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Cognitive Social Robotics: Intelligence based on Embodied Experience and Social Interaction

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November 11 - 14, 2013

National Institute of Informatics
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Cognitive Social Robotics: Intelligence based on Embodied Experience and Social Interaction

Organizers:
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Sethu Vijayakumar (The University of Edinburgh, United Kingdom)

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Understanding mechanisms underlying intelligence of human beings and animals is one of the key approaches towards developing intelligent robot systems. Since the mechanisms of such real-life intelligent systems are so complex, physical interactions among agents and their environment and the social interactions among agents should be considered. On the other hand, the interactions among robots, autonomous systems, their environments and people at various scales present some of the most sophisticated scientific challenges we must solve to realize the next generation of robots. Comprehension and knowledge in many related fields such as cognitive science, developmental psychology, brain science, evolutionary biology, and robot engineering is also required - making a case for strong interdisciplinary interaction of minds for implementing this approach. In this decade, an academic field named *cognitive developmental robotics* has been formalised with these aims. This approach focuses on embodied intelligence which is one of the deficient points in GOFAI (Good Old Fashioned Artificial Intelligence). While huge strides are being made in cognitive robotics, the quality and performance of the robots' intelligence has not matched the versatility of human counterparts. One of the reasons for this deficiency is that perhaps we do not yet fully exploit the interactions and embodiment, both in the physical and social (and virtual) domain. One of the difficulties is the huge cost of collecting embodied and social experience due to limitation of robots' operating time, robustness and limited opportunity of social interaction with humans due to limits in deployment. A promising direction is to accelerate the development of intelligence from large-scale long-term, persistent embodied experience we term 'big social experiences' - addressing many of the issues analogous to the 'Big Data' challenges in Informatics.

This Shonan meeting focuses on synthetic research in cognitive social robots, building on the premise that intelligence develops based on physical embodied interaction between body and environment, social interaction between agents and human, with the aim to address both the following aspects:

1. Exploiting Physical Embodiment and Interaction: Actuators, Control, Multi-contact Planning, Natural Dynamics and Design

2. Networked Social Intelligence: Networked interactions, Multi-agent systems, Software for connectivity, Emergent Capabilities

To foster this, we aim for interdisciplinary discussions with wide viewpoint from various research fields such as cognitive science, developmental psychology, brain science, and not just robotics. The scope of this meeting will include human-robot interaction, machine learning, cognitive science, simulation technology for long-term large scale interaction, learning by demonstration, human biomechanics, multimodal sensory experience (auditory, speech, gestures). One of the target applications as material for the discussion would be acquisition of knowledge and skills from natural interaction between embodied agents and human beings; however, this meeting would like to touch on other future big challenges related to the cognitive social robotics with a broad perspective.

The following three sessions are assigned to discuss emergent Intelligence which covers from sensorimotor experience to symbols and language.

- Embodied Experience and Interaction
- Biologically Inspired Design
- Networked Social Intelligence

Participants

- Rüdiger Dillmann, Karlsruhe Institute of Technology, Germany
- Tomohiro Shibata, Nara Institute of Science and Technology, Japan
- Jun Morimoto, Advanced Telecommunications Research Institute International(ATR), Japan
- Sethu Vijayakumar, The University of Edinburgh, United Kingdom
- Madhusudhan M. Venkadesan, National Centre for Biological Sciences, India
- Neelima Sharma, National Centre for Biological Sciences, India
- Yoshihiko Nakamura, The University of Tokyo, Japan
- Ales Ude, Jozef Stefan Institute, Slovenia
- Sylvain Calinon, Italian Institute of Technology, Italy
- Florention Wörgötter, Georg August University Goettingen, Germany
- Giorgio Metta, Italian Institute of Technology, Italy
- Tamim Asfour, Karlsruhe Institute of Technology, Germany
- Patrick van der Smagt, Technical University of Munich, Germany
- Nihav Dhawale, National Centre for Biological Sciences, India
- Naoki Fukaya, Tokyo Metropolitan College of Industrial Technology, Japan
- Minoru Asada, Osaka University, Japan
- Angelo Cangelosi, University of Plymouth, United Kingdom
- Yiannis Demiris, Imperial College London, United Kingdom
- Angelika Peer, Technical University of Munich, Germany
- Tadahiro Taniguchi, Ritsumeikan University, Japan
- Tetsunari Inamura, National Institute of Informatics, Japan
- Takayuki Nagai, The University of Electro-Communications, Japan
- Flörian Rohrbein, Technical University of Munich, Germany

Program

Arrival Day (Sunday, 10th November)

15:00-18:30	Check-In Shonan Center
19:00-20:30	Welcome Dinner
21:00-	Free time

Day 1 (Monday, 11th November)

07:30-09:00	Breakfast
09:00-09:10	Shonan Introduction by Staff
09:10-12:00	Opening briefing from organizers
	Position talks from participants
12:00-13:30	Lunch
13:30-18:00	Session: Embodied Experience and Interaction I with Coffee break
18:30-19:30	Dinner
19:30-	Free Time

Day 2 (Tuesday, 12th November)

07:30-09:00	Breakfast
09:00-12:00	Session: Embodied Experience and Interaction II
12:00-13:30	Lunch
13:30-15:00	Session: Biologically Inspired Design
15:00-15:30	Coffee break
15:30-18:00	Session: Networked Social Robotics I
18:30-19:30	Dinner
19:30-	Free Time

Day 3 (Wednesday, 13th November)

07:30-09:00	Breakfast
09:00-12:00	Session: Networked Social Robotics II
12:00-13:30	Lunch
13:30-18:00	Excursion to Kamakura
19:00-21:30	Banquet Dinner
21:30-	Free Time

Day 4 (Thursday, 14th November)

07:30-09:00	Breakfast
09:00-12:00	Session: Wrap-up
12:00-13:30	Lunch

Session: Embodied Experience and Interaction I

Overview of Talks

Anthropomatics and Robotics

Rüdiger Dillmann, Karlsruhe Institute of Technology, Germany

"Is it from man is it from the machine or from both?" - Anthropomatics addresses this problem focusing on the symbiosis between humans and machines. Robotics stands for automation. Modelling, representing and understanding the sensomotoric mechanisms, learning and development of skills and cognitive capabilities to enable humans to interact with the world is the key to design technical systems operating closely and interactively with humans. However, the problem of learning skills and task knowledge by observation of human activities and the related context is still an open field. My research interest is on interactive machine learning and multimodal channels between humans and robots to design anthropomatic systems and to discuss the underlying paradigms.

Assist-As-Needed Robotic Training for Motor Skill Learning

Tomohiro Shibata, Nara Institute of Science and Technology, Japan

How can we accelerate motor skill learning of humans? For this, obvious obstacle is on the individual difference in their bodies and brains. Furthermore, the guidance hypothesis states that humans tend to rely too much on external assistive feedback, resulting in interference with the internal feedback necessary for motor skill learning. Here I present our framework for assist-as-needed robotic training and its application to learning darts-throwing skill.

Policy learning in high-dimensional state space

Jun Morimoto, Advanced Telecommunications Research Institute International(ATR), Japan

We introduce a policy learning framework for a high-dimensional system through fewer interactions with the real environment than standard RL methods. In our learning framework, we first use mental simulations to improve the controller parameters using an approximated environment model to generate samples along locally optimized trajectories. We then use the approximated dynamics to improve the performance of a tool manipulation task in a path integral RL framework, which updates a policy from the sampled trajectories of the state and action vectors and the cost.

Working in Alternate Spaces: Exploiting Topology and Dynamics for Efficient Movement Adaptation

Sethu Vijayakumar, The University of Edinburgh, United Kingdom

Our mature work on high dimensional, online learning and adaptation, especially in the context of optimal control and apprentice learning paradigms, have highlighted the need for efficient representations - in order for the prototype ML techniques to scale to real world problems. I will outline our recent attempts at exploiting redundancies at the level of variable impedance as well as using topological metrics to plan in contextual spaces, with applications to spatio-temporal optimisation of contact rich motion in dynamic environments – highlighting how working in the right spaces automatically exploits natural dynamics of the embodied plant to deliver efficient, 'natural' solutions.

Bioinspired design of a throwing machine: Mechanics, materials and control

Madhusudhan M. Venkadesan, National Centre for Biological Sciences, India

Through measurement of humans, numerical optimization, and experiments on a throwing machine, I will show how kinematics and elasticity form an essential part of the human ability to throw accurately at high speeds. These essential elastic elements in humans arise from the passive properties of ligaments, as well as the active and tunable elasticity of muscles. Using these examples in high speed throwing, I argue that animals are finely tuned through evolution to create mechanical solutions for otherwise hard control problems.

Contact stability in fingers

Neelima Sharma, National Centre for Biological Sciences, India

Be it holding a mug of water, or making origami, you need to control both the force at your fingertips and the fingers' posture. Simultaneous control of endpoint force and posture in a robotic finger requires accurate and fast feedback with loop delays of less than 10ms. How then are humans, with feedback delays of over 60ms, able to remain stable in contact? To achieve robustness to long time delays, we develop a control scheme that is linearly stable without the need for feedback. A proposed physical implementation of our scheme naturally leads to cable driven mechanisms that are driven by actuators with nonlinear elasticity like in muscles. I end with a discussion of the implications of our results to both robots and humans.

Summary

Rüdiger Dillmann presented an overview over Anthropomatics and Robotics and emphasized that this is a very wide field, highly multimodal, and interdisciplinary. He asked the question: How teams humans and robots can "make shared experience" towards the advancement of the knowledge bases of the machines. Especially there was also the question of complexity put forward. Can one address ALL the difficult problems in Anthropomatics at the SAME time in ONE system? Here asking, too, How strongly embodiment would indeed underly higher functions.

Jun Morimoto discussed policy learning in high dimensional state spaces and the problems of decision making using reinforcement learning methods. He presented aspects of optimal control using a formalisms derived from the HJB equation. Specifically he addressed the problem of assessing the value function (specifically in non-linear cases). The central problem seems to be the curse of too many degrees of freedom in robotics. Here he suggested as a solution to use mental simulation (prediction) by ways of a forward model to update the policy. Then try out the policy, then improve the model, then perform the next prediction etc. A remaining problem is how to accurately emulate the cost/reward function in a simulation. The link to forward/inverse models in the human Cerebellum remains also an open question.

Tomohiro Shibata presented aspects of the smart life care community (Assistive robotics). He discussed problems of assisting learning of motor skills (model free) and addressed the issue of therapy, too. He emphasized the need of high functionality as well as individualized, "assist-as-needed" assistance. As a case study he used the very complex motor control problem of dart throwing asking "what is the essence of a motion?" versus what are random inter-individual differences. What happens when there are patients who need non-standard controls? His answer was: It's the goal that is trained and not the motion-as-such, which will address this issue.

Sethu Vijayakumar addressed optimal control issues working in alternate spaces and focused mainly on movement generation problems. An interesting aspect was how to perform impedance transfer via EMG signals. The question arose how much is here explicit and how much is implicit (learnable)? To this one possible answer would be that only the TYPES of control costs need to be specified. The actual WEIGHTS of the costs can be learned. As often it was asked: How optimal is optimal control, how objective are objective functions? Mainly this was discussed in view of the point that biological agents usually do not operate under optimal control but rather clearly beneath optimality.

Madhusudhan Venkadesan presented an interesting mathematically complex study on optimal control in biological systems using the example of throwing by humans, which is a biomechanically difficult problem but also from the viewpoint of control. He focused much on the biomechanical constraints. He addressed the difficult question of the required millisecond temporal accuracy which is needed to achieve repeatable optimal release. Here accuracy and speed are both required for an optimal throw.

Neelima Sharma taked about the contact stability of fingers using the xxample of buckling. She described how adding stiffness and damping leads to improved stability and discussed the relation of muscle and joint stiffness.

Discussion

During the general discussion several aspects were raised:

The session "Embodied Experience and Interaction" did not cover much the aspects "cognition", "planning" and "social domain"

Other questions were: How can we arrive at higher levels of symbolic information? Where do they emerge? How much does prediction play a role for cognitive agents? We do NOT continuously predict stuff. We rather ignore large parts of our world and get surprised but not because of explicitly prediction-failure, rather in a reflexive way. Something that catches our attention.

The question of interactions by language was raised not only for naked communication as such but also as a means for abstraction. How to get to this in machines?

Scalability issues were discussed, too, especially in conjunction with the huge sensori-motor spaces with which we are faced in this field.

In Summary: The presentations in this part of the WS covered wide ranging and diverse aspects towards the title of this topic. The discussion raised interesting and important additional aspect which may help to lead to improved approaches in the future

Session: Embodied Experience and Interaction II

Overview of Talks

Anthropology and Robotics

Yoshihiko Nakamura, The University of Tokyo, Japan

The domain of humanoid robotics is not only to make a bipedal and bimanual robot any more. Technical challenges expand from following the human-like geometry for robot design to asking about the use of the human geometry for the design of robot intelligence. Scientific challenges may include investigating the role of human geometry for human cognition. This may be better explained by the word of "anthropomorphism." Anthropomorphism means how we interpret things as we see humans. To discover the principle of informatics behind anthropomorphism is the main scientific goal of humanoid robotics. Anthropomorphism lies as the foundation to understand human psychology, human developments, human behaviors, and human society. Many applications will follow from the scope for medical care, social service, and industrial developments.

On-line adaptation of robot skills in contact with the environment

Ales Ude, Jozef Stefan Institute, Slovenia

Compliant robots can adapt their movements to account for force feedback arising in tasks that involve contact with the environment including other robots. We study how such movements can be adapted in a predictive way, thus minimizing the unwanted impacts and optimizing the task execution. A robust and compact representation of movement, which enables fast on-line modification and ensures stability, is essential for this purpose. Similar strategies can also be applied when altering robot movements based on human in the loop coaching gestures, where real forces are replaced with virtual force fields.

Robot learning by imitation and exploration with probabilistic dynamical systems

Sylvain Calinon, Italian Institute of Technology, Italy

Robot programming by demonstration facilitates the transfer of skills by kinesthetically guiding the robot through the task or by letting the robot observe the user executing the task. One key challenge is that the robot needs to start generalizing skills from very small training sets, with a representation that needs to be shared by other learning strategies such as stochastic optimization and self-improvement.

Designing machine learning tools with extrapolation capability seems to be a crucial element to move the imitation challenges to more complex real-world applications. This can be achieved in various ways, such as goal-directed imitation (copying the intent underlying the demonstrations instead of directly copying the actions), learning the underlying structure of the task, or with learning strategies combining social interaction and self-refinement. I will show an approach jointly using statistics and dynamical systems to exploit the varying accuracy requirements of the task.

Understanding human manipulations

Florention Wörgötter, Georg August University Goettingen, Germany

The ability to reliably manipulate objects is a major aspect that has fostered our cognitive phylogeny and that is in the core of every human's individual mental development. As a consequence we can understand (manipulation) actions! Robots cannot! And the transfer of the semantics of an action onto artificial agents has so far defied our efforts. Here we will argue that actions can be understood as sequences of simple events, leading to a limited ontology of manipulation actions and to a direct link to the symbolic domain (language).

Exploring affordances and tool use on the iCub

Giorgio Metta, Italian Institute of Technology, Italy

One of the ensuing goals in robotics is the development of various robotic learning mechanisms that would predict the effects of certain actions on objects and improve task execution over time. It is paramount to predict the properties of an object from afar, for example on a table, in a rack or a shelf, which would allow the robot to select, beforehand, an appropriate action in order to accomplish a particular goal. Here I show an approach to the design of cognitive skills in a robot able to interact with the surrounding physical world and manipulate objects in an adaptive manner. I describe a general pipeline for learning object-rolling affordances, tool exploration and tool handling. I will show successful learning in the real world where the iCub humanoid robot interacts with objects.

It's All about Force

Tamim Asfour, Karlsruhe Institute of Technology, Germany

Considerable progress has been made towards the realization of humanoid robot systems which are able to move in a human-like way and perform tasks in human-centered environment. However, versatile 24/7 humanoid robot systems integrating perception, action, prediction, planning and lifelong learning capabilities in the real world are still missing.

In this talk I will discuss the role of force in the formalization and unification of sensorimotor and semantic representations and introduce the force space as unifying space of perception and action and mechanism for bootstrapping the development of high performance 24/7 humanoid robots. I will argue that objects, agents and their actions can be described based on a new concept of sensorimotor force fields (SFF) which provides a unified representation and computational mechanism for solving tasks related to grasping, dexterous manipulation, balancing and robot control. SSFs are based on the assumption that different (all) types of sensory modalities such as position, pressure, tactile, audio and vision do share significant commonalities with each other as they can be mapped into the same space: The force space. This does not only provide a unifying representation of perception and action in the same space but also will bootstrap the development of new generation of high performance robotics systems.

Session: Biologically Inspired Design

Overview of Talks

Building useful robotic hands

Patrick van der Smagt, Technical University of Munich, Germany

Studying the human hand, one cannot help noticing that a number of its kinematic and static properties are important for grip stabilization and manipulation. Also, the human hand's neural control structure, differing considerably from arms and legs, demonstrate its special role in the human's body. I will highlight a few of the hand's properties, from an engineering perspective, and demonstrate how these properties can be exploited in robotic hands.

Stability and energetics of running on uneven terrains

Nihav Dhawale, National Centre for Biological Sciences, India

Stable running requires that the kinetic energy of the runner is mainly associated with a nearly periodic mode of movement. Uneven terrains challenge stability by redirecting the kinetic energy of the runner into other, orthogonal modes of movement, falling can be a consequence of this. Any strategy to remain stable should absorb energy associated with the undesired modes, and inject it back into the desired mode. We propose a minimal model for running locomotion, and show how energy and stability trade-off when running on uneven terrains. I discuss how such a model can be used to understand the feedback and open-loop strategies employed by human runners.

Development of good hardware made by unique, smart and noble mechanical design

Naoki Fukaya, Tokyo Metropolitan College of Industrial Technology, Japan

The good hardware made by unique, smart and noble mechanical design realizes small size and a weight saving, and makes structure simple. It leads to improvement in reliability and durability. Moreover, it realizes the reduction of incidence of a control system. Our target is to imagine and develop the mechanical design with many merits.

Session: Networked Social Robotics I

Overview of Talks

How to design artificial emotion

Minoru Asada, Osaka University, Japan

Emotion, a driving force to generate different behaviors, is one of the most fundamental but difficult structures/functions to design for robots. Starting from primitive emotions, the secondary emotions may be differentiated from them. During this developmental process, sociality has an important role to derive the differentiated emotions. In this talk, I argue how artificial emotion can be more realistic in the social context by showing some attempts, and discuss the future stories in SFs and comics.

Embodied Language Learning in Robots

Angelo Cangelosi, University of Plymouth, United Kingdom

The talk will introduce the issues of symbol grounding and language embodiment in cognitive and neural sciences and show how this has contributed to developmental robotics experiments on language and action learning and interaction.

Can you learn this? Recognising and assisting children's actions for optimising their long-term sensorimotor development

Yiannis Demiris, Imperial College London, United Kingdom

As educators, mentors, and parents, we do not assist our less experienced ones constantly and unconditionally. We do so on the basis of individual models we have built based on our previous interactions. We give them tasks that are neither outside their reach, nor trivial for their skillset, but challenge them optimally. Determining the learnability of a new task is a challenging and complex inference process that combines models of the development of an individual, with statistical models of typical developmental trajectories at the population level. In this talk I will describe my research in a principled computational framework for modelling and assisting sensorimotor development, and describe its application for assisting children: example tasks include robotic wheelchair navigation for children with disabilities, dancing, and learning car racing games.

Embodying yourself into (remote) robot avatars

Angelika Peer, Technical University of Munich, Germany

Having the possibility to embody oneself into a robot avatar allows to perform manipulation tasks at a distance, to enter human inaccessible environments or to overcome limitations of the own sensorimotor system, e.g. in case of paralyzed people. Control architectures for such systems range from bilateral, shared to supervisory control depending on the specific capabilities and cognitive state of the human operator. I will discuss typical challenges in realizing such systems ranging from robust stability, transparency, intention recognition, and authority sharing to the personalization of robot actions and show examples of robot avatars controlled by means of force/motion signals as well as brain and body computer interfaces.

Summary

In this session, we discussed about networked social intelligence including emotion, language and shared autonomy. First presenter, Minoru Asada, gave a talk about "How to design artificial emotion". Emotion, a driving force to generate different behaviors, is one of the most fundamental but difficult structures/functions to design for robots. After introducing his projects and approaches to developmental robotics, he introduced several future stories in SFs and comics for discussing artificial emotion. Secondary, Angelo Cangelosi told about "Embodied Language Learning in Robots". Starting from symbol grounding problem, he explained the importance of embodiment for language acquisition problem. We discussed about learning system for language acquisition, abstraction and embodied cognition. The third speaker was Demiris Yiannis. The title of his presentation was "Can you learn this? Recognizing and assisting children 's actions for optimizing their long-term sensorimotor development". He introduced his research topics including assistive wheel chair system and robotic system which help children learn dancing, and so on. Finally, Angelika Peer told about "Embodying yourself into (remote) robot avatars". She introduced telexistence technology she has been studying. Control architectures for such systems range from bilateral, shared to supervisory control depending on the specific capabilities and cognitive state of the human operator. We discussed related topics to the telexistence.

Session: Networked Social Robotics II

Overview of Talks

Symbol emergence in robotics

Tadahiro Taniguchi, Ritsumeikan University, Japan

Humans can acquire language through physical interaction with their environment and semiotic interaction with other people. To understand computationally how humans can obtain semiotic skills through their mental development is very important problem. In the research field of symbol emergence in robotics, we are challenging to construct a robotic system which can obtain language through embodied multimodal interaction. I also introduce double articulation analyzer (DAA) which is a nonparametric Bayesian machine learning technique. DAA can extract latent double articulation structure in a semiotic time-series data, e.g., human motion and driving behavior, in unsupervised way.

Simulator Platform for Cognitive Social Robotics

Tetsunari Inamura, National Institute of Informatics, Japan

Research on high level human-robot interaction systems that aim skill acquisition, concept learning, modification of dialogue strategy, and so on requires large-scaled experience database based on social and embodied interaction experiments. However, if we use real robot systems, costs for development of robots and performing various experiments will be too huge. If we choose virtual robot simulator, limitation arises on embodied interaction between virtual robots and real users. Our group thus proposes an enhanced robot simulator that enables multiuser to connect to central simulation world, and enables users to join the virtual world through immersive user interface. As an example task, we propose an application to RoboCup@Home tasks. In this talk, I explain the configuration of our simulator platform and feasibility of the system in RoboCup@Home.

Long-term Learning of Concept and Word by Robots

Takayuki Nagai, The University of Electro-Communications, Japan

One of the biggest challenges in intelligent robotics is to build robots that can understand and use language. Such robots will be a part of our everyday life; at the same time, they can be of great help to investigate the complex mechanism of language acquisition by infants in constructive approach. To this end, I think that the practical long-term on-line concept/word learning algorithm for robots and the interactive learning framework are the key issues to be addressed. This talk highlights our efforts on the development of such a practical on-line learning framework based on Bayesian learning, and some preliminary results on experiments using a real robot platform to show its potential toward the ultimate goal.

Neurorobotics in the Human Brain Project (HBP)

Flörian Rohrbein, Technical University of Munich, Germany

The HBP will develop six ICT platforms, dedicated respectively to Neuroinformatics, Brain Simulation, High Performance Computing, Medical Informatics, Neuromorphic Computing and Neurorobotics. The Neurorobotics Platform will allow researchers to conduct closed-loop experiments, in which a virtual robot is connected to a brain model, running on the HPC platform or on neuromorphic hardware. This platform will be the first robotics environment that allows to couple robots and detailed models of the brain and to explore the links between neural activity and high level brain functions. It will be designed for non-robotics and robotics researchers alike and will go far beyond the capabilities of current platforms for experimental robotics by allowing researchers from many disciplines to design and perform robotics experiments.

Summary

The Wednesday AM session on networked social robotics focused on two issues: (i) multimodal categorization and language (and time-series) learning for HRI (Nagai and Taniguchi), and (ii) the contribution of robotics simulators to hybrid virtual/physical HRI (Inanura) and to neurorobotics (Röhrbein).

Nagai presented a multimodal categorization and language learning system for human-robot communication. The key concept on his approach was multimodality, in particular through the implementation of a Bag of Feature model for multimodal signal processing. This was based on three input modalities on the object being categorized/named (visual DSIFT, non-speech auditory MFCC, and tactile information) and the additional speech modality of the teacher's word utterance. This method is based on unsupervised classification and statistical, graphical model MLDA (Multimodal Latent Dirichlet Allocation). A key component of the model is also the online interaction and learning with the user. One experiment on 20 objects x 5 categories Showed the correlation between Mean-Length Utterances and categorization. Another novel experiment on long-term interaction and learning sessions involved 200 objects, with a preliminary experiment based on 1000 utterances over a week. Moreover, the Multilayer Multimodal LDA is being proposed and tested for categorization of motion, e.g. for the meaning of the action/verb "shake".

Taniguchi focused on symbol emergence in robots within the context of developmental psychology of semiotic communication. He support an embodiment, constructivist approach for evolving symbol systems, with concepts learned bottom-up from sensorimotor information and via social interaction and constraints. To operationalize such an approach he uses The Double Articulation Analyzer (DAA) method as an unsupervised, non parametric Bayesian learning system. In general, this can be considered as a method for the segmentation of sensorimotor time-series information, which ranged from pure linguistic tasks (segment speech time series into words) to other series as human motion data, driving behavior. Chunking of driving; chunk separation corresponds to changes og the driver's intention For example, in his ongoing work on unsupervised morphological analysis to segment sentences into words (based on NPLYM, Nested language model) he also proposes a balance of supervised and unsupervised learning: hybrid model using supervised labels as part of the unsupervised learning.

The other two talks have a key focus on robot simulators. Inamura proposes the use of simulators to address the issue of high cost of HRI with physical robots (e.g. robot building/maintenance + experiments/participants time and money costs). Hybrid systems based on virtual/physical robots and agents also offers the extra benefits of long-term HRI experiments with participants entering the virtual simulator word and interact with the virtual robot to teach it new words and concepts. Examples of his previous work on HRI on virtual and physical robots include learning by demonstration for humans (sports coach robot), geometric representation of sensorimotor patterns, and interpolation and extrapolation of movements (squat/punch experiments). The SIGVerse robot simulator was briefly presented, specifically for its role in embodied social intelligence experiments and the bridging between Virtual and Real worlds (though WWW-based login interaction, VR Headset and Kinect). He also presented the use of the SIGVerse software in the RoboCup@Home project for daily environment task simulator (clean-up task in JapanOpen2013). Other application areas include learning of manipulation skills, driving simulator for multi-users, language acquisition experiments. This tool also offers research application opportunities in a variety of contexts and disciplines, and the dream to reaching the wider beyond-robotics community: macrosimulations, crosscultural studies, language evolution models, developmental modeling, animal modeling.

Röhrbein introduced the HBP project with its main double aim to (i) understanding by building; (ii) developing more intelligent IT systems and robots and the three research areas of Future neuroscience, Future medicine, Future computing. In particular, details on the NeuroRobotics SubProject were presented. The first 2.5 year ramp-up phase is specifically aimed at the design of a general neurorobotic simulator for both roboticists and neuroscientists. The aims of this simulator are (i) to develop principles and build (larger) community; (ii) simulate all constituents (robot body, behavior, environment) with highest fidelity robot simulator; (iii) the grounding of these simulations in real world systems and closed-loop robotics experiments.

The key general issues and open challenges for future research resulting from this session are:

- Multimodal categorization and language learning approaches
- Close integration of both sensorimotor and social mechanisms in HRI and language learning
- Developmental and constructivist approaches to language learning in robots
- Importance of long-term HRI studies (training the robot for weeks and more)
- Contribution of hybrid virtual/physical robot experiment/simulation tools to extended the reach beyond the restrict robotics community
- The use of simulator and closed-loop systems to validate neurorobotics theories and hypotheses
- The multi-scale level of neurorobotics studies (from molecular, compartment models, to spiking networks, to average firing rate models)
- Importance of closed-loop approaches in neurorobotics