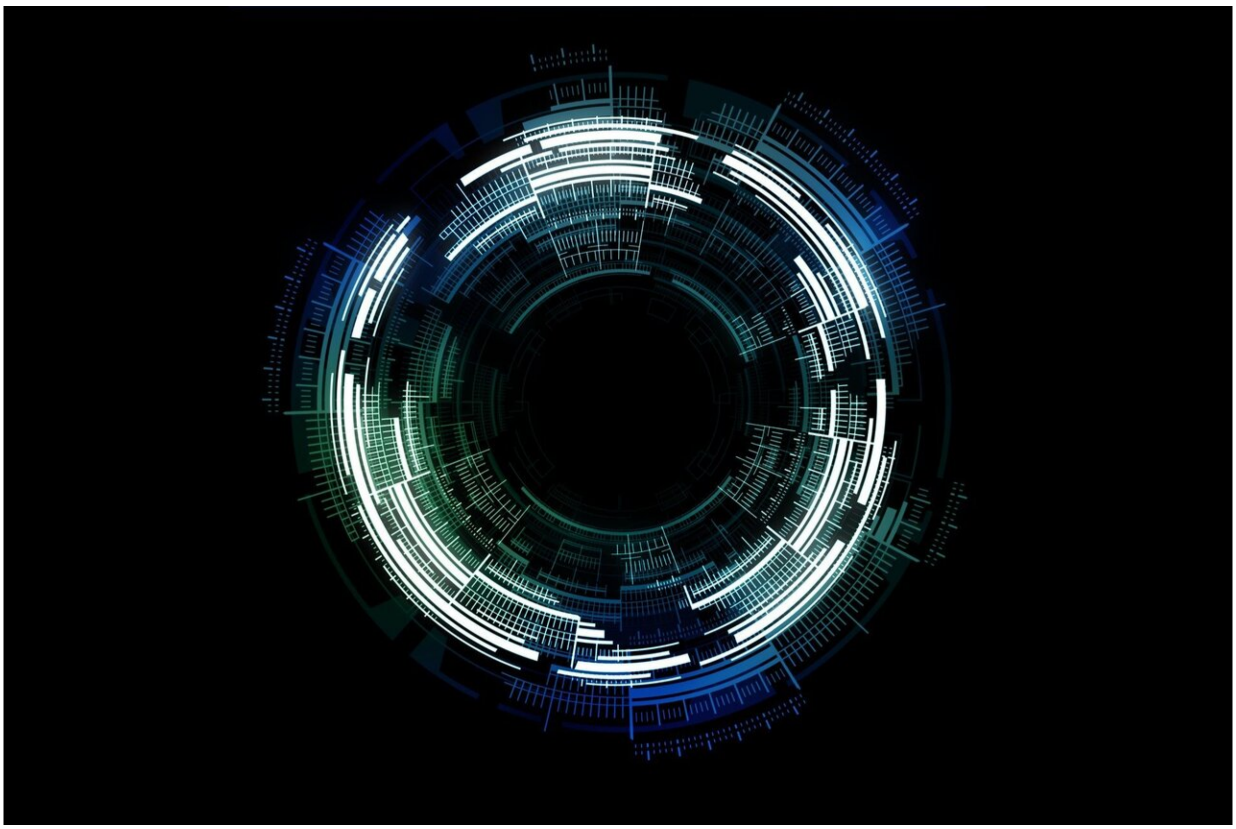
Deep learning outperforms standard machine learning in biomedical research applications, research shows

January 14 2021, by Jennifer Rainey Marquez



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Compared to standard machine learning models, deep learning models are largely superior at discerning patterns and discriminative features in brain imaging, despite being more complex in their architecture, according to a new study in *Nature Communications* led by Georgia State University.

Advanced biomedical technologies such as structural and functional magnetic resonance imaging (MRI and fMRI) or genomic sequencing have produced an enormous volume of data about the human body. By extracting patterns from this information, scientists can glean new insights into health and disease. This is a challenging task, however, given the complexity of the data and the fact that the relationships among types of data are poorly understood.

Deep learning, built on advanced neural networks, can characterize these relationships by combining and analyzing data from many sources. At the Center for Translational Research in Neuroimaging and Data Science (TReNDS), Georgia State researchers are using deep learning to learn more about how mental illness and other disorders affect the brain.

Although deep learning models have been used to solve problems and answer questions in a number of different fields, some experts remain skeptical. Recent critical commentaries have unfavorably compared deep learning with standard machine learning approaches for analyzing brain imaging data.

However, as demonstrated in the study, these conclusions are often based on pre-processed input that deprive deep learning of its main advantage—the ability to learn from the data with little to no preprocessing. Anees Abrol, research scientist at TReNDS and the lead author on the paper, compared representative models from classical machine learning and deep learning, and found that if trained properly, the deep-learning methods have the potential to offer substantially better results, generating superior representations for characterizing the human brain.

"We compared these models side-by-side, observing statistical protocols so everything is apples to apples. And we show that deep learning models perform better, as expected," said co-author Sergey Plis, director of machine learning at TReNDS and associate professor of computer science.

Plis said there are some cases where standard machine learning can outperform deep learning. For example, diagnostic algorithms that plug in single-number measurements such as a patient's body temperature or whether the patient smokes cigarettes would work better using classical machine learning approaches.

"If your application involves analyzing images or if it involves a large array of data that can't really be distilled into a simple measurement without losing information, deep learning can help," Plis said.. "These models are made for really complex problems that require bringing in a lot of experience and intuition."

The downside of deep learning models is they are "data hungry" at the outset and must be trained on lots of information. But once these models are trained, said co-author Vince Calhoun, director of TReNDS and Distinguished University Professor of Psychology, they are just as effective at analyzing reams of complex data as they are at answering simple questions.

"Interestingly, in our study we looked at sample sizes from 100 to 10,000 and in all cases the deep learning approaches were doing better," he said.

Another advantage is that scientists can reverse analyze deep-learning models to understand how they are reaching conclusions about the data. As the published study shows, the trained deep learning models learn to identify meaningful brain biomarkers.

"These models are learning on their own, so we can uncover the defining characteristics that they're looking into that allows them to be accurate," Abrol said. "We can check the data points a model is analyzing and then compare it to the literature to see what the model has found outside of where we told it to look."

The researchers envision that deep learning models are capable of extracting explanations and representations not already known to the field and act as an aid in growing our knowledge of how the human brain functions. They conclude that although more research is needed to find and address weaknesses of deep-learning models, from a mathematical point of view, it's clear these models outperform standard machine learning models in many settings.

"Deep learning's promise perhaps still outweighs its current usefulness to neuroimaging, but we are seeing a lot of real potential for these techniques," Plis said.

More information: Anees Abrol et al. Deep learning encodes robust discriminative neuroimaging representations to outperform standard machine learning, *Nature Communications* (2021). DOI: 10.1038/s41467-020-20655-6

Provided by Georgia State University