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Tiansi Dong

A Geometric Approach to the Unification of Symbolic Structures and Neural Networks

Springer

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The Sixth Law of Cognition: Spatial thinking is the foundation of abstract thought.

—Barbara Tversky (2019) p. 72, p. 142

to Elias, Sophia, Peiling, and my parents

Preface

It takes decades to edit a dictionary, to explain each word in terms of other words, and with examples. Alternatively, the neural approach simply learns a vector for each word from texts. We may encounter a new word that is not in our dictionary, but with the neural approach, we can always have a vector of this new word, search its neighbours in vector space, and guess the meaning (without guarantee). Neural-networks (Deep learning) are robust to noisy inputs, able to learn at a level of approximation from enough high-qualified data, but lack of explainability. In contrast, symbolic systems have a set of manually designed rules. This makes outputs explainable and the results guaranteed, but inputs are not robust to noisy inputs. Do the two kinds of systems talk about the same thing ("human intelligence")? Neural people hope this, struggle for decades to design elegant neural-networks that can reach symbolic levels of reasoning, and land at a certain level of approximation. Would they change next year? To answer this question, we designed a very simple experiment. Given a manually edited dictionary that only has tree structured category relation among words, and given vectors of these words provided by well-designed neural-networks, what kinds of mechanism can let these vectors precisely encode the given tree structure? The mechanism that we found is to blow these vectors into balloons in higher dimensional space, so that spatial inclusion relations among balloons could precisely encode tree structured category relations. For symbolists, the configuration of these balloons is a spatial semantics of the tree structure. It seems hard for neural people to change next year, if they restrict vectors as processing objects of neural-networks and fix the dimension of outputs. In a survey of the neural-symbol debates in the literature, we found that the mechanism that we found is an open chapter to solve many questions raised in the debates. Without reservation, we collect these observations in this book, hoping that this could activate symbolists and promote the joint research with Deep learning researchers.

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Tiansi Dong

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