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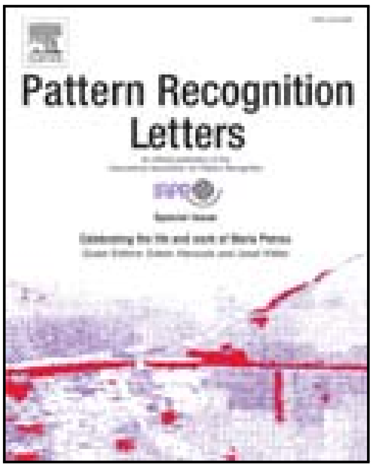

Computation and dissipative dynamical systems in neural networks for classification

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Research Highlights (Required)

- Neural models of classification provide new tools to study foundational issues.
- Induction is possible but requires given forms of structure and representation.
- Models of cognition are based on a relation between dynamics and computation.
- Open and dissipative dynamical systems are needed for cognition.
- Neural networks of the brain are maximally open and dissipative dynamical systems.

Computation and dissipative dynamical systems in neural networks for classification

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ABSTRACT
Foundational issues related to learning, processing and representation underlying pattern recognition have been discussed in history and in recent times. The scientific approach to pattern recognition could provide new tools to investigate these foundational issues, which in turn could inform the scientific approach to pattern recognition as well. One such tool could be the analysis of learning, processing and representation in connectionist (or neural) networks, which have been extensively used for pattern recognition. Based on a mathematical analysis of the classification behavior of feedforward networks an analysis is given of the empiricist versus rationalist debate on the possibility or impossibility of induction. The analysis aims to show that forms of induction are possible but not without certain given forms of structure and representation. The analysis is then extended to cover the role of representation in pattern recognition, and the nature of the underlying forms of processing, aiming to show that models of cognition derive from a specific relation between dynamics and computation. These examples illustrate that an interaction between modeling and the discussion on foundational issues could be beneficial for both and could open new avenues in the philosophical and foundational debate not available in previous times.

1. Introduction

Foundational issues related to pattern recognition and learning have been topics of debate since the beginning of philosophy. But with the development of the computer, they have also turned into topics of scientific research.

The transition from philosophy to science is not unique for pattern recognition and learning. Similar transitions have occurred in astronomy, physics and other sciences. Yet, compared to these sciences, foundational issues related to pattern recognition still remain to be debated in a philosophical way as well. This could be because they concern the nature of human cognition. An example is the debate between rationalism, and the related notion of nativism, and empiricism. The debate can be traced back to antiquity (Plato) but is still a controversial issue today (e.g., Piattelli-Palmarini, 1980).

Here I aim to argue and illustrate that the scientific approach to pattern recognition can provide new information to influence the philosophical debate on foundational issues. In turn, this could inform the scientific approach to pattern recognition as well.

As an example, consider the role of induction in epistemology and philosophy of science. Induction can be seen as a key notion in the history of empiricism, ranging from Bacon in the 16th century to (logical) positivism, behaviorism and (part of) connectionism in the 20th and 21st century. The basic tenet of empiricism, as exemplified in epistemology and philosophy of science, is that we acquire knowledge exclusively through experience. Using induction, we can generalize our experience to arrive at law-like regularizations and categorizations. In turn, these can be used to explain our experiences (e.g., as belonging to a given category) or to predict new experiences. However, although induction provides categorizations and law-like regularities, these are entirely based on experience according to empiricism. No innate forms of knowledge would be needed.

According to rationalism this view on induction is untenable. An argument against it is given by the Goodman paradox (e.g., Chomsky & Fodor, 1980). A simple example of this paradox was given by Hempel (Chomsky & Fodor, 1980). Consider a set of observations relating two variables. Assume that they can be plotted as a set of points in a two dimensional space, with one variable on the x-axis and the other on the y-axis, and that the points can be linked by a linear line. The question is whether this linear line is an induction provided solely on the basis of the set of points itself. The argument of the Goodman paradox is that this cannot be the case, because the linear line linking the points is just one of the choices that could be made. Another choice, for example, would be a sinusoidal curve linking the points in an oscillatory manner. The choice between these two (and other) options cannot be based on the data alone. Instead, it derives from a prejudice that precedes the induction (for example, the prejudice to choose the more 'simple' curve).

In other words, induction is impossible without some set of prejudices that precede it. This view underlies the reintroduction of rationalism (and with it nativism) in cognitive science in the 20th century, as exemplified by the notion that the structure of human