Research Journal of Applied Sciences, Engineering and Technology 5(6): 2180-2191, 2013
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: August 02, 2012 Accepted: September 08, 2012 Published: February 21, 2013

Model of Competencies for Decomposition of Human Behavior: Application to Control System of Robots

Jose Vicente Berna-Martinez and Francisco Macia-Perez
Department of Computer Science, University of Alicante, Carretera San Vicente s/n,
San Vicente Del Raspeig, Spain

Abstract: Humans and machines have shared the same physical space for many years. To share the same space, we want the robots to behave like human beings. This will facilitate their social integration, their interaction with humans and create an intelligent behavior. To achieve this goal, we need to understand how human behavior is generated, analyze tasks running our nerves and how they relate to them. Then and only then can we implement these mechanisms in robotic beings. In this study, we propose a model of competencies based on human neuroregulator system for analysis and decomposition of behavior into functional modules. Using this model allow separate and locate the tasks to be implemented in a robot that displays human-like behavior. As an example, we show the application of model to the autonomous movement behavior on unfamiliar environments and its implementation in various simulated and real robots with different physical configurations and physical devices of different nature. The main result of this study has been to build a model of competencies that is being used to build robotic systems capable of displaying behaviors similar to humans and consider the specific characteristics of robots.

Keywords: Bioinspired robots, human behavior, human model of competencies, robot behavior, robot-human interaction

INTRODUCTION

For many years, human beings share our lives with other artificial beings of very different nature, robots. Although these systems are artificial, our desire is to make them like us both physically and cognitively. We want robots have reactions and mistakes like us and even the same moral values (Kajita *et al*., 2011). This claim also increases when these robots share our day to day. They are little beings who assist us in performing our daily tasks that we cannot make ourselves, performing dangerous tasks for us or just easing our daily duties. For many years, in our laboratory, we study to create robots that can display a humanized behavior (Berna-Martinez *et al*., 2006; Berna-Martinez and Macia-Perez, 2010), but, despite the large number of the studies on bio-inspired systems, appears to be no agreement on how to analyze human behavior to deploy it to any robot and allow robots execute this behavior like a human. It is therefore necessary to analyze what makes up or produces human behavior so as to know what are the functions performed, how they communicate with each other and the chronological order followed in their execution. This study should also include the specific requirements of the robots. Finally, is necessary proposing a model of competencies in form of tasks map that identifies the functions and shows the relationships analyzed between them. With this model we can decompose the desired behavior in several of functional blocks similar to those in humans but implementable in robotic systems.

To create artificial systems with advanced human skills has been a desire pursued for many decades by the complex field of robotics. There are several approaches from which we have tried to introduce human behavior in machines and these approaches have produced different trends of study, generally from one side reactive, deliberative, or combination of both, producing some sort of hybrid system (Bekey, 2005). In addition to using the general behavior, there are many studies focusing on a particular skill of human behavior: the generation of thinking, decision-making mechanisms, creativity and the sources of fear or the motion estimation. These studies look for patterns, architectures or schemes to generate biologically inspired intelligence and particularly in humans (Bekey *et al*., 2008).

All these studies show a great change in the study and development of robots. Until recent years, researchers have sought to improve the accuracy, speed and control. Now researchers aim to produce adaptive systems, autonomous and able to learn. To achieve this goal, researchers observe human beings and use their behavior as a model. This indicates that the current

Corresponding Author: Jose Vicente Berna-Martinez, Department of Computer Science, University of Alicante, Carretera San Vicente s/n, San Vicente Del Raspeig, Spain, Tel.: +34-965-903400, Fax.: +34-965-909643

proposals start from a human standpoint that is, analyzing the desired behavior from the biological point of view. This view results in losing the needs and constraints of artificial systems in the process of building intelligent behaviors. On the other hand there are also many studies that use a different approach. These studies create environments, modules, functions and programming languages to meet the requirements of the machines as time constraints, the parallelism or the distributed memory and then use ad-hoc approaches for the construction of a control system using these tools (Pfeifer *et al*., 2005)

In this study we proposed the analysis and the decomposition of human behavior from the standpoint of human and machine, i.e., specify which are the functional blocks that are to be produced and interrelationships of these to carry out intelligent behaviors but while taking into account specific characteristics of robots. This analysis of the behavior is done in general terms and independently of the physical systems. We will use the same biological principles of the functional division, competencies, but these competencies will be analyzed according to the needs of artificial entities as well. To support the validity of our proposal, we used our study on the implementation of behaviors for various robots. These robots are both simulated and real. With these experiments we can see how it is possible to decompose a desired behavior in its competencies, how these competencies can be used in robots of different types and how they produce the same emergent behavior, regardless of the characteristics and physical devices. Our study does not study the following aspects: to produce efficient robotic systems, analysis of techniques and algorithms to perform a specific job, analyzing technologies or physical devices. This study is directed to the decomposition of behavior based on a competencies model.

LITERATURE REVIEW

To understand how human behavior is generated we must 1st know where such behavior is generated. The control system that governs our behavior is the nervous system. One of the greatest advances in the field of neuroscience was started by Hughligs-Jackson (1998). This researcher proposed for the 1st time the division of the nervous system in layers that implement multiple levels of sensory-motor competencies until then, the nervous system was seen as a set of morphological features, i.e., each part of the control system was responsible for part of the body. Jackson demonstrated that the nervous system organizes its functions in different layers forming lower centers, middle centers and high centers. And those levels exert their influence on same morphological areas of the body, but in different ways. The higher level centers are responsible for performing the cognitive and social functions of the human being, while the lower levels produce more reactive type activity and control the sensory-motor organs. Since then, advances in neuroscience are directed to locate the specific regions of our nervous system responsible for each function and the hierarchy between them (Gallistel, 1980). These studies demonstrated that each brain is semi-autonomous level except for the lower levels. Lower levels exert the final action sensory-motor, but that each level is involved in the generation of an action by modifying, improving, inhibiting or enhancing the lower-level functions. This hierarchy is not only at functional level but also is supported at morphological level (Jerison, 1973; Hodos, 1982) and this morphology has evolved to support specialization and separation of functions in different brain areas (Miklos, 1993; Butler and Hodos, 1996). Thus, the innermost regions of the brain are responsible for the primitive functions and the outer regions are responsible for the more advanced features that characterize our species (Belkhova and Veselkin, 1985). When an area develops an intense activity for a given task, the area is specialized and functionally and morphologically separated from other surrounding areas. Although we know many of the functions performed by different regions of the nervous system, there are still many undiscovered, although we are limited by analytical techniques and the ability to invade a human nervous system in operation (Brailowsky, 1996).

Brooks proposed a revolution in robotics like Jackson to neuroscience. Brooks was the first researcher to propose a robotic control system based on the decomposition behavior using tasks. Until then, the behavior was decomposed using the devices as a base. This proposal was called Subsumption Architecture (Brooks, 1985). No matter the implementation of the architecture that made Brooks. The important is the conceptual disruption to the process of decomposition of tasks. Until then used a traditional structure of artificial intelligence, the structure of perception-deliberation-execution. This proposal was the first attempt at rapprochement between artificial systems and biological systems and had a far-reaching among specialists in robotic systems. These proposals will help in the division of behavior from a biological point of view, but must do more. These new proposals should help to better understand the biological behavior (Winston, 1984). Since then and until today, many studies are close to biology and perform different approaches to systems with multiple layers and functions, such as: competitive/ cooperative mechanisms of interaction (Arbib and Lee, 2007); multi-layer architectures and multi-hierarchical decision (Madhavan *et al*., 2007); multi-level frame studies that allow greater flexibility in the development of control systems (Pivtoraiko *et al*., 2008); tools dedicated to the development and coordination of tasks (Ingrand *et al*., 2001); or modular architectures focused on specialized behavior such as navigation (Gillen *et al*., 2002; Benjamin, 2007; Rauskolb *et al*., 2008).

As shown, the field of robotics attempts to align with the biology for many years, but however, for implementing a behavior, human behavior, the first step is the decomposition into simple steps of actions to be performed. Often, this decomposition is made from a biological point of view. In other words, we think of what would be the actions that would make a human being to achieve a certain behavior. Then we implement this behavior and applied it to an artificial system. In this way we achieve an artificial system that behaves like a human being, intelligently. But the decomposition of biological behavior is not easy tasks. Just a few general methodologies are engaging in this activity. In Mataric (1992) we find one of the 1st methodologies, based on decomposition of behavior using a successive few simple steps: specification of desired behavior, specification of this behavior in terms of actions and specification of these actions in terms of effectors. This simple methodology allows the decomposition of a complex behavior in simple actions depending on the effectors of the system by successive refinements top-down and bottom-up. But this approach does not clarify the level of granularity and is subject to the physical system. Neither this methodology specifies what functions we have to look. Imagine not knowing what robot or number of robots will be used. We should apply this methodology for each case. In Reich (1997) implementation starts with a system of locomotion. Then, the behavior is selected according to certain criteria (necessity, sufficiency, locality, robustness, scalability and simplicity) and the system is divided by the degree of representation of the components. In Pfeifer *et al*. (2005) describes several heuristics that guide the design process of systems, but the principles here are obtained only affect specific characteristics of the implementation and produce general requirements. Behavior Oriented Design (Bryson, 2002) divides the development process in 2 steps, an initial decomposition and iterative development. DBO uses hierarchical reactive plans to perform arbitration between their component modules and provides a methodology for building these modules. But DBO is not exposed lines, for example, access to low level or the interactions in the behavior. Other more generic and comprehensive frameworks as Proetzsch *et al*. (2010) present a development fully focused on developing its future implementation. Which, though it is a system based on behavior, not is behavior with biological essence, but is rather oriented low-level implementation.

MODEL OF COMPETENCIES

The idea is likened to the processes of software engineering where requirements are captured, the system is specified and then chooses the programming environment and finally physical resources are allocated. Currently, there are specialized environments for the development of robotic systems. These environments provide to designers the communication mechanisms, details of low-level control, real time control and other issues, such as iB2C (Proetzsch *et al*., 2010) o MRDS (Johns and Taylor, 2008). Our proposal tries to find out what are the functional modules to be implemented starting from the basis of human behavior.

As we have seen above, the robot developers are interested in using human behavior to create intelligent robots. But we see how this task is approached from a biological perspective. Our study proposes to use a hybrid view human-machine. We propose to decompose the behavior using a model based on human competencies and contemplate on these competencies the restrictions and requirements of robots. This will produce a model of competencies that follows functional and organizational principles of biology but also including the specific characteristics of robots.

Using this model, we specify what are the competencies required to develop a robot with a human-like behavior. That is, as we analyze a desired behavior and what tasks must be produced so that it can be implemented in any robot. Through this organization we can indicate functions, modules, components, signals and relationships between them. We will use a constructive approach in which the various principles and specifications shall be established gradually and these rules will mark which competencies are reflected in the model and the relationships between them.

In a first step towards the global model will use one of the pillars of modern neuroscience, the division of functional elements based on their autonomy (Hughligs-Jackson, 1998; Dubuc, 2012). This principle postulates that the nervous system is divided into different control centers that are grouped into three levels: low level, middle level and high level, according to degree of autonomy possessed by the functions at each level. This first division also exists at anatomical level (Bear *et al*., 2007; Dubuc, 2012).

You have to understand that the autonomy of a function expresses the ability to operate in the real world environment without external intervention or control (Bekey, 2005). The autonomous functions are related to reactive activities or reflective activities of a system. The less autonomous deliberative relate to, since they depend on the objective of the robot and usually external control of a human or another system. Between these 2 levels are semi-autonomous functions, dependent on cognitive activity as decision making or planning and who prepare specific tasks must be carried out by reactive levels. Our model includes all the functions organized by competencies.

This 1st basic functional division establishes our internal organizational architecture of the artificial system, understanding architecture in terms of how actions are generated from a perception of the environment (Russell and Norvig, 2002). Although this 1st division uses three levels, these do not correspond to the three traditional levels of Perception-Deliberation-Execution (Brooks, 1985) used in traditional artificial intelligence. Each of the three levels includes different features that develop in the nervous system (Bear *et al*., 2007; Dubuc, 2012) depending on the autonomy of these functions broadly:

- **High level:** Provides cognitive functions of the system, related to the tasks of learning, thinking, planning and social relations. Usually develop in the outer areas of the brain.
- **Middle level:** It relates to functions of a semi-autonomous, dependent on the cognitive activity level and aimed to lead ultimately sensory-motor actions. These functions are performed by intermediate levels in the brain.
- **Lower level:** is directly related to sensory-motor tasks and system functions called reactive or reflex actions. These functions are completely autonomous and are carried out by the lower nerve centers and spinal cord.

Once the major functions levels have been established, each level are divided into competencies again (Hughligs-Jackson, 1998; Dubuc, 2012). This principle of division of competencies has also been used in several studies on artificial systems and decomposition behavior (Brooks, 2002; Bekey, 2005; Mataric, 1992; Mataric, 1997; Mataric, 1998; Mataric, 1999). The division of competencies helps to separate the functions in blocks of related tasks of the same type, thus avoiding that the functions are coupled or overlapping each other. This division allows us to classify all the functions needed to generate a behavior in a particular competence. At the same time, the competencies at higher levels determine the functions that exist at lower levels (Merker, 2007). That is, on one hand the lower levels have an autonomous activity related to direct control over the physical part and on the other hand, higher levels exert conscious control over lower levels.

In our model we propose a classification of competencies learned from the analysis of multiple artificial systems and the organization of the nervous system. Each competence is contained inside a functional level. In a competence will take place one or more functions to be developed in modules, functions, services or software components to be developed in the environment selected. These competencies cover the one hand the competencies of biological behavior and on the other hand, as we shall see, will collect the powers of artificial systems. These machine competencies will be different from biological competencies.

The sets of competencies allow us to establish a classification of the functional entities involved in the artificial system behavior generator. At the same time, these sets define the flow of afferent and efferent signals of each entity, following the mimicry with the biological system. Each entity may communicate with the entities of the same competition and may receive or send signals to other functional entities of competencies at their level, lower or higher level, following the parallelism of biological nervous system communication. In general, the competencies will be developed by functions, modules, services or items which we call functional software entities or simply entities. Therefore we will refer interchangeably to entities or competencies.

Competencies at high level: This level includes all the system functions related to reasoning, decision, learning, memory, planning and social activity or ability to interact with other systems. This level develops the actions of a more cognitive and conscious human being and therefore a robot must be similar. Among the social activities there are two distinct groups of competencies. On the one hand, there are cooperative competencies that allow multiple systems to agree and negotiate with each other to perform a complex action. On the other hand, there are organizational competencies, in which a system is subjugated to the actions of another, acting like a component of the system in question. The groups of high level competencies are listed and described below.

Cooperation: Cooperative competence Co brings together all the entities that will develop tasks designed to allow 2 agents to be able to study together to produce a more complex task. The possibility that 2 or more systems are able to work together has been widely used in robotics to enable to produce complex tasks that a robot alone could not make or to build robots many small, cheap and simple that work together to achieve tasks that only are produced by expensive robots (Cao *et al*., 1997). This same principle also applies to humans, since through the collaborative work we achieve broader objectives. This competence aims to emergent behavior through the cooperation of individuals in the community (Arkin and Bekey, 1997; Wagner and Arkin, 2008; Lefranc, 2008) and is closely related to the competence of reasoning, leading the deliberation of the system. This competence will enable a human and machine work together in a coordinated manner but not subordinated.

Organization: The elements of the set of organization or are responsible for providing an interface to other systems for a robot working under the orders of another system, i.e., that can be controlled like a lower-level element. This competence allows a complex system consisting of various competencies interact with another system as if it were one single element, hiding the complexity of the processes occurring inside (Lee *et al*., 2010). This operation is very similar to an arm interacts with the body. When we move the arm we do not think about the individual actions of each muscle, we think of global action and an intermediate nerve center hides the complexity of each act. This also occurs in a mobile robot consists of a mobile platform and a robotic arm. The robotic arm directs the mobile platform to where you want to reach. A control element hides the details of the movement. These elements are responsible for allowing a man to control the actions of an artificial system or a system can handle a subsystem encapsulates all internal logic through this element (Lefranc, 2008).

Learning: Learning Le is one of the most important tasks in robotic systems because we can increase speed on tasks, perform tasks more accurately, expand skills or simply avoid system errors. Learning allows the acquisition of knowledge through study and experience (memorization). There are many ways to implement learning mechanisms and also each of them can be oriented to different objectives (Russell and Norvig, 2002). Functional learning entities use the information obtained by the lower competencies elements and transmit the knowledge learned to reasoning entities for making global decisions.

As we said before, learning competence be held by a number of functional elements as complex as necessary. This competence brings together all the elements related to learning, but not means it is a single or simple task. Learning alone is one of the most active areas of research in robotics. Learning allows robot to do that for which it has been programmed. Learning can have as many variants as needed (Brooks and Mataric, 1993).

Planning: Planning elements Pl are responsible for obtaining the sequence of actions that modify the state of the environment to its ultimate goal (Volpe *et al*., 2001). In principle, the planning can be so-called an intractable problem because of its complexity (Chapman, 1987). This is why it is interesting to decompose the planning in other simpler processes and each simple process performs a planning sub-task. The planning competencies should not be confused with the path planning function used in robotics (Saha and Isto, 2006), they are much more. The entities that develop this competence are related to planning the actions the robot must perform: how to get to a target, how to wait for an order, how to get to safety point, etc., much more than path planning (Montreuil *et al*., 2007).

Deliberation: This competence concerns the decision-making functions De. Normally the control system of a robot can be seen as a set of elements for the decision-making. We consider that they are a set of elements to carry out a decision, but there is a specific element that makes that decision. Between all the elements of the control system, there are a few whose sole mission is the decision-making. These elements must balance the current conditions of the environment, the knowledge learned, the demands of other systems or user and accordingly makes a decision (Pivtoraiko *et al*., 2008). These elements in our proposal will be the decision makers who will conduct a strategy or guidelines for the performance of the robot. Deliberative skills are often in higher cognitive levels of control systems (Gottifredi *et al*., 2010).

Competencies at middle level: The function of this level is weakly coupled to the robotic system. These require some knowledge about the system to be implemented in terms of structure and capabilities, but not require knowledge of low-level interfaces. These elements are directly related to the processing of information and skills that will own the system. At this level are collected following competencies.

Interpretation: A robot perceives a data set of the environment or from within. These data are not structured in the form and manner that the system needs to work with them (Czarnetzki and Rohde, 2010). In fact, they can often barely contain useful information or even be full of errors. Thus, the received data should be treated, processed and interpreted to use them correctly (Fehlman and Hinders, 2009). For example, a robot has a collection of ultrasonic sensors, the combination of all data provided by them can produce more useful information than the data separately, similarly, normalize these values to an integer in centimeters may be more useful that a numeric value not related to any measure. Generally artificial systems require of functional elements to process, combine, filter and adjust all data received to produce a proper flow of information to other system elements. These other elements use this information for its activity, not data received from low level. This competence is specific to the robots and is often forgotten. This forgetting leads to serious units in the implementation of artificial systems. The human system does not require this adjustment because their sensors have the same nature as the system. These interpretation in elements combine received data to infer information that cannot be obtained separately (Luo and Chang, 2010).

State: The state St elements are responsible for providing knowledge to the system about yourself and about your status in the environment. The entities responsible for developing this competence provide a proprioceptive and exteroceptive vision of the system (Ippoliti *et al*., 2007). These elements are responsible for performing calculations as the position of the robot in an environment, position in which each actuator is level of internal temperature and generally any other information required to establish its internal and external state. These functional elements are those that provide state of consciousness, status, position and location to recognize himself and everything around him (García *et al*., 2008).

Constraints: The entities managing the competencies of constraint Cn are responsible for finding the limits, conditions and constraints of both the world and the system itself (Manso *et al*., 2010). A characteristic feature is the location of obstacles, but may also be other such as calculating impossible movements, banned pathways, speed of movement or determine if the ground is impracticable or inaccessible space (Elmaliach *et al*., 2009). These elements receive information from the entities of interpretation and the results are used by entities of learning and movement.

Motion: The motion functional entities Mo are responsible for calculating the motions of the system. These movements may be simple turns into joints, or complicated maneuvers, depending on the paths to follow and system characteristics (Diehl and Mombaur, 2006). These elements use the information produced by the planning, the constraints and the status of the system and calculate the next move to be made by the system. The generation of movement from planning can be very complex (Miura *et al*., 2009) but it must be totally independent of the physical structure of the robot. The movement should be defined as actions and not rely on effectors of the system.

Embodiment: Although cognitive processes are abstract comes a time when such abstract manipulations must be linked to the physical structures and this transformation is called by Brooks's embodiment (Brooks, 1985). These elements of embodiment Em translate abstract actions. The system should have elements which are aware of the physical structures available to carry out the skills system that implements a behavior. These elements are the embodiment and translate the wishes of the system to device actions. These translations can be done intelligently and more generic for example through the use of ontology's (Juarez *et al*., 2011), allowing this process to be more automatic and dynamic.

Competencies at low level: The lower level is formed by all those autonomous elements responsible for interacting with the world. Their actions are more closely related to the physical structures that form the robot. The competencies for this level are showed in this section.

Sensing: Sensing entities Se are the elements responsible for measuring the world, to obtain distances, temperatures, positions, contact, pictures and other data for which permit an acquisition or measurement. Furthermore, these elements are responsible for converting these magnitudes to values understood by the system, applying error correction when necessary (Bekey, 2005). Generally we deal with 2 types of sensors:

- **Exteroceptives sensors:** Are responsible for obtaining information from the outside world, the environment surrounding the robotic system.
- **Proprioceptive sensors:** Are responsible for obtaining information from the robotic system itself, the state of the inner world.

The signals are received from multiple sources and handling each of these sources should be specialized and precise (Czarnetzki and Rohde, 2010), therefore, each source must be serviced by a specific sensor element.

Action: The entities of action Ac are the functional elements responsible for modifying the world physically interacting with it (Bekey, 2005). A robot

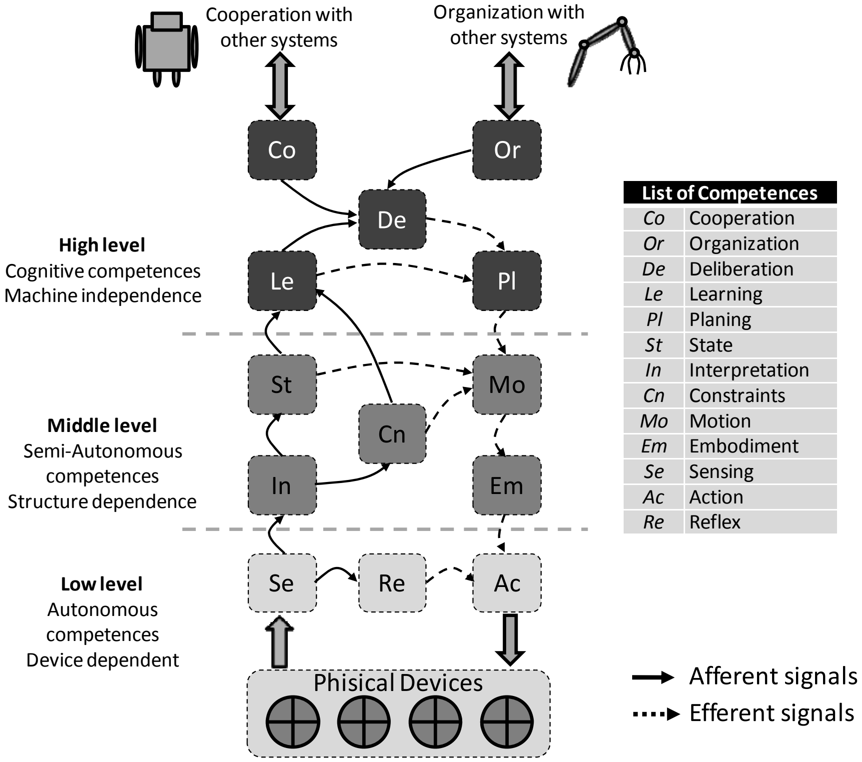

Fig. 1: Map of competence and relationships between them. The information flowing from the outside to high levels are considered afferent. The information flowing from the high levels towards the devices is considered efferent

requires physical interaction with the environment in which it operates and it exerts forces on it or scroll through it. Actuators are devices that allow us to perform these actions. Each actuator device is governed by a specific item that performs the competence of action. Thus the control is more efficient and accurate.

Reflex: In living beings there are actions that are executed quickly, from a sensing, automatically, on the actuators, which do not require the intervention of the higher centers of the control system. These reflexes are usually associated with those behaviors designed to safeguard the integrity and system security (Bekey, 2005) or to maintain and enhance the activity of the robot (Hengyu *et al*., 2011). These actions are commonly called reflexes re. For example: if a robot collides with an obstacle has to stop, if a Platform detects a hole has to stop, if the motor temperature is too high the motor should brake, etc. These reflex actions are independent of cognitive tasks that are performed at the highest level and cause certain effects on the actuators. These effects may contradict the overall intentions of the higher levels, depending only on the sensing and affecting directly the action. We do not distinguish what actions are innate and what actions are learned, considering all these actions within the competence of reflection.

The model of competencies: Human behavior can be divided into various functional blocks in response to competition held every function. All functions are in a competition. Next, we show a map of competence and relationships between them. The relationships indicate information flows between the functions that implement each competence.

Figure 1 shows all the competencies described above and the relationships between them. These relationships indicate the flow of information between the modules that implement the competencies. On the basis of the image are the physical devices of the robot which communicate with the functions that implement the competencies of sensing and actuation. At the top of the system, competencies for coordinating permit coordination of the robot with other robots to work collaboratively amongst these. The functions that implement organizational competencies provide an interface to other systems that can be handled as if they were a single element that is part of another robot. Each level also reflects a different level of autonomy in accordance with the autonomy of the competencies of human control system.

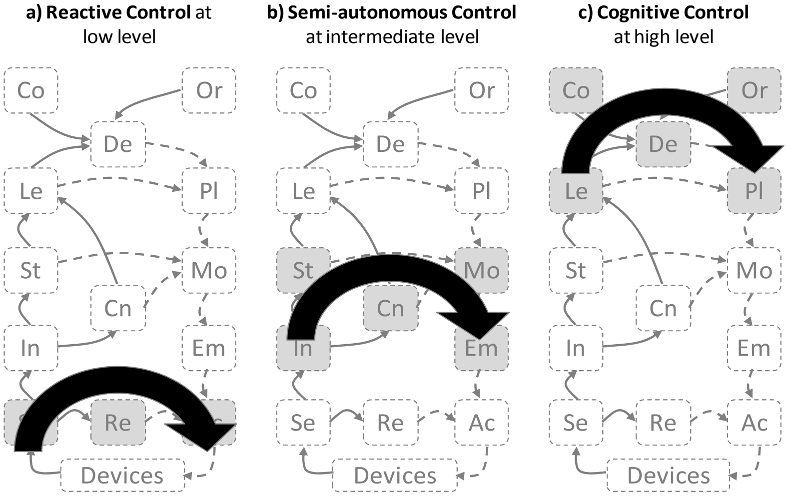

Fig. 2: Control loops of different competencies levels

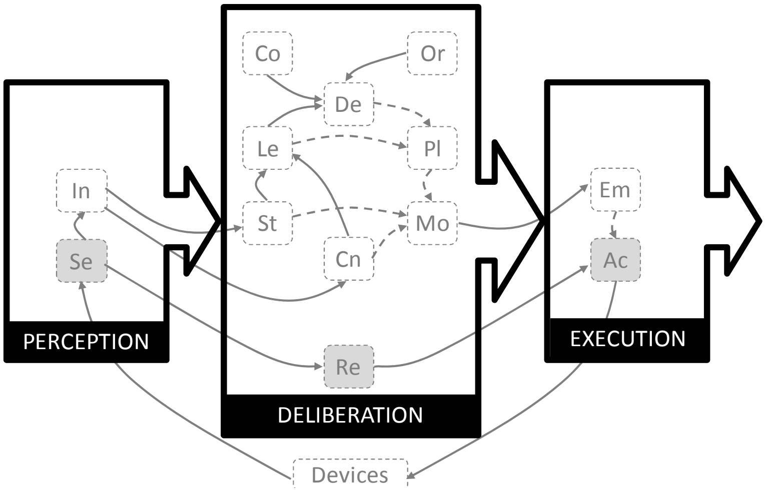

Fig. 3: General model of competencies seen as decomposition of the PDE architecture

The competence map provides similar information to Core J2EE Patterns (Alur *et al.*, 2007). The map provides a catalog of competencies that allows a preset division of functions to be developed based on the experience of developers who have previously addressed these same issues. In addition, takes advantage on the experience of nature because this division is based on the human nervous system.

Comments about the model: Looking at the model from different points of view we can see that the model reflects the general functional and organizational principles of biological systems. First competencies cover the different functions of the three basic levels of autonomy of the nervous system. Each of the levels develops their competencies allowing signals to flow both horizontally and vertically between different levels. As we see, the processes have a cognitive essence at high levels and functions performed involve more abstraction of the mechanical system. Actually, only the functional entities of sensing and action have real knowledge of the mechanical system, while the rest only has knowledge of the afferent and efferent signals of other elements. This behavior is consistent with the account in background. In the biological system at lower levels layers are actually control the sensory-motor activity, while the other performs at higher level. The cancellation, malfunction or damage of higher elements does not lose all the functionality of the system. Lose only the affected functions. All other functions remain intact. In the case of robots, if there is no function in a contest, information continues to flow to the next competition as appropriate.

The model also reflects the different levels and control loops of the nervous system. Connections between elements of the same level can create a control loop in that layer. As shown in Fig. 2a, connections between entities at reactive level allow the development of reactive control loops. In humans we call this control reactions or instincts as stop in front of a danger or go away from a fire. These are fast action without deliberation normally available to safeguard the integrity of the system.

As shown in Fig. 2b, connections between elements of mid-level create semi-autonomous control loops, as when we walk and unconsciously move our feet in a coordinated manner. Our cognitive deliberation does not establish when a foot or other advance. A conscious desire makes us walk, but they are semi-autonomous control loops which develop the complexity of the movement for us.

Finally, Fig. 2c, the interconnections between high-level elements are those that establish cognitive control loops. These loops are developed at outermost part of our brain, such as developing a strategy to jump a river, communicate with other humans and perform a task together or take orders. These control loops also reflect a similar function to human neurorregulador system. They can produce actions contrary. Reflex control loop can stop the robotic system because it has collided and at the same time, cognitive control loop may indicate progress to achieve its goal.

Each control loop shows different level of priority and action. Control loops at low level are faster and act 1st, High control loops require more time to be carried out because the information has to flow over various communication channels, but they can control to some extent loops at low-level. In addition, all control loops are given in a parallel. As can be seen, while at low level may be reacting to an event, the high level can make decisions.

Another noteworthy aspect of the model is that in essence does not break with the traditional architecture of Perception-Deliberation-Execution (PDE) of traditional AI. Our proposal is in fact an internal division of architecture (Brooks, 1985).

As we can see in Fig. 3, the competencies described are part of the components of the traditional PDE architecture. In fact, competencies of our proposal decomposed PDE elements in types of tasks decoupled from each other.

CONCLUSION

This study has presented a model of division of behavior based on competencies. Each competence describes and brings a type of tasks with a common skills or expertise. The model also reflects the relationship between competencies; these relations express the flow of information between the competencies. This competencies model and their relationships allow defining how information is captured from the environment, transformed, processed and produces actions. Competencies have been defined based on the analysis of the human nervous system combined with the requirements of robotic systems extracted from multiple robotic systems, proposals of other authors and our own experience in robotics. The model provides a map on the type of tasks to be broken behavior. This map can be used on any robot, any behavior and by any developer.

Using this model, we have a common vision for the analysis of any behavior. This allows defining the same tasks, regardless of the physical layer and the person who examines the behavior. Describing the same types of tasks, systems with common behaviors can use the same modules, even common tasks but not for the same behavior.

The model isolates features of the robot in each competence. The low-level competencies encapsulate the characteristics of physical devices. The middle level competencies encapsulate the characteristics of the physical structure of the robot. The high level competencies encapsulate the cognitive and social skills of the robot. Using the model: it is easier to define software modules because tasks are not mixed in the same component, it is easier to define relationships between components, it is easier to break down the behavior and is easier to design complex behaviors because combining simple modules can be obtained more complex functions. Furthermore, this division also facilitates use distributed architectures for implementation because functions are decoupled from each other and are decoupled from the physical layer (except sensing and acting).

The model allows considering the functional and organizational characteristics of the biological system. Is a decomposition of the classical PDE architecture and can be applied in realistic environments and simulated.

Our study is currently divided into two main lines. On the one hand to create a methodology to formalize the process of division of behavior. So far, only there are some methodologies, general heuristics or principles on which basis for this division. In our case, we used an iterative refinement process to divide the behavior into blocks and these blocks of competencies in the functions that implement. But, we need a methodology to formalize this process, thus preventing errors or different results depending on who analyze the behavior to implement.

On the other hand, we need to deepen the competencies model and expand the current level of competence description. Competencies allow us to obtain large functional blocks of a behavior, but within each competence may be exist many sub-competencies. We need to continue with the parallelism of human biological system to expand existing competencies, looking at the restrictions and requirements of the robots. For example, the competence of state is divided into two main blocks, functions relating to the external condition of the robot and those related to the internal state. It is necessary to identify these sub-competencies that will improve the functional division of behavior.

REFERENCES

Alur, D., J. Crupi and D. Malks, 2007. Core J2EE Patterns: Best Practices and Design Strategies. 2nd Edn., Prentice Hall, Upper Saddle River, NJ.

Arbib, M.A. and J.Y. Lee, 2007. Vision and Action in the Language-Ready Brain: From Mirror Neurons to SemRep. In: Mele, F., G. Ramella, S. Santillo and F. Ventriglia (Eds.), BVAI. LNCS, Springer, Heidelberg, 4729: 104-123.

Arkin, R.C. and G.A. Bekey, 1997. Robot Colonies: Kluwer Academic, Boston, Dordrecht, London.

Bear, M.F., B.W. Connors and M.A. Paradiso, 2007. Neuroscience: Exploring the Brain. Lippincott Williams and Wilkins, Philadelphia, PA.

Bekey, G.A., 2005. Autonomous Robots: From Biological Inspiration to Implementation and Control. MIT Press, Cambridge, Mass.

Bekey, G., R. Ambrose, V. Kumar, D. Lavery, A. Sanderson, B. Wilcox, J. Yuh and Y. Zheng, 2008. Robotics: State of the Art and Future Challenges. Imperial College Press, London.

Belkhova, M.G. and N.P. Veselkin, 1985. Telencephalozation and transfer of function in the central nervous system of vertebrates in light of current data. J. Evol. Biochem. Phys., 21: 357-365.

Benjamin, M.R., 2007. Autonomous control of an autonomous underwater vehicle towing a vector sensor array. IEEE Conference on Robotics and Automation, Rome, pp; 4562-4569.

Berna-Martinez, J.V. and F. Macia-Perez, 2010. Model of integration and management for robotic functional components inspired by the human neuroregulatory system. IEEE International Conference on Emerging Technologies and Factory Automation, Bilbao, pp: 1-4.

Berna-Martinez, J.V., F. Macia-Perez, H. Ramos-Morillo and V. Gilart-Iglesias, 2006. Distributed robotic architecture based on smart services. IEEE International Conference on Industrial Informatics. Singapore, pp: 480-485.

Brailowsky, S., 1996. Substances of Dreams: Neuropsychopharmacology. FCE-CONACYT.

Brooks, R.A., 1985. A robust layered control system for a mobile robot. IEEE J. Robot. Automat., 2(1): 14-23.

Brooks, R.A. and M.J. Mataric, 1993. Real Robots, Real Learning Problems. In: Connell, J. and S. Mahadevan (Eds.), Robots Learning. Kluwer Academic Press, pp: 193-213.

Brooks, R.A., 2002. Flesh and Machines: How Robots Will Change Us. Ed. Pantheon, New York.

Bryson, J.J., 2002. The behavior-oriented design of modular agent intelligence. Proceedings of the NODe Agent-Related Conference on Agent Technologies, Infrastructures, Tools and Applications for E-services, Springer-Verlag Berlin, Heidelberg, pp: 61-76.

Butler, A.B. and W. Hodos, 1996. Comparative Vertebrate Neuroanatomy. Wiley-Liss, New York.

Cao, Y.U., A.S. Fukunaga and A.B. Kahng, 1997. Cooperative mobile robotics: Antecedents and directions. Auton. Robot., 4: 1-23.

Chapman, D., 1987. Planning for conjunctive goals. Artif. Int., 32(3): 333-377.

Czarnetzki, S. and C. Rohde, 2010. Handling heterogeneous information sources for multi-robot sensor fusion. IEEE Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI), pp: 133-138.

Diehl, M. and K. Mombaur, 2006. Fast Motions in Biomechanics and Robotics: Optimization and Feedback Control. Springer, Berlin, New York.

Dubuc, B., 2012. The Brain from Top to Bottom. Canadian Institutes of Health Research: Institute of Neurosciences, Mental Health and Addiction. Retrieved from: http://thebrain.mcgill.ca.

Elmaliach, Y., N. Agmon and G.A. Kaminka, 2009. Multi-robot area patrol under frequency constraints. Ann. Math. Artif. Intel., 57: 293-320.

Fehlman, W.L. and M.K. Hinders, 2009. Mobile Robot Navigation with Intelligent Infrared Image Interpretation. Springer-Verlag, Dordrecht.

Gallistel, C.R., 1980. The Organization of Action: A New Synthesis. L. Erlbaum Associates, Hillsdale, NJ.

García, R., M.A. Sotelo, I. Parra, D. Fernández, J.E. Naranjo and M. Gavilán, 2008. 3D visual odometry for road vehicles. J. Intell. Robot. Syst., 51(1): 113-134.

Gillen, M., A. Lakshmikumar, D. Chelberg, C. Marling, M. Tomko and L. Welch, 2002. A hybrid hierarchical schema-based architecture. Proceedings of the AAAI Spring Symposium on Intelligent Distributed and Embedded Systems.

Gottifredi, S., M. Tucat, D. Corbatta, A.J. García and G.R. Simari, 2010. A BDI architecture for high level robot deliberation. Inteligencia Artif., 46: 74-83.

Hengyu, L., L. Jun, L. Chao, L. Lei and X. Shaorong, 2011. Active compensation method of robot visual error based on vestibulo-ocular reflex. Jiqiren Robot, 33(2): 191-197.

Hodos, W., 1982. Some Perspectives on the Evolution of Intelligence and the Brain. In: Griffin, D.R. (Ed.), Animal Mind-Humand Mind. Springer-Verlag, Berlin, pp: 33-56.

Hughligs-Jackson, J., 1998. Evolution and Dissolution of the Nervous System. (1881-7; Collected 1932). Thoemmes Continuum, ISBN-10: 1855066696: ISBN-13: 978-1855066694

Ingrand, F., R. Chatila and R. Alami, 2001. An Architecture for Dependable Autonomous Robots. IARP-IEEE RAS Workshop on Dependable Robotics, Seoul, South Korea.

Ippoliti, B., L. Jetto, S. Longhi and A. Monteriù, 2007. Comparative Analysis of Mobile Robot Localization Methods Based On Proprioceptive and Exteroceptive Sensors. In: Kolski, S. (Ed.), Advanced Robotic Systems International and proliteratur Verlag. Mobile Robots: Perception and Navigation, pp: 215-237, ISBN: 3-86611-283-1.

Jerison, H., 1973. Evolution of the Brain and Intelligence. Academic Press, New York.

Johns, K. and T. Taylor, 2008. Professional Microsoft Robotics Developer Studio. Wiley Publisher, Indianapolis.

Juarez, A., C. Bartneck and L. Feijs, 2011. Using semantic technologies to describe robotics embodiments. Proceedings of the 6th International Conference on Human-Robot Interaction, Lausanne, pp: 425-432.

Kajita, S., K. Kaneko, F. Kaneiro, K. Harada, M. Morisawa, S. Nakaoka, K. Miura, K. Fujiwara, E.S. Neo, I. Hara, K. Yokoi and H. Hirukawa, 2011. Cybernetic human HRP-4C: A humanoid robot with human-like proportions. Spr. Tra. Adv. Robot., 70: 301-314

Lee, T.P.J., H. Wang, S.Y. Chien, M. Lewis, P. Scerri, P. Velagapudi, K. Sycara and B. Kane, 2010. Teams for teams performance in multi-human/multi-robot teams. IEEE International Conference on Systems, Man and Cybernetics, Istanbul.

Lefranc, G., 2008. Colony of robots: New challenge. Proceedings of ICCCC International Journal of Computers, Communications and Control, III: Suppl. Issue: 92-107.

Luo, R.C. and C. Chang, 2010. Multisensor fusion and integration aspects of mechatronics: Synergistic combination of sensory data from multiple sensors. IEEE Ind. Electron., 4: 20-27.

Madhavan, R., E.R. Messina and J.S. Albus, 2007. Intelligent vehicle systems: A 4D/RCS Approach. Nova Science Publishers, ISBN-10: 1600212603: ISBN-13: 978-1600212604.

Manso, J.L., P. Bustos, P. Bachiller and J. Moreno, 2010. Multi-cue visual obstacle detection for mobile robots. J. Phys. Agent., 4(1).

Mataric, M.J., 1992. Behavior-based control: Main properties and implications. Proceeding of IEEE International Conference on Robotics and Automation, Workshop on Intelligent Control Systems, pp: 304-310.

Mataric, M.J., 1997. Behavior-based control: Examples from navigation, learning and group behavior. J. Exp. Theor. Artif. In. Spec. Issue Softw. Architect. Phys. Agent., 9(2-3): 323-336.

Mataric, M.J., 1998. Behavior-based robotics as a tool for synthesis of artificial behavior and analysis of natural behavior. Trends Cogn. Sci., 2(3): 82-87.

Mataric, M.J., 1999. Behavior-Based Robotics: The MIT Encyclopedia of Cognitive Sciences. Robert, A., Wilson and Frank, C. Keil (Eds.), MIT Press, pp: 74-77.

Merker, B., 2007. Consciousness without a cerebral cortex: A challenge for neuroscience and medicine. Behav. Brain Sci., 30(1): 63-134.

Miklos, G.L.G., 1993. Molecules and cognition: The latterday lessons of levels, language and iac. J. Neurobiol., 24: 842-890.

Miura, K., M. Morisawa, S. Nakaoka, F. Kanehiro, K. Harada, K. Kaneko and S. Kajita, 2009. Robot motion remix based on motion capture data towards human-like locomotion of humanoid robots. 9th IEEE-RAS International Conference on Humanoid Robots. Japan, Dec. 7-10, pp: 596-603.

Montreuil, V., A. Clodic, M. Ransan and R. Alami, 2007. Planning human centered robot activities. IEEE International Conference on Systems, Man and Cybernetics ISIC, Toulouse, pp: 2618-2623.

Pfeifer, R., R. Iida and J. Bongard, 2005. New robotics: Design principles for intelligence systems. Artif. Life, 11(1-2): 99-120.

Pivtoraiko, M., I.A. Nesnas and H.D. Nayar, 2008. A Reusable Software Framework for Rover Motion Control. International Symposium on Artificial Intelligence, Robotics and Automation in Space, Los Angeles, CA.

Proetzsch, M., T. Luksch and K. Berns, 2010. Development of complex robotic systems using the behavior-based control architecture iB2C. Robot. Auton. Syst., 58(1): 46-47.

Rauskolb, F.W., K. Berger, C. Lipski, M. Magnor, K. Cornelsen, J. Effertz, T. Form, W. Schumacher, J. Wille, P. Hecker, T. Nothdurft, M. Doering, K. Homeier, J. Morgenroth, L. Wolf, C. Basarke, C. Berger, F. Klose and B. Rumpe, 2008. Caroline: An autonomously driving vehicle for urban environments. J. Field Robot. Arch., 25(9): 674-724.

Reich, B., 1997. An architecture for behavioral locomotion. Ph.D. Thesis, University of Penssylvania, Philadelphia.

Russell, S.J. and P. Norvig, 2002. Artificial Intelligence: A Modern Approach. Prentice Hall, Englewood Cliffs, NJ.

Saha, M. and P. Isto, 2006. Multi-robot motion planning by incremental coordination. IEEE/RSJ International Confrence on Intelligent Robots and Systems. Stanford Univirsity, CA pp: 5960-5963.

Volpe, R., I. Nesnas, T. Estlin, D. Mutz, R. Petras and H. Das, 2001. The Claraty architecture for robotic autonomy. IEEE Proceedings of Aerospace Conference, 1: 121-132.

Wagner, A.R. and R.C. Arkin, 2008. Analyzing social situations for human-robot. Interact. Stud., 9(2): 277-300.

Winston, P.H., 1984. Artificial Intelligence. 2nd Edn., Addison-Wesley, Reading, MA.