Onboard Electronics, Communication and Motion Control of Some Self-Reconfigurable Modular Robots

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Abstract: *The modular self-reconfiguring robots are an interesting branch of robotics, which aims to provide multifunctional robots at low cost. In the past 20 years, numerous studies in the field of the modular robots structure have been published, but relatively few have focused on the inter-module communication and on the robot motion control. The current paper aims to contribute to filling this gap by presenting an analysis on seven modular robots.*
Key words: *self-reconfigurable, modular, robot, communication, motion control, electronics*

INTRODUCTION

The modular self-reconfiguring robots are machines, which consist of a plurality of modules, connected in a variety of configurations. To fulfill their task, at the most optimal way, to adapt to a new circumstances or to self repair after damage, the robots can reconfigure their modules.

The variable form of the robots makes them extremely flexible. This allows them to overcome various terrains by applying various movement strategies: worm-like or snake-like movement; moving with the help of legs (like a spider); moving by rolling (as a wheel); mixed. The variable form also allows the self-reconfiguring robots to form different three-dimensional objects or to build buildings.

MODULAR SELF-RECONFIGURABLE ROBOTS

A group of seven self-reconfiguring modular robots was examined. Brief information, related to the onboard electronics, to the method of communication, between modules and to the motion control, is given for each robot.

1. POLYBOT

Each POLYBOT module (Fig. 1) contains Motorola PowerPC 555 processor with 1 MB external RAM. The computational power of each module is used to collect data from the sensors (currently only one sensor for the angle of rotation), to manage the electrical engines and various electronic components. Communication between the modules is achieved by two common buses, formed by all interconnected modules. Data sent on the central bus follow the CAN BUS standard (Controller Area Network BUS). The two CAN buses, allow the formation of several independent groups of modules, within the modular robot, which have the ability to communicate independently from each other.

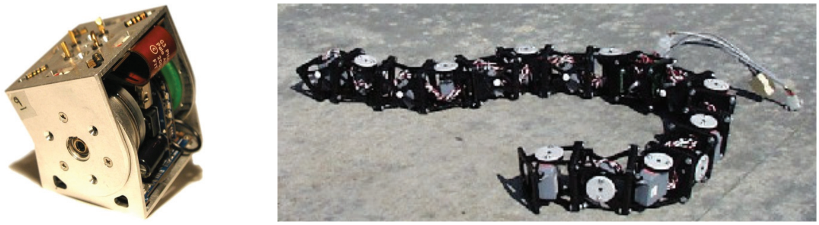

Figure 1. POLYBOT III: One module and multiple connected modules

2. M-TRAN

Each module (Fig. 2) contains several microcontrollers and a battery that powers it. As with the POLYBOT, each individual module of M-TRAN II uses the CAN BUS standard to communicate with each other, Fig. 3. The figure shows that each of the modules is comprised of a main microcontroller (TMPN3120FE5M, Echelon Corporation) and two PIC microcontrollers: PIC16F877, called PIC-L and PIC16F873, called PIC-A [5]. Each module contains also a RS 485 transceiver and a proximity sensor.

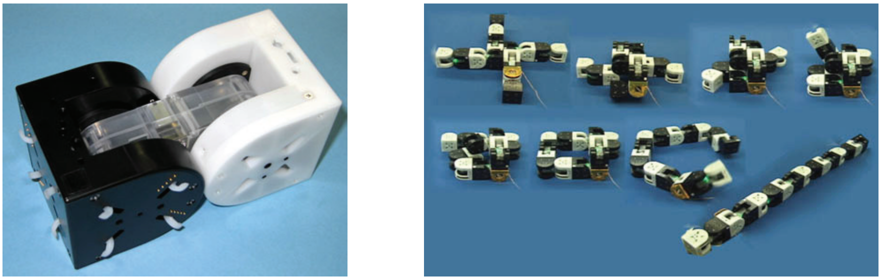

Figure 2. M-TRAN: One module and multiple connected modules

Some modules may contain a radio frequency receiver, which accepts control signals from the remote control and a PIC microcontroller, which processes the radio communication. The received radio signals can change the direction of movement of the modular robot, to change the configuration of the modules (and of the entire robot) or to change the robot locomotion (worm-like, rolling, etc.).

Each module also has an internal data bus, which connects the main microcontroller, the PIC-A, the PIC-L and the PIC microcontroller, that handles the radio communication, if the module supports such.

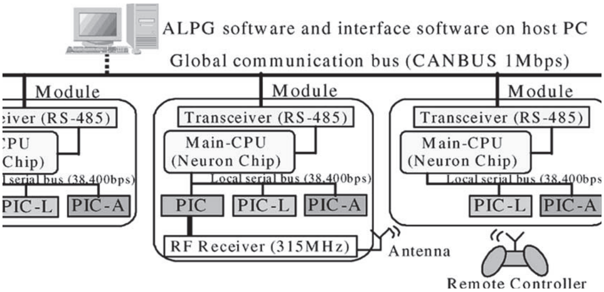

Figure 3. M-TRAN inter-module communication

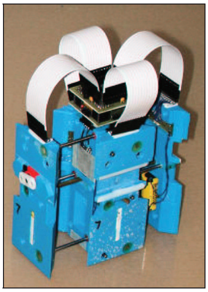

Figure 4. 2D Crystalline module

3. CRYSTALLINE 2D

Each module has an Atmel AT89C2051 microcontroller and five lithium batteries size 2/3 A, which supplies it with electricity [7].

The modules can be connected to a computer via serial connection, which allows them to download a control program. When the connection to the computer is turned off, each module executes the downloaded program. During the program execution, the robot is constantly listening for infrared synchronization signals, sent by the computer.

Signals are received by all modules simultaneously, over time, which allows them to synchronize their motion, respectively, the motion of the whole modular robot.

4. MILLI-MOTEIN

A continuous flex circuit passes throughout the whole modular robot. That allows the individual modules to communicate, to be controlled or to receive power. The circuit is also connected to a computer. This provides a serial communication between it and the modules.

The separate modules are entirely controlled from the computer. They cannot calculate their new positions individually and cannot initiate a rotation.

The first time the computer program starts, it sends a command over the serial BUS. That allows every module to announce its existence and to obtain a unique number. Through that unique number, the computer program can read the current angle of rotation of each module or to set a new one.

After finish reading all of the angles of rotation of the modules, the computer program can identify the current form of the mechanical protein. The shape of the robot is uniquely defined by the angle of rotation of each of the modules.

Figure 5. Milli Motein: one module and four connected modules

5. ATRON

The transmission of electrical signals and power, between the modules, is done like in the electrical motors, with brushes (Fig. 6). The brushes are attached to the fixed hemisphere and by friction in metal rings (slip-rings) on the other hemisphere a power supply and messages-transmission are carried out. The three most outer metal tracks, on Fig. 6, help the robot to position itself according to the “Gray code” [3] .This type of communication avoids twisting of wires.

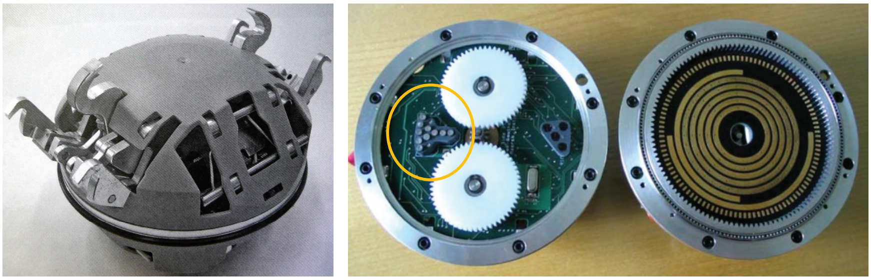

Figure 6. ATRON module: the right picture shows the brushes, in the circle, and the metal rings, that transmit power and communications over the two hemispheres.

Since the use of too large number of metal rings is not possible, due to physical limitations, a microcontroller is placed in each hemisphere [4]. This allows the electric connections to be reduced and currently the only signals that are transmitted are: two RS485, 10V power supply, 5V power supply and ground.

Unlike some previously described modular robots, ATRON has no central bus of communication. Instead, each connector has infrared receiver/transmitter (eight in general for the whole robot). Except for communication between two neighboring modules, the infrared sensors are also used as proximity sensors which allow the robot to detect various objects around him.

Each hemisphere contains one microcontroller ATmega8 and 512 B EEPROM for data storage.

Each module also has an accelerometer, which measures the direction of gravity. This allows the module to determine its position in space and to detect module motion, which is not self-initiated (for example, if the current module is moved by another module).

6. PEBBLES

Each module (Fig. 7) contains an Atmel ATMega328 microprocessor, a capacitor for storing electrical energy, and four electro-permanent magnets, which are used for communication and for transfer of power supply between the modules. The magnets are soldered directly to a flexible electrical circuit and one copper wire is wrapped around each magnet.

Communication between modules is done with speed of 9.6 Kbps (9600 Bd). Due to design features [2], each module can communicate with only one neighbor.

At the moment of sending the message, it is not known if the neighboring module is listening for an incoming message. That is why several attempts must be made, for a successful message delivery.

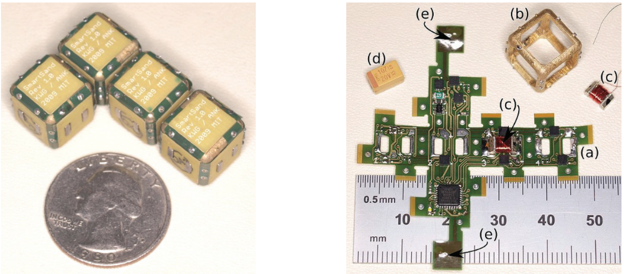

Figure 7. Pebbles robot: four connected modules and module inside

When two modules are connected to each other, their electro-permanent magnets form a small transformer. This effect is used for signals transmission between modules. When one of the modules powers the coil of his electro-permanent magnet, it affects on a coil in other module. Thus, second module can accept incoming messages and power supply.

Parallel serial interface (SPI) for each microcontroller is displayed outside the Pebbles module. Thus, the modules can be connected to a computer that can be used to run a variety of experiments on the robot behaviour.

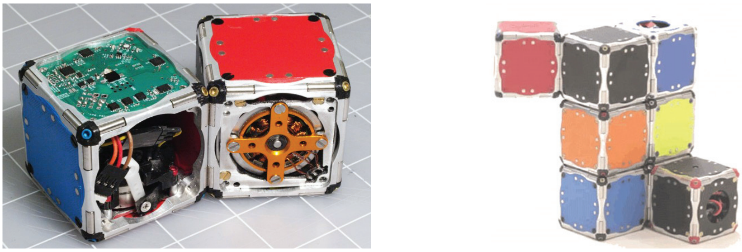

Figure 8. M-Blocks modules

7. M- Blocks

Each of the M-Blocks modules (Fig. 8) contains ARM microcontroller, XBee 802.11.4 radio module and three LiPo batteries.

The locomotion of each module cannot be self initiated and the modules cannot communicate with each other. They can only be driven by a computer by radio signals. The signals, they receive, tell them how fast to turn the electric motor (and flywheel). This allows the modules, after stopping the flywheel, to obtain a different momentum and to move to a certain position.

ANALYSIS AND COMPARISON

Table 1, shows summarized information, related to the examined self-reconfigurable robot1s. The “Taxonomy of architecture” and “Design of the modules” columns, show information about the robots classification, according to [9]. In the “Motion control” column, “Playback” means that the only thing that the robot can do is to execute a previously downloaded sequence. “Centralized” means that the robot cannot calculate its next move by itself, so it needs a computer, which performs the calculations and then sends the necessary commands to the robot. “Real time” means that the robot is capable to take decision, of its own, about its next move, according the surrounding environment.

It is interesting to note that only one of the examined robots (M-TRAN) can reconfigure itself in real time, under the influence of the surrounding environment. Reconfiguration is possible, due to the use of a neural network [5].

Each of the examined robots has unique and interesting engineering solutions. This is evident in the variety of wireless communications, used in the modules – infrared or electromagnetic communications, or radio signals.

Some robots have a common central data bus, designed to provide communication between modules. The design of other robots, however, is such that they do not need central bus or deliberately decided not to use such, as their creators want the modules to solve their problems locally.

Table 1. Comparative table of examined modular robots

Robot name	Taxonomy of architecture	Design of the modules	Release	Motion control	Central BUS	Wireless Communi-cation
CRYSTALLINE 2D	Lattice	Homogeneous	2000	Playback	No	IR
POLYBOT III	Chain	Homogeneous	2000	Playback, Centralized	Yes	No
M-TRAN	Hybrid	Homogeneous	2005	Playback, Real time	Yes	Radio signal
ATRON	Lattice	Homogeneous	2006	Playback	No	IR
PEBBLES	Lattice	Homogeneous	2010	Centralized	No	Electromag-netic field
MILLI-MOTEIN	Chain	Homogeneous	2011	Centralized	Yes	No
M- Blocks	Lattice	Homogeneous	2013	Centralized	No	Radio signal

CONCLUSION

This paper brings together various engineering solutions for onboard electronics, inter-module communication and motion control of seven modular robots. The future robot developments could benefit from the current work by drawing ideas from it.

Based on the analysis made, the following conclusions can be drawn:

1. Seven self- reconfigurable modular robots are examined.

2. An analysis of locomotion of the robots is made. It was found that most of the robots can move by playing some sequence, but as whole, most of the robots have no idea for the overall movement that they are performing.

3. Most of the robots cannot configure themselves autonomously in diverse environment. They are not capable of taking a decision for the appropriate form they have to take, according to the surrounding environment.

4. There are a wide variety of engineering solutions of the inter-module communication. Some of them include a central data bus, infrared communication, electromagnetic field and radio communication.

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