Chapter IV
Stratified Constraint Satisfaction Networks in Synergetic Multi-Agent Simulations of Language Evolution

Alexander Mehler
Bielefeld University, Germany

ABSTRACT

We describe a simulation model of language evolution which integrates synergetic linguistics with multi-agent modelling. On the one hand, this enables the utilization of knowledge about the distribution of the parameter values of system variables as a touch stone of simulation validity. On the other hand, it accounts for synergetic interdependencies of microscopic system variables and macroscopic order parameters. This approach goes beyond the classical setting of synergetic linguistics by grounding processes of self-regulation and self-organization in mechanisms of (dialogically aligned) language learning. Consequently, the simulation model includes four layers, (i) the level of single information processing agents which are (ii) dialogically aligned in communication processes enslaved (iii) by the social system in which the agents participate and whose countless communication events shape (iv) the corresponding language system. In summary, the present chapter is basically conceptual. It outlines a simulation model which bridges between different levels of language modelling kept apart in contemporary simulation models. This model relates to artificial cognition systems in the sense that it may be implemented to endow an artificial agent community in order to perform distributed processes of meaning constitution.

INTRODUCTION

Computer-based simulation of sign processes is a much considered topic in cognitive linguistics, computer science and related disciplines. Starting from the insight that a biological agent's capacity to survive correlates with its ability to process linguistic signs, a lot of simulation models of the evolution of sign systems have been elaborated (Batali, 1998; Cangelosi & Parisi, 2002b; Kirby, 2002; Steels, 1996, 1998, 2000; Turner, 2002). According to these approaches, neither rule-based nor statistical models alone account for the dynamics of sign systems as an outcome of countless events in which agents make use of signs to serve their communication needs (Andersen, 2000). Rather, the evolution of sign systems—which natural agents use in order to collectively survive—is simulated by means of computer-based *multi-agent systems* (Christiansen & Kirby, 2003).

The paradigm of multi-agent modelling opposes any approach to the simulation of intelligent behaviour by means of *single* artificial agents operating (and thus processing language) in isolation. Rather, intelligent behaviour is seen to emerge from the cooperation of many cognitive systems without being reducible to any single one of them. This is what Hollan et al. (2000) call *distributed cognition*—cf. Maturana and Varela (1980) for a more philosophical grounding of this approach. According to this view, a full *semiotic* (i.e., sign processing) *agent* is seen to be definable only against the background of a community of structurally coupled agents. That is, a single agent is not supposed to re-use a pre-established language, but to cooperatively acquire a sign system as a means of representing and mastering his or her environment (Maturana & Varela, 1980; Rieger, 2002). This is tantamount to a reconstruction of the *grounding problem* (Ziemke, 1999; Riegler et al., 1999) in terms of distributed, social intelligence (Hollan et al., 2000; Steels, 2002). In methodological terms, this means to abandon the approach of strong *artificial intelligence* (Searle, 1980) and artificial life (Pattee, 1988)—insofar as they aim at *realizing* intelligent behaviour by means of artificial agents—in favour of computer-based *simulations* of language evolution.[1]

Approaches to simulation models of language evolution are well documented in the volume of Cangelosi and Parisi (2002b)—see also Kirby (2002) for a comprehensive overview of this field of research.[2] These approaches have in common that they utilize *multi-agent* computer-simulations (Cangelosi & Parisi, 2002a; Gilbert & Troitzsch, 1999) in order to model aspects of phylo, onto or glossogenetic evolution of language (Christiansen & Kirby, 2003).[3] The *iterated learning model* (Kirby, 2002) can be referred to as an architectural simulation model which addresses the bottleneck problem, according to which a language is transmitted from generation to generation via agents who evidently do not have access to the totality of knowledge characterizing the language to be learned. Consequently, language change—subject to the pressure of varying speaker and hearer needs—is inescapable. Generally speaking, in this and related models language learning is tackled with respect to referential semantics and symbolic grounding in a multi-agent setting (Cangelosi et al., 2002; Steels, 1996, 2002), the learning of lexical knowledge (regarding the articulation of content and expression plane) (Hashimoto, 2002; Hutchins & Hazlehurst, 2002; Kirby & Hurford, 2002), the learning of syntax formation (Hashimoto, 2002; Kirby & Hurford, 2002) and the interrelation of lexico-grammar and semantics (as regards, for example, the emergence of compositionality) (Kirby & Hurford, 2002). All these approaches apply machine learning techniques (e.g., classification, grammar induction, etc.) in order to model language learning of individual agents and thus relate—from a methodological point of view—to *computational linguistics*. Moreover, Kirby and Hurford (2002) demonstrate the usability of frequency distributions as they are studied in quantitative linguistics. Generally speaking, knowledge about the validity of such distributions can be utilized in two respects: First, this knowledge can be used to constrain the model itself. That is, simulations can be endowed by the experimenter with probability distributions restricting the actualization of meanings as represented in semantic space.[4] The semantic space model is a reference model for mapping a certain meaning aspect in cognitive linguistics.

Second, they can be seen as specifying necessary conditions for the validity of the outcome of

Related Content