Cognition and AI

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Understanding human cognition and reconstructing it on machines has been the initial motivation of AI. Today, only a small part of AI research is explicitly concerned with modelling natural cognition. Nonetheless engineering oriented AI cannot ignore its role model: Insights into natural cognition can inspire new algorithmic approaches and are necessary for designing helpful human-computer or human-robot interfaces for problem domains where humans and artificial systems must work together.

1 Cognitive AI: Past and Present

To grasp the mechanisms underlying cognition has been a challenge for humankind over many centuries. How does the human cognitive system realize fast and reliable perception of objects independent of illumination, scaling, orientation, and embeddeding in different contexts? How is it possible for a cognitive system to acquire a large vocabulary of words, many of them representing highly abstract concepts, and to learn to compose and understand sentences and texts in a language as complex as the natural language? How can a cognitive system be able to make decisions about actions to perform in order to achieve immediate or longterm goals based on planning and problem solving? How is a cognitive system able to draw valid conclusions about things that must hold based only on the knowledge at hand? What gives a cognitive system the power to interact socially with other cognitive systems, assigning them emotions and motives? What enables cognitive systems to work together on complex problems, formulate scientific theories and to invent helpful tools and instruments? These are only some questions which humans ask in order to get a better understanding about ourselves. Such questions were the motivation which brought together computer scientists in Dartmouth to discuss how to build an "artificial intelligence".

About the same time, a paradigm shift in psychology – the cognitive revolution – occurred and cognitive psychology became the dominant direction. Asking questions about the makings of human cognition from then on was no longer reserved to the domain of philosophy, but became a topic in a formal and engineering science (AI) and in an empirical science (psychology). That is, ideas about structures and processes underlying cognitive abilities could now be formalised and reconstructed as computer programs and tested in psychological experiments based on the framework of information processing systems (Strube & Schlieder, 1995).

Since the mid-seventies, the original epistemological motivation of AI research was replaced by more engineering oriented research. The leading goal became the construction of computer programs which are able to solve complex problems without the claim to mimic human cognitive processes. Cognitive AI, together with a sub-discipline of cognitive psychology that is concerned with building generative theories about cognition, became two of the central building blocks of the new "inter-discipline" cognitive science in the eighties (Boden, 2006). Nevertheless, human or animal cognition can be a source of inspiration in engineering oriented AI: As biological systems can give an engineer ideas about new construction principles or materials, human cognitive systems can give an AI researcher ideas for new algorithmic approaches. In analogy to bionics, just as biology inspired engineering, this cognitive inspired engineering can be termed as "psychonics". Furthermore, the more complex AI systems become, the more necessary helpful interfaces are for human-computer (or human-robot) interaction, especially in domains where humans and computers (or robots) must work together to solve complex problems. To present the "right" information in the "right" way at the "right" time, it is necessary to consider the principles and constraints of human cognition. In the following, I will give a short overview of current AI research (a) concerned with modelling human cognition, (b) borrowing ideas from natural cognition, and (c) tackling complex problems with assistance systems where humans and AI systems must collaborate.

2 Theoretical Psychology

To reach scientific insight about the structures and processes underlying natural cognitive systems, there are three methodological approaches (Strube, Habel, Hemforth, Konieczny, & Becker, 1993): formal and analytical methods can be used to describe and characterise aspects of cognitive systems and formulate general constraints; computer models can be constructed which can be seen as generative theories of cognition (see below); and (parts of) theories about human cognition can be tested in psychological experiments and explored in psychological studies. In cognitive AI, the core methodology is to create simulation models, ideally based on formal analyses of the problem domain and derived from or compared with empirical data (e.g., see the work of Ragni and Knauff in this volume).

Computer modelling of general high-level cognitive abilities and skills was the focus of early AI, with the General Problem Solver as a starting point (Newell & Simon, 1972). While originally computer modelling was seen as a means to create artificial cognitive systems (as documented in the physical symbol system hypothesis, Newell & Simon, 1976), currently a more moderate viewpoint is dominant, which, for example, is formulated by (Johnson-Laird, 1988): *Is the mind a computational phenomenon? No one knows. It may be; or it may depend on operations that cannot be captured by any sort of computer. [. . .] Theories of the mind, however, should not be confused with the mind itself, any more than theories about the weather should be confused with rain or sunshine.*