Sensory-Motor Learning by Deep Neural Networks: From the Viewpoint of Cognitive Developmental Robotics

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Traditional conceptions of artificial intelligence are based on a deductive approach, whereby the machine works with models created by human designers in terms of low-dimensional parameters. As such, the way it works is fully intelligible to humans. In contrast, deep learning performs inductive inference, generating its own models based on vast amounts of high-dimensional data. Its workings are thus often unintelligible to humans.

Deep learning is a machine learning method implemented with an artificial neural network, comprised of multiple layers of “neurons”. Each of these neurons “spikes” when the sum of weighted inputs from those in the preceding layer reaches a threshold, and sends an output to the succeeding layer. This process, involving multiple “deep” layers, is how the deep learning program performs calculations and obtains solutions. It also uses what is known as “backpropagation of error”, whereby the weight assigned to each input is adjusted according to the errors made in the final output.

In robotics, one of the ways in which deep learning can be used is to give robots an ability to imitate and predict. This can enable robots to perform a wider range of actions than has previously been possible. In this “imitation and prediction learning”, humans demonstrate an action as would be experienced by the actual robot performing it. The robot then seeks to imitate the action by predicting each next step in terms of visual and kinesthetic experiences and executes an autonomous (predictive) learning algorithm. This has enabled robots, for instance, to fold towels, open and go through doors, and measure powders and liquids such as medicines.

So will deep learning bring about the ‘singularity’? Will artificial intelligence learn to fall in love? For such to happen, I believe that there need to be multiple additional revolutionary innovations of equal magnitude to deep learning, which is a fundamental technology in its early stage of development. Deep learning today, in fact, appears to be where personal computers and the internet were at their inception.

One idea that is often raised about deep learning is that it is a “black box”, whose internal workings cannot be fully grasped from the outside. In considering this issue, now being debated in forums involving legal scholars and other experts, we may take a similar approach to how we have treated service dogs, which can also be likened to black boxes but are now in common use.

Lastly, regarding the possibility of AI programs coming to equal or surpass humans, there are two vastly different approaches to minimizing the associated risks. The Asilomar AI Principles, developed in the United States, require potent artificial intelligence to be placed under strict surveillance, whereas the Japanese Society for Artificial Intelligence's Code of Ethics states that AI must follow the same guidelines as its fellow (human) members.