



Evolution/Development of Action and Language

Stefano Nolfi

Laboratory of Autonomous Robotics and Artificial Life Institute of Cognitive Sciences and Technologies, CNR Roma, Italy http://laral.istc.cnr.it/nolfi/ stefano.nolfi@istc.cnr.it

Outline & Objectives

1. Theoretical background

2. How population of evolving robots can co-develop behavioral and communication skills

How signals and "meanings" emerge

How the development of action skill support the development of communication skills and vice versa

 How robots can acquire early language comprehension capabilities How robots can display compositional language/action skills How language exposure and self-talk facilitate action development

4. Discussion and Conclusions

Theoretical Hypothesis

Behavior and cognition are complex adaptive systems characterized by emergent properties and by a multi-level and multi-scale organization

Behavior and Cognition as Dynamical Systems



Behaviour and cognition are dynamical processes that extend over time and result from a large number of robot/environmental interactions occurring at a fast time rate between the robot's control system, body, and the physical and social environment.

Behavior and Cognition as Complex Multi-Level and Multi-Scale Dynamical Systems



(i) The interactions between lowerlevel processes (that extend for a limited time duration) give rise to higher-level processes (that extend for longer time spans)

(ii) higher-level processes later affect the lower-level processes from which they originate

Behavior and Cognition as Adaptive Systems

Systems with varying fine-grained characteristics in which variations are retained or discarded on the basis of the their effects at the level of the overall behavior produced by the agent in interaction with the physical/social environment.



To adapt to variation of the task/environment

To synthesize functions emerging from the interactions of lower-levels components among themselves and with the environment.

Evolution of behavioral and communication skills in groups of cooperating robots



Fitness Function: The group is reward with 1 point every time the robots are concurrently located in the two areas for the first time or after a switch

De Greef & Nolfi, 2010









De Greef & Nolfi, 2010

Summary of the main evolutionary progresses



Infrared-off -> move-forward Infrared-on -> avoid-obstacles move-f. & avoid-ob. -> find areas ground-black -> remain on the black area look-robot-and-follow-border ground-white/black -> signal A/B Sound-B & ground-black -> exit from black area Sound-A & ground-white -> remain on white area follow border Sound-B & ground-white & seerobot_-> exit from white area toward the other robot exit from white & move-f -> navigate-to-black look-r.-follow-b. & & move-f -> navigate-to-white

De Greef & Nolfi, 2010.

Multi-level formation, innovations, incrementality & complexification



New higher-level capacities emerge through the interactions between pre-existing skills or through new traits combined with skill re-use

Innovations are enabled by the new adaptive opportunities created by the effects of agents' behaviors and by the possibility to re-use existing capacity

Old skills (assuming new functions) tend to be preserved thus leading to an incremental process

De Greef & Nolfi, 2010.

Language and action integration and synergies between language and action development



Signals/meanings originate through the development (and are grounded in) behavioral skills

Signals constitute one of the main drive enabling the development of new behavioral skills.

De Greef & Nolfi, 2010.

Development of early language comprehension capabilities





Fitness: The robot is rewarded for the ability to realize the goals of the experienced utterances.

	BLUE	RED	GREEN
IGNORE	YES	YES	YES
тоисн	YES	YES	NO
MOVE	NO	YES	YES

Tuci, Ferrauto, Zeschel, Massera, Nolfi (2009, 2011)

Development of early language comprehension capabilities



INDICATE RED



TOUCH YELLOW

GRASP RED

Ferrauto and Nolfi (2012)

Generalization in Comprehension and Action Production

By post-evaluating the robots at the end of the training process with observed that some of them display an ability to comprehend the two new utterances by displaying the corresponding appropriate behaviors.



Robots trained to produce related skills tend to lead to solutions based on multi-level organizations supporting skill re-combination and re-use.

Tuci, Ferrauto, Arne, Massera, Nolfi (2010, 2011)

Language exposure and self-talk facilitates action development

Significantly facilitates the capacity to acquire high-level behaviors (e.g. moving a object to a basked) by combining a set of lower-level behavior (reaching-object, grasping, reaching-target, releasing-object)





Discussion 1/2

An important challenge for scaling ER methods toward real-world applications concerns the development of agents displaying several integrated capacities and possibly able to expand their capacity repertoire overt time.

The multi-level organization of behavioral and cognitive skills:

Enable generalization and compositionality at the level of behaviors

Facilitate the development of new skills through competence re-use

Support incremental processes leading to a progressive expansion of the agents' capacities repertoire

Discussion 2/2

Communication/language and action are two tightly integrated phenomena.

The interaction between adaptive agents and humans mediated by symbolic interactions can allow the former to develop richer and more complex capacities.

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http://www.italkproject.org/ Cognitive Systems and Robotics



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Future and Emerging Technologies