Artificial intelligence—cogito, ergo sum

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Artificial intelligence (AI) uses machine learning algorithms to simulate human cognition in the analysis and comprehension of complex data. Specifically, AI is the ability of computer algorithms to learn and generate conclusions based on a ground truth input of data or, in some advanced cases, self-generating analysis. Conceptually, artificial neural network is patterned after the brain's neural network and uses multiple layers of information to learn how to understand data. These thinking machines have vast potential for rapid and precise pattern recognition, to approximate conclusions, or to provide guidance to aid in the diagnostic, prognostic, and dispensing of therapeutics in medicine. AI is of particular relevance given the rapid expansion of clinical knowledge, which is estimated by IBM to double every 18 months and is on a trajectory of doubling every 12 hours with the growth of the internet. Morning reading of journal articles is no longer sufficient to keep up with the latest advances in your field. The expansion of clinical data and knowledge requires a revolutionary intermediary to help synthesize this data to provide guidance in seconds or real-time diagnostics and future prognostics.

The concept of “thinking machines” dates back to ancient Greek mythology. Automaton were described as animated metal statues of men and monsters crafted by the divine smith Hephaistos and the Athenian craftsman Daidalos. These automaton were thinking machines mimicking human cognition. The beginnings of modern AI can be traced to classical philosophers' attempts to describe human thinking as a symbolic system. In 1950, Alan Turing first described the concept of using computers to simulate intelligent behavior and critical thinking. He described a simple, but now disputed, test known as the “Turing test,”

to determine whether computers were capable of human intelligence [1]. The term Artificial Intelligence was first coined in 1956, at a conference at Dartmouth College, in Hanover, New Hampshire [2]. Research in the 1960s and 1970s generated the first problem-solving program, known as Dendral designed for applications in organic chemistry [3]. Dendral provided the basis for a subsequent system MYCIN which was one of the most important early uses of artificial intelligence in medicine [4].

In the beginning, enthusiasm increased about this new field's potential with the press's inevitable hyping of AI utility. However, disappointments in its application created a quiet era or “AI winter.” The first AI winter started around 1973 with the arrival of a critical report by Lighthill for the British Research Council [5]. Hope for modern AI came in the 1980s and 1990s through a remarkable increase in connectivity with the proliferation of the microcomputer. Additionally, the development of new approaches involving logic theory, fuzzy logic, Bayesian networks, and artificial neural networks resulted in new tools for AI implementation. During this time, there was a recognition that AI systems in healthcare must take into account imperfect data and build on the expertise of the clinician. AI algorithms must be guided or taught. In the early 2000s, many of these limitations were overcome by the advent of deep learning, initiating the term “Deep Medicine.”

Deep Learning (DL) uses layers of sub-algorithms to process data. Information is passed through each layer of the DL architecture, with the previous layer's output providing input for the next layer. The first layer in the network is called the input layer which contains input neurons, while the last is referred to as the output layer. The middle or hidden layers or neurons create weights to scale the effect of one neuron on another similar to the logical, and sometimes illogical, network of interactions in the human brain. This architecture can recognize patterns in behavior and create its own logic. The basis of deep learning began with integrating neural networks with multiple pooling or down sampling and convolutional layers in a hierarchical multilayered design

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inspired by the biological processes in the animal visual cortex. This design allowed the computer to “learn” and recognize patterns. With the development of backpropagation techniques, DL algorithms could use error propagation to correct and train. By 2011, the speed and memory of graphical processor units (GPUs) had increased significantly. This enabled training of deep neural networks using large data sets “without” the need for layer-by-layer pre-training. GPUs also allowed for the implementation of three-dimensional DL constructs more closely mimicking the human brain. With the increased computing speed, it became apparent that Deep Learning had significant advantages in efficiency and speed over human cognition.

To gain valuable insights and predictions, DL models must train with extensive amounts of input data. Once taught, these programs become powerful tools for diagnosis and treatment protocols, drug development, and personalized medicine by recognizing patterns and predicting behavior. Technologies, such as IBM Watson, are being used to leverage millions of medical reports, patient records, clinical trials, and medical journals to reveal data insights. New uses in deep learning structures are evolving toward not only pattern recognition, but complex signal recognition in a confounding background. For example, our group uses what would be closer to DL speech recognition in a crowded room, rather than image recognition, to identify molecular signatures from Raman spectroscopy interrogation of biological specimens. This has advanced applications ranging from pathogen and antimicrobial resistance identification to determining the boundary of a glioblastoma tumor during surgery [6]. In glioblastoma, tumor constituents, such as specific lipid and protein content, are readily elucidated. These biomolecular signatures can clearly differentiate normal from cancerous tissue but become subtle

at the tumor boundary. Visual presentations of tumor margins during surgery are problematic, but a Raman spectroscopy probe using Deep Learning can discern these subtle differences in milliseconds providing a Geiger counter-like feedback of malignant infiltration to the surgeon in real time. This type of guidance could have a profound impact on patient outcomes and the future of medicine. However, one word of caution on this revolutionary journey is the old adage “garbage in, garbage out.”

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