Third Int. Workshop on GNs, Sofia, 1 Oct. 2002, 37-41

A Metamorphic Robot Described in Generalized Nets Terms

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Abstract: The metamorphic robots are a new sphere of robotics that belongs to the Distributed Artificial Intelligence realm. These robots can dynamically adapt their shape and have many useful applications in hostile enviroments on the Earth or on other planets in the space.
The metamorphic robot, considered in the paper is described as a multiagent system in generalized nets terms - a new tool for design and simulation that saves the logics and dynamics of the investigated objects but at the same time gives compact and full description.

Key words: multiagent systems, generalized nets, modular robots, metamorphic robots, modelling, simulating

1. Introduction

The metamorphic robots are a swarm of autonomous controlled units that could connect, disconnect and climb over adjacent modules [1].

As it was discussed in [2], the metamorphic robots could be considered as a multiagent system.

The theory of multiagent systems is an extension of artificial intelligence (AI) theory but concerns distributed AI in multiple reasoners [3].

Distributed AI can be devided into two subfields: Distribited Problem Solving (DPS) and Milti-Agent Systems (MAS) [4]. DPS deals with centrally designed systems solving global problems and using build-in cooperations strategies. In contrast, MAS deals with heterogeneous, not necessarily centrally designed agents faced with the goal of a utility - maximizing coexistence [5].

The paper is a combination of both problems - the robots should communicate between themselves in order to solve a common task that is not preliminary known to them.

A method for solving such task with a great extent of uncertainty for a chain locomotion and an ameboid movement could be found in [1], [2].

The leading scope of this paper is to present a method for discribing such modules in the terms of generalized nets (GN).

The least are a new likelihood that gives an opportunity to describe the dynamics and the logic of a process simultaneously.

As the GNs give also a ossibility to describe parallel processes, they could be a convinient tool for ascribing modular robots (metamorphic robots).

Each module is ascribed with an identical GN model and there is an element of the generalized net for communication.

The revealed model describes the construction of a mechatronic ameboid [1], [2].

2. The Design of the Robotic Module

The robotic module is a 2D structure, capable to move and reconfigure autonomously. On Fig.1 it is shown the computer design of the module. It is of hexagonal shape and is equipted with optical receptors for each side of the hexagon.

The modules are equipted also with a microcontroller unit and an actuator mechanism. The detailed construction of the module will be discussed in another paper.

Fig.1. The computer design of the module

3. Generalized Nets Model of the Mechatronic Ameba

The model is depicted in Fig.2:

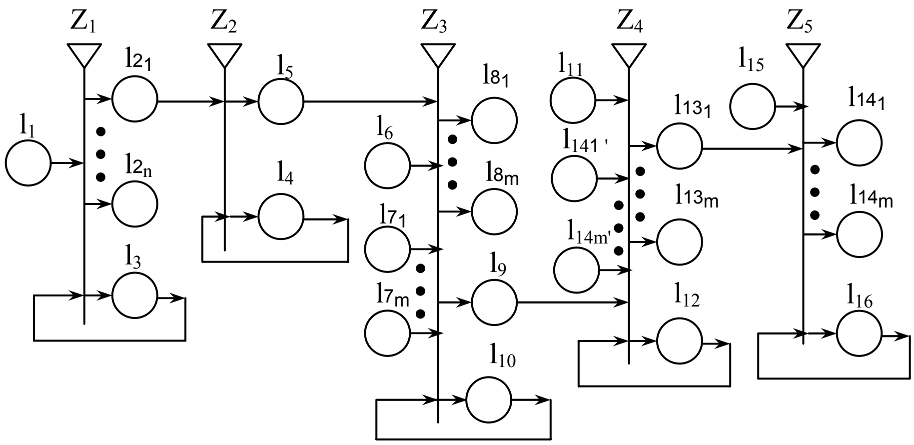

Fig.2. The generalized nets model of the mechatronic ameba

The symbols and signatures used at this model could be found in [6].

<u>Note:</u> The indeces m and n are relevant to the number of sides in each module and the number of modules in the mechatronic ameba respectively.

The transition Z_1 and the places l_1, $l_{21}, \dots, l_{2n}$ and l_3 represent a generalized nets model of a random oscillator [7], which drives the ascendancy of the negotiations among the agents (modules).

Z_1 contains the following:

$Z_1 = \langle \{l_1, l_3\}, \{l_{21}, \dots, l_{2n}, l_3\}, r_1, \vee(l_1, l_3)\rangle$,

where $r_1 =$

	l_{21}	…	l_{2n}	l_3
l_1	false	…	false	true
l_3	$W_{3,21}$	…	$W_{3,2n}$	true

The tokens α_i (where i is the consecutive number of the running token) enter the Generalized Net with an initial characteristic $X_o^{\alpha i}$ = "E", i.e. the supply voltage. On the second step, they enter the place l_3 and obtain a new characteristic - $X_1^{\alpha i}$ = "U_{rnd}", i.e. the voltage of the random oscillator. On the third step, the tokens α_i enter the places $l_{21} \dots l_{2n}$, according to the value of the predicates - $W_{3,21} \dots W_{3,2n}$ = "U_{rnd1}",…,"U_{rndn}"is true.

The value of the of the random voltage determines the place (of the set-$\{l_{21} \dots l_{2n}\}$) that will be entered from the tokens α_i. Their new characteristic is $X_2^{\alpha i}$ = "U_{drive}", i.e. the driving voltage that specify the prominent (initial) module.

The second transition Z_2 supersedes a logical scheme - AND [8].

$Z_2 = \langle \{l_2, l_4\}, \{l_4, l_5\}, r_2, \wedge(l_2, l_4)\rangle$,

where $r_2 =$

	l_4	l_5
l_2	$W_{2,4}$	false
l_4	true	true

The tokens α_j enter the place l_4 of the transition Z_2 with an initial characteristic - $X_0^{\alpha j}$ = "U_{ref}", which is equal to a logical unit. On the second step, the tokens α_i enter the place l_2 with an initial characteristic - $X_2^{\alpha i}$ = "U_{drive}". If the predicate $W_{2,4}$= " U_{drive} & U_{ref} are logical units " is true, then the tokens α_i enter the place l_4 and unite with the tokens α_j. The new tokens $\alpha_k = \alpha_i \cup \alpha_j$, enter the place l_5 with an initial characteristic - $X_0^{\alpha k}$ = "U_{drive1}".

The third transition Z_3 represents an Intuitionistic Fuzzy Microcontroller with optical receptors and optical feed-back.

$Z_3 = \langle \{l_5, l_6, l_{71}, \dots, l_{7m}, l_{10}\}, \{l_{71}, \dots, l_{7m}, l_9, l_{10}\}, r_3, \wedge(l_5, l_6)\rangle$,

where $r_3 =$

	l_{81}	…	l_{8m}	l_9	l_{10}
l_5	false	…	false	false	true
l_6	false	…	false	false	$W_{6,10}$
l_{71}	false	…	false	false	$W_{71,10}$
.	.	…	.	.	.
.	.	…	.	.	.
.	.	…	.	.	.
l_{7m}	false	…	false	false	$W_{7m,10}$
l_{10}	$W_{10,81}$	…	$W_{10,8m}$	$W_{10,9}$	true

The tokens α_k enter the place l_5 of the transition Z_3 with an initial characteristic - $X_0^{\alpha k}$ = "U_{drive1}". On the second step, they enter the place l_{10} with the same characteristic. On the third step, the tokens α_l enter the place l_6 of the transition Z_3 with an initial characteristic - $X_0^{\alpha l}$ = "E". On the fourth step, they enter the place l_{10}, unite with the tokens α_k and obtain their characteristic. This is possible if $W_{6,10}$ = "$\exists\ \alpha_k \in l_{10}$"is true. On the fifth step, the new tokens $\alpha_m = \alpha_k \cup \alpha_l$, with an initial characteristic - $X_0^{\alpha m}$ = "E" are divided into *m* new tokens that enter the places $l_{81} \dots l_{8m}$. Their new characteristic is - $X_1^{\alpha m}$ ="U_{LED}", i.e. the voltage necessary for the light emitting diodes.

This is possible if $W_{10,81} = \ldots = W_{10,8m}$ = "$\exists\ \alpha_m \in l_{10}$ & $X_0^{\alpha m}$ = "E" "is true. On the sixth step, the tokens α_k enter the place $l_{71} \ldots l_{7m}$. Their initial characteristic - $X_0^{\alpha k}$ = "$U_{feed\text{-}back}$ ", i.e. the voltage from the optical feed-back. On the seventh step, they enter the place l_{10} with a new characteristic- $X_1^{\alpha k}$ = "U_{stored}", i.e. the voltage of the memory bank. This is conceivable if: $W_{71,10} = \ldots = W_{7m,10}$ = "$\exists\ \alpha_k \in l_{71} \vee \ldots \vee l_{7m}$ & $X_0^{\alpha k}$ = "$U_{feed\text{-}back}$" is true. On the eighth step, the tokens α_k enter the place l_9 with a new characteristic - $X_2^{\alpha k}$ = "U_{drive2} ", i.e. the driving voltage for the servo motor controller. This is possible if $W_{10,9}$ = "the previous steps has been passed successfully"is true.

The transition Z_4 is a servo-microcontroller [8].

$Z_4 = \langle \{l_9, l_{11}, l_{10}, l_{141'}, \ldots, l_{14m'}\}, \{l_{12}, l_{131}, \ldots, l_{13m}\}, r_4, \wedge(l_9, l_{11})\rangle$,

where $r_4 =$

	l_{12}	l_{131}	$\ldots$	l_{13m}
l_9	$W_{9,12}$	false	$\ldots$	false
l_{11}	true	false	$\ldots$	false
l_{12}	true	$W_{12,131}$	$\ldots$	$W_{12,13m}$
$l_{141'}$	$W_{141',12}$	false	$\ldots$	false
.	.	.	$\ldots$	.
.	.	.	$\ldots$	.
$l_{14m'}$	.	.	$\ldots$	.

The tokens α_l enter the place l_{11} of the transition Z_4 with an initial characteristic - $X_0^{\alpha l}$ = "E". On the second step, they enter the place l_{12} with the same characteristic. On the third step, the tokens α_k enter the place l_9 of Z_4 with an initial characteristic - $X_0^{\alpha k}$ = "U_{drive2} ". On the fourth step, they enter the place l_{12}, unite with the tokens α_l (from the previous step) and obtain their characteristic.This is possible if: $W_{9,12}$ = "$\exists\ \alpha_l \in l_{12}$" is true. On the fifth step, the tokens $\alpha_m = \alpha_k \cup \alpha_l$ are divided into *m* new tokens for the places $l_{131}, \ldots, l_{13m}$ and enter these places. This is conceivable if: $W_{12,131} = \ldots W_{12,13m}$ = "$\exists\ \alpha_m \in l_{12}$" is true. Their new characteristic is - $X_1^{\alpha m}$ = "$U_{drive31}$", … , "$U_{drive3m}$", i.e. the *m* driving voltages for the six servomotors. On the sixth step, the tokens α_n enter the places $l_{141'}, \ldots, l_{14m'}$ with an initial characteristic - $X_{0i}^{\alpha n}$ = "$U_{servo\ feed\text{-}back\ i}$", i = {1, *m*}. They enter the place l_{12} (on the seventh step) and unite with the tokens α_m. This is possible if: $W_{141',12} = \ldots = W_{14m',12}$ = "$\exists\ \alpha_n \in l_{14i'}$" is true. On the eighth step, the tokens $\alpha_0 = \alpha_n \cup \alpha_m$ enter the places $l_{13\,i}$ (i = {1, *m*}) with a new characteristic - $X_{0\,i}^{\alpha o}$ = "$U_{drive3\,i'}$", i.e. the corective driving voltage for the servomotors.

The transition Z_5 is a servomotor implementation with a feed-back to Z_4 [8].

$Z_5 = \langle \{l_{131}, \ldots, l_{13m}, l_{15}\}, \{l_{141}, \ldots, l_{14m}, l_{16}\}, r_5, \wedge(l_{131}, \ldots, l_{13m}, l_{15})\rangle$,

where $r_5 =$

	l_{141}	$\ldots$	l_{14m}	l_{16}
$l_{131'}$	true	$\ldots$	true	$W_{131,16}$
.	.		.	.
.	.		.	.
.	.		.	.
$l_{13m'}$	true	$\ldots$	true	$W_{131m,16}$
l_{15}	false	$\ldots$	false	true
l_{16}	$W_{16,141}$	$\ldots$	$W_{16,14m}$	true

The tokens α_p enter the place l_{15} of the transition Z_5. Their initial characteristic - $X_0^{\alpha p}$ = “E”. On the second step, the tokens α_m enter the place l_{13i}, (i={1, *m*}) with an initial characteristic - $X_{1\,i}^{\alpha m}$ = “$U_{drive3\ i}$”. On the third step, the tokens α_p enter the place l_{16} of Z_5 with the same characteristic and on the fourth step, the tokens α_m enter the place l_{16}. This is possible if: $W_{131,16} = \ldots = W_{13m,16}$ = “$\exists\ \alpha_p \in l_{16}$” is true. On the fifth step, the tokens $\alpha_q = \alpha_m \cup \alpha_p$ are divided into *m* new tokens that enter the places $l_{141}, \ldots, l_{14m}$ with an initial characteristic - $X_{0\,i}^{\alpha q}$ = “$U_{servo\ feed\text{-}back}$” (i={1, *m*}). This is conceivable if: $W_{16,141} = \ldots = W_{16,14m}$ =“$\exists\ \alpha_q \in l_{141}, \ldots, l_{14m}$” is true. On the seventh step, the tokens α_o enter the place l_{16} with the same characteristic. They unite with the tokens α_p.On the eighth step, the tokens are $\alpha_r = \alpha_o \cup \alpha_p$ are divided into *m* new tokens that enter the places $l_{141}, \ldots, l_{14m}$. Their initial characteristic is - $X_{0\,i}^{\alpha r}$ = “$U_{servo\ feed\text{-}back}$”, i.e. the corrective driving voltage for the servo motors after the correction (step six of the transition Z_4 /servo-microcontroller/).

4. Conclusion

The revealed GN model gives a possibility to explore the metamorphic ameboid and the metamorphic robots as MASs that solve tasks with a great extent of uncertainty.

Through the characteristics and the predicates of the generalized nets, the described model gives a really generalized and compressed discription without losing the information for the dynamics and logics of the system.

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