modular robotics, multiagent systems, metamorphic structures of robots

*Rudolf JÁNOŠ**

MULTIAGENT SYSTEMS IN MODULAR ROBOTICS

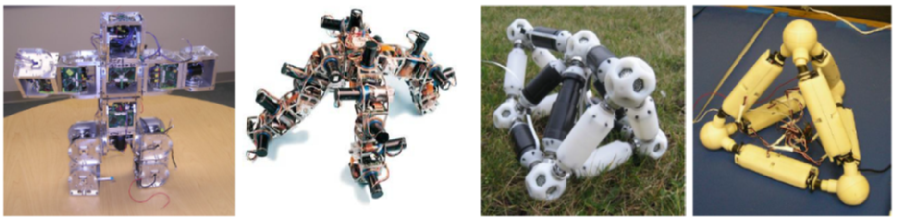
Abstract

The article describes the use of a multi-agent system in modular robotics. Multi-agent systems originated as an extension of the field of distributed artificial intelligence which allows understanding the individual modules as independent agents. By adopting this concept, design direction, which gives the robot a new quality, which is based on the possible effective reconfigure its kinematic and functional structure, thereby taking advantage of the original robot modules generate new variants of the robot with the required new parameters and behavior.

1. INTRODUCTION

In a modular robot system (MSR), each module is usually equipped with its own independent computation, sensing, communication, and actuation capabilities and can thus be viewed as an independent agent. Each module can usually also send messages to other modules that are physically connected to it. Modular robots have three main advantages over traditional robots. They are capable of changing their configurations to become different structures or shapes based on deferent tasks. Two types of modular robots are considered in this article (Fig. 1 a,b). Chain-style modular robots, SUPERBOT (a) and Polybot (b). Each square unit is an independent module, and there is a rotary motor mounted on each module (c, d). Strut-based modular robots. Each link/node module is an independent module; each link module can perform linear actuation to elongate or contract its length [7,8].

* Technical University of Kosice, Faculty of Mechanical Engineering, Department of Production Systems and Robotics, Nemcovej 32, 042 00 Kosice, Slovak Republic
rudolf.janos@tuke.sk



a **b** **c** **d**

Fig. 1. Types of modular robots [source: own study]

Most modular robots, there are distributed sensors in the whole systems because each module is equipped with a sensor. Such sensor-rich robots can potentially perform tasks more adaptively and reactively in changing environments than other robots with limited sensors. Because all modules are identical, the whole system is more robust with regard to module failures as long as we program each module in the system with an identical controller.

2. METAMORPHIC STRUCTURES OF SERVICE ROBOTS

Theoretic robotics characterizes metamorphic robots as modular systems with the ability to self-reconfigure their own kinematics and functional structure to create a „new“ robot with different functional features and technical parameters flexibly [1,2,6,9].

One of the main functions of MSR is the locomotion function, i.e. mechanic relocation of MSR within some space. MSR movement is understood as the change of status in the space (position and orientation) of MSR. MSR relocation into the status B in relevant (referential) space Z is the demonstration of certain type of relation of the movement M in the space Z.

$$M(B;Z) = \vartheta \tag{1}$$

MSR movement can be described by a twelve-component vector expression (x_E, y_E, z_E) – position of the center of gravity connected with a non-mobile coordinate system (i_E, j_E, k_E); u, v, w – speed of the movement of the center of gravity connected with the body of a service robot; θ, φ, ψ – Euler angles; p, q, r – angle speed connected with a mobile coordinate system).

$$X = \left(x_E, y_E, z_E, u.v, w, \theta, \varphi, \psi, p, q, r\right) \tag{2}$$

Functional and locomotion features of MSR, in relation to the effect of the demonstration of locomotion mechanism (kinematics – locomotion chain) of the robot ML (superposition of the movements of discrete locomotion elements of the locomotion mechanism), can be described of the locomotion function FM (locomotion equations). The function expresses the relation RM of the function ML and the space Z. The above said can be also described by the values of characteristic parameters X1, X2,, ..., Xn of different elements of kinematics structures of locomotion mechanism of MSR, generated by relevant drives on the base of control instructions.

$$R_M\ (M_L; Z) = \vartheta_M = F_M\ (X_1, X_2, ..., X_n) \qquad (3)$$

System model of MSR sets that the output of locomotion mechanism ML is bound with the chassis (mobility subsystem) CH, their mutual connection is given by the relation RCH (sum of the movements of different elements of locomotion mechanism - MSR movement).

$$R_{CH}\ (CH; M_L) = \vartheta_{CH} \qquad (4)$$

Taking into account the locomotion function of MSR, the relation RB of MSR into the status B and the chassis CH is similarly defined as

$$R_B\ (B; CH) = \vartheta_B \qquad (5)$$

consequently the status B of MSR in the space Z, in relation ϑCH, ϑB (relations can be constant or variable) is a superior function φ of the kinematics function FM

$$R\ (B; Z) = \varphi\ [F_M\ ; \vartheta_{CH}\ , \vartheta_B] \qquad (6)$$

while standard MSR have constant relations ϑCH, ϑB. Generally speaking, function FM realization is given by the features of locomotion mechanism of MSR with a defined character of its mobility (principle of physical realization).

In given circumstances, MSR reconfigurability means the development of locomotion structures of MSR (MSR locomotion structures of locomotion mechanism) by the control of the variability of the relations RCH and RB within the system structure of the robot mobility subsystem, the development of increasing/decreasing the number of elements realizing the locomotion function FM, the development by increasing the share of active members (at the expense of the passive ones) on the final mobility of the kinematics chain of the locomotion mechanism [9,10].

Reconfigurable MSR (metamorphic MSR – MMSR) are based on modular structure, Fig. 2, i.e. on the set of autonomous modules AM (set of locomotion, mechanical, control, ...modules) and their mutual organization and connections.

By the change of mutual organization (serial, parallel, combined structures) and the connection of AM it is possible to construct different functional and kinematics (open, close, combined kinematics chains) of the robot configuration.

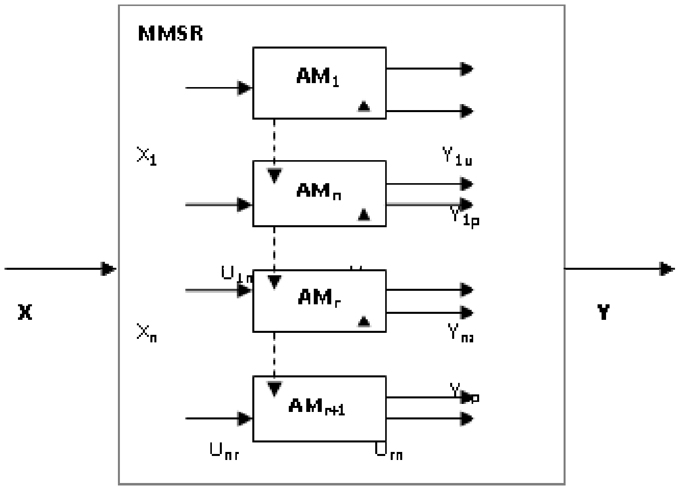


Fig. 2. System setting of modular structure [source: own study]

The inputs into the module AM_{r+1}, Fig. 3, are the following: parameters X of the task of MMSR transformed into the parameters X_{r+1} of the partial task of the module X_{r+1}, parameters of compatibility U_{rr+1} transformed as the interaction of directly connected following module AM_r in the structure of MMSR. The outputs from the module AM_{r+1} are the following: output parameters Y_{r+1u} a Y_{r+1p} of the module AM_{r+1} representing fulfilling of the partial task of the module transformed into the output parameters Y of the robot MMSR, parameters of compatibility U_{r+1r} by which the module AM_{r+1} directly influences directly connected following module AM_r in the structure of MMSR.

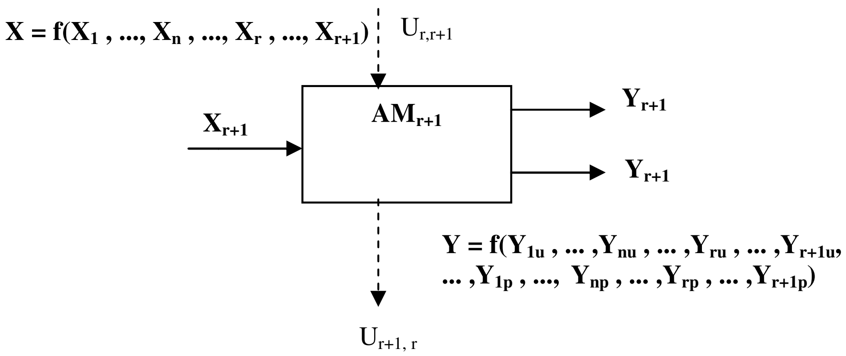


Fig. 3. Module characteristics [source: own study]

Module AM is defined as a unified structurally, functionally and construction ally independent unit (constructed from the elements E; mechanic module, servo drive, or also the source, control and communication module) with given level of function integration (main, secondary, help) and intelligence (control – integration, control and decision-making function), with the ability to connect mechanically and to control other modules into functionally superior wholes.

$$MMR_{\psi} \approx \sum_{j=1}^{a} AM_{j} \approx \sum_{j=1}^{a} \sum_{i=1}^{e_j} E_{i,j} \tag{7}$$

From the point of view of the application, metamorphic structures can be applied on the level of the inner structure of MMSR (by reorganizing its own modules, the robot can change its kinematics structure, functional structure and disposition setting, functional features and technical parameters), or on the level of outer structure of the application of robotic system (simple robots integrate into one, functionally higher level robot or a complicated robot disassembles into a group of simple, more active and more effective robots).

3. EXAMPLES OF THE DESIGN OF METAMORPHIC SERVICE ROBOTS

Recent practice offers several solutions to the design of MMSR (on the level of the inner structure, on the level of outer structure), from the solutions of theoretical character up to the solutions of the models for concrete technical application, Fig. 4 [3].

Use of the principles of metamorphic structures on the level of the inner structure MMSR in construction of the details of locomotion mechanism of MMSR can be presented on the design of metamorphic wheel, Fig. 5. Model EGON (designed at the workplace of the author), by the inner construction of its parts (modules) and the possibility to control the change of their arrangement it can fulfil the function of a „wheel" or a „track" [3,12,13]. The application of the model with wheeled MMSR gives the robots new driving abilities which can be adjusted to the requirements of the terrain.

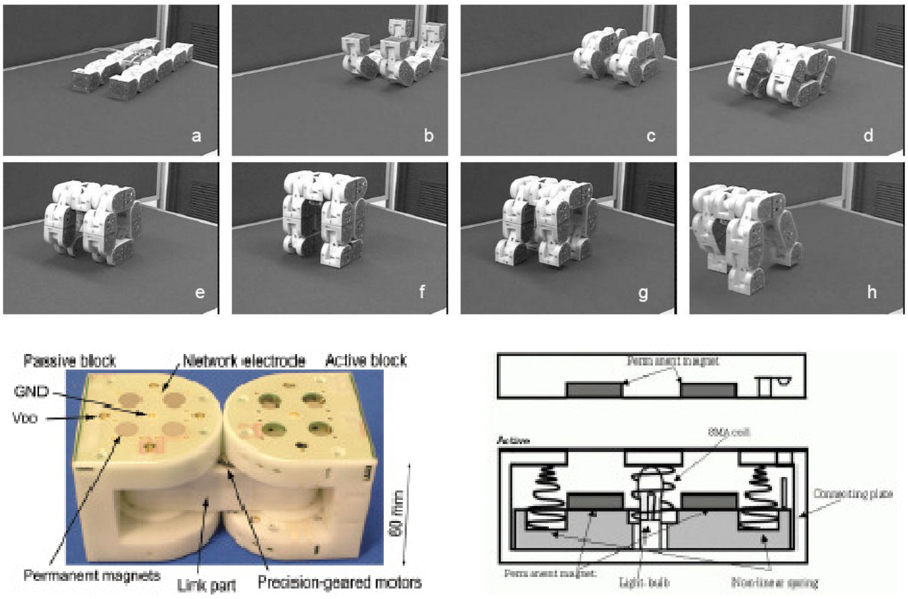


Fig. 4. Example of the possibility of reconfiguration of M-TRAN model [source: own study]

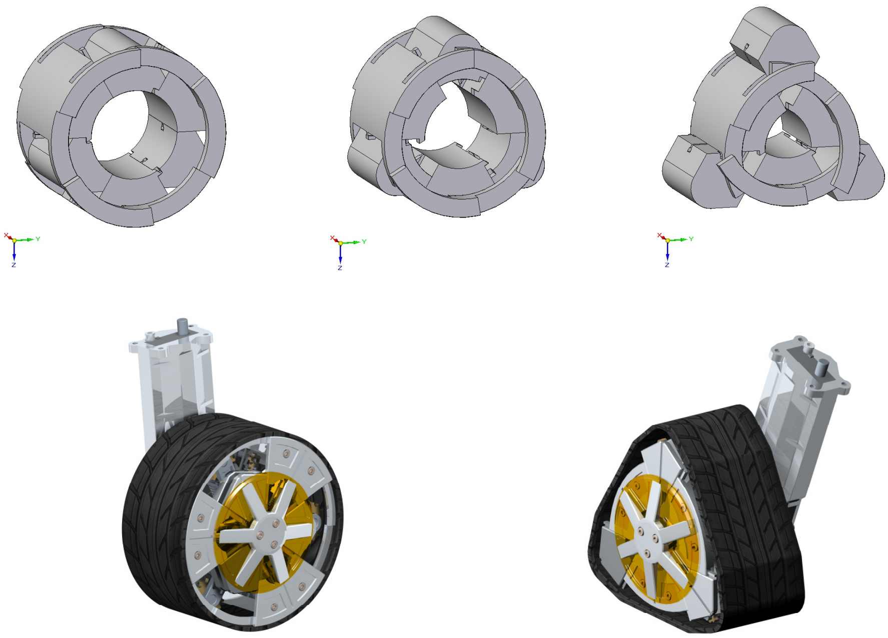


Fig. 5 Model EGON of metamorphic wheel – track system [source: own study]

Heterogeneous modular robots consist of a set of different modules with varying functionality. Typically, these modules will not work individually, but when put together, each module's functionality adds up to form a robot capable of performing a task. The modules with some sort of actuation usually integrate a motor, increasing the cost and complexity of the module. Example of this type is study of robot Thorn (Fig. 6) [4,13].

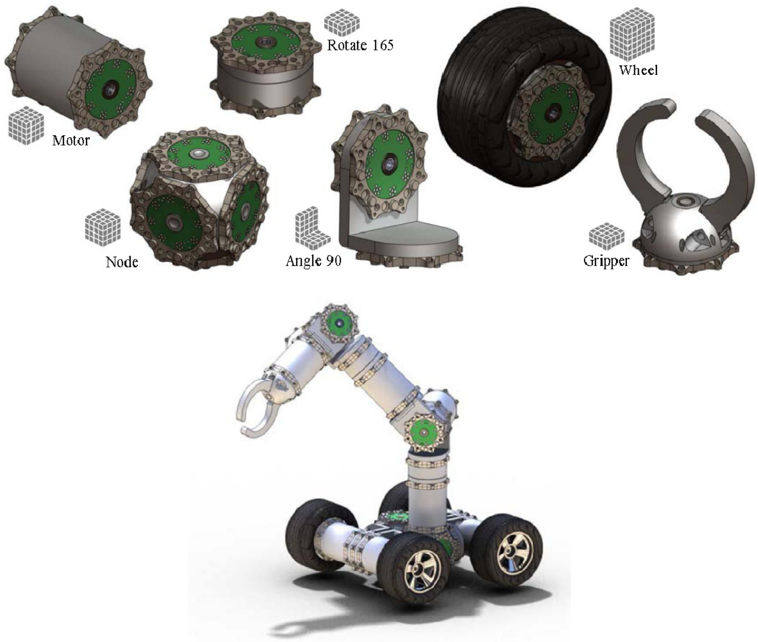


Fig. 6 Example of the possibility of reconfiguration of Thor model [source: own study]

4. CONCLUSION

The problem of the design and application of MMRS has become a highly recent topic for theoretical as well as practical robotics. It echoes the dynamics of the service robotics development and searching new technical designs of the MSR construction for the applications into non-traditional, demanding environments. The trends of the application of *metamorphic – self-regulating* structures in the design of mobility of MSR subsystem, on the base of existing results and their evaluation, have proved technical usability and suitability to design new requirements on MSR. So it can be concluded that the problem of MMSR has the reason to be solved also in our conditions.

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