Tutorial Title: *Imitation and Robotics - Background, Theories and Practice*

Lecturers:
Aris Alissandrakis, *Tokyo Institute of Technology, Japan*
Joe Saunders, *University of Hertfordshire, UK*

Abstract: Imitation is a powerful mechanism that allows agents to learn via their interactions within a social context. An artificial system that is capable of exploiting this imitative learning capability would be able to acquire new skills and tasks from interaction with another agent (typically a human or another robot). Imitative social learning therefore presents a very interesting paradigm in robotics and computer science and within this paradigm robotics researchers are heavily influenced from interdisciplinary studies typically in biology, ethology and psychology. This tutorial takes such an interdisciplinary approach and aims to present the background and theories of imitation from biology, ethology and psychology together with some of their practical implementations in robotics. The aim of tutorial is to disseminate this research field to a wider audience.

Motivation/Background: In order for robots to become useful social partners to humans they will necessarily need to break free from the rigid pre-programmed confines of laboratories or industrial plants and use more 'natural' means of learning and interaction. For this to occur, the social environment is of prime importance in providing such learning situations. In fact we can look for inspiration from social environments in nature by studying how animals (including humans) socially interact and then exploit these mechanisms to allow us to design robots that learn new skills and tasks in a more 'natural' way. For example, pre-programmed behaviours (in a traditional sense) could be replaced by a process whereby the robot is simply 'shown' how to perform desired behaviours – the robot thus learning though imitation. Unfortunately, imitation learning is far more involved than simply 'copying' an observed demonstration and as such it is currently a hard (and therefore interesting and worthwhile) research problem in robotics.
In this tutorial we will start by presenting some background to imitation research from biology, ethology and psychology in order to highlight the complexity of the issues involved. We will then give an overview of proposed theories of imitation and how these have been interpreted in a robotics context. Finally we will present some systems in practice that realise some of the aforementioned theories and approaches. Overall this tutorial aims to bring more attention to this highly interdisciplinary area and hopefully inspire participants in their own research.

Proposed Length: 3 hours.

Structure and Overview:
Part I: Background
- Social Learning and Matched Behaviour
- Imitation, Contagion, Autism and Kinethestic-Visual Matching
- The How, Who, When and What of Imitation
- The Agent Based Perspective and the Correspondence Problem in Imitation

Part II: Theories
- String Parsing Theory
- Active Intermodel Mapping
- Associative Sequence Learning Theory
- Extended Ideomotor Theory
- Mirror Neurons, Opaque and Transparent Imitation
- The Evolution of Imitation
- Comparison of Theories, Strengths and Weaknesses

Part III: Practice
- Behavioral Cloning
- Programming by Demonstration/Example
- Learning from Observation
- Imitation in Reinforcement Learning
- The ALICE framework

- The ROSSUM architecture

Who should attend:

Anyone with an interest in Robotics and Social Learning. Participants with diverse backgrounds are especially welcome as this tutorial aims to give an interdisciplinary perspective to the research area of how to design artificial adaptive systems that can learn from observing and interacting with humans.

Biographies:

Aris Alissandrakis received the Ph.D. degree in Computer Science (Adaptive Systems Research Group, Department of Computer Science, University of Hertfordshire, UK, 2003) for work on imitation in adaptive systems and proposing a framework for solving the correspondence problem in imitation, and the M.Eng. degree in Cybernetics (University of Reading, UK, 1999). He is currently at Miyake Lab, Tokyo Institute of Technology, Japan, after receiving a FY2007 Postdoctoral Fellowship for Foreign Researchers from the Japan Society for Promotion of Science (JSPS), studying imitation in the context of human-robot interaction. He is currently also a Visiting Research Fellow at the University of Hertfordshire where he was previously working in the European Integrated Project Cogniron ("The Cognitive Robot Companion"). His research interests include Imitation and Social Learning in Adaptive Systems, Human-Robot Interaction (HRI) and Artificial Life. (`http://www.myk.dis.titech.ac.jp/~alissandrakis/`)

Joe Saunders received the Ph.D. degree in Computer Science (Adaptive Systems Research Group, Department of Computer Science, University of Hertfordshire, UK, 2007) for work on observational imitation, self-imitation and environmental scaffolding in robotic systems, and the M.Sc. degree in Artificial Intelligence (University of Hertfordshire, UK, 2004). He previously spent some 20 years leading software development teams in the design, development and implementation of large scale projects in international and investment banking systems. He is currently at the University of Hertfordshire, with the Adaptive Systems Research Group, as a Research Fellow in the European Integrated Project Cogniron ("The Cognitive Robot Companion"), studying imitation in the context of human-robot interaction. His research interests include Imitation and Social Learning in Adaptive Systems with a special interest in volition motivated theories of imitation and architectures supporting Human-Robot Interaction. (`http://homepages.feis.herts.ac.uk/~sj2ay/`)

Related References:

- Imitation and Social Learning in Robots, Humans and Animals: Behavioural, Social and Communicative Dimensions, C. L. Nehaniv and K. Dautenhahn, Eds. Cambridge Univ. Press, 2007.
- Imitation in Animals and Artifacts, K. Dautenhahn and C. L. Nehaniv, Eds. MIT Press, 2002.
- J. Saunders, C. L. Nehaniv, K. Dautenhahn and A. Alissandrakis, Self-Imitation and Environmental Scaffolding for Robot Teaching. International Journal of Advanced Robotics Systems, Special Issue on Human - Robot Interaction, Vol. 4, Issue 1, pp. 109-124, 2007.
- J. Saunders, C. L. Nehaniv and K. Dautenhahn, An Examination of the Static to Dynamic Imitation Spectrum. Proceedings of the Third International Symposium on Imitation in Animals and Artifacts, The Society for the Study of Artificial Intelligence and Simulation of Behaviour, Hatfield, UK, April 12-15, pp.109-118, 2005.
- A. Alissandrakis, C. L. Nehaniv and K. Dautenhahn, Towards Robot Cultures? - Learning to Imitate in a Robotic Arm Test-bed with Dissimilar Embodied Agents. Interaction Studies: Social Behaviour and Communication in Biological and Artificial Systems, Vol. 5, Issue 1, pp. 3-44, 2004.
- A. Alissandrakis, C. L. Nehaniv and K. Dautenhahn, Imitating with ALICE: Learning to Imitate Corresponding Actions across Dissimilar Embodiments. IEEE Transactions on Systems, Man, & Cybernetics, Part A: Systems and Humans, Vol. 32, Issue 4, pp. 482-496, 2002.
- A. Billard, Learning Motor Skills by Imitation: A Biologically Inspired Robotic Model. *Cybern. Syst.*, vol. 32, no. 1/2, pp. 155–193, Jan. 2001.
- C. Breazeal and B. Scassellati, Robots that Imitate Humans. *Trends Cogn. Sci.*, vol. 6, no. 11, pp. 481–487, Nov. 2002.
- J. Demiris and G. Hayes, Imitation as a Dual-Route Process Featuring Predictive and Learning Components: A Biologically-Plausible Computational Model. *Imitation in Animals and Artifacts*, K. Dautenhahn and C. L. Nehaniv, Eds. Cambridge, MA: MIT Press, pp. 327–361, 2002.
- W. Erlhagen, A. Mukovskiy, E. Bicho, G. Panin, C. Kiss, A. Knoll, H. van Schie, and H. Bekkering, Action Understanding and Imitation Learning in a Robot–Human Task. *Proc. ICANN*, W. Duch, J. Kacprzyk, E. Oja, and S. Zadrozny, Eds. New York: Springer-Verlag, Sep. 11–15, 2005, vol. 3696, pt. 1, pp. 261–268, 2005.
- Y. Kuniyoshi, M. Inaba, and H. Inoue, Learning by Watching: Extracting Reusable Task Knowledge from Visual Observations of Human Performance. *IEEE Trans. Robot. Autom.*, vol. 10, no. 6, pp. 799–822, Dec. 1994.
- M. N. Nicolescu and M. J. Matarić, Learning and Interacting in Human-Robot Domains. *IEEE Trans. Syst., Man, Cybern. A, Syst. Humans*, vol. 31, no. 5, pp. 419–430, Sep. 2001.
- S. Schaal, Is Imitation Learning the Route to Humanoid Robots? *Trends Cogn. Sci.*, vol. 3, no. 6, pp. 233–242, 1999.