An Introduction to a Cognitive Decision Unit Applied to Autonomous Robots

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Abstract. A novel approach to equip robots with human-like capabilities is to use meta-psychology – the theoretic foundation of psychoanalysis. We used meta-psychology as archetype for a decision making framework to control a robot. This has been achieved recently in theory and in software simulation. However, when moving to a real robotic platform, additional things have to be considered. In this article we show how to fill the gap between sensing, environmental interaction, and decision making by grounding these topics with an agent's internal needs using the concepts of meta-psychology. The use of the common humanoid robot platform NAO compelled us to deal with complex situations and disturbed sensor readings. An implemented visual marker detecting system helps to detect objects in the surrounding environment, representing energy sources. We show how it is possible to use the psychoanalytically inspired framework A.R.S. to control a real world application, the robot NAO.

Keywords: Cognitive Automation, Robotic Control Unit, Simulation, Sensor Data Interpretation

1 Introduction

The range of applications using current artificial intelligence (AI) is impressively wide. Not only has a computer beaten a human world champion in chess long ago [1], but clever gadgets operated by AI algorithms like vacuum cleaning robots support humans in everyday life. Nevertheless, the great promise of early AI to build systems with human-like intelligence has not been delivered so far. A novel approach to this promise is represented by a new research community called Artificial General Intelligence (AGI).

The Artificial Recognition System (A.R.S.) project develops such an architecture. Ten years ago, when this project started, the motivational question was how to extract meaning from data provided by hundreds of thousands of sensor nodes each second [2]. This is an important question for the area of building automation. A possibility to solve this problem is to model mechanisms of the human mind. A novel concept is to use the theoretical background of psychoanalysis as foundation [3]. The resulting model is described in depth in [4-6] and a brief overview is given in Section 3.

The first application used to evaluate the model was a kitchen equipped with various types of sensors [7]. In the course of the project, focus shifted to a simulated world of artificial life [8]. A first attempt to use the psychoanalytically inspired control system to control a robot is mentioned in [9]. The used robot was Tinyphoon [10]: a small, two-wheeled, cube shaped soccer robot equipped with various sensors. This approach was limited, as a rich control system was applied to a robot with only two wheels as actuators. This violated the demand of ecological balance formulated in the design principles for embodied agents [11].

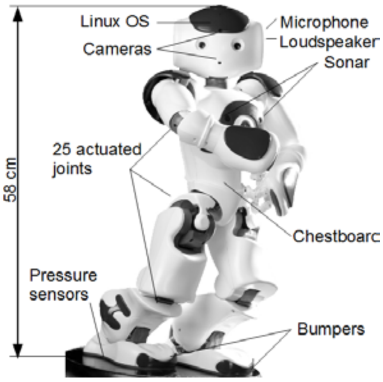

Fig. 1. NAO Robot

More opportunities arose when moving from highly specialized robots to humanoid robots. They offer a wide range of actuators and sensors together with more interesting body features like motor temperature, joint sensors, and power supply. This article aims at presenting the application of a psychoanalytically inspired decision unit to such a robot. The chosen platform is NAO – a standard robot platform (see Fig. 1).

The full report of this work has been published earlier [12].

2 State of the Art

2.1 Mobile Platforms

Typical research platforms in the field of mobile robotics are the wheel driven pioneer robots manufactured by Mobile Robots and for a short time the high priced PR2 robots sold by Willow Garage. ROS [13] as an open-source meta-operating system for robots is available for both systems and can be used to control the platforms in a ’standardized’ way. Pioneer robots are designed in a modular way and are in their standard configuration not capable to grasp or sense objects in an environment. Nevertheless, various enhancements shown at the last RoboCup events demonstrated the potential of the robot beyond an educational level.

The PR2 robot with its two arms is able to grasp and to transport objects [14]. Although this would qualify it for the tasks at hand, this platform has only wheel locomotion. The NAO robot platform shown above provides a full featured humanoid robot along with a mature control API.

2.2 Control Architectures

Often AI control architectures are based on the subsumption architecture [15] or the Believe-Desire-Intention (BDI) model [16]. While the approach of the subsumption architecture leads to good results in simple setups like line following or can collecting, more complex tasks are difficult to implement.

In contrast to that, the advantage of BDI is that changing tasks does not result in code change but only in changing the databases. The downside of BDI is that no forward planning exists and learning is not specified.

Control architectures with a different focus in application are for example SOAR [17] and ACT-R [18]. They have been developed to define a model of the human cognitive apparatus. These cognitive architectures tend to integrate basic mechanisms and structures, similar to those in human cognition, to control systems. The central element of both models is their memory system that introduces a production system.

A new generation of control systems is based on so called AGI models. Other than AI which uses solutions for small isolated tasks, AGI uses a holistic approach to generate human-like deliberation capabilities. The used model has to be based on a theory on “intelligence” as a whole. Two important examples are LIDA [19] and OpenCog [20]. LIDA is based on neurology and psychology and its target application is to assign tasks to Navy employees. OpenCog is based on ideas on how humans think formulated by its project team. Applications for OpenCog range from virtual pets to child learning simulations. Both projects lack of a unitary model, they select concepts from various sciences without justifying their compatibility. Up to our knowledge, no AGI model has been applied to real robots as so far.

3 Model

The above mentioned AGI-framework A.R.S. and its current implementation ARSi10 [4] is developed by transferring psychoanalytic theory into technical feasible concepts. Based upon the second topographical model of the psychoanalytic metapsychology, every functional module is assigned to one of the three main agencies: Id, Ego, and Super-Ego.

In order to provide a general applicable framework, the framework A.R.S. was designed with a clear interface, defining handover-points of the incoming sensory data as well as the actuator control commands, both in form of computational symbols. Figure 2 shows the top-level view of the A.R.S. control architecture with its interfaces.

The psychic representatives of the bodily needs origin from the Id and are formed as drives. The Ego deals with contradictory inputs and has to draw final decisions, influenced by the Id (bodily-related), the Super-Ego (social-related), and the reality.

In the following chapters, the interface between decision unit and body will be referred to as the brain-socket, because it makes it possible to change either the complete implementation of the decision unit or the agent-specific platform that hosts the decision unit. In the following, the psychoanalytically inspired decision unit described here will be used and it will be shown how the basic platform from the virtual agents within the simulation (ARSINI) is changed to the NAO-robot-platform.

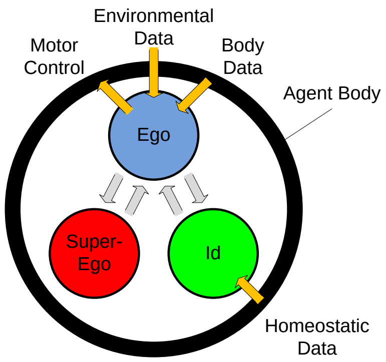

Fig. 2. Psychoanalytically inspired architecture

4 Implementation

The artificial life world simulation framework (ARSINI World) is based on the multi-agent simulation toolkit MASON. An agent is placed within an environment that assigns specific tasks to the agent and drives the agent to conflictive situations. Every agent is equipped with certain actuator and sensor arrays that enable to operate in observance of the environmental, homeostatic, and bodily states. In order to cope with embodiment requirements, a physics engine is introduced. Even though this cannot replace realistic conditions, the provided physical body-world interactions are sufficient for a prototype implementation.

The ARSINI World software design is specified to decouple the environment from the agent as well as the agent body from its control unit. Hence, it is possible to compare different decision units on the same foundation – same body and in the same environment – respectively, or to interface these decision units with different kinds of bodies. The latter one forms the basis for this article and allows testing the A.R.S. decision unit in a NAO robot.

5 Results

The aim of this work is to show the feasibility of using a psychoanalytic based control unit in a real world application, a humanoid robot in this case. For that purpose the brain-socket interface that combines the A.R.S. decision unit and the NAO body must be implemented. Instead of the simulated ARSINI World, a Webots simulation [21] serves as environment. The A.R.S. decision unit interacts with this environment via the NAOQi API. Though it is still a simulated world, Webots differs from the ARSINI World as it is used for testing programmed functionalities before applying them to the physical robot. The NAOqi for Webots project considers the NAO robot's actuator and sensor arrays. It is presumed that functionalities which are tested within Webots also work after applying them to the physical robot in case the laboratory environment fits to the sensor and actuator requirements (e.g. lightning conditions). This could be also confirmed.

In the following, the proposed concept is tested on the basis of the above mentioned use case. The agent is placed within the ARSINI World and aims at staying fully functional. Thus it must keep its energy resources filled by consuming energy sources (e.g. cakes, agents). A rule set is defined by the system engineer that allows generating action plans by using the backward chaining approach [4, p. 99]. These action plans are converted to action commands which drive the agent's actuators.

Fig. 3. Interpretation of marker symbols

The same use case is now integrated into the Webots simulation. However, a few adaptations are introduced due to condition changes. For this work, the authors rely on the NAO robot's perception engine that is able to differentiate between marker objects of different size and shape (see Figure 3). In the ARSINI World, input parameters are compared with templates that are stored in the knowledge base. In order to avoid changes of the A.R.S. decision unit and the knowledge base, the proposed brain-socket interface synchronizes identified markers with ARSINI World objects. Figure 3 shows these markers as well as their mapping to their knowledge base counterparts. The TU-Wien marker is interpreted as stone, the markers 1 - 4 represent energy sources, and those between 5 and 9 represent other agents.

Regarding the actuator interface, three actions must be implemented to accomplish the proposed use case – Move, Turn, and Consume.

6 Conclusion

This article reports the first ever implementation of a psychoanalytically inspired decision unit as control system for a biped humanoid robot. Previously, the developed architecture was evaluated using an artificial life simulation only. While this was a necessary intermediate step, we showed how to adapt the model and its database to an embodied real world agent, the NAO robot. The experiments show that the resulting behavior is comparable to the one observed in the simulation. Thus, the model is robust regarding calculation time differences (deliberation takes zero time in the simulation) and different locomotion types. In the simulator a two wheeled simple locomotion is used, which is much simpler than the biped holonic drive of the robot.

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