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MODELING AND ANALYSIS OF BIOLOGICALLY INSPIRED ROBOT

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ABSTRACT:

Biologically inspired robot encompasses application of biological principles to tackle the technological issues for design of a resourceful robot. The present paper portrays the modeling and analysis of the design issues pertaining to biobots. With a focus on topological modeling of biological and bio-inspired hardware sensor and systems using diagraphs, architecture of a biobot is presented.

Keywords: diagraph, biobot, DSP, Microcontroller, biomimetic systems

1. Introduction:

The last decade of the twentieth century saw a tremendous growth in neurobiology, information technology, and microsystems engineering. One of the most significant trends in the neuro-technology field has been the development of “biomimetic” electronic systems that emulate the function of biological neural systems. "Biomimetics" refers to technologies that immitate or mimick certain biological functions or even whole organisms. The concept has been used in a bewildering variety of definitions. It is all about examining how biological systems solve problems and then to construct analogous, biomimetic, mechanisms by using reconfigurable hardware and software.

The main design theme in Biomimetic Systems is the relationship between the various entities and their functionality under conditions of normal functioning and malfunctioning. This requires detailed characterization of the biological systems to be emulated in terms of hardware and software. To organize this detail and arrive at a better fundamental understanding of life processes, it is imperative that powerful conceptual tools from mathematics, graph theory and the physical sciences be applied to the frontier problems in biology. Thus a starting point of designing successful biomimetic systems is to develop a model of the actual biological system. Such model is then useful to simplify the hardware and software design issues. This paper focuses on topological modeling of biological and bio-inspired hardware sensor and systems by using digraphs.

2. Topological digraphs of Biological systems:

A digraph is nothing but a graph having directed edges. Prof. Janis Osis carried out pioneering work in using the digraphs for modeling the complex biological systems [2-4].

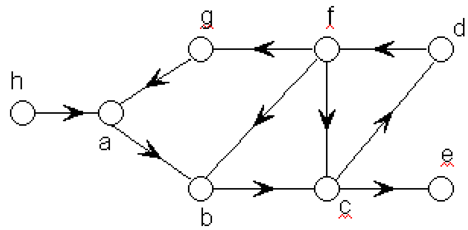

Figure 1: Topographical digraph of a biological system

In order to obtain the model of the biological system its digraph G(X,V) is derived where, X is a finite set consisting of functional characteristics of the system under observation and all other systems interacting with that system and V is a set of directed lines containing elements of X.

As an example a topological digraph of a biological system [2] is shown in figure 1. Here a= contact with food, b= swallowing of food, c= digesting of food, e= absorption of digested food by cells, e= throwing out of waste, f= energy distribution, g= movement in search of food, h= food from the surroundings.

3. Digraphs modeling applied to robots:

A biologically inspired robot also called as biobot is designed by insights gained through the study of biological mechanisms. It imitates the structure or physiology of the biological system and or connects and integrates biological and mechanical components in its operation. Data from biological organisms such as the Deathhead, Cockroach and crickets are used to create robots that can flexibly traverse irregular terrain. The resulting robots are also serving as models for understanding the dynamics of biological systems.

The topological modeling scheme proposed for biological systems can directly applicable to biobots. In order to define topological model (Y,π) of the biologically inspired robot, a system B is defined as follows:

$$B = R \cup S \qquad \text{\_\_\_\_\_\_\_(I)}$$

Where R is a finite set constituting the functional properties of the biobot and S comprises of functional properties of the systems interacting with the biobot (environment). Architecture of a biobot is proposed in the following section and the topological model has been applied to it.

4. Architecture of a biobot:

The biobot is based on the structure that parallels insects and animals. A hierarchical biological diagram of the implementation is as shown in figure 2. The biological system can be realized interms of electro-mechanical structure by executing the various block interms of equivalent mechatronic systems. The left brain may be executed with a peripheral intensive microcontroller like PIC processors from microchip technology. The ultimate choice for the right brain will be a combination of reconfigurable devices like FPGA together with the intensive computational processors oriented towards DSP architectures [5,6]. The locomotion is executed by means of motors with separate controllers if needed. The sensory inputs are implemented by using micro switches for touch, CCD for vision, IR transmitter-receiver pair for obstacle detection etc. However, all these implementations differ largely with the ambient environment and the nature of intended applications.

The digraph for one of the implementations is as shown in the figure 3. One of the possible implementations of nodes is given in table 1. The main environmental factors acting on the biobot have been summarized in table 2.

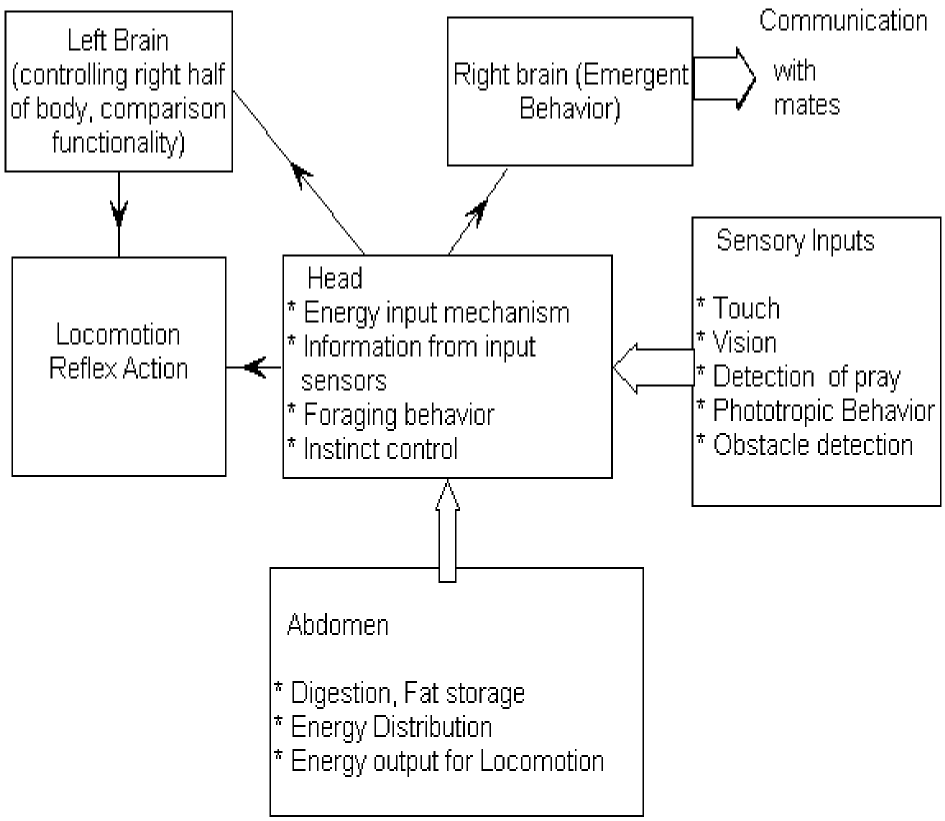

Figure 2: Proposed architecture of a biobot

Table 1: A possible Implementation of biobot derived from digraph of the system

A: head (combination of DSP and microcontrollers)	I,j : motor controllers for hand
B: left brain (micorocontroller rich in motor control resources)	l: binary touch sensor (microswitch)
C: right brain (neural network main processor)	m: precision touch sensor (capacitive)
D,e,f,g: individual neurons (combination of FPGA and microcontroller)	N: vision system (CCD interface)
H,k : motor controllers for legs	o,p: other robots (indicates communication)

Table 2: Environment interacting with the biobot

α : friction of the terrain	φ, χ : environments parameters affecting other biobots, communicated to each other for emergent behaviour
β : obstacles	σ : focussing/resolution problems of vision system
γ : path holes	δ : pray/object moving from biobot
ψ : fog/fumes	ε : opposition from pray/object

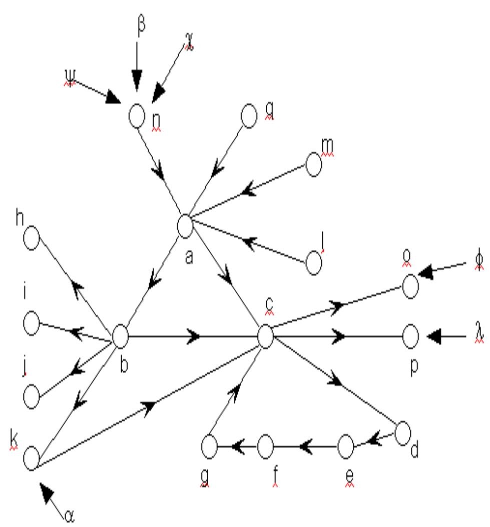

Figure 3: Digrpah modeling of the biobot

5. Conclusions

Developing topological modeling using digraphs can facilitate the study of the biologically inspired robot. An in depth generalized model of a bio-inspired robot has been discussed in the paper. The topological space of this bio-inspired robot has been derived by using digraphs. The following conclusions are evident from the modeling of the bio-inspired robot:

The bio-inspired robot is a subsystem of environment and one of the important aspects of its functioning is knowledge acquisition of the various parameters of its surrounding or ecosystem. This knowledge is very useful to tailor the performance of the robot with highest throughput. One example with respect to the model proposed in this paper, is optimization of speed as per the parameter 'friction of the terrain' (α). This result into the most power optimization, which is also some kind of foraging behaviors, found in biological elements.

The topological space of the bio-inspired robot (Y,π) is obtained by subdividing it into a series of subsystems. In the mathematical form it is given as equation I. Defining the sets R and S completes the modeling of the robot.

R = { a, b, c, d, e, f, …,q } _____(II)

S = { α, β, χ, φ, . . ., ψ } ______(III)

The most important property of the topological model (Y,π) is absence of any isolated vertices. The system must be connected to facilitate the communication and cause effect relation to imitate the intelligent behavior of a biological system. The complexity of the model depends on the level of system description required to implement the behavior interms of individual blocks.

The digraph modeling of the bio inspired robot helps in finalizing the 'priority list' of the tasks to be performed. This eases the job of programmer for developing driver routines without any latency by avoiding the deadlocks between the tasks. The digraph modeling also gives an idea of infraction of any functional property of a system, which may cause infraction of series of other functional properties of the system. The routine of the maintenance schedule may be planned to avoid such infractions. It is possible to deduce the differential diagnosis of the robot, which is referred to as homeostasis in living objects.

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