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ARTIFICIAL INTELLIGENCE AND MEDICAL SCIENCE: A SURVEY

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***Abstract*—** Tech titans like Google, Amazon, Microsoft, and Apple already have made huge investments in artificial intelligence to deliver tailored search results and build virtual personal assistants. Now, that approach is starting to trickle down into health care, thanks in part to the push under the health reform law to leverage new technologies to improve outcomes and reduce costs–and to the availability of cheaper and more powerful computers. In an effort to better treat their patients, doctors are now exploring the use of everything from IBM's Watson supercomputer, the machine that won at *Jeopardy*, to iPhone-like pop-up notifications that appear in your online medical records.

Keywords— Artificial Intelligence, Genetic Engineering, Induction algorithm, Expert and Knowledge based system

1. INTRODUCTION

From the very earliest moments in the modern history of the computer, scientists have dreamed of creating an 'electronic brain'. Of all the modern technological quests, this search to create artificially intelligent (AI) computer systems has been one of the most ambitious and, not surprisingly, controversial .It also seems that very early on, scientists and doctors alike were captivated by the potential such a technology might have in medicine. With intelligent computers able to store and process vast stores of knowledge, the hope was that they would become perfect 'doctors in a box', assisting or surpassing clinicians with tasks like diagnosis. With such motivations, a small but talented community of computer scientists and healthcare professionals set about shaping a research program for a new discipline called Artificial Intelligence in Medicine (AIM). These researchers had a bold vision of the way AIM would revolutionise medicine, and push forward the frontiers of technology. Artificial intelligence is still in the very early stages of development–in so many ways, it can't match our own intelligence–and computers certainly can't replace doctors at the bedside. But today's machines are capable of crunching vast amounts of data and identifying patterns that humans can't. Artificial intelligence–essentially the complex algorithms that analyze this data–can be a tool to take full advantage of electronic medical records, transforming them from mere e-filing cabinets into full-fledged doctors' aides that can deliver clinically relevant, high-quality data in real time. "Electronic health records [are] like large quarries where there's lots of gold, and we're just beginning to mine them," said Dr. Eric Horvitz, who is the managing director of Microsoft Research and specializes in applying artificial intelligence in health care settings.

Increasingly, physician practices and hospitals around the country are using supercomputers and homegrown systems to identify patients who might be at risk for kidney failure, cardiac disease, or postoperative infections, and to prevent hospital re-admissions, another key focus of health reform. And they're starting to combine patients' individual health data–including genetic information–with the wealth of material available in public databases, textbooks, and journals to help come up with more personalized treatments.

Medical artificial intelligence is primarily concerned with the construction of AI programs that perform diagnosis and make therapy recommendations. Unlike medical applications based on other programming methods, such as purely statistical and probabilistic methods, medical AI programs are based on symbolic models of disease entities and their relationship to patient factors and clinical manifestations [1].

2. IS AI EQUIVALENT TO HUMAN INTELLIGENCE?

How will we know when a computer program has achieved an equivalent intelligence to a human? Is there some set of objective measures that can be assembled against which a computer program can be tested? Alan Turing was one of the founders of modern computer science and AI.When he came to ponder this question, he brilliantly side-stepped the problem almost entirely.

In his opinion, there were no ultimately useful measures of intelligence. It was sufficient that an objective observer could not tell the difference in conversation between a human and a computer for us to conclude that the computer was intelligent. To cancel out any potential observer biases, Turing's test put the observer in a room, equipped with a computer keyboard and screen, and made the observer talk to the test subjects only using these. The observer would engage in a discussion with the test subjects using the printed word, much as one would today by exchanging e-mail with a remote colleague. If a set of observers could not distinguish the computer from another human in over 50% of cases, then Turing felt that one had to accept that the computer was intelligent.

Another consequence of the Turing test is that it says nothing about how one builds an intelligent artefact, thus neatly avoiding discussions about whether the artefact needed to in anyway mimic the structure of the human brain or our cognitive processes. It really didn't matter how the system was built in Turing's mind. Its intelligence should only to be assessed based upon its overt behaviour [2].

3. ARTIFICIAL INTELLIGENCE ALGORITHMS

AI systems can be divided into two broad categories: knowledge representation systems and machine learning systems. Knowledge representation systems, also known as expert systems, provide a structure for capturing and encoding the knowledge of a human expert in a particular domain. For example, the knowledge of medical doctors might be captured in a computerized model that can be used to help diagnose patient illnesses.

The second category of AI, machine learning systems, creates new knowledge by finding previously unknown patterns in data. In contrast to knowledge representation approaches, which model the problem-solving structure of human experts, machine learning systems derive solutions by "learning" patterns in data, with little or no intervention by an expert. There are three main machine learning techniques: neural networks, induction algorithms, and genetic algorithms [4].

3.1 NEURAL NETWORKS

Neural networks are composed of richly connected sets of neurons forming layers. The neural network architecture consists of an input layer, which inputs data to the network; an output layer, which produces the resulting guess of the network; and a series of one or more hidden layers, which assist in propagating. This is illustrated in Figure 1.

During processing, each neuron performs a weighted sum of inputs from the neurons connecting to it; this is called activation. The neuron chooses to fire if the sum of inputs exceeds some previously set threshold value; this is called transfer.

Inputs with high weights tend to give greater activation to a neuron than inputs with low weights. The weight of an input is analogous to the strength of a synapse in a biological system. In biological systems, learning occurs by strengthening or weakening the synaptic connections between nerve cells. An artificial neural network simulates synaptic connection strength by increasing or decreasing the weight of Neural networks are trained with a series of data points. The networks guess which response should be given, and the guess is compared against the correct answer for each data point. If errors occur, the weights into the neurons are adjusted and the process repeats itself. This learning approach is called backpropagation, and is similar to statistical regression.

Neural networks are used in a wide variety of business problems, including optical character recognition, financial forecasting, market demographics trend assessment, and various robotics applications[4].

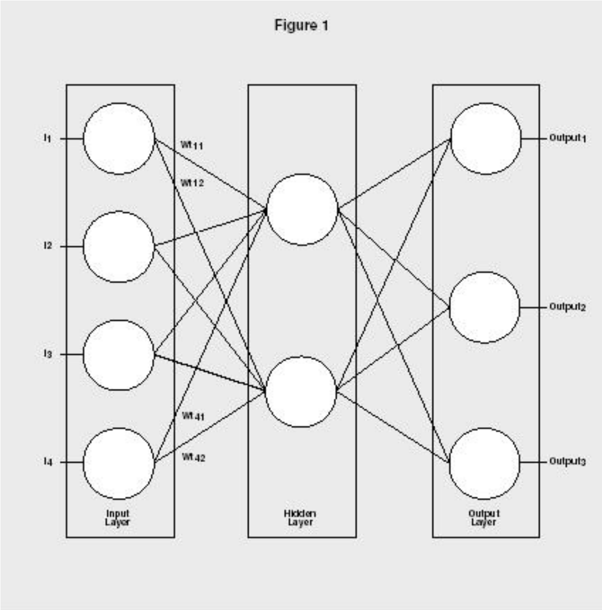

Figure1: Graphical representation of Nueral Networks

3.2 INDUCTION ALGORITHMS

Induction algorithms form another approach to machine learning. In contrast to neural networks, which are highly mathematical in nature, induction approaches tend to involve symbolic data. As the name implies, these algorithms work by implementing inductive reasoning approaches. Induction is a reasoning method that can be characterized as "learning by example." Unlike rule-based deduction, induction begins with a set of observations and constructs rules to account for these observations. Inductive reasoning attempts to find general patterns that can fully explain the observations. The system is presented with a large set of data consisting of several input variables and one decision variable. The system constructs a decision tree by recursively partitioning data sets based on the variables that best distinguish between the data elements. That is, it attempts to partition the data so that each partition contains data with the same value for a decision variable. It does this by selecting the input variables that do the best job of dividing the data set into homogeneous partitions [4].

3.3 GENETIC ALGORITHMS

Genetic algorithms use an evolutionary approach to solve optimization problems. These are based on Darwin's theory of evolution, and in particular the notion of survival of the fittest. Concepts such as reproduction, natural selection, mutation, chromosome, and gene are all included in the genetic algorithm approach.

Genetic algorithms are useful in optimization problems that must select from a very large number of possible solutions to a problem. A classic example of this is the traveling salesperson problem. Consider a salesman who must visit n cities. The salesperson's problem is to find the shortest route by which to visit each of these n cities exactly once, so that the salesman will tour all the cities and return to the origin. For such a problem there are $(n - 1)!$ possible solutions, or $(n - 1)$ factorial. For six cities, this would mean $5 \times 4 \times 3 \times 2 \times 1 = 120$ possible solutions. Suppose that the salesman must travel to 100 cities. This would involve 99! possible solutions. This is such an astronomical number that if the world's most powerful computer began solving such a problem at the time that the universe had begun and worked continuously on it since, it would be less than one percent complete today. Obviously, for this type of problem a brute strength method of exhaustively comparing all possible solutions will solutions will not work. This requires the use of heuristic methods, of which the genetic algorithm is a prime example. For the travelling salesperson problem, a chromosome would be one possible route through the cities, and a gene would be a city in a particular sequence on the chromosome. The genetic algorithm would start with an initial population of chromosomes (routes) and measure each according to a fitness function (the total distance travelled in the route). Those with the best fitness functions would be selected and those with the worst would be discarded. Then random pairs of surviving chromosomes would mate, a process called crossover. This involves swapping city positions between the pair of chromosomes, resulting in a pair of child chromosomes. In addition, some random subset of the population would be mutated, such that some portion of the sequence of cities would be altered. The process of selection, crossover, and mutation results in a new population for the next generation. This procedure is repeated through as many generations as necessary in order to obtain an optimal solution.

Genetic algorithms are very effective at finding good solutions to optimization problems. Scheduling, configuration, and routing problems are good candidates for a genetic algorithm approach. Although genetic algorithms do not guarantee the absolute best solution, they do consistently arrive at very good solutions in a relatively short period [4].

4. AI SUPPORT BOTH CREATION AND USE OF MEDICAL KNOWLEDGE

Human cognition is a complex set of phenomena, and AI systems can relate to it in two very different ways. Proponents of so-called 'strong' AI are interested in creating computer systems whose behaviour is at some level indistinguishable from humans . Success in strong AI would result in computer minds that might reside in autonomous physical beings like robots, or perhaps live in 'virtual' worlds like the information space created by something like the Internet.

An alternative approach to strong AI is to look at human cognition and decide how it can be supported in complex or difficult situations. For example, a fighter pilot may need the help of intelligent systems to assist in flying an aircraft that is too complex for a human to operate on their own. These 'weak' AI systems are not intended to have an independent existence, but are a form of 'cognitive prosthesis' that supports a human in a variety of tasks.

AIM systems are by and large intended to support healthcare workers in the normal course of their duties, assisting with tasks that rely on the manipulation of data and knowledge. An AI system could be running within an electronic medical record system, for example, and alert a clinician when it detects a contraindication to a planned treatment. It could also alert the clinician when it detected patterns in clinical data that suggested significant changes in a patient's condition.

Along with tasks that require reasoning with medical knowledge, AI systems also have a very different role to play in the process of scientific research. In particular, AI systems have the capacity to learn, leading to the discovery of new phenomena and the creation of medical knowledge. For example, a computer system can be used to analyse large amounts of data, looking for complex patterns within it that suggest previously unexpected associations. Equally, with enough of a model of existing medical knowledge, an AI system can be used to show how a new set of experimental observations conflict with the existing theories. We shall now examine such capabilities in more detail [2].

5. REASONING WITH MEDICAL KNOWLEDGE

Expert or knowledge-based systems are the commonest type of AIM system in routine clinical use. They contain medical knowledge, usually about a very specifically defined task, and are able to reason with data from individual patients to come up with reasoned conclusions. Although there are many variations, the knowledge within an expert system is typically represented in the form of a set of rules.

There are many different types of clinical task to which expert systems can be applied.

Generating and reminders

In so-called real-time situations, an expert system attached to a monitor can warn of changes in a patient's condition. In less acute circumstances, it might scan laboratory test results or drug orders and send reminders or warnings through an e-mail system.

Diagnostic assistance

When a patient's case is complex, rare or the person making the diagnosis is simply inexperienced, an expert system can help come up with likely diagnoses based on patient data.

Therapy critiquing and planning

Systems can either look for inconsistencies, errors and omissions in an existing treatment plan, or can be used to formulate a treatment based upon a patient's specific condition and accepted treatment guidelines.

Agents for information retrieval

Software 'agents' can be sent to search for and retrieve information, for example on the Internet, that is considered relevant to a particular problem. The agent contains knowledge about its user's preferences and needs, and may also need to have medical knowledge to be able to assess the importance and utility of what it finds.

Image recognition and interpretation

Many medical images can now be automatically interpreted, from plane X-rays through to more complex images like angiograms, CT and MRI scans. This is of value in mass-screenings, for example, when the system can flag potentially abnormal images for detailed human attention.

There are numerous reasons why more expert systems are not in routine . Some require the existence of an electronic medical record system to supply their data, and most institutions and practices do not yet have all their working data available electronically. Others suffer from poor human interface design and so do not get used even if they are of benefit.

Much of the reluctance to use systems simply arose because expert systems did not fit naturally into the process of care, and as a result using them required additional effort from already busy individuals. It is also true, but perhaps dangerous, to ascribe some of the reluctance to use early systems upon the technophobia or computer illiteracy of healthcare workers. If a system is perceived by those using it to be beneficial, then it will be used. If not, independent of its true value, it will probably be rejected [3]

6. AI AFFECTING THE MEDICAL FIELD

AI affects the hospital and medical field in the following ways,

Reduced mortality rate

Artificial intelligence is what gives computers the ability to learn, think, reason, and even understand human emotions, allowing computers to do more than just repeat tasks. In the medical field, AI is being designed to assist doctors (not replace them) in the effort to reduce the mortality rate among patients awaiting care from specialists.

Fast and accurate diagnostics

In the case of AI, the neural network of the brain is successfully imitated, even including the ability to learn from past cases. Several studies on artificial neural networks showed that they are able to accurately diagnose some diseases including malignant melanoma, eye problems, and many forms of cancer by analyzing spectral information and diagnostic criteria.

Therapeutic robots

Cuddling and caring for pets has always had a cathartic effect on our health, which is the basis for therapeutic animal robots that have been developed to help Alzheimer's patients. Robotic pets help nurture brain function by delaying cognitive problems that in turn improves quality of life, and reduces the reliance on social services, allowing a person to stay in their home longer with less medical assistance.

Reduce errors related to human fatigue

Doctors see roughly 80 patients per week, which can be very exhausting considering the individual amount of attention and knowledge each person requires. Unlike a human doctor, AI is un-phased by numbers of patients, long work hours, and task redundancy. Think of AI as sort of a super-human spell checker, assisting doctors by eliminating human error and relieving them of time consuming, monotonous tasks.

Decrease in medical costs

AI assistants/programs could significantly reduce medical costs by eliminating office visits with online care. Patients would be asked to submit data more frequently via online medical records, and the improved line of communication could result in less office visits. Further cost reductions could come from efficient AI diagnosing and screening of high-risk patients as well as by eliminating human errors in record keeping and diagnosis.

Minimally invasive surgery advances

The HD Surgical system has already made great strides in surgical robotics. The system offers doctors superior visualization, precision, and comfort. Such surgical robots already deliver smaller incisions, reduce patient pain, minimize need for medication, and shorten hospital stays all of which reduce medical costs.

Improved radiology

Robotic Radio survey Systems like Cyber Knife offer a non-invasive alternative to treating malignant and benign tumours anywhere in the body. The system uses image-guided technology and computer controlled mobility to detect and correct tumour and patient movement throughout the treatment. It delivers precise radiation to the tumour, reducing damage to surrounding healthy cells.

Virtual presence

Thanks to virtual presence technology, you may never have to leave your bed again. Using a remote presence robot, doctors are able to engage with patients and staff without actually being there. They are able to move around and interact almost as effectively as if they were present. This allows specialists to assist patients that may not be able to travel to see a particular doctor [4].

7. ANSWERING GENERAL QUESTION FOR PATIENT CARE

Although these advances demonstrate the potential of AI and machine learning to improve patient care, nearly all of the aforementioned techniques focus on the prediction problem (either classification for predicting a discrete-valued attribute or regression for predicting a real-valued attribute). As such, they are typically limited in scope to specific diseases or diagnoses or only applicable to a small subset of the patient population. Perhaps the next great challenge for AI in healthcare is to develop approaches that can be applied to the entire population of patients, monitoring huge quantities of data to automatically detect problems and threats to patient safety (including patterns of suboptimal care, as well as outbreaks of hospital-acquired illness), and to discover new best practices of patient care. Two very different AI approaches, each having great potential for addressing these challenges, are respectively based on question-answering (QA) and on large-scale Two very different AI approaches, each having great potential for addressing these challenges, are respectively based on question-answering (QA) and on large-scale anomalous pattern detection. Continued advances in general QA led to the design of the Deep QA architecture by IBM Research. IBM is currently partnering with the Memorial Sloan-Kettering Cancer Centre to enable patient-specific diagnostic test and treatment recommendations for various types of cancer [5].

8. ANOMALOUS PATTERN DETECTION FOR PATIENT CARE

A pattern can be a thing, a number, a digit or it can be a face which is called as a visual pattern , or a voice or video which is termed as an audio pattern. Pattern matching is the main mechanism that works out here because all the predictions are understood by the system by pattern detection mechanism. IBM recently developed a machine learning method based on fast subset scanning which can detect massive data sets. Using these technique Data entered into the system is scanned systematically and anomalous patterns can be recognized. In the patient care technique our primary goal is to focus anomalous patterns of care that influence patient outcomes.

Although these techniques provide an efficient anomalous pattern detection in general data sets, there are several challenges in identifying those patterns. First, even though any patterns identified by the system would undergo rigorous evaluation by the medical community before being directly applied to patient care, a practical and usable system must assist this process by focusing attention on those patterns that are most likely to be medically relevant. We wish to identify patient care patterns that are not just correlated with outcomes, but are likely to be casual factors influencing those outcomes.

A second set of challenges is posed by the use of massive quantities of streaming data for real-time monitoring of patient health and safety. Current techniques might be insufficient to analyze such massive quantities of data, and thus techniques for dimensionality reduction, clustering, aggregation, and data summarization might be useful [6].

9. CONCLUSSION

Although the primary roles of AI in patient care to date have mainly been in patient diagnosis and image analysis, the future holds great potential for applying AI to improve many aspects of the patient care process. Some example include personalizing treatments to maximize efficiency while minimizing side effects, recommending appropriate sequences of diagnostic tests, monitoring the patient population's health and safety, and discovering new medical knowledge that can directly impact the quality of care. Great challenges remain due to the health data's size and complexity, but the AI community is well on its way to meeting these challenges by developing new pattern detection techniques, scalable algorithms, and novel approaches that use massive quantities of health data to answer general questions [1].

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