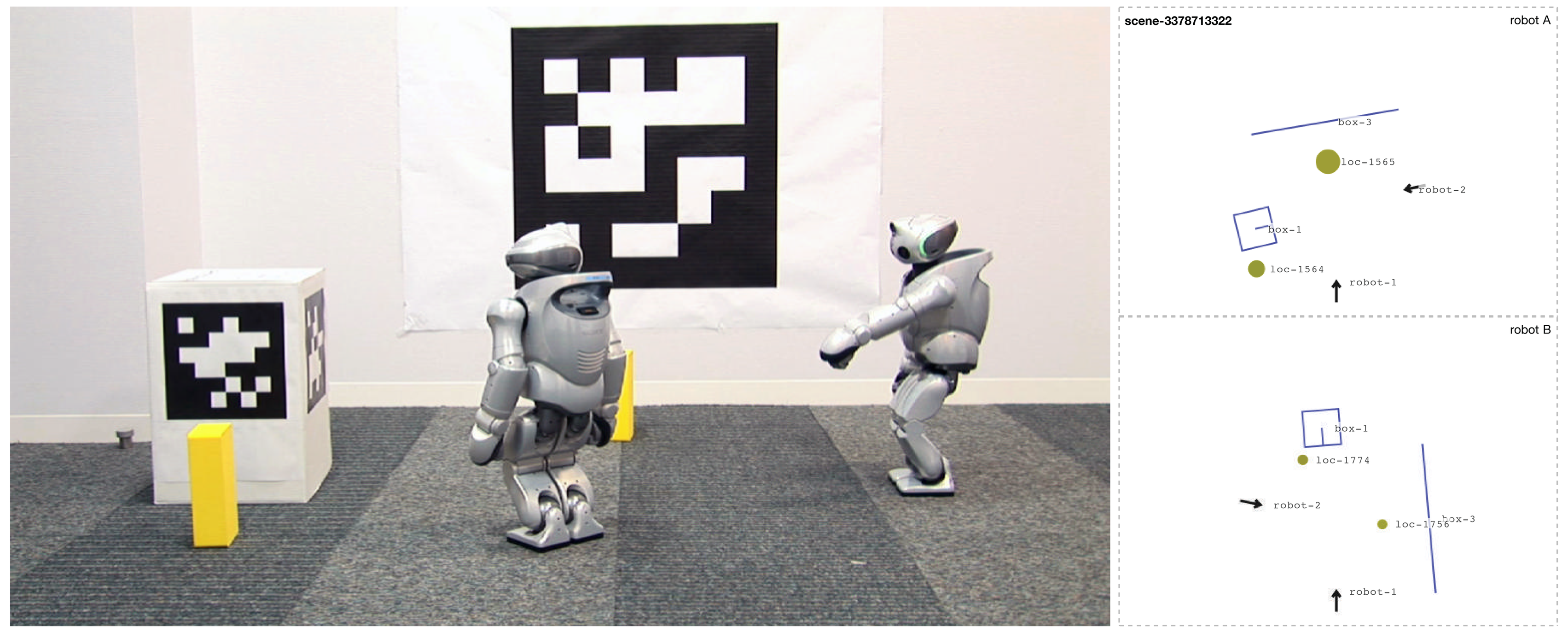
Open-ended semantics co-evolving with spatial language

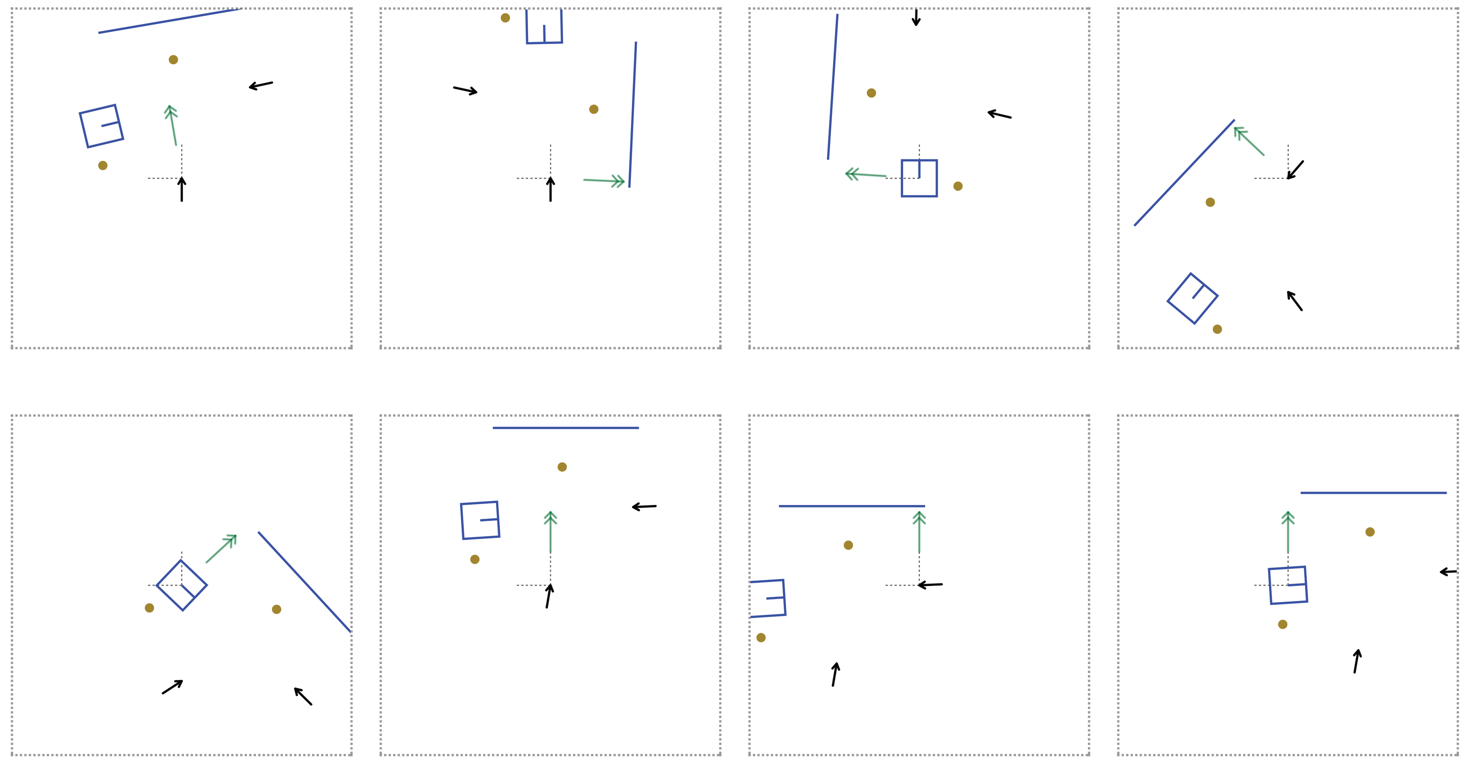
Experiments with humanoid robots



We hypothesize that open-ended flexible semantics is a key to understanding the enormous amount of creativity and flexibility in spatial language usage observed in humans. We introduce our approach that allows cognitive agents to conceptualize reality in different ways and show how the system interacts with grammar in the evolution of spatial language in populations of humanoid robots.

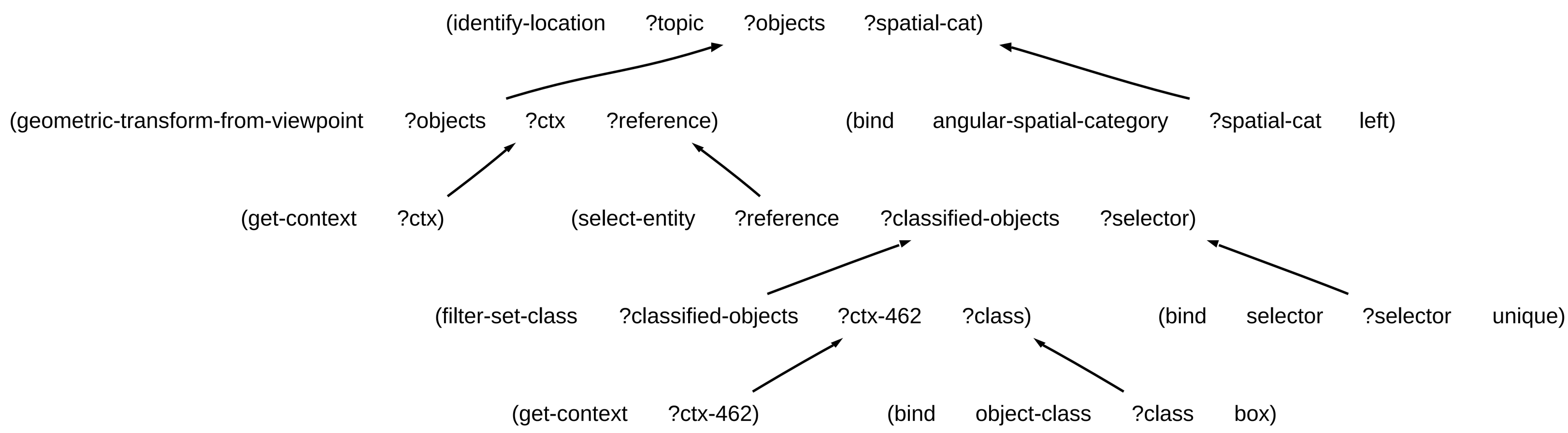
Introduction

Language describing spatial relations is subject to great diversity, both cross-culturally as within languages. For instance, different cultures use different frames of reference. Tenejapan (Mayan, Mexico) speakers use a geocentric frame of reference even for referring to proximal items. In many languages different frames of reference can be freely combined with different spatial category systems. Typically three frames of reference are distinguished: 1) *intrinsic,* as in 'in front of the house', 2) *relative,* as in 'left of the house from my perspective', and 3) *absolute,* as in 'north of the house'[1]. Together with the possible reference objects in the context and the spatial categories available to language users, they form the space of conceptual possibilities for a given scene. Possible conceptualization strategies, also called *perspective transformations*, for robot A from the above example scene are shown below. From top left to bottom right, it starts with intrinsic (egocentric, interlocutor, box) frames of reference, continues with relative (interlocutor, box) frames of reference (top right and bottom left). The last three on the bottom right are absolute frames of reference (egocentric, interlocutor and box).

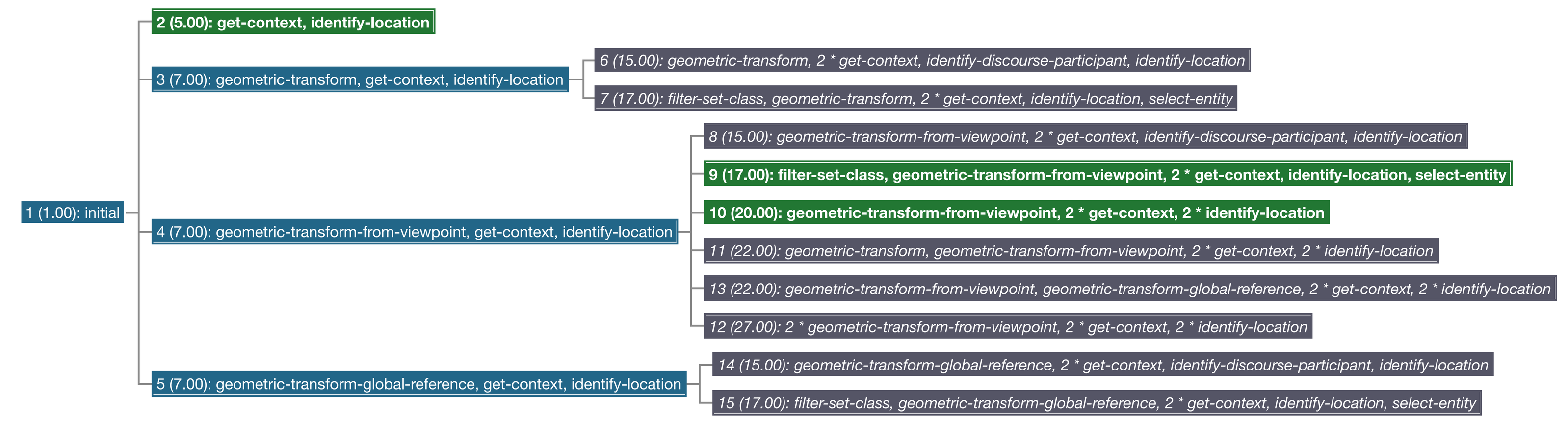


Open-ended flexible semantics

We represent the meaning of the utterance 'left of the box' as a program that the speaker wants the hearer to execute. The following graph shows a network representing such a program. The network consists of 1) cognitive operations, e.g. *filter-set-class*, which are concrete operations that can be executed and 2) explicitly introduced semantic entities, e.g. *box*, which are used to represent the data that operations work on. Cognitive operations and semantic entities are explicitly linked via variables (starting with '?').



Agents are equipped with elaborate machinery in order to interpret, execute and build large conceptual structures destined for communication. For instance, speakers are building conceptual structures as the one shown above in order to plan what to say, which amounts to finding the right combination of frames of reference, reference objects and spatial categories. Hearers parsing the utterance are left with actively interpreting, e.g. filling in missing variable links, cognitive operations or other parts of the network only partially transmitted or parsed. It is up to the language system that speaker and hearer use to determine the amount of work needed for hearers to disambiguate the utterance of the speaker. For instance, choosing a reference object typically leaves the frame of reference (intrinsic, relative, absolute) underspecified. Hence, the utterance 'left of the box' in English is ambiguous as to which frame of reference is meant. Sometimes this ambiguity can be resolved by taking the context into consideration. A search tree in which a speaker constructs such a network is exemplarily shown below.



The system for dealing with conceptual structure is called Incremental Recruitment Language (IRL) and together with Fluid Construction Grammar (FCG)[3] constitutes a complete system for learning and adaptation of communication systems in autonomous cognitive agents.

References

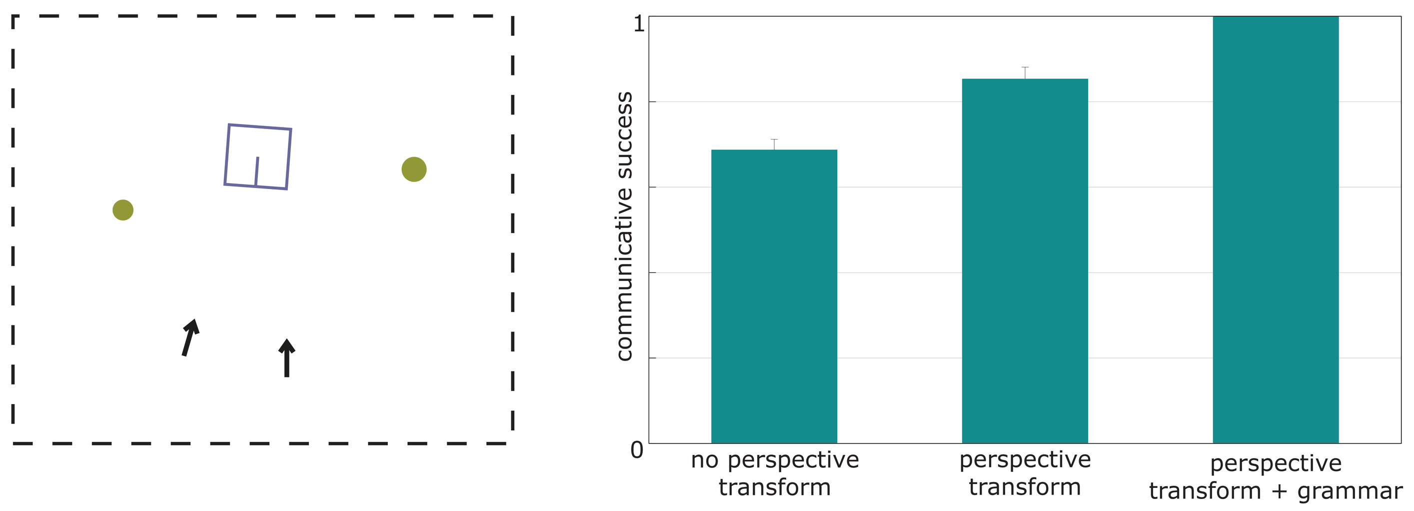
[1] Levinson, S.C. (2003). Space in Language and Cognition: Exploration in Cognitive Diversity. Cambridge University Press.

[2] Spranger, M., Pauw, S. and Loetzsch, M. (2010). Open-ended Semantics Co-evolving with Spatial Language. Proceedings of the Eighth International Conference on the Evolution of Language: Evolang8.

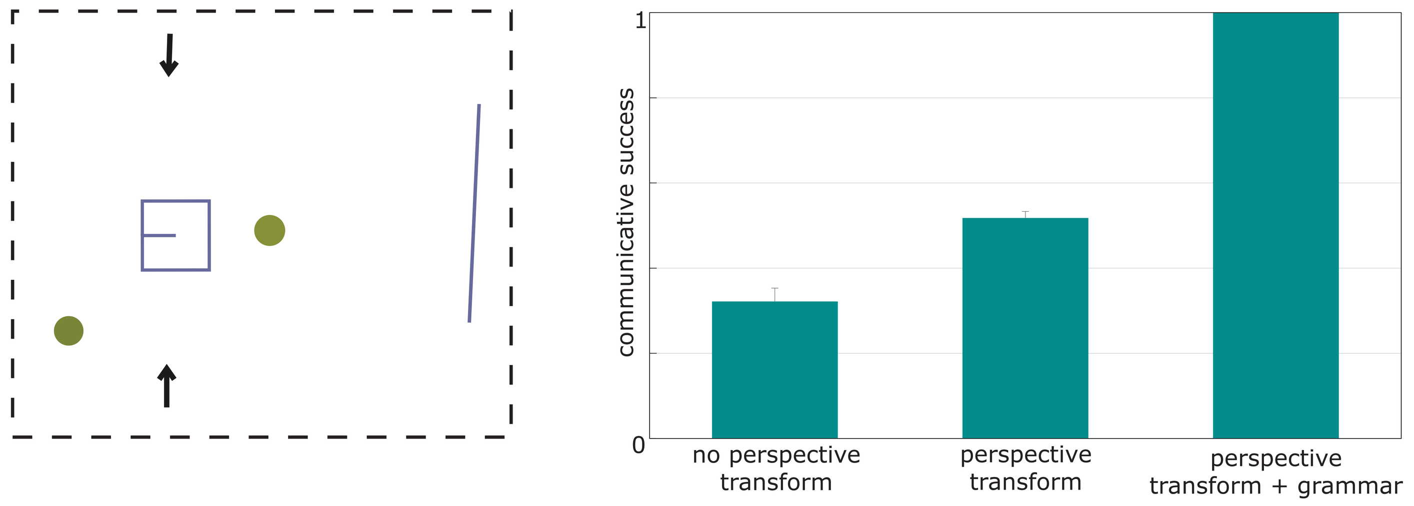
[3] De Beule, J. and Steels L. (2005), Hierarchy in Fluid Construction Grammars. LNCS 3698. Springer

Results I

When the complexity of scenes increases, the use of perspective transformations becomes more and more important. At the same time, the need to grammatically express which frame of reference is used, grows. In simpler scenes agents still reach high communicative success without flexible semantics and grammar:

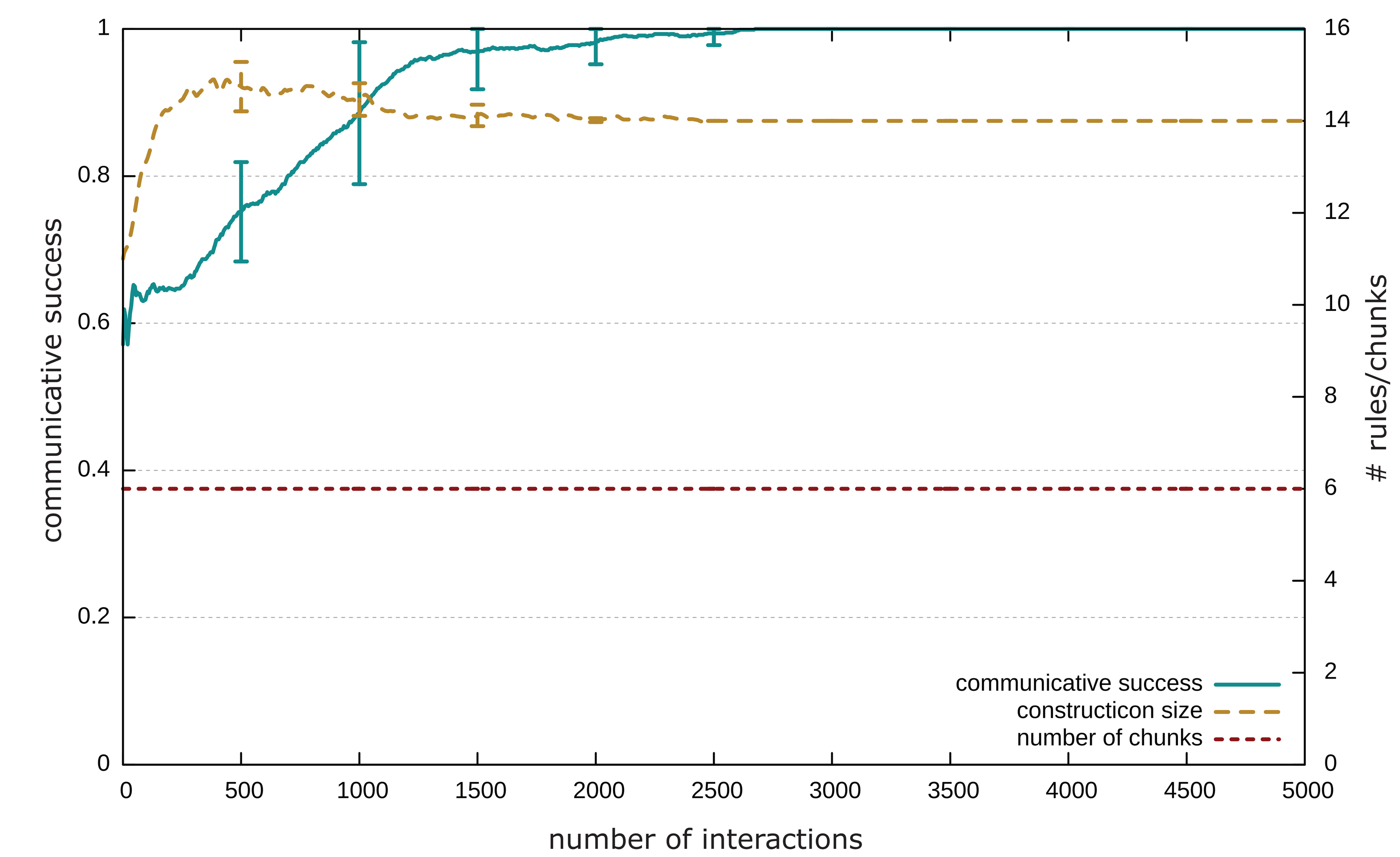


However, when the scenes become more complex, open-ended flexible semantics (IRL) plays out its potential:



Results II

Given such strong incentives for open-ended semantics and grammar, agents can self-organize a spatial vocabulary and a grammatical system, when equipped with the right set of learning, shaping and adaptation operators.



Michael Spranger (spranger@csl.sony.fr)
Simon Pauw
Martin Loetzsch

SEVENTH FRAMEWORK PROGRAMME

Artificial Language Evolution on Autonomous Robots

Vrije Universiteit Brussel

Sony CSL
Sony Computer Science Laboratory Paris