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Cognitive design for artificial minds
Lieto A., Routledge, New York, NY, 2021. 136 pp. Type: Book

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How does the human mind work? And how can we build artificial systems that display intelligent behavior? These two questions lie at the core of cognitive science and artificial intelligence (AI), respectively. While they have been treated independently from each other in the recent past, Lieto argues here that the two fields have a common history and that it is time to rebuild the bridge between cognitive science and AI.

One can distinguish artificial systems into two broad groups. Functional approaches consider a given (cognitive) task as a mere mapping between inputs and outputs. In order to solve the given task, any suitable implementation is allowed as long as it targets the overall input-output relation. Since no attention is paid to the internal structure and mechanisms used to reach this goal, systems built as part of this functional approach have, in general, only little explanatory power with respect to the human mind. The functional approach taken by contemporary AI has yielded great successes with respect to individual tasks (such as image classification or game playing), but the resulting systems are not able to generalize to other tasks, let alone provide insight into ways in which humans solve these problems. Structural approaches, on the other hand, incorporate additional constraints into their models. They try to match the internal structure of the model to the internal structure of natural systems. These kinds of approaches are commonly applied in cognitive science in order to test hypotheses about the process of human cognition.

In his book, Lieto retraces the common roots of cognitive science and AI. In order to make the distinction into structural and functional approaches more graspable, he proposes the minimal cognitive grid (MCG) as a novel evaluation tool. The MCG assesses the degree of cognitive plausibility based on three criteria: the "functional/structural ratio" describes how many components of the artificial system are built on a functional level (just caring about the input-output mapping) or on a structural basis (modeling the internal structure of natural systems); "generality" expresses to what extent the system is able to perform different tasks or simulate different cognitive functions; and, finally, the "performance match" compares the system's performance to the human performance level, taking into account execution time as well as the type of errors made. All of these criteria can be qualitative or quantitative.

Using the MCG, Lieto shows that many modern AI systems, such as IBM Watson and DeepMind's AlphaGo, follow a purely functional approach, despite being marketed as "cognitive computing systems." He furthermore illustrates that many cognitive architectures, like Soar and ACT-R, are too committed to a symbolic representation

scheme, which prevents them from storing and processing imprecise commonsense knowledge. This, however, seems to be an important property of human information processing. Lieto also argues that the MCG provides a more useful evaluation tool than the famous Turing test and other evaluation approaches from the literature, since it is less subjective and language-dependent. Looking forward, Lieto identifies several applications where a renewed collaboration of AI and cognitive science seems promising, including areas such as unsupervised machine learning and commonsense reasoning.

Lieto's book is based on similar ideas to those expressed in *Rebooting AI* by Marcus and Davis [1]. While Marcus and Davis put their emphasis on providing a strong motivation for cognitive AI to laypeople, Lieto appeals mainly to an audience of researchers from cognitive science and AI. Moreover, he focuses more on historical perspective and concrete evaluation methods for the cognitive plausibility of artificial systems. The two books can thus be seen as natural complements to each other. In my opinion, Lieto's book is a valuable resource for researchers in both AI and cognitive science. Parts of this book may well be used in courses on cognitive AI.

1)Marcus, G.; Davis, E. *Rebooting AI: building artificial intelligence we can trust*. Pantheon Books, New York, NY, 2019.

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