Explorations in Cognitive Robotics*

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Abstract. We describe a number of research projects at Lund University Cognitive Science. The first project focuses on visual attention. The second area is haptic perceptions by robots. The third area is anticipation in groups of robots. The final research area concerns building computational tools that can be used to design large-scale cognitive models which will ultimately allow results from the different project areas to be merged into a single cognitive architecture.

1 Computational Models of Attention

One of the research areas at Lund University Cognitive Science is the modelling of visual attention and in particular how a visual attention system for a robot can develop autonomously through its interaction with the environment (Balkenius & Johansson, 2005, 2007). In particular, we have been looking at different types of learning mechanism and how they can be used to control visual attention.

We developed a model based on reinforcement learning that can tune a preattentive vision system to a specific task based on the reinforcement it receives (Balkenius, Åström, Eriksson, 2004). We have now enhanced this model with a number of additional components.One is a learning anticipatory control system that can be used to control smooth pursuit while looking at moving targets. Another development involves the ability to detect and predict transitions between different forms of motion. We have also designed a model that can identify deviations from an anticipated movement that learns to predict these initially unexpected events from visual cues in the environment.

These ideas are currently being extended to a system that is able to learn the physics of scenes with a bouncing balls and marbles on a marble roll. In the future, we want to look at how contextual cues can be automatically integrated in dynamic models. We also want to extend our attention models to include interaction with emotional and motivational systems.

2 Bio-Inspired Haptic Perception in Robots

Another project focuses on haptic perception, i.e. active tactile perception. This project started in October 2004 with the aim to research the human haptic per-

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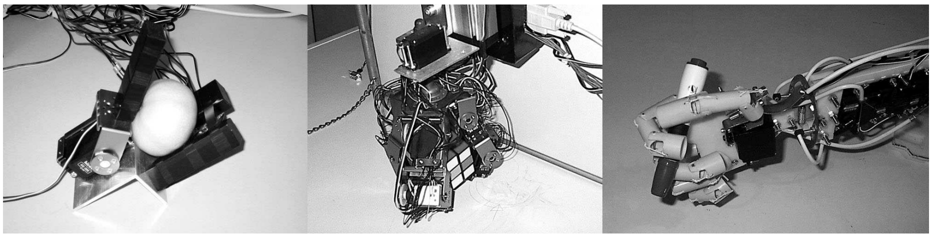

FIG. 1: *Fig 1. A: The LUCS Haptic Hand I grasping a mandarine. B: The LUCS Haptic Hand II grasping Rubik's cube. C: The LUCS Haptic Hand III holding a pen.*

ception and to design and implement artificial bio-inspired haptic perception in robots. We intend to create systems able to learn their sensory apparatus and to discriminate objects by tactile exploration. Beside the applications perspective, we hope to provide insights on the function of the human haptic system. This is due to the inspiration from the human system.

Our first haptic system system (Johnsson, 2004; Johnsson et al, 2005a, b; Johnsson & Balkenius, 2006a) employed a simple three-fingered robot hand with 9 piezo electric tactile sensors and only a single of freedom (Fig. 1A) and was intended as a system for haptic size perception. This system used self-organizing maps, (Kohonen, 1988) and a neural network with leaky integrators and it successfully learned to categorize a test set of spheres and cubes of different sizes.

Our second system (Johnsson & Balkenius, 2006b, 2006c, 2006d, 2007a) used a three-fingered 8 dof robot hand equipped with a wrist for horizontal rotation, a mechanism for vertical re-positioning and 45 piezo electric tactile sensors, Fig. 1B, and was intended as a system for haptic shape perception. This system used active explorations of the objects by several grasps with the robot hand to gather tactile information. Depending on the version, the system employed either tensor product (outer product) operations or a novel neural network, the Tensor Multiple Peak SOM, T-MPSOM, (Johnsson & Balkenius, 2006c, 2006d, 2007a) to code the tactile information in a useful way and a SOM for the categorization. It successfully learned to discriminate between different shapes as well as between different objects within a shape category when tested with a set of spheres, blocks and cylinders. Currently we are trying to extend the haptic system so that it can benefit from expectations provided by another modality (e.g. vision).

The current efforts in this research project aim mainly at the development of an anthropomorphic haptic robot hand, the LUCS Haptic Hand III (Fig 1C). This hand has five fingers and 12 dof. It is of the same size as a human hand and all its parts have approximately the same proportions as their human counterparts. The LUCS Haptic Hand III will be equipped with 18 very sensitive binary tactile sensors of our own design, as well as with 11 proprioceptive sensors, to allows us to research exploratory haptic behaviour, and to continue our research in integration of haptics with other modalities. Movies of the hands in action are available at our web site (www.lucs.lu.se).

3 Anticipation in Groups of Robots

The ability to anticipate the behaviors of others is something we take more or less for granted and we often do not appreciate the complexity of this ability. When attempting to build robots with anticipatory abilities, it becomes clear that this is far from trivial. Not only does the robot need to control its own movement, it also needs to predict what other robots or possibly humans will do. Moreover, it needs to use the anticipated behaviors of others in a sensible way to change its own behavior.

To investigate the benefits of anticipatory behaviors, we performed an experimental study using two robots (Johansson & Balkenius, 2006, 2007). In the experiment, the robots navigated through an area with or without obstacles and had as their goal to shift places with each other. Four different approaches (random, reactive, planning, anticipation) were used during the experiment and the times to accomplish the task were compared. The results indicate that the ability to anticipate the behavior of the other robot could be to an advantage. However, the results also clearly show that anticipatory behavior is not always better than a purely reactive strategy. We are now extending these experiments to a larger number of robots and more complex tasks.

4 Tools for Cognitive Modelling

The above projects all use the Ikaros modeling infrastructure. This project started in 2001 with the aim at developing an open infrastructure for system-level brain modeling (Balkenius, Morén & Johansson, 2007). The core concept of system-level modeling is the module which encapsulates a part of a model. A module can have a number of inputs and outputs and encapsulates a particular algorithm. A system-level approach to cognitive modeling acknowledges that different cognitive components interact in many ways and it is one of the strengths of the approach that it explicitly shows these interactions as connections between modules.

The ultimate goal of all the robotics and modeling projects at LUCS is to eventually be able to merge the different models into a complete cognitive architecture that includes a large number of functions. Since the start, more than 25 people have contributed to the Ikaros project and version 1.0 will be released in May 2007. The system has developed into a general tool for cognitive modeling as well as robot control. The infrastructure supports a seamless transition from a pure modelling set-up to real-time control systems for robots running on one or several computers in single or multiple threads. More information is available at the project home page (www.ikaros-project.org).

References

Balkenius, C., Eriksson, A. P. & Åström, K. (2004). Learning in Visual Attention. In *Proceedings of LAVS '04*. St Catharine's College, Cambridge, UK.

Balkenius, C & Johansson, B. (2007). Event prediction and object motion estimation in the development of visual attention. In Berthouze, L. et al., *Proceedings of the Fifth International Workshop on Epigenetic Robotics: Modeling Cognitive Development in Robotic Systems*, Lund University Cognitive Studies, 123.

Balkenius, C., Morén, J., Johansson, B. (2007). System-Level Cognitive Modeling with Ikaros. *Lund University Cognitive Studies, 133.*

Balkenius, C & Johansson, B. (2007). Anticipatory Models in Gaze Control: A Developmental Model. *Cognitive Processing, in press.*

Johansson, B. and Balkenius, C. (2006). The benefits of anticipation: an experimental study. In Butz, M., Sigaud, O., Pezzulo, G., and Baldassarre, G. (Eds.), *Proceedings of third workshop on anticipatory behavior in adaptive learning systems (ABiALS)*, Rome.

Johansson, B. and Balkenius, C. (2007). An Experimental Study of Anticipation in Simple Robot Navigation. In Butz, M. (Ed.) *Anticipatory Behavior in Adaptive Learning Systems II.* Springer, in press.

Johnsson, M. (2004). Lucs Haptic Hand I - Technical Report, *LUCS Minor, Lund University Cognitive Studies - Technical Reports*, 8.

Johnsson, M., Pallbo, R, & Balkenius, C. (2005a). Experiments with haptic perception in a robotic hand, *Advances in artificial intelligence in Sweden*, 81-86, Mälardalen University.

Johnsson, M., Pallbo, R., & Balkenius, C. (2005b). A haptic system for the Lucs Haptic Hand I, *Proceedings of IWINAC 2005*, 338-397, Springer Verlag.

Johnsson, M., & Balkenius, C. (2006a). Experiments with Artificial Haptic Perception in a Robotic Hand, *To be published as a special issue in The Journal of Intelligent and Fuzzy Systems.*

Johnsson, M., & Balkenius, C. (2006b). Lucs Haptic Hand II, *LUCS Minor, Lund University Cognitive Studies - Technical Reports*, 9.

Johnsson, M., & Balkenius, C. (2006c). Haptic Perception with a Robotic Hand, *Proceedings of the Ninth Scandinavian Conference on Artificial Intelligence (SCAI 2006), Espoo, Finland.*

Johnsson, M., & Balkenius, C. (2006d). A Robot Hand with T-MPSOM Neural Networks in a Model of the Human Haptic System, *Proceedings of TAROS 2006*, Surrey University, Guildford, UK, 80-87.

Johnsson, M., & Balkenius, C. (2007a). Neural Network Models of Haptic Shape Perception, *Journal of Robotics and Autonomous Systems*, in press.

Kohonen, T. (1988). *Self-Organization and Associative Memory*, Berlin Heidelberg, Springer-Verlag.