Abstract

It is desirable for humans to control robots through high-level commands, and it is tedious for humans to issue detailed commands to direct actions for every fraction of a second. However, it is extremely challenging for humans to program a robot to execute such high-level commands in unknown human environments. How can we address this fundamental challenge in robotics? Can a robot develop its skills autonomously as a human infant or a higher animal does? What is the fundamental difference between the paradigm of mental development and that of traditional engineering?

Autonomous mental development by robots is a new field that has drawn increasing attention in robotics and artificial intelligence. Recent advances in neuroscience have cast serious doubt on the notion that the brain structure and its representation are very much predetermined by the human genes. The developmental program in the human gene seems more of a general-purpose nature that many have thought, and it enables a human to develop its mind from infancy to adulthood through real-time experience. For example, recent results have showed that if visual signal is rewired to auditory cortex early in life, the primate can develop to perform visual tasks using its rewired auditory cortex. In this tutorial, we will present computational models that enable robots to develop its mental skills autonomously through online interactions with its environment. Such robots are called developmental robots. This requires that the internal architecture and representation of the robot be generated automatically and incrementally through the developmental process. The goal of this new research field is to enable humans to “raise” developmental robots “mentally” through online, interactive “robot sitting” and “robot classes.” We will also describe some experimental robots built at MSU and elsewhere as early prototypes of such a new kind of robot along with some video demonstrations. Finally, the potential social and economical impact of developmental robots will be discussed.

Tutorial topics:

Length: 3 hours

1. Muddiness of tasks
2. Overview of approaches --- knowledge-based, learning-based, behavior-based, evolutional and the new developmental approach
3. Human mental development, results from neuroscience and developmental psychology
4. Review of animal learning theories
5. Supervised, reinforcement and communicative learning
6. Architectures for automatic mental development
7. Sensory mapping: representation, development and computation
8. Cognitive mapping: representation, development and computation
9. Motor mapping: representation, development and computation
10. Value system
11. Integration of mental capabilities: audition, touch, language, reasoning, decision making, planning, object manipulation and navigation
12. Thinking by a developmental robot
13. Examples of developmental robot
14. Theoretical completeness and performance metrics
15. Applications and the future of developmental robots

Prerequisites: general programming experience, basic knowledge about vector and matrix operations. Students in neuroscience and psychology can understand most of the material.

Primary audience: researchers and graduate students working on robots, machine intelligence, neuroscience and psychology.

Secondary audience: system developers for autonomous robots (e.g., entertainment robots and service robots), educators, philosophers, investors, and government policy makers.

Handout: Some written tutorial material will be provided.

Biographical sketch of the lecturer:

Juyang Weng is an associate professor at the Department of Computer Science and Engineering, Michigan State University, East Lansing, Michigan, USA. His research interests include autonomous learning robots, computer vision, autonomous navigation, human-machine multimodal interface using vision, audition, speech, gesture and actions. He is the author of over one hundred research articles and book chapters. He is a coauthor (with T. S. Huang and N. Ahuja) of the book *Motion and Structure from Image Sequences* (Springer-Verlag, 1993). He is the program co-chair of the NSF/DARPA Workshop on Development and Learning (WDL), held April, 5-7, 2000 at Michigan State University (MSU), East Lansing, MI (http://www.cse.msu.edu/dl/), and a program co-chair of International Conference on Development and Learning 2002 (ICDL’02), to be held at Massachusetts Institute of Technology (MIT), Cambridge, MA 2002. He initiated and supervised the SAIL (Self-organizing Autonomous Incremental Learner) project in which he and his coworkers have designed and custom built their SAIL robot for autonomous mental development. He and his coworkers are currently working on the next generation developmental humanoid robot: Dav. More detail is available on line at http://www.cse.msu.edu/~weng/.