Chapter 13
Modeling The Formation of Language in Embodied Agents: Methods and Open Challenges

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Abstract This chapter introduces the cultural approach towards the question how a symbolic communication system could form in a population of agents. This approach emphasises the role of communication, high level cognition, and social interaction. The chapter introduces briefly the main challenges for working out this approach and which methods could be used to address these challenges.

1 Introduction

Motivated by attempts to understand the origins and evolution of language, various researchers have been investigating during the past decade how a communication system with similar properties as human natural languages can form through self-organization in a population of ‘agents’. This approach rests on the assumption that the origins of language was a cultural event (Tomasello 1999); in other words, that anatomically modern humans used their available cognitive resources to invent complex communication systems similar to the way they invented and propagated tools, agriculture, or societal organizations, and that these communication systems have since propagated in a cultural fashion from one generation to the next (Steels 2007). This assumption contrasts with the alternative hypothesis that the origins of language has a biological origin, i.e., that there was a genetic mutation or series of mutations which has given rise to a highly specialized area in the brain, a language organ, and that the genes laying down this language organ then propagated by the well known processes of genetic transmission and natural selection (Bickerton 1984; Cangelosi and Parisi 1998; Pinker 2003).

There are of course intermediary hypotheses possible. Specifically, some researchers have argued for Baldwinian genetic assimilation of the neuronal structures that support language (Szathmáry 1991; Briscoe 2003). However, this would require that language or precursors of language arise through cultural evolution in the first place, suggesting a tight interaction between cultural evolution and genetic evolution (Dowman et al. 2006). Note that the cultural approach does not argue that language...
appears out of nothing. Communicating individuals must have a ‘language-ready’ brain (Arbib 2002) with a broad range of cognitive skills, embedded in a sufficiently complex body whose control is very non-trivial. In order to make sophisticated rapid symbolic communication beneficial, they must be confronted with an environment of high ecological complexity and live in social groups that must cooperate in order to survive. These two aspects are both preconditions for the origins of language, just like pre-biotic chemistry is a precondition for the origins of life and complex ecologies are preconditions for pushing life towards greater complexity.

Research to understand the formation of language has a secondary motivation. Current interfaces and language technologies invariably start from the idea that a communication system is static once it has been established, either by design or by machine learning. However, analysis of natural dialogue clearly shows that humans constantly adapt to their partners at all levels: sound, vocabulary, syntax, grammar, semantics, conceptualization (Garrod and Anderson 1987). For example, perceptually grounded categories like colors and the words for them, i.e., color terms, are normally only partially coordinated even among speakers of the same language, but once two individuals start to engage in interactions, they become coordinated as failed communications get repaired. Investigating how communication systems form and continue to adapt has therefore the potential to lead to totally new kinds of interfaces both between humans and computer systems and between artificial systems such as autonomous robots. Indeed, this has already happened. In contrast to the top-down design of ontologies as practiced in the semantic web, social tagging and the interactive use of such tags for searching has lead to fluid communication systems which are no longer static but adapt through the collective behavior of their users (Steels 2006).

2 Methods

The cultural hypothesis raises three questions: (1) What are the needed cognitive resources, embodiments, and interaction patterns required to get a communication system off the ground that has similar characteristics as those found in human natural languages? (2) What are the mechanisms that allow a communication system to propagate in a population? (3) What are the mechanisms by which a communication system can be culturally transmitted from one generation to the next?

Scientific research on these questions now typically proceeds through multi-agent experiments, where the agents can be both software agents operating in a simulated world or real physical agents, i.e., robots, that move around and act in the real world (Steels 2001). To set up an experiment, the architecture of each agent and the script for a possible interaction is defined, a restricted environment is designed or set up, and then agents are made to engage in one-on-one situated embodied interactions that involve some form of verbal and non-verbal communication to achieve a cooperative goal within this environment. It is of course crucial that the experiments start from a state in which none of the agents has a communication system, because otherwise we would put in what we are trying to explain. Instead, the communication