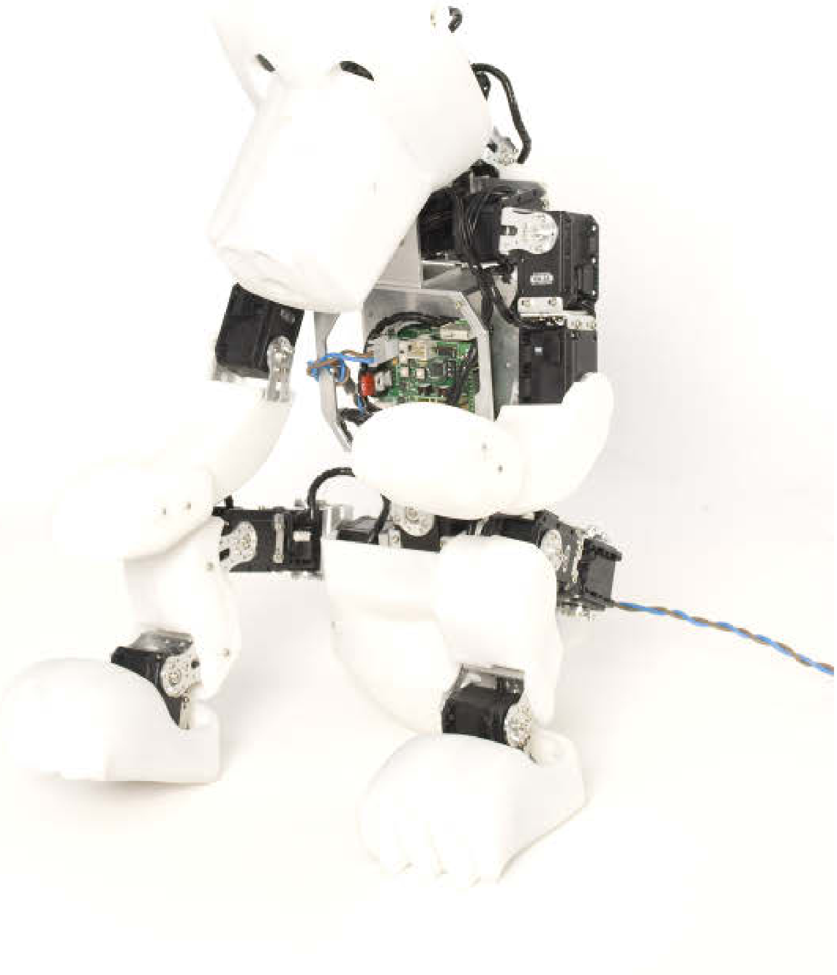

Flexible Attention-based Cognitive Architecture for Robots

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as a part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Rony Novianto

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Abstract

Robots have been working in factories to achieve tasks autonomously with little human intervention for some time. Even though robots are commonly found as vacuum cleaners in homes and assistants in hospitals, by comparison with factory robots, service robots have not been widely deployed in society because there remains several challenges deploying robots to achieve complex tasks in open, unstructured, uncontrolled and complex environments.

Critical research gaps arise from the lack of cognitive architectures that support robots to undertake tasks in open and complex environments. Throughout the history of AI, researchers have developed various algorithms, representations and mechanisms, to solve specific tasks. However, each of these techniques has different strengths and weaknesses when applied to particular problems. A cognitive architecture provides a unifying infrastructure that can integrate various techniques to solve open and complex tasks.

However, four important issues become apparent when current cognitive architectures are applied to service robotic tasks. First, they are not capable of managing robot resources and as a result robotic developers must take responsibility for managing the resources manually. Second, they are not capable of integrating independently developed techniques, which are often needed to solve problems. Third, they are inflexible, unable to adapt to design changes and require considerable time and effort to modify. Fourth, they are inadequate for supporting the necessary capabilities required by robots such as multiple goals, reliability and maintainability. These issues are confirmed when cognitive architectures are applied to a standard benchmark problem in AI: the autonomous robot soccer problem.

The purpose of this dissertation is to address these significant gaps so as to accelerate the development, deployment and adoption of service robots undertaking tasks in open and complex environments. This dissertation develops a novel bio-

inspired cognitive architecture (called ASMO) that has been designed and developed to address all four identified shortcomings of current cognitive architectures.

In ASMO, intelligent behaviours to solve open and complex tasks is a result of the emergence of constituent processes, rather than from careful top-down control engineering. Minsky has argued in his Society of Mind that intelligent behaviours can emerge from the interaction of many simple processes, even though each process may lack ‘intelligence’ in isolation. In addition, Anderson argued that an emergent system produces more complex behaviours and properties that cannot be reduced to the sum of its components.

ASMO has attention, emotion and learning mechanisms that are inspired by human intelligence. It treats each action as a concurrent, independent and self-governed black box process that competes for the robot’s attention to perform actions. The attention mechanism is used to mediate the competition among processes, which correspond to the set of potential actions. The emotion mechanism is used to bias the attention demanded by the processes. The learning mechanisms are used to modify the attention in order to improve robots’ performances.

Combining concurrent, independent and self-governed black-box processes with attention and emergent approaches allows ASMO to address the four shortcomings of current cognitive architectures. First, the attention mechanism manages resources explicitly. Second, the black-box design allows any kind of independently developed technique to be integrated without the need to know its internal algorithm, representation or mechanism. Third, attention weighted values enables various techniques to be (re)integrated or (re)structured on the fly with considerably less time and effort. Fourth, the concurrent, independent and self-governed designs support the capabilities required by robots by allowing processes to (i) achieve multiple goals concurrently, (ii) fail without causing the whole system to fail and (iii) be maintained in isolation.

ASMO is evaluated using two robotic problems: (i) the RoboCup soccer standard benchmark problem is used to demonstrate proof-of-concept that a team of robots can be supported by ASMO. In particular, a real robot can be governed by ASMO’s attention mechanism to undertake complex tasks. (ii) a companion robot problem is used to demonstrate that ASMO’s attention, emotion and learning mechanisms overcome the four identified shortcomings of current state-of-the-art cognitive architectures.

This dissertation presents ASMO, an innovative cognitive architecture that addresses the four shortcomings of current state-of-the-art cognitive architectures, and that can also accelerate the development, deployment and adoption of service robots. ASMO provides a more natural and easier approach to programming robots based on a novel bio-inspired attention management system. ASMO allows researchers and robot system developers to focus on developing new capabilities as processes rather than having to be concerned about integrating new capabilities into a cognitive architecture.

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