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Artificial Intelligence in Medical Practice: The Question to the Answer?

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ABSTRACT

Computer science advances and ultra-fast computing speeds find artificial intelligence (AI) broadly benefitting modern society—forecasting weather, recognizing faces, detecting fraud, and deciphering genomics. AI's future role in medical practice remains an unanswered question. Machines (computers) learn to detect patterns not decipherable using biostatistics by processing massive datasets (big data) through layered mathematical models (algorithms). Correcting algorithm mistakes (training) adds to AI predictive model confidence. AI is being successfully applied for image analysis in radiology, pathology, and dermatology, with diagnostic speed exceeding, and accuracy paralleling, medical experts. While diagnostic confidence never reaches 100%, combining machines *plus* physicians reliably enhances system performance. Cognitive programs are impacting medical practice by applying natural language processing to read the rapidly expanding scientific literature and collate years of diverse electronic medical records. In this and other ways, AI may optimize the care trajectory of chronic disease patients, suggest precision therapies for complex illnesses, reduce medical errors, and improve subject enrollment into clinical trials.

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KEYWORDS: Analytics; Artificial intelligence; Big data; Chronic disease; Deep learning; Electronic medical record; Machine learning; Medical imaging; Natural language processing; Neural networks; Precision medicine

In 1936, mathematician Alan Turing published *On Computable Numbers, With an Application to the Entscheidungsproblem*, a paper later dubbed "*the founding document of the computer age.*"[1] Turing's life was reprised in the 2014 film, *The Imitation Game*. Attempting to solve the *Entscheidungsproblem*, Turing and his Princeton colleague, Alonzo Church, used calculus to define the concept of "*effective calculability.*" Such intelligent human problem-solving became the basis of computational models called algorithms.

In 1943, neurophysiologist Warren McCulloch and mathematician Walter Pitts modeled brain neuronal interactions using a simple neural network made of electrical circuits. The first computer research with artificial neural networks was done in the 1950s by Nathanial Rochester at International Business Machines (IBM), and Bernard Widrow and Marcian Hoff at Stanford. Today's computer scientists apply multilayered algorithms using a variety of artificial neural network configurations to solve complex problems. Modern artificial neural networks represent one of the most active areas of artificial intelligence (AI) research.

In 1964, television guru Merv Griffin invented *Jeopardy!*, America's third-longest running game show. In 2011, a supercomputer named for IBM's first chief executive, Thomas J. Watson, used AI to defeat 2 very intelligent humans in an exhibition match culminating with the correct response to this question: "*Which author's most famous novel was inspired by William Wilkinson's 'An Account of the Principalities of Wallachia and Moldavia'?*" (Answer: Bram Stoker's *Dracula*).

ANSWERABLE QUESTIONS

Some questions about AI's role in modern society have been answered:

Why has AI emerged as useful in several diverse sectors (business, science, government)?

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How does AI differ from standard biostatistics?
What is "*big data*"? How does AI enable big dataset analysis?
How do AI applications differ from smart technologies (medical devices, digital diagnostics, data management systems) already used in medical practice?

INSIDE AI'S BLACK BOX

While AI encompasses a wide range of symbolic and statistical approaches to learning and reasoning (**Figure**), recent advances in algorithms, computational power, and access to large datasets have enabled artificial neural networks to emerge as the leading AI method. Artificial neural networks are flexible mathematical models that use multiple algorithms to identify complex nonlinear relationships within large datasets (analytics). Machines learn when errors encountered in response to minor algorithm modifications are corrected (training), progressively improving predictive model accuracy (confidence).[2]

Deep learning uses ultra-fast computing to rapidly optimize large multilayered datasets organized in a variety of configurations, including filter layers as convolutional neural networks and recursive layers as recurrent neural networks. Deep learning has been applied commercially since the 1990s,[3] and while modern math is similar to that employed in the 1980s, supercomputer speeds and Cloud networking permit deconvolution of massive datasets. In 2006, Hinton et al introduced a novel method to train very deep neural networks by pretraining one hidden algorithm layer at a time using an unsupervised machine learning procedure[4] and Bengio et al validated Hinton's work with test data and used it with other unsupervised techniques such as auto-encoders.[5]

Ten years later, deep learning modeling of big datasets exerts major influences on modern society—from Web searching to social media networking, and from financial technology banking to facial recognition.[3] Advanced algorithms achieve acceptable performance with ~5000 data points per category, and exceed human performance with datasets of >10 million labeled examples.[2] The bigger the dataset, the easier it is for machines to learn (gain confidence) because the burden of standard biostatistical estimation is reduced.[2] Despite this, like human thinking, predictive model confidence never reaches 100%.

CLINICAL SIGNIFICANCE

- Artificial intelligence (AI) medical image analysis achieves diagnostic speed exceeding, and accuracy paralleling, experts.
- AI will impact medical practice by applying natural language processing to "read" the expanding scientific literature and collate diverse electronic medical records.
- Machines learning directly from medical data could avert clinical errors due to human cognitive biases, positively impacting patient care.
- Because AI is neither astute nor intuitive, physicians will remain essential to cognitive medical practice.

THE AI UNIVERSE

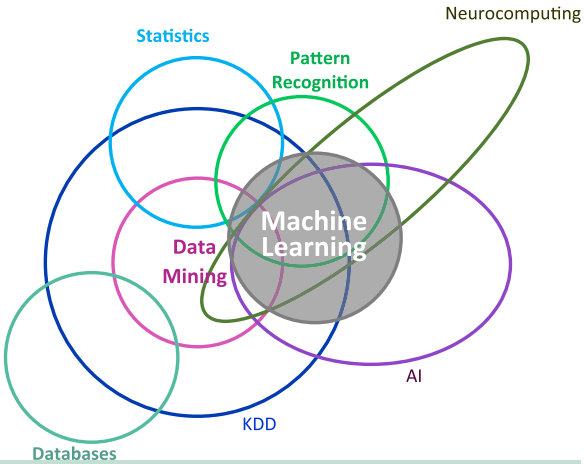

Figure In the computation science universe, artificial intelligence (AI) is distinguished from standard statistics and databases, but overlaps with knowledge discovery and data mining (KDD) methodologies that extract useful insights from large datasets. The mathematics of pattern recognition (kernel machines, cluster analysis) overlaps significantly with machine learning edge-detection algorithms and with neurocomputing based on artificial neural networks. The area of machine learning outside AI and within statistics/pattern recognition is linear regression analysis.

WORKS IN PROGRESS

Questions remain about the applicability, practicality, and value of AI in medical practice:

How is AI use in medical practice distinguished from big data analytics applications for health care delivery and population health?
Can AI address medical practice "*pain points*," providing more efficient and efficacious care while de-escalating physician burnout?
Will AI improve patient outcomes when used at the point of care?
Can Internet-of-Things health care facilities and medical homes become a platform for safer, higher quality, more connected patient care?

USE CASES FOR COGNITIVE MEDICAL PRACTICE

Simple neural networks have been used in medicine since the early 1990s to interpret electrocardiograms,[6] diagnose myocardial infarction,[7] and predict intensive care unit length of