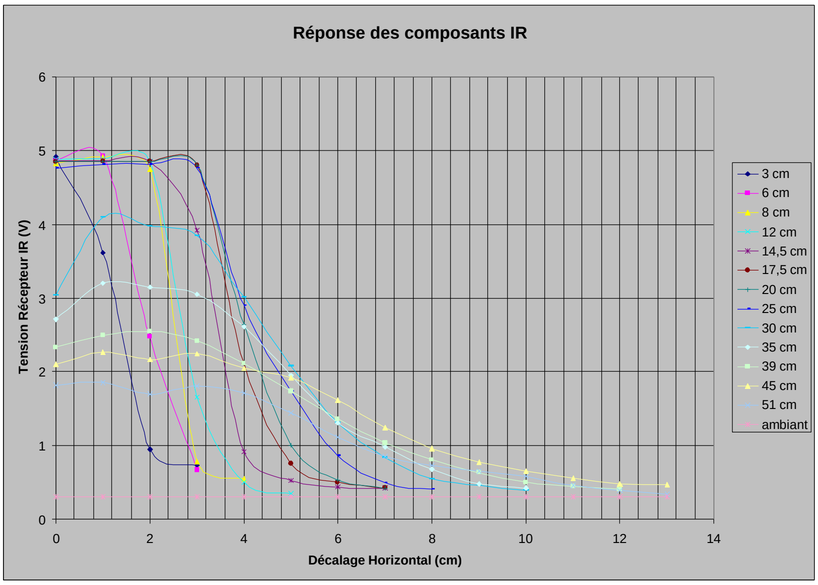
The displacement of the leg in the cone is 45° from the base position (perpendicular to the face), 90° from extreme to the other. Connection system is not fixed yet because it depend on the results of the quality of alignment that we can obtain with the IR sensors. If it is good enough (see next section 3-2) a good solution for assembling the modules would be to use a screw/nut system. In this case the translation movement of the leg would give a turning movement to the part of the leg in translation. This has its extremity that is a nut that screw on the opposite leg, see the next figure.



If this solution is not possible we will design a classical connection system based on the one mentioned in the previous section.

3-2 The electonics architecture

The proposed architecture for the control of each atom is to use an FPGA based system. In the VIRTEX we propose to install in hardware the low level loops : control of the servo motors, input of the sensors (IR for communication and localisation, force sensor at the base of each leg, contact sensor on the end of each leg). The decision level will be taken in a CPU installed in the FPGA. We will use the LEON [12] design which is a CPU compatible Sparc. This organisation will allow to keep the computer only for the behaviour computation all the low level task will be running concurrently in hardware design. The choice of FPGA is motivated by the fact that we will reduce the dimension of the atom it will authorises a single chip integration. A wireless communication is used trough the Ethernet connector.



On the IR we study the response of the sensor at different distances in front of a constant IR emitter. The results gives (in the range 0 .. 60 cm) the result shown in the previous figure We can see with this result that the following algorithm will permit to two separate elements M1 &M2 which does not know where they are in the space to align.

M1 : Ask M2 to set IR emitter ;

Search in the space the response of the emitter with the receiver at the end of a leg;

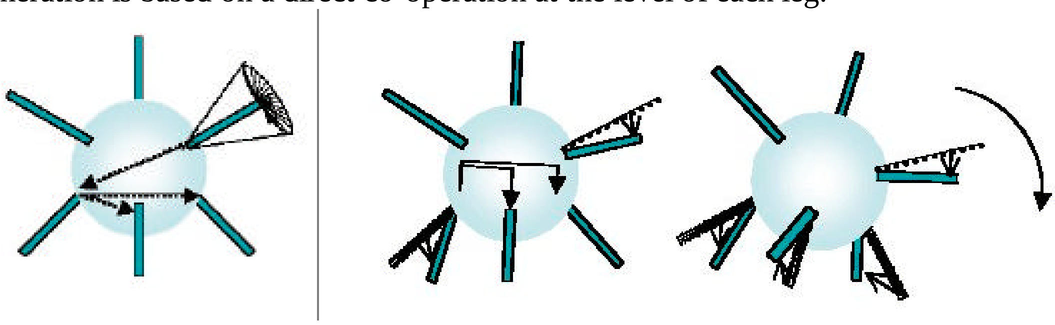
If response id far then roll in the direction and try again else put the position of the leg of M1 in the maximum beam; exchange the role with M2;

Do this until no change in the final position. this algorithm is based on the idea that if elementary components are able to communicate then we should extensively use this feature in the assembling part.

3-3 Path generation

This first problem if to define and build the behaviour of each element to realise the desire goal. In this field we propose to approach : a multi-agent one and a reactive one.

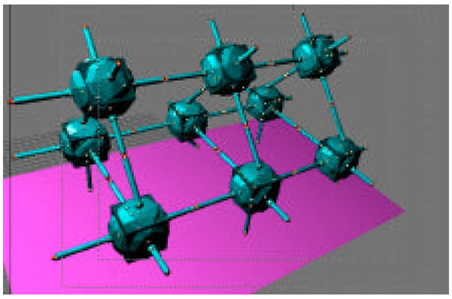
The multi-agent approach is working in a discrete world in which we compute off line a Markov decision process (MDP). Given a configuration we compute for an initial configuration and a final configuration the MDP with a simple fitness function based on the Euclidean distance to the target position makes the convergence. On an other hand the reactive generation is based on a direct co-operation at the level of each leg.



In this system the leg which want to reach a goal send constraints to the other legs. This co-operation makes the emergence of the general movement of the atom. At the molecule level (set of atom connected together) the same structure is computation is constructed. An atom which want to reach a target send to the other constraints which generate the emergence the restructaration of the modular system.

3-4 Language generation

The reconfigurable programming language is a parallel language which permits to programme the all modular structure with classical instructions.



The main idea is to hide the execution problems (synchronous tasks, scheduling …) in a language which defines the semantic of the execution. Each path generation level (MDP or reactive programming) will generate directly a source code in this language. This universal interface to program the structure is a major issue because we build this language with a simulation system (java-openGL) to debug applications before their execution. The first developpenment are shown in this previous picture.

4- Conclusions

We presented here the first ideas and results of this project “Robot Atom”. We first shown the classical works in the field of reconfigurable robots. We presented after the four original aspects of our approach: design autonomous component able to move by themselves, electonics based on a FPGA for future integration in small size, an universal programming language to set the behaviour with a text file, the actual first work on path generation with two different approachs MDP or reactive. This project is a long term project we expect the fist molecule with 10 elementary component in 3 years.

Acknowledge
This project is supported by the Robea project of the CNRS. All references to people participating to this work can be found in [12]

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