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Review

Intentional systems: Review of neurodynamics, modeling, and robotics implementation

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Abstract

We present an intentional neurodynamic theory for higher cognition and intelligence. This theory provides a unifying framework for integrating symbolic and subsymbolic methods as complementary aspects of human intelligence. Top-down symbolic approaches benefit from the vast experience with logical reasoning and with high-level knowledge processing in humans. Connectionist methods use bottom-up approach to generate intelligent behavior by mimicking subsymbolic aspects of the operation of brains and nervous systems. Neurophysiological correlates of intentionality and cognition include sequences of oscillatory patterns of mesoscopic neural activity. Oscillatory patterns are viewed as intermittent representations of generalized symbol systems, with which brains compute. These dynamical symbols are not rigid but flexible. They disappear soon after they emerged through spatio-temporal phase transitions. Intentional neurodynamics provides a solution to the notoriously difficult symbol grounding problem. Some examples of implementations of the corresponding dynamic principles are described in this review.

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Keywords: Intentionality; Neurodynamics; Metastability; Intermittency chaos

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> "We have now accumulated sufficient evidence to see that whatever language the central nervous system is using, it is characterized by less logical and arithmetic depth than what we are normally used to."
>
> (Von Neumann, 1958)

1. Prologue

Exploring the origin, functioning, and the very nature of human intelligence have been among the major scientific endeavors mankind has been fascinated with for millenniums. The invention of digital computers over half a century ago has drastically changed the focus of investigations into intelligence. Digital computers represent a new research tool, which potentially parallel the capabilities of brains. Von Neumann has been one of the pioneers of the new digital computing era. While appreciating the enormous potential of computers, he warned about a mechanistic parallel between brains and computers. In his last work about the relationship between computers and brains, he pointed out that the operation of brains follows principles other than the potentially very high precision of algorithms postulated by Turing machines [1], which provide a theoretical framework for the design of digital computers. Von Neumann finds it implausible that brains would use such algorithms in their operations. At higher levels of abstraction, in the last pages of his final post humus work, Von Neumann contends that the language of the brain cannot be mathematics [2]. He continues:

> "It is only proper to realize that language is a largely historical accident. The basic human languages are traditionally transmitted to us in various forms, but their very multiplicity proves that there is nothing absolute and necessary about them. Just as languages like Greek and Sanskrit are historical facts and not absolute logical necessities, it is only reasonable to assume that logics and mathematics are similarly historical, accidental forms of expression. They may have essential variants, i.e. they may exist in other forms than the ones to which we are accustomed. Indeed, the nature of the central nervous system and of the message systems that it transmits, indicate positively that this is so. We have now accumulated sufficient evidence to see that whatever language the central nervous system is using, it is characterized by less logical and arithmetic depth than what we are normally used to."
>
> (Von Neumann, 1958)