Teaching machines to spot essential information in physical systems

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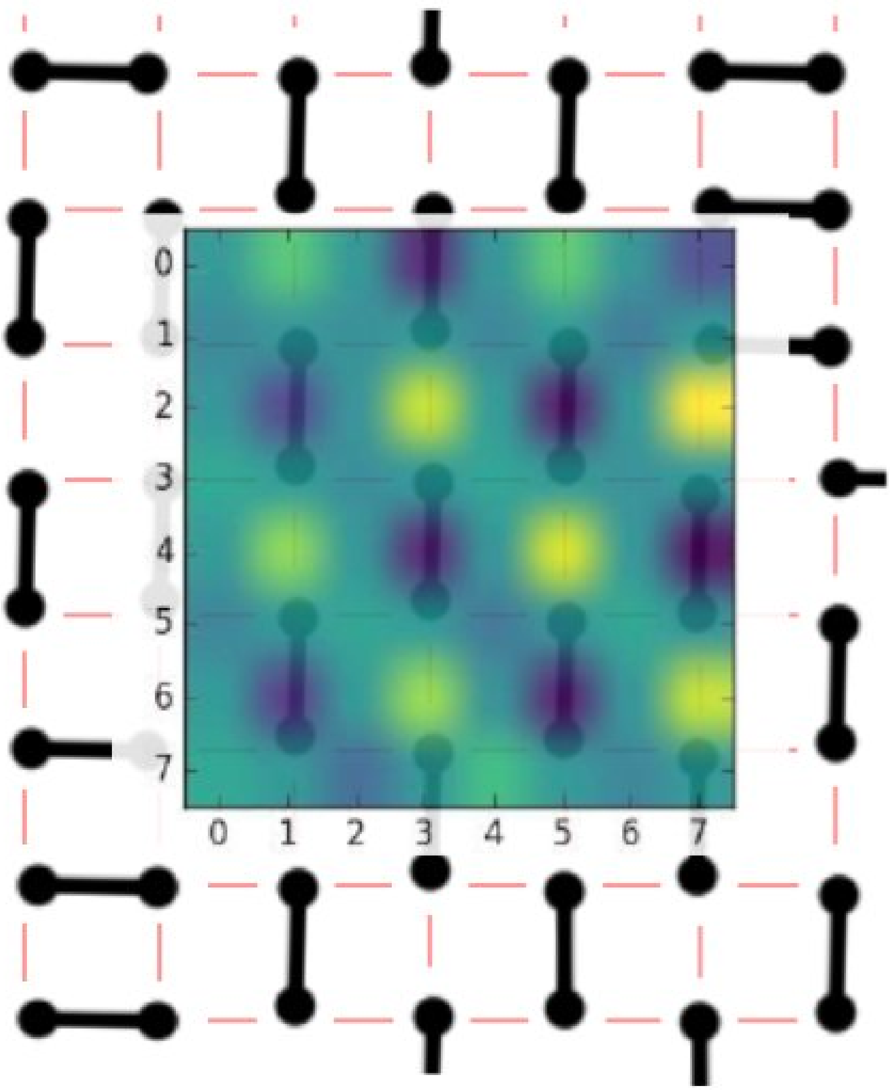

The output of the algorithms of Koch-Janusz and Ringel (in color) overlapped with the pattern of the underlying dimer model (in black) on a two-dimensional lattice (indicated in red). The algorithm extracts the relevant physical entities without any prior knowledge of the connectivity pattern. Credit: Maciej Koch-Janusz & Zohar Ringel

Two physicists at ETH Zurich and the Hebrew University of Jerusalem have developed a novel machine-learning algorithm that analyses large data sets describing a physical system and extract from them the essential information needed to understand the underlying physics.

Over the past decade, machine learning has enabled groundbreaking advances in computer vision, speech recognition and translation. More recently, machine learning has also been applied to physics problems, typically for the classification of physical phases and the numerical simulation of ground states. Maciej Koch-Janusz, a researcher at the Institute for Theoretical Physics at ETH Zurich, Switzerland, and Zohar Ringel of the Hebrew University of Jerusalem, Israel, have now explored the exciting possibility of harnessing machine learning not as a numerical simulator or a "hypothesis tester," but as an integral part of the physical reasoning process.

One important step in understanding a physical system consisting of a large number of entities—for example, the atoms making up a magnetic material—is to identify among the many degrees of freedom of the system those that are most relevant for its physical behaviour. This is traditionally a step that relies heavily on human intuition and experience. But now, Koch-Janusz and Ringel demonstrate a machine-learning algorithm based on an artificial neural network that is capable of doing just that, as they report in the journal *Nature Physics*. Their algorithm takes data about a physical system without any prior knowledge about it and extracts those degrees of freedom that are most relevant to describe the system.

Technically speaking, the machine performs one of the crucial steps of one of the conceptually most profound tools of modern theoretical physics, the so-called renormalization group. The algorithm of Koch-Janusz and Ringel provides a qualitatively new approach: the internal data representations discovered by suitably designed machine-learning systems are often considered to be obscure, but the results yielded by their algorithm provide fundamental physical insight, reflecting the underlying structure of physical system. This raises the prospect of employing machine learning in science in a collaborative fashion, combining the power of machines to distil information from vast data sets with human creativity and background knowledge.

More information: Koch-Janusz M, Ringel Z. Mutual information, neural networks and the renormalization group. *Nature Physics*, (2018). DOI: 10.1038/s41567-018-0081-4

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