Cognitive Systems Doctoral Consortium

Munich
28 June 2008

Abstracts of Student Presentations

Cognitive behavior modeling in Multi-Agent systems in a dynamic environment

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***Abstract*—The main goal of the research is to develop a new method to measure and forecast the effects on urban development, housing markets and quality of life by combining a new micro simulation tool (Interaction Spaces (IS), a new type of mathematical model for complex systems developed by the Modeling and Applications of Complex Systems Laboratory (Macs-Lab), University of Lugano), Cognitive science and Artificial Intelligence (AI). In modeling of housing markets and segregation phenomena there are a large number of interacting components (agents, processes, etc.) whose aggregate activity is nonlinear and typically exhibits hierarchical self-organization under selective pressures. Therefore it seems that we need a wide array of scientific disciplines for modeling of this complex system, like Cognitive science, AI (distributed learning algorithm and fuzzy expert system to model agents' behavior), mathematics (differential equation), economic and psychology.**

The purpose of the proposed thesis is to have a new approach for modeling of complex system. The ambition is to model complex distributed systems as a set of (possibly organized) agents that interact in a common environment. The decomposition of a system into a number of agents lets the system react and adapt better in a changing environment. Moreover, organized structures ("social" structures) can emerge from interactions between agents, which in turn constrain and coordinate the agents' behavior. An important issue when dealing with this increasing complexity is to build some adaptive individual thinker that takes their metaphor of interaction from social systems. We are going to model the individual behavior and social behavior of agents in a dynamic, surprising and changeable environment. In this approach all the structure is made based on the interactions between agents; these interactions are shown as some causal-effect graphs. These causal-effect graphs that show the individual and society behavior of agents are analyzed by AI algorithm. At the same time we will use some mathematical properties like differential equation to study bifurcation, equilibrium and stationary conditions.

Sequencing Embodied Gestures in Speech

Juraj Simko

***Abstract*—The embodied character of cognitive motor systems has manifestly influenced research in locomotion, grasping, etc. However, the embodied nature of speech production has been disregarded by most phonological research up to date. We introduce here a new and abstract modeling platform developed to investigate the embodied character of speech. The physically instantiated nature of the system allows us to define and exactly evaluate various cost functions associated with speech motor action. We show that many phonological phenomena, in particular those linked to gestural sequencing, coarticulation, fluency and prosodic modulation, emerge as consequences of a non-trivially formulated efficiency principle.**

Computational and psycho-physiological investigations of musical emotions

Eduardo Coutinho and Angelo Cangelosi

Abstract

In the _rest part of this paper we present a new computational modelling investigation of musical emotions based on connectionist spatiotemporal models. This connectionist model is able to consider both temporal dimensions (the dynamics of musical sequences) and spatial components (the parallel contribution of various music and psychoacoustic factors) to predict human participants emotional ratings of various music pieces. After training, the networks are able to successfully generalize the emotional ratings of music, including novel musical sequences. Detailed analyses of the networks parameters and dynamics allows us to identify the role of specific psychoacoustic variables (e.g. tempo, mean pitch, timbre etc.) in music emotional appraisal (in terms of Arousal and Valence).

The second part of the paper describes an experiment that investigates the pattern of psycho-physiological emotional dynamics elicited by musical experience. It also focuses on the dynamics of Arousal and Valence (psychological dimensions), but it extends the measurements to physiological responses, namely Heart Rate and Skin Conductance Level. We report a preliminary analyses based on static (mean) and dynamic (second-by second measurements) relationships between sound and the active dimensions considered. Results show strong relationships between linear combinations of the music dimensions Tempo and Loudness with psychological Arousal reports. For example, Arousal increases for higher levels of Tempo and/or Loudness. Data also show increased Heart Rate and Skin Conductance levels for sections with faster Tempo and higher Loudness. A negative relationship between Valence and Heart Rate was also found.

Keywords: music, emotion, physiology, psychoacoustics.

Probabilistic Pose Recovery Using Learned Hierarchical Object Models

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Abstract—This paper presents a probabilistic representation for 3D objects, and details the mechanism of inferring the pose of real-world objects from vision. Our object model has the form of a hierarchy of increasingly expressive 3D features, and probabilistically represents 3D relations between these. Features at the bottom of the hierarchy are bound to local perceptions; while we currently only use visual features, our method can in principle incorporate features from diverse modalities within a coherent framework. Model instances are detected using a Nonparametric Belief Propagation algorithm which propagates evidence through the hierarchy to infer globally consistent poses for every feature of the model. Belief updates are managed by an importance-sampling mechanism that is critical for efficient and precise propagation. We conclude with a series of pose estimation experiments on real objects, along with quantitative performance evaluation.

A Conceptual Model of Investor Behavior

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***Abstract*—Behavioral finance is a subdiscipline of finance that uses insights from cognitive and social psychology in order to enrich our knowledge of how investors make their financial decisions. Agent-based artificial financial markets are bottom-up models of financial markets that start from the micro level of individual investor behavior and map it into the macro level of aggregate market phenomena. It has been recognized in the literature, yet not explored, that such agentbased models are a very suitable tool to generate or test various behavioral hypotheses. To pursue this research idea, first we develop a conceptual model of individual investor that consists of a cognitive model of the investor and a description of the investment environment. In the modeling tradition of cognitive science and intelligent systems, the investor is seen as a learning, adapting, and evolving entity that perceives the environment, processes information, acts upon it, and updates its internal states. This conceptual model can be used to build stylized representations of (classes of) individual investors, and further studied within the paradigm of agent-based artificial financial markets.**

Toward a ‘chaotic’ cognitive architecture

Boris Dur´an Giulio Sandini Giorgio Metta

***Abstract*—The increasing complexity of humanoid robots and their expected performance in real dynamic environments demands an equally complex, autonomous and dynamic solution. The goal of this project is to design and implement a cognitive architecture based on the *enactive* paradigm of cognition. The core of this architecture will make use of Nonlinear Dynamical Systems Theory, and especially coupled chaotic systems. Previous feasibility studies with these kinds of systems showed interesting results and motivated the proposed ideas. This paper will present a theoretical background for understanding the proposed architecture and some of the results that encouraged our current and future work.**

The Cognitive Body: from Dynamic Modulation to Anticipation

Alberto Montebelli

Abstract—Starting from the situated and embodied perspective on the study of biological cognition as a source of inspiration, this paper programmatically outlines a path towards an experimental exploration of the cognitive role of the body in artificial agents. Biological cognition is here conceived and synthetically analyzed as a broadly extended and distributed dynamic process emerging from the interplay between body, environment and nervous system. Accordingly, we first analyze a minimalist case study where the 'body', through a very simple non-neural internal bio-regulatory system (an 'energy level'), acts as a self-organized dynamic action selection mechanism. It modulates the activity of the neurocontroller as appropriate to the current context. The availability of the slower non-neural internal dynamic boosts the cognitive potential of the system, constituted of simple reactive components, providing it with the ability to integrate information over time. Then we examine the intrinsic anticipatory potential of viable dynamic attractors.
Finally, we propose a new minimally cognitive architecture, currently under development for experimental investigation, where an explicit model for dynamic anticipation might be coherently exploited via bodily mediation.

Reinforcement Learning for Multi-Action Probabilistic Fuzzy Controllers

W. Hinojosa, S. Nefti, John Gray, U. Kaymak

Abstract: In this paper a new hybrid learning approach combining Reinforcement Learning and a Multi-Action Probabilistic Fuzzy Controller (MAPFC) is proposed. This structure is based on a reinforcement learning agent that measures the performance of a system and uses this to adapt a set of probabilities corresponding to a set of possible actions of a fuzzy controller. The proposed reinforcement learning algorithm is based on a modified version of the actor-critic architecture. Experiments based on simulations using a DC motor numerical model were carried out in order to validate the proposed approach. The obtained numerical results show that our proposed algorithm outperforms the classic Reinforcement Learning in term of learning time and an improved accuracy over Dual-Action PFC.