Studies and experiments related to modular structure robot
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Abstract: - The modularity of robotic subsystems is a big opportunity for robotics to compel recognition on the market as a viable and efficient alternative, thanks to the development of standardized modulus, especially, but also because of the robots’ features-such as productivity and flexibility. The idea of this proposal roots in the structure of a personal computer. The winding and the upgrade of a pc is an extremely simple and quick process thanks to the standardization of the functional modulus. Extrapolating this idea to robots, and to robotic systems, in general, it is necessary the conceiving of a modular system, as far back as in the primary design phase. The modular system should be conceived as intelligent structures with a high degree of sensorial, communicational, functional and control autonomy. These elements are presented and experimented with functional models, for validation. The conclusions are formulated and future directions are targeted.

Key-Words: - modular robots, standardization, plug and play structure, robotics

1 Introduction
The reconfigurable robots structures (Figure 1) are characterized by changeability, maintenance and increased adaptability.
From kinematical and especially mechanical point of view, the idea to realize reconfigurable robotic structures, in modular format, even if at a first sight is enough hopeful and it could be characterized as a total solution, at a more careful analysis it prove its limitations.
The modular solutions ask for more Lego concept, through which the use of identically interconnected entities has as a result the achievement of some complex structures [1].
The technological implementation of this concept has as a result experimental robotic structures, developed especially in the big laboratories of the American and Japanese universities.
The disadvantage of those systems is given by the redundancy due to the use of some more complex systems in respect with the fulfilled task has as a result not only an increased cost price toward the classical systems, but, contrary to the expectations, at a lower viability and at an extremely complex command and control structure.
The first step in industrial implementation of the modularity concept, at functional level and at the maintenance level was realized by MOTOMAN. In Figure 2 can be identified the imposed design direction for the last robotic revolutionary architecture, realized during 2006-2007.

Figure 1. Modular robotic structure experiments

Figure 2. Motoman structure
(http://www.motoman.co.uk/IA20.htm)
2 Considerations Regarding the Modular Industrial Robotic Structures

The command and control system of a reconfigurable modular robot can be watched as an informatics network composed from more modules equipped with calculus processors. Due to the characteristics of those robots, where the network structure is dynamical (can have different characteristics at different time intervals), can be realized many operations [2]:
- the differentiation of the modulus or the division of those role
- the modulus synchronization to generate a coherence motion
- the use of some command distributed methods of high level for taking decisions.

One of the solutions that can be adopted refers to the introduction of “hierarchically principle” inside the robot control system. Such of structure could have the following levels [3,4]:
- the maintenance level of the system;
- the control level of the robot structure morphology;
- the control level of the motion;
- the decisional level.

Each level or process inside a level requires different resources to allow the communication between modules such as the case of communication speed or of the distance between modules. By analogy with biological systems, it can be told that alive systems have nervous systems such as different chemical substance which allow inter-cellular communication.

Same as in the animal case, robot system needs different types of communication devices and protocols with different properties, such peer-to-peer or master-slave type communications.

2 Design Solution for Robotic Modules

The Lego NXT brick controller was used for the first experiment. Around this control architecture was developed a chess player robotic architecture. The study was focused on the component modularity and assembly versatility. - Figure 3. The sensors and the actuators are Lego structure. Only coupling elements and joints are created. For communication between controller and PC was used the Bluetooth connection.

Figure 3. Modular robotic structure based on Lego NXT Brick

A simple, but efficient graphic user software interface was developed. - Figure 4.

Figure 4. User interface for modular robot based on Lego NXT Brick

The structure modularity was good but the system redundancy and the development possibilities were reduced.

The second structure developed used cubic module structure (Figure 5) with servo actuator Hitec (Figure 6) and for control a BasicStamp controller Figure 7.

Figure 5. Cubic robotic module - experiment 1
This second experiment distribute the basic control to module level, control for dc actuator, all the modules are controlled by the centralised structure Basic Stamp.

The key aspect of this experiment was to use usual actuators, sensors, controllers in order to offer low price solution for developing modular robotic structure.

The structure performances were better than the first experiments, for control being used a simple interface as Visual Show Automation.

The third experimental structure resolve the modularity problems indentified to second experiments, separating the coupling module from the actuator module.

The coupling module offers the possibility of connecting the actuator in 5 different spatial positions, increasing in this way the spatial robotic structure modularity.

The control solution was centralised around a MiniSSC PIC 16C61.

Every module (Figure 9) has a dc actuator and included controller module and a coupling module, which make a basic robotic module, using for control a low cost control solution (MiniSSC – Figure 11). For communication between PC and the control module pair of Bluetooth network adapter module are used.

The main disadvantages of these solutions are related to communication system and the strong centralized control structure, even with the relative independent actuator module solution. These problems conduct the research to other experiments regarding the robotic structure organisation similar with computers networks. Every robotic module has a relative independence such as a computer in networks, the central control
distributing only the tasks such as a server. The central control offers the interface access for user and the configuration for the robotic structure. Every module has a relatively independent functionality, the communication with other robotic module or with central module is made using traditional rigid data buses or wireless communication. The robotic module has 4 substructures (Figure 12, Figure 13, Figure 15):

- Sub module with dc actuator and the electronic driver for motor actuation - 1;
- The control sub module - 2;
- The communication sub module / wireless module- 3;
- The power system sub module - 4.

The control sub module is based on Intel 80C296SA (Figure 14). This controller offers the brain-less solution for every robotic module. It as an internal clock and power supply self management control, a Central Unit and a RAM memory block of 2Kbyte size, a interrupt controller and an I/O interface with peripheries, serial communication - SIO, and dc control with PWM. The internal CPU bus ahhs 24 bits, and the external bus has 8 bits. The calculi are made by UAL on 16 bits, using a hardware accumulator of 40 bits.

The power system sub module can be implemented in two ways:
- General power system for all robotic module – accepted for heavy robotic structure because the power system is located in base robotic module
- Individual power system sub module – using a rechargeable battery 8, 4 V. The voltage is reduced using a tension regulator 7805 to 5V, in order to assure the power supply for integrated circuits.

The general solution is a better solution, but the individual module power supply solution can offer rotation possibilities for the modules bigger then de 360°.

For module connection it is used the central axe. This part is a rigid one and can be used for implementing connectors for general power supply or for data buses connector.

Actuators sub system. This sub system iss implemented by one/two dc actuator FAULHABER (Figure 16). Every actuator has a gear unit with 8:1 rate and rotational optical sensor with 512 imp / rotation.
The control of actuator is a classical bridge with circuit LM 629. The integrated function of this controller are Reset, DFH - Define Home, Load filter parameters for PID kP, kI, kD regulator (LFIL - Load Filter Parameters), UDF - Update Filter, LTRJ - Load Trajectory Control Command, STT - Start Motion Control, RDSTAT - Read Status Byte, RDRP - Read Real Position, RDRV - Read Real Velocity.

**Communication sub system** is assured by direct physical rigid data bus connection trough central axe, or by using a wireless communication module. For this experiment a Radiometrix 433 MHz module is used. The Radiometrix features are:

- Miniature PCB Mounting module
- SAW controlled FM transmission at -6dBm ERP.
- Double conversion Superhet receiver
- -107dBm receive sensitivity
- Single 4.5 to 5.5 Volt supply < 15mA (TX or Rx)
- Half duplex data at up to 40 Kbit/s
- Reliable 30 metre in-building range
- Direct interface to 5V CMOS logic
- Fast 1ms power up enable for duty cycle power saving
- On board data slicer, supply switches and antenna change over.

The module frame design is the second target of these studies. The main idea is the versatility and the PC like modularity applied to robotics. The module frame has to be divided in parts and the parts can be produced with slight modification and by non specialised enterprises. If the parts are simple then the cost are reduced and can be made even by small enterprises. If the offer is bigger than the prices go down and the interest for robotics implementation can be increased. If the price is satisfactory then every enterprise will use robots for usual manufacturing process and activities with strong repetitive action.

The proposed structure divide the robotic frame module in: coupling module, electronic system support module and actuators module. The division of frame in individual electronic system support module is related to men tenability: if the malfunction concurs to electronic parts, these parts can be easily replaced. Or if the malfunction concurs to actuator module, then this module will be replaced. (Figure 17; Figure 18; Figure 19)
The robot modules – practical implementation

For increasing the frame module flexibility the actuator cases was divided in upper frame sub module and lateral walls with or without actuator support system (holes). The module case is octagonal to allow the coupling of every module with other additional module for implementing the usual industrial architecture (parallel module axis, perpendicular modules axis, modules axes with angle multiples of 45°).

The coupling sub module and the actuators sub module can extend the general modular architecture by adding and other non-active additional supports for implementing translational module and non-collinear axis module coupling.

The software control architecture is based on Plug and Play – PnP concept – Figure 20. For implementing this concept, every robotic module offers an individual ID, with his electrical specification and “name”. Every module has 3 switches with will implement the individual code of module. The central PC receives the module ID, include the specification in databases and configure the particular parameters control for every module. For the moment only the manual control is implemented for this modular robotic module.
structure (the robot is moved, using joysticks to indexed point, the points are memorized, and in final the user specify the speed, the tolerance and the acceleration of the particular movement of for the global trajectory and the robot execute)

Another problem of the algorithms characteristics is represented by the modules connectivity [5]. In the most approaches till now, the reconfigurable robotul was regarded as a grouped structure, with a fix number of modules. The robot limitations are naturally defined and the behavior is given for entire group. nevertheless, if it is consider the more general case in which are involved two robots which are join in a single robot, the system limitation can be predicted. The fundamental definition of the robot system architecture must be extended to consider the all flexibility reconfigurable robot.

4 Conclusion
The studies and the experiments accomplished up today have created an adequate base to develop the research which highlights the potential of the modular approach in robots engineering. The next steps are to develop a fully modular kinematical description for implementing an algorithm for direct and inverse kinematics for the case on n robotic modules. Present studies continue for develop an easy upgrade full module structure and a scalable solution for heavy industrial robots.

References: