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A basic Growing Functional Modules "artificial brain"

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ABSTRACT

The purpose of this paper is to exhibit the internal process of the Growing Functional Modules (GFM) controllers. These learning based controllers are graphically designed by the user, interconnecting four kinds of components: Global Goals, Acting Modules, Sensing Modules and Sensations. Global Goals specify the intrinsic motivations, Acting and Sensing Modules develop their respective functionalities while Sensations provide the controlled system's feedback. GFM Controllers engage in a learning process to satisfy the specified motivations while interacting with the environment and thus can be considered as artificial brains. The traditional systems programming task is replaced by a design phase that consists in graphically configuring and interconnecting the GFM components. This paper gives a description of the aforementioned components and of their specific roles in the learning based control process. The behavior of the controller and its components is exemplified with the characterization of a simple control application.

1. About artificial brains

The real world is characterized by its complexity, illegibility, dynamics among other confusing aspects. To face these adverse conditions, programmers drastically reduce the intricacy of the robot's environment; otherwise, the number of lines of code required to deal with countless situations would increase drastically. Classical Artificial Intelligence does not offer much help because replacing sequential-imperative programming by another paradigm – for example, functional or logical – implies a different but equally huge coding effort. Meanwhile, biological entities successfully deal with the complexity of the real world thanks to their learning abilities.

These considerations have led to develop cognitive architectures inspired by the human brain and, in particular, by its learning abilities. Currently labeled as Biologically Inspired Cognitive Architectures (BICAs) – see [1,2] for a review of the leading cognitive architectures – these architectures share the purpose of achieving brain-like functionalities. The Growing Functional Modules (GFM) should be classified in a subcategory of the BICAs that is focused on developmental robotics; a concept introduced by Brooks and Schmidhuber at the beginning of the 1990s. The IM-CLeVeR European project [3] illustrates the research efforts in this approach. Some examples of corresponding architectures could include Self-Adaptive Goal Generation Robust Intelligent Adaptive Curiosity (SAGG-RIAC) [4] and Qualitative Learner of Action and Perception (QLAP) [5]. Another recent review of adaptive control architectures [6] makes a special emphasis on the hierarchical organization of behavior. Hierarchical organization of behavior and modularity are identified as organization principles of the brain, both of which are present in the GFM proposal.

Moreover, developmental robotics architectures are mainly focused on robots control, the underlying reason being that only the interaction with the real world – though sometimes in a simplified environment – can offer a consistent feedback to the learning process. Some characteristics that the GFM architectures shares with most of the developmental robotics architectures include

- Exploration of the robot sensing and acting capacities.
- Introduction of motivation through predefined internal goals.
- Integration of neural networks modules in the internal representation.
- Evolution of this representation based on a bottom-up approach.

The purpose of the present paper is to illustrate how GFM controllers perform, describing their components and their internal process. For didactic purposes, the content is organized as follows: Section 2 describes the GFM control loop, Section 3 specifies the functionalities and interconnections of each of the four controller's components. Finally, Section 4 depicts the design and behavior of a basic controller.

2. The control loop

Controllers, as biological brains, have to perform in the real world and must provide real time response to events sensed by their control system; therefore learning based controllers match

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biological brains. The GFM paradigm has thus been implemented as a feedback control system divided in an Acting Area and a Sensing Area. Both Areas are provided with learning capacities. These areas host some interconnected acting and sensing modules. Initially, these modules do not integrate any knowledge but gradually elaborate it while the controller interacts with the environment. Consequently, such controllers may be considered as artificial brains.

As shown in Fig. 1, the GFM control loop shares many similarities with a standard one. At each cycle, the controller – delimited by a dotted line – sends an output command to trigger a specific actuator and to receive, in return, a feedback composed of a sequence of sensors values.

Nevertheless, the concept of "Reference Value" used in a classical controller is replaced by one of the "Global Goals" which is integrated to the controller. The Global Goals concept refers to a set of motivations that induces the controller's activities and consequently, the system's behavior. An illustration of such a motivation, given in Section 4, may be interpreted as a "find a clear path".

More specifically, the GFM controller's structure is divided in two areas, the "Sensing" and the "Acting" ones. The Sensing Area is in charge of interpreting the feedback sent by the system. This feedback is referred as "Sensations" (Fig. 1). Sensations are processed by a set of interconnected Sensing Modules that produce "Perceptions". Perceptions, and eventually some Sensations, are submitted to a set of Acting Modules located in the Acting Area. One of the Acting Modules will trigger the next command to the controlled system taking into account the Perceptions values and the input requests specified by the Global Goals. Triggering this command initiates the next cycle of the control loop.

A controller command is composed of two 32 bits integers. The first one specifies the actuator or set of actuators whose position must be moved while the second one indicates the amplitude of this motion. Moreover, specific control commands may also be sent to the controlled system, for example, initialization, end of processing, do nothing or enter/quit parallel mode. The feedback sequence is also composed of two 32-bits integers that correspond to sensor values followed by a bitmap image and finally by an audio event. The feedback corresponding to Sensations provides the outcome resulting from the last command.

3. The GFM components

The controller includes four kinds of components: Sensations, Global Goals, Acting Modules and Sensing Modules. An editor has been developed to visualize these components displaying their configurations and interconnections. An illustration of a controller designed to learn path finding is displayed in Fig. 2. The control process of this controller will be exposed to Section 4; the components functionalities and their interconnectivities will be described in the following subsections.

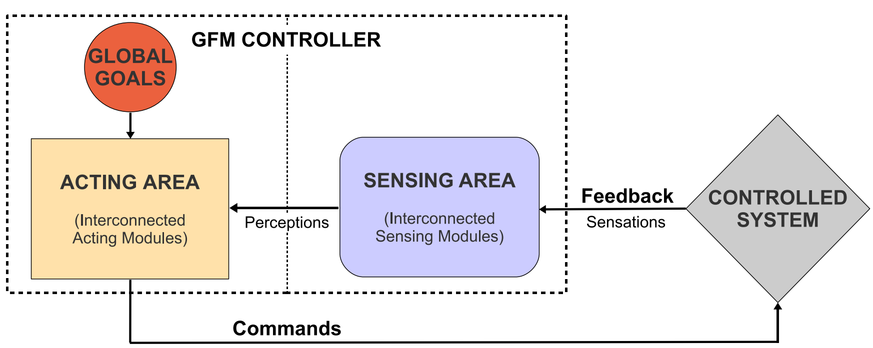

Fig. 1. The GFM controller's structure (delimited with dotted lines) and its control loop.

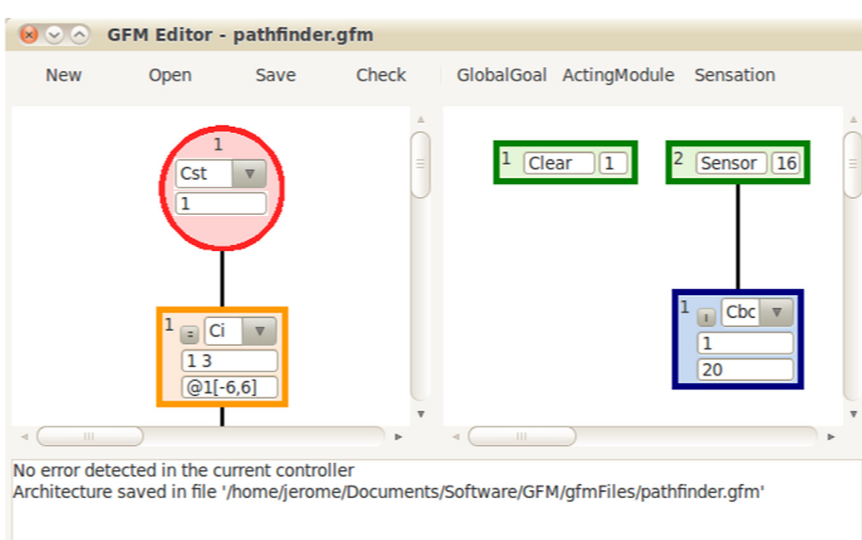

Fig. 2. A GFM controller designed to learn path finding that included all components. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)