Laboratory for Behavior and Dynamic Cognition (Jun Tani)

Nominal Objectives
1. To describe the essential mechanism of sensory-motor cognition by using a dynamical systems approach.
2. To determine how symbolic representations are realized in the dynamical systems of the brain.
3. To explore neuronal mechanisms for acquiring the sequential organization of behaviors.
4. To obtain a theoretical understanding of adaptive behaviors in an open environment.

Actual Research

Principles of learning neuronal dynamics with multiple time scales are developed using robotic implementations of action sequences as a test bed. The models are interpreted in terms of prefrontal-premotor-parietal cortical structures and shown to account for imitation, compositionality and aspects of the development of cognitive skills. Similar networks are used to demonstrate that executive function may emerge including rule-switching and self-monitoring. Also within this class of models simple forms of generating sequences with language-like structure are demonstrated. This work is used to account for the development of bird song.

Appropriateness

Dr. Tani's group generates ambitious demonstrations of how cognition emerges from neuronal dynamics and learning rules in systems that are grounded in sensori-motor processing. The models are constrained by neuronal principles, in particular, the autonomous, time-continuous processing of subsymbolic information, that is closely linked to sensory and motor processes. At the same time, the models achieve forms of cognition and learning that approach what we typically think of as "higher cognition" including the compositional generation of sequences. The implementation of the learning of goal directed actions on a Humanoid Robot is impressive and provides an attractive paradigm of learning from example with support by a teacher. The scaling of the learning algorithms used may be a concern that must be addressed.

Other existing lines of research involve executive control and the learning of structured sequences that realize a simple form of grammar, both also implemented on autonomous robots and inspired by the human development of language skills. The research strategy of exploring neuronal principles that may underlie embodied cognition through robotic demonstrations of cognitive function is appropriate. Although the link to the systems neuroscience of such complex behavior is necessarily speculative, this type of more abstract computational modeling is very important for outlining possible mechanisms for control and flexibility as well as for studying how the structure of neuronal representations may enable learning. There is much interest in mainstream neuroscience in many of the areas to which this approach is being applied including cognitive control and imitation learning.

The goal of the group is to move the approach toward language, generating neuronal process models with language like properties that are grounded in sensori-motor processes and are open to learning and development. This goal very is worthwhile and timely. This group is in an excellent position to contribute to this central problem of cognitive and neuroscience. The choice of exemplary problems, around which this goal will be pursued, makes sense and brings to bear the current know-how of the group.

This program is complemented by an effort to link the theoretical work to experimental problems in neuroscience. Noteworthy is, in particular, a new collaboration in which electrocorticographical data will be modeled using the framework of the MTRNN architecture developed by Tani's group. This looks like a logical link to experiment, which can profit, moreover, from the local collaboration within the RIKEN Brain Institute with the group of Dr. Fujii. This collaboration may enable Dr. Tani to move toward a closer relationship to neurophysiology, so long as a correspondence can be made between the rather abstract units in the model and neurophysiological measures. This may also promote a more quantitative approach toward assessing the functions that emerge from Dr. Tani's architectures, which will add to the theoretical strengths.

Quality and impact

The group has been very productive, publishing a substantial number of journal papers each year, most of these in premier journals such as IEEE SMC, Neural Networks, and Advanced Robotics. The group has also published very strongly in refereed proceedings of top conferences in robotics, which play an important role in the engineering. Over his career, Dr. Tani has had a good rate of productivity, with a clearly increasing trend over the last 5 years. The quality of his papers is high, they tend to be well structured and written and carefully prepared. Dr. Tani is leader worldwide for neuronally based, dynamical systems approaches to higher cognition and learning with the capacity to produce demonstrable robotic implementations.

Potential for future development

Dr. Tani's group pursues an ambitious, highly original research program in an important area of theoretical neuroscience. Its combination of neuronal dynamics, learning, and autonomous robotics has produced and is producing high-quality demonstrations of neuronal principles underlying key elements of cognition. The research program extends this agenda in ambitious ways, planning to exploit opportunities that currently exist for such an approach. A new link to experimental neurophysiology will provide richer feedback to the group. Establishing a similar link at the level of behavior, perhaps in a neuropsychological setting, may be a potential improvement of this research plan. This would strengthen the planned project on models of mental diseases.

Contribution to BSI synergies, and career development of junior scientists

Joint work with Okanoya's lab already led to an interesting paper in 2008. An attractive collaboration within the BSI is beginning to emerge through the collaboration with the group of Dr. Fujii around a quantitative account for ECoG data. Perhaps there is scope to increase interactions with BSI members involved in human EEG/MEG for use with brain machine interfaces (Cheng, Yamaguchi, Cichocki) along similar lines.

We were pleased to see that many previous lab members have attained academic positions at Japanese and International premier universities.

General Comments

The committee had initially some difficulty in positioning Dr. Tani's work within the field of theoretical neuroscience. This could be clarified both during discussion and in the lab visit. It may be useful, however, for Dr. Tani to position his work in the scientific landscape more proactively. Dr. Tani and the reviewing committee agreed that his research field can be termed as cognitive robotics, neuroscience motivated robotics, or neuro-robotics. He is one of the top 5% world leaders in any of those disciplines. He is especially unique and the only one to tackle higher cognitive function based on sensory motor data.

Conclusion

The Laboratory for Behavior and Dynamic Cognition has a strong, original, and well-structured research program. It leads worldwide within an important specialized area that explores fundamental neuronal principles of cognition in embodied systems using robots as demonstration platforms. The learning ability in the robotic demonstrations is impressive. The current trajectory of the group will intensify the links between its approach and neurophysiology.

Reviewers:
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