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LOCOMOTION AND RECONFIGURATION OF A MODULAR ROBOTIC CHAIN

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Articolul prezintă un sistem robotic modular, proiectat pentru a fi capabil de reconfigurare, putând să se deplaseze prin păşire sau târâre. Sunt prezentate structura sa mecanică şi sistemul de control. De asemenea, este propusă o soluţie modificată de modul cu două grade de libertate, pentru care este analizată influenţa geometriei robotului asupra locomoţiei şi strategiei de auto-reconfigurare, prin simularea într-un mediu virtual.

The paper deals with a modular robotic system, which is designed for reconfiguring, in order to achieve both walking and crawling locomotion. Its mechanical architecture and control system are presented. A modified robotic module, with 2 degrees of freedom, is proposed, for which the influence of the robot geometry upon the locomotion and self-reconfiguration strategy is pointed out, by simulations performed in a virtual environment.

Keywords: Modular robotics, Autonomous system, Distributed control, Self-reconfiguration, Self-replication.

1. Introduction

Self-reconfigurable robots are complex distributed systems, consisting of several modules, with one, two or three degrees of freedom (DOF), as simple robotic units. These ones can be assembled in such ways, that form different mechanical structures, able to meet the requirements of the specific tasks concerning locomotion and self-reconfiguring. A self-reconfigurable modular robot is meant to adapt both to unstructured working environment and to malfunction of some own modules, by changing its configuration.

The existing modular robots are still laboratory achievements, built as demonstrators, but they proved to have real skills for locomotion and inspection in environments with strong variable geometric configuration, such as narrow spaces. There are many modular robotic systems, but a general classification can

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cubic mesh, by dividing the robot working space into cubes having the dimension of its basic elements. The movements for reconfiguring or displacement are obtained by filling of the a priori defined cubic locations of the mesh with robotic elements, according to the control algorithm. The concept was previously verified by simulation of the components movement within Blender, a free software resource.

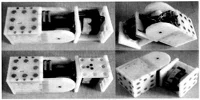
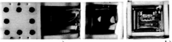


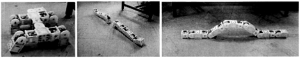
Fig.1. Module DOFs

The right side cube of the module (fig. 2, a), which performs the rotation around the longitudinal axis, mainly houses a RC servo type motor - MG995 (1 N.m) and a Ni-Mh battery. The rotation around the transversal axis is performed within central cube, which houses a RC servo of the same type. The left cube (fig. 2, b) is used to host the microcontroller (Basic Stamp 2 SX), RF communication modules, both from Parallax Inc. and the detaching mechanism. The connection between modules is accomplished by means of permanent magnets, while their detaching is helped by a leverage system, powered by a third motor. The size of an elementary cube is 70 mm, resulting a 210 mm length of a module.



a) b)

Fig.2. a) ROMAR module; b) Left-side cube



a) b) c)

Fig.3. Several configurations with ROMAR modules: four-legged walker (a), and self-replication into mini-chains (b), six-module caterpillar (c)

mechanical part, the rotor inertia, gear ratio and the robot segments inertia, as well as a constant resistant torque at the maximum value were also introduced.

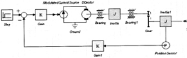


Fig.8. Robot simplified model in 20-sim

The model response (fig. 9) shows the capability of an active joint to move at least an additional module, in an acceptable period of time.

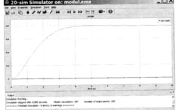


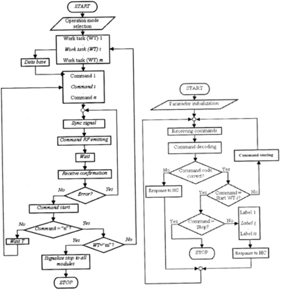
Fig.9. System response of the model in fig.8

4. Locomotion and reconfiguring strategy

The locomotion abilities of the robot ROMAR I are the ones associated with the shapes in fig.3: a) four-legged walking structure; b) three modules crawling structure; c) six modules chain structure with snake-like (or worm-like) movement. A self-reconfiguring procedure for transforming the four-legged structure into an open chain was conceived and tested, as well as the locomotion of the above mentioned structures. The main difficulty of the ROMAR I locomotion is related to walking, because the legs don't have the adequate mobility and must pull along the floor.

ROMAR II is an attempt to correct this deficiency. Module design allows the same ability of building a cubic mesh, by dividing the robot working space into cubes, like the previous version. The concept was verified by simulation within *Blender 3D*, a free software resource. Several movement and reconfiguration possibilities have been investigated, with a different number of modules, in order to determine the mobility of different structures with ROMAR II modules.

time and return to the next command in the list. If there are no more commands to be sent and no more work tasks, the host computer program emits a stop signal to all modules and stops itself.



a) b)

Fig.13. Flow charts: a) of the host computer program
b) of the robotic module program

The flow chart of the program implemented on the robotic module is shown in fig. 13.b. From the structure point of view, the programs on each the robot modules are identical. The significant differences are regarding parameter initializing with the specific calibrated values for the motors, and the specific program execution of the received commands.