LETTER Special Section on Cyberworlds **A Bio-Inspired Cognitive Architecture**

A Bio-Inspired Cognitive Architecture of the Motor System for Virtual Creatures

Daniel MADRIGAL^{†a)}, Gustavo TORRES^{†b)}, Nonmembers, and Felix RAMOS^{†c)}, Member

SUMMARY In this paper we present a cognitive architecture inspired on the biological functioning of the motor system in humans. To test the model, we built a robotic hand with a Lego MindstormsTM kit. Then, through communication between the architecture and the robotic hand, the latter was able to perform the movement of the fingers, which therefore allowed it to perform grasping of some objects. In order to obtain these results, the architecture performed a conversion of the activation of motor neuron pools into specific degrees of servo motor movement. In this case, servo motors acted as muscles, and degrees of movement as exerted muscle force. Finally, this architecture will be integrated with high-order cognitive functions towards getting automatic motor commands generation, through planning and decision making mechanisms.

key words: cognitive architecture, artificial intelligence, robotic hand

1. Introduction

One of the main challenges in the development of cognitive architectures is to define the requirements and components that comprise the system [1]. In order to give a solution to this problem we propose the following hypothesis: "If we want to develop artificial entities capable of perform tasks considered uniquely as human capabilities, it is necessary to design synthetic components that recreate the functionality of the elements that produces the intelligence of humans". Although the idea is intuitive, the compliance of this hypothesis requires a broad understanding of how the central nervous system (CNS) of humans works, which is, as explained by the neuroscientist, the producer of almost all living things behavior. Therefore, we are supporting our approach with the neuroscience, which gives us information about the functions, components and their interaction of CNS in order to produce behavior.

With this approach in mind, we present a part of a bioinspired motor system cognitive architecture, which is the responsible of the execution of motor actions (movements) of living beings.

2. Model Description

One of the most important abilities that the virtual entity must have is the one for the self-motion. In order to develop it, we need to consider two aspects of human motion.

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a) E-mail: dmadrigal@gdl.cinvestav.mx

b) E-mail: gtorres@gdl.cinvestav.mx

First, we need to build a body that can be manipulated at will, taking into account all interactions with environments' phenomena. Second, we need to design the synthetic systems for the generation of coordinated movements that are provided by high-order cognitive processes.

In order to have a body that can be manipulated by the architecture, we have developed a hand with fingers using a Lego MindstormsTM kit. This model recreates the operation of the middle and distal phalanges of the finger. A nylon thread and rubber bands act as tendons and ligaments, respectively. Finally, two motors act as the agonist and antagonist muscles for every finger.

The motor system is comprised by all the structures of the CNS that are involved in the planning and execution of human beings motion [2]. In this paper we focus on the lower levels of the system, because in this level the structures that are responsible of execute the motor actions are found [2].

The skeletal muscles are responsible for the movement of the bone structures. This is achieved by muscle contraction, which pulls the tendons to which they are attached, which in turn pull the bones. In humans three different types of muscle fibers have been found [3], ranging from fibers that are resistant to fatigue but are not able to exert much force, to muscle fibers that exert great force, but are not resistant to fatigue.

Within the spinal cord and the brainstem, the local circuit neurons that are responsible of controlling the activation of motor neurons are found [2]. This control is used, among other things, to maintain a posture or disable the motor neurons of the antagonist muscle while neurons of the agonist perform a muscle contraction. Also, the motor neurons within the spinal cord have the function of controlling the contraction of different muscle fibers. Two different types of motor neurons have been found [3], the first type are the alpha motor neurons, which are responsible of controlling the force applied by the muscles. The other type are the gamma motor neurons that control the contraction of the muscle fibers in which a certain type of sensory receptor is found.

3. Implementation

We found that the structure *Spinal Cord Neurons and Brainstem Circuits* (Fig. 1) performs the following functions [4]: it controls the activation of motor neurons and sends pulses to the muscles. These functions were imple-

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[†]The authors are with the CINVESTAV Guadalajara, Mexico.

c) E-mail: framos@gdl.cinvestav.mx

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Fig. 1 Architecture of the biological motor system.

mented using the following three assumptions [5]: the activation of the neurons follows the size principle of motor neurons, the recruitment of more motor neurons is linear, and the firing rate of each neuron remains constant.

With this assumptions we established that the only factor that will determine the force that would be exert by the muscle is the number of alpha motor neurons that are active. Therefore, the muscle in this implementation will "transduce" the number of active neurons in the force applied by the motor. This was achieved using the following equation:

$$F(n) = M(1 - \exp^{-n})$$
 (1)

Where F is the force that must be applied by the motors, expressed in Newtons, M is the maximum force that the muscle can apply, expressed in Newtons, and a positive integer value n that is the number of active neurons in a given window.

4. Experiments and Results

To test the model, two scenarios were designed. The first scenario involves the flexion and extension movements in the different fingers of the robotic hand. This was done in order to validate the communication between the architecture and the fingers. The aim of the next scenario was to prove that the hand is capable of perform the grasping of a variety of objects.

4.1 Movement of the Fingers

The finger motion was performed by delivering motor commands to robotic fingers' motors sent from the cognitive architecture. In this experiment we achieved the desired movements of flexion and extension (see Fig. 2).

4.2 Grasping

This experiment aims to test the use of a robotic finger as-



Fig. 2 Flexion of the robotic finger.



Fig. 3 The images show the hand grasping two different objects.

sembly as a hand, which has the ability to grasp objects. Each finger is controlled separately by delivering independent motor commands [6] (see Fig. 3).

5. Discussion and Future Work

This research work intends to show the advances on the development of a cognitive architecture that pretends to give movement capabilities to virtual entities, more details can be found in [6]. In summary, the model design takes into account the neuroscience results on how human motion is achieved by the CNS. Using the approach proposed in this paper we expect that eventually, virtual entities can express motor behaviors as humans do.

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