AUGUST 10 & 11

Minoru Asada

"Artificial Empathy"

&

Yukie Nagai

"Emergence of self awareness in robot based on predictive learning"

(Report by Jeff Ames, Dror Cohen, Ray Lee, Olaf Witkowski, & Karen Yamazaki)

Brief report about the activities of the ISSA summer school on the mornings of August 10 and 11

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1 Cognitive developmental robotics

Both the Asada and Nagai labs take the Cognitive Developmental Robotics (CDR) approach to try to understand how cognitive functions emerge through the developmental process. The central focus of CDR is understanding how cognition develops through the interaction of a "physical embodiment" with the environment. To do this, CDR draws on and informs diverse areas such as robotics and cognitive and neural science.

In the following we briefly summarize our perception of the information conveyed from the lectures and our experience from visiting the Asada and Nagai labs.

2 Minoru Asada: Artificial empathy

The behaviors shown by the robots are increasingly richer. Robotics competitions including search and rescue, soccer competitions, and home assistance show a huge potential for robots in a variety of tasks. However, we still don't know how to give them human-like cognitive abilities.

The Asada lab approaches robotics from a perspective of design theory (providing a constructive approach to cognitive issues), developmental aspects, and looking at robots as tools for studying cognitive science.

In human development, we develop various abilities as we age, e.g. regarding our hands around 5 months and imitating movement around 10 months. Investigating this using robotics may be a new way to address age-old questions such as the balance between nature and nurture. In addition, robotics and human developmental studies create a feedback loop and each can learn from the other.

There are two main aspects emphasized in the Asada lab: embodiment and social interaction. Both are conjectured to be crucial to understanding how cognition and consciousness work. Robot learning looks at these through tasks such as walking, social communication, and imitation.

In one line of research the Asada lab investigates artificial empathy. One view suggests that empathy develops analogously to motor development. Motor development proceeds from mimicry to having shared goals to more advanced imitation, and empathy starts with contagion, evolving sympathetic concern, and develops to more advanced forms such as perspective-taking. Also, we may develop self-awareness and self-other distinction along the way, which may be crucially tied to the idea of empathy.

A distinction can be made between cognitive empathy, which is classified as conscious (what is perceived), and emotional/affective empathy, which is considered unconscious (what is felt). The general development is conjectured to be emotional contagion leading to emotional empathy, then cognitive empathy, followed by sympathy/compassion (the "Russian doll" model).

Studies show intuitive parenting, for example when mothers imitate their baby's state, helps the baby learn vocalization and facial expressions. The Asada lab develops this by creating simulations of fetal muscle and brain development, and has shown that the simulated brain distinguishes tactile areas such as arms vs. legs, etc. Interestingly, variation in tactile sensitivity in the body (e.g. lips vs. the back) seems important to the frequency of the fetus's self-touch.

Our visit to the Asada lab allowed us to better understand how this type of research is undertaken. In particular, seeing how to construct Ando, a robot that uses artificial vocal tracts to produce vowels, was a very different part of robotics from what some of us have presupposed. To see the work and effort required to faithfully produce some of the features of speech was quite illuminating.

We also got to see how a new version of the baby robot Affto is being developed. We saw that in order to investigate cognitive development the robot has to be resilient and lightweight.

Another highlight was the simulation of a fetus in a womb environment. This provocative project aimed to understand what affects the bodily movements (dynamics) of a fetus. The Asada team showed that the distribution of sensory inputs has a direct effect on the movements exhibited when compared against behavioral data. When the distribution of sensors was matched to the known physiology more realistic dynamics were observed compared to non-physiological arrangements.

3 Yukie Nagai: Emergence of self awareness and social cognition in robots based on predictive learning

The Nagai lab has a wide ranging scope. Previous and current experiments include:

- joint attention: following eye gaze
- imitation: imitating arm movement
- examining the effects of parents' emphasized behavior
- examining the effects of attention guiding

Human development is continuous, with inter-related processes (e.g. joint attention and imitation), whereas robotics has traditionally proceeded with discrete elements. Integration between processes continues to be a challenge in robotics.

The Nagai lab focuses on a few key areas:

- predictive learning of sensorimotor information and its relation to cognitive development
- modeling cognitive development in robots based on predictive learning
- studying autistic spectrum disorder (ASD) and its relation to prediction error

A previous proposal from the lab suggest a two component model in which a 'predictor' is attempting to match the sensory feedback provided by the sensory-motor system. The sensory-motor system takes motor commands and the current state as inputs and produces sensory feedback. In turn, the predictor produces new motor commands and predicts sensory feedback. The error signal, the difference between the true and predicted sensory feedback, is continuously minimized. This can be done in two ways. First, by updating the predictor. This step may be related to self-other cognition and goal-directed action. Secondly, the system can produce an action to reduce error, and this may lead to imitation and altruistic behavior.

One suggestion is that the spatiotemporal predictability in sensorimotor information provides a means to distinguish self from other. In the case of the self, the error between predicted sensory feedback and actual feedback should be very low, but for others, the prediction error would be relatively high.

Initially, infants have an undeveloped predictor, which is hypothesized to lead to difficulty in distinguishing self from others. But as this predictor is tuned, infants begin to show self-awareness (e.g., as shown by the red dot in the mirror experiment).

Another novel view from the Nagai lab suggests that the mirror neuron system emerges due to perceptual development. In a robot imitation experiment, initial low visual acuity led to no significant distinction between self and other motion. But as acuity increased the neural network showed strong connections, not only between self motion and perception, but also between other motion and perception. In the low acuity case, while there was still a link between self motion and perception, there was almost no link between others' motion and perception.

One hypothesis regarding autistic spectrum disorder (ASD) is that these individuals have an abnormal tolerance for prediction error. This may be abnormal tolerance for prediction error (hypoesthesia, 'underfitting' their sensory inputs), or abnormal sensitivity to prediction error (hyperesthesia, 'overfitting' prediction error). A possible mechanism for this may be abnormal neuron excitatory/inhibitory (EI) balance.

Visting the Nagai lab gave us the opportunity to better understand some of the exciting research taking place and see how the lecture ideas are implemented in practice. The opportunity to try the newly developed ASD-virtual reality glasses gave us a first person impression of some of the difficulties individuals with ASD may develop. Another highlight was interacting with the iCub robot and understanding some of the mechanisms and implementation issues involved in the seemingly simple action of following someone's gaze.

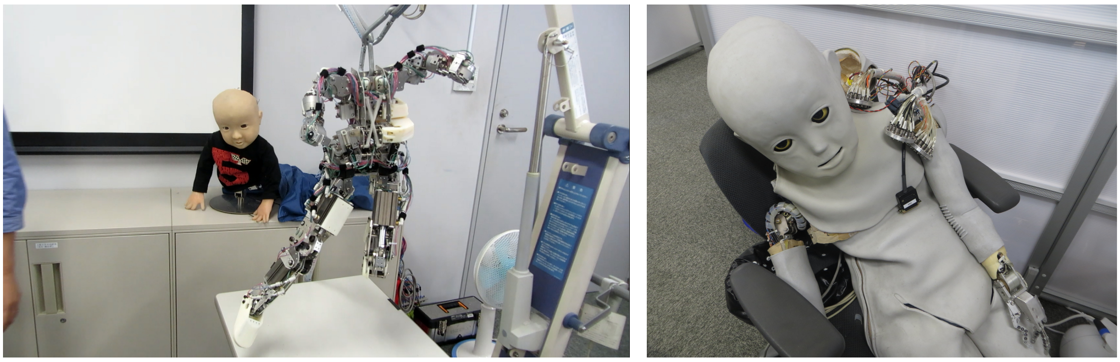

Figure 1: *Left*: Asada lab's affetto robot, aimed at studying the role of to study the development of sensorimotor integration and proprioception. *Right*: The child robot is a previous humanoid robot with artificial skin.

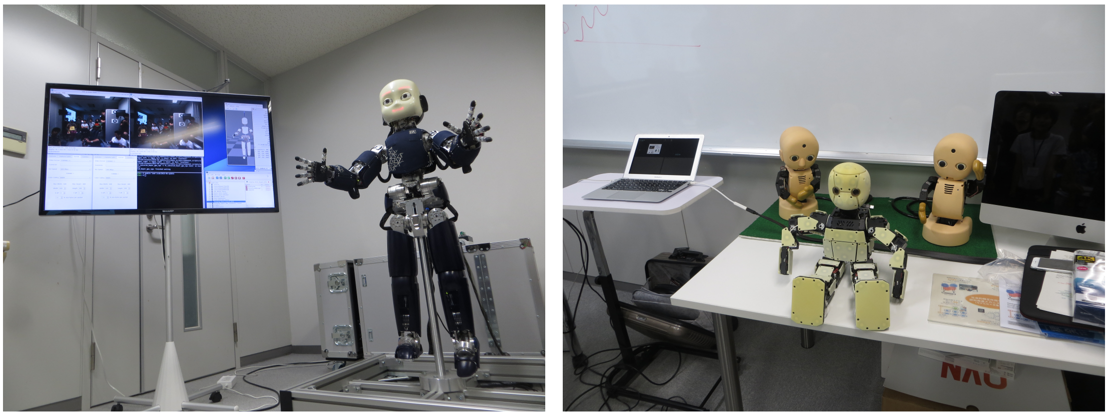

Figure 2: *Left*: Nagai lab's iCub robot is used for gaze tracking research and a wide range of other cognitive functions experiments. *Right*: These smaller robots were used for the study of social interactions in previous studies.

4 Summary

The presentations and lab tours (Figures 1 and 2) gave us a great overview of how cognitive developmental robotics can help in the study of cognition and awareness. By constructing simulated or robotic models, one can study sufficient and necessary conditions to the emergence of every aspect of intelligence and awareness during child development. Alternatively, one can rely on empathy and social components to achieve a comparative analysis of human versus robots behavior/awareness.

The effort of the developmental approach seems therefore to be twofold. On the one hand, it pursues the scientific goal to understand the underlying brain mechanisms to human cognition and awareness by focusing on the early stages of life, including empirical contributions to the nature versus nurture debate. On the other hand, it also focuses on practical applications such as implementing medical care robots and ASD diagnostic tools.

Once past the first natural surprise one might have at the contact of child-like robots on the bottom of the uncanny valley, the cognitive developmental robotics method turns out to bring a rich, distinct perspective to consciousness studies. The machines are an increasing part of our modern society, and even without going to the extreme of self-recursive improvements of robots beyond the human state, we found that the robotics approach presents obvious interesting insights and direct applications for the study of awareness in a broad sense. We are grateful for the chance to get an introduction to the field, and are excited to use this perspective in our respective future works.