

## Special Issue on Symbol Grounding

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How can we achieve artificial systems that are capable of understanding human language? This question has been addressed by the field of artificial intelligence for decades and has undergone several paradigm shifts from rule-based approaches, proposing sets of symbolic rules to process language input to produce an intelligent behavior, to the insight that symbolic rules are not sufficient to deal with new situations, let alone new symbols, that have not been encountered before. Rather, it has been proposed that the symbols of a language need to be grounded in perception in order to allow for generalisation to new situations. This new formulation of the problem has been termed “Symbol Grounding” and proposes that any system capable of understanding symbols needs to be embodied in the sense that it has to be able to perceive its environment and to produce actions within this environment that cause significant changes and that these percepts and actions need to be tied to symbols that allow to abstract and thus to transfer knowledge. Research thus focuses either on simulated embodied agents or robots that are situated in a physical environment. Given the complex nature of the challenge, a range of different strands of research has emerged from which we tried to capture the most relevant ones in this Special Issue.

Focusing on the development of grounding capabilities in infants brings in new perspectives and has, for example, lead to the insight that while the learning system has to be extremely adaptive to the environment, the social environment itself also adapts to the learner. In the contribution by Paul Vogt & J. Douglas Mastin it is thus discussed which aspects of such interactions should be modelled in artificial systems with a special focus on data “from the wild”.

This social component is taken up in the question of social symbol grounding which focuses on the idea that through the communication of symbols within a community a much higher level of knowledge can be achieved by each individual. In this Special Issue we focus on several approaches that look in detail how such communication processes can be achieved on robots not only acting in real physical environments but also in interaction with humans in order to achieve shared representations. Peltason et al. focus on the question of grounding in the application of human-robot interaction and through detailed analysis show which mechanisms enable to achieve common ground - and which, if missing, may lead to failure. De Kruijff takes up on this question and argues that due to the inherent asymmetry between humans and robots mutual understanding can only be achieved by taking the differences explicitly into account in the logical representations and allow for differences by considering the notion of “judgment” rather than “truth”, which is currently being used in logical representations and reasoning approaches based on propositions. An approach taken up in the contribution by Buschmeier & Kopp where it is argued that symbol grounding in dialogue is a joint construction process which is modeled with a Bayesian network capable of taking uncertainties into account. An approach that considers language acquisition in general artificial systems is presented by Michael Spranger. This paper examines the emergence of language and how conceptualization strategies can not only be represented but also how they influence the development of lexical systems and evolve over time.

A number of papers consider symbol grounding for objects in a robotic context. In Heintz et al. an anchoring framework which enables reasoning about physical objects is presented. In particular, the work consid-

ers anchoring of objects given streams of tagged sensor data. Another direction explored in Albrecht et al. is the grounding of activities and objects in intelligent system e.g. smart home environment. The paper is based on the supposition that the bottom-up symbol grounding of detecting objects in the sensor data stream and the top-down symbol grounding of generating object and activity hypotheses are closely intertwined.

It is a pleasure to include within this issue an interview with Stevan Harnad. Two dissertation summaries on symbol grounding are also included. The first by Severin Lemaignan deals with knowledge representation and reasoning for robots and in particular focus is given to the modelling of agent dependent symbolic perspectives and their relations to the theory of mind. In a second dissertation summary by Marios Daoutis, knowledge representation and reasoning (KRR) techniques are also considered in the context of perceptual anchoring. Finally, a short review of symbol grounding for robotics and intelligent systems is included in this special issue.

While this Special Issue can only be a snapshot of the broad range of research in the area of symbol grounding, we believe that our selection shows some of the most promising research trends.

## Content

### Fachbeiträge

- Michael Spranger, *Evolving Grounded Spatial Language Strategies*  
 Julia Peltason, Hannes Rieser, Sven Wachsmuth, Britta Wrede, *On Grounding Natural Kind Terms in HRC*  
 Fredrik Heintz, Jonas Kvarnström, Patrick Doherty, *Stream-Based Hierarchical Anchoring*  
 Silvia Coradeschi, Amy Loutfi, Britta Wrede, *A Short review of Symbol Grounding in Robotic and Intelligent Systems*

### Project

- Hendrik Buschmeier, Stefan Kopp, *Co-constructing Grounded Symbols Feedback and Incremental Adaptation in Human-Agent Dialogue*  
 Paul Vogt, J. Douglas Mastin, *Anchoring social symbol grounding in childrens interactions*  
 Geert-Jan M. Kruijff, *Symbol Grounding under Asymmetric Agency and Social Sentience in Human-Robot Interaction*

Sven Albrecht, Thomas Wiemann, Joachim Hertzberg, Hans W. Guesgen, Stephen Marsland *From Object Recognition to Activity Interpretation and Back, Based on Point Cloud Data*

### Interview

An interview with Stevan Harnad

### Dissertation

Marios Daoutis, *Knowledge Based Perceptual Anchoring*  
 Severin Lemaignan, *Grounding the Interaction: Knowledge Management for Interactive Robots*

### Service

Given the range of research foci that have emerged in the field of Symbol Grounding we provide in the following a list of activities focusing on different aspects of the problem.

## Projects and Organizations

### Developmental Robotics

ITALK, <http://www.italkproject.org/>

### Cognition

EU-COG, <http://www.eucognition.org/>

## Journals

### Developmental Robotics

IEEE Transactions on Autonomous Mental Development (TAMD), <http://cis.ieee.org/ieee-transactions-on-autonomous-mental-development.html>

## Conferences

### Developmental Robotics

The 3rd Joint International Conference on Development and Learning and on Epigenetic Robotics (ICDL-EpiRob), <http://www.icdl-epirob.org/>

### Cognition

ICCM 2013, the 12th International Conference on Cognitive Modelling <http://www.iccm-conference.org/2013/>

9th International Conference on Cognitive Science <http://www.iccs2013.org/>

The annual meeting of the cognitive science society (CogSci 2013), <http://cognitivesciencesociety.org/conference2013/index.html>

## Workshops

### **Cognition**

Interdisciplinary College,  
<http://www.interdisciplinary-college.de/>

### **Communication**

Workshop Series on the Semantics and Pragmatics of Dialogue (SemDial), <http://www.illc.uva.nl/semDial/>

The 9th International Summer Workshop on Multi-modal Interfaces - eNTERFACE'13 <http://eventos.fct.unl.pt/enterface13/pages/projects-teams>

## Summer Schools

### **Human Robot Interaction**

International Summer School on Social Human-Robot Interaction <http://www.eucognition.org/>