

Artificial Neural Networking in Applied Dentistry

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Abstract

Advancements in digital technology have transformed our daily lives, bringing everything within reach of our fingertips. In the last few decades, technologies have developed, trying to simulate the functioning of the human brain. The extensive search to simulate the human brain has led to the development of artificial intelligence (AI). AI deals with the computational understanding and ability of computers to mimic the human brain and perform tasks. With emerging technologies, AI has begun to establish the field of health care. The field of medicine and dentistry has encouraged the use of these technologies from data acquisition to even performing virtual surgeries. This paper highlights the role of AI in various fields of dentistry.

Keywords: Artificial intelligence, data acquisition, machine learning, neural networks, virtual reality, virtual surgery

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INTRODUCTION

The human brain is a distinctive structure consisting of interlinked networks called neurons, which impart signals all through the body. This unprecedented nature of the human brain had made researchers evaluate how a brain functions. Plato, in 400 BC, envisioned a basic model of brain function.^[1] Since then, the branch of science has witnessed several innovations for designing a model that can function like a human brain. This unabating search has given rise to Artificial intelligence (AI). AI was first coined by McCarthy^[2] in 1950s. AI refers to the machines that mimic the tasks performed by humans.^[2,3]

There are many fields in AI, and one such field is machine learning (ML), used for statistical analysis of data. A popular model of ML applied in the field of health sciences are neural networks (NN). NN consists of an artificial neuron, which is a nonlinear mathematical model. By assembling and connecting the layers of artificial neurons using mathematical functioning, a network that directs to solve a particular task is developed.^[3]

It is an algorithmic program that calculates an unknown dependency between a set of given input variables and its output variable [Figure 1]. When such dependence is noticed, it can anticipate the expected output by recognizing the target function that best depicts the behavior governing the input-output patterns [Figure 2].^[3]

STRONG AND WEAK ARTIFICIAL INTELLIGENCE

There are two base classifications, known as “strong” and “weak” AI.

Weak AI refers to a program that focuses on a single task and works based on pre-programmed algorithms. The mechanism seen is limited to organization power, rather than the ability of the AI to comprehend or understand the command being given (e.g., Apple’s Siri and Amazon’s Alexa).^[4]

Strong AI replicates the cognitive functions of the human brain. Instead of using sheer organization power, a strong AI program, machine, or software on clustering and association to process data. Just like the human brain, it is hard to tell how a strong AI would respond to specific keywords-only that it’d make an independent decision based on how it evaluates and reacts to the data provided to it.^[4]

HISTORY

Aristotle^[5] first introduced the idea of AI. He did not propose a direct aspect of the use of machinery to replace human

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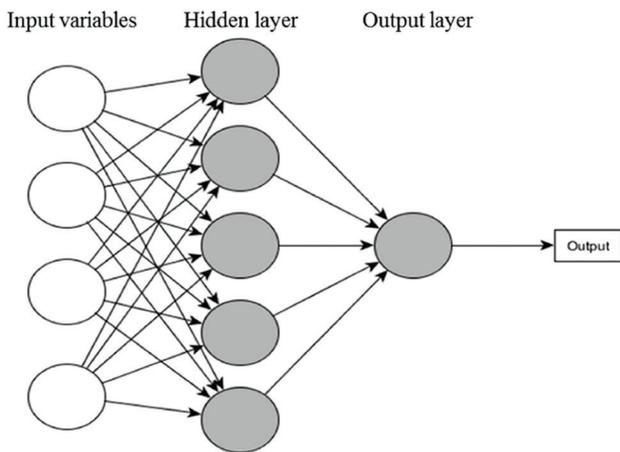


Figure 1: A basic neural network

thinking. Nevertheless, his strive to correlate human’s method of reasoning has become an origin of the belief that computing can reinstate the human’s thought process.^[5]

In 1308, Ramon Llul,^[4] a Catalan poet and a preacher published a book entitled *Ars generalis ultima* (The Ultimate General Art). Based on Aristotle’s logic, he developed a machine to design the mental capacity of man through a rational combination of concepts.^[4] In 1666, Gottfried Leibniz,^[4] a German mathematician, published a book called *Dissertatio de arte combinatoria* (On the Combinatorial Art). In his work, he stated that every thought of man is put into effect with a collaboration of simple ideas.^[4] In 1854, George Boole^[4] stated that logical reasoning is carried out just the same, as a solution of the equation with a set of systems, assuring confidence in the probability of complete substitution of analytical reasoning and computing.^[4] In 1943, a paper was published by Warren McCulloch and Walter Pitts^[6] proposed NN s as a method to mimic the human brain.^[6] Minsky and Dean Edmonds^[4] in the year 1951, introduced the first NN, known as the stochastic neural analog reinforcement calculator.^[4]

AI programs were first developed by Allen Newell and Herbert Simon^[4] in 1955. In 1959, Arthur Samuel further advanced the evolution of weak AI by introducing the term “Machine Learning”.^[4] In 1965, research was put through to identify the fundamental problems of strong AI. In his book, *Dreyfus*^[7] emphasizes that there is an area in the human brain that works in a way that computers cannot reach.^[7]

ARTIFICIAL INTELLIGENCE IN DAY TO DAY LIFE

The use of AI is becoming a reality that is mainstreaming all areas of modern human life. Over the past two decades, the development of AI is exceptional and is being used in all ordinary and professional activities.

Today’s AI is designed as a representative that self-enhances the processing power of controlling environmental variables. Typical examples of these characteristics are AI applications for recognition and identification activities (image, voice,

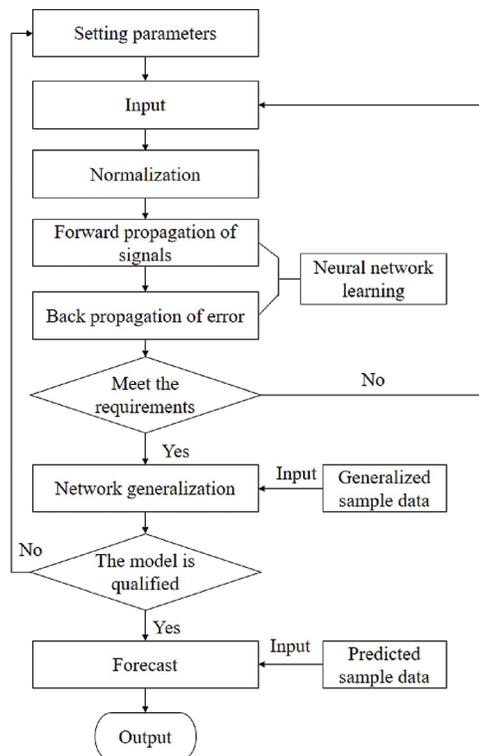


Figure 2: Mechanism of neural networks

and body recognition) and activities that replace daily human life (translation, autonomous navigation, etc.).^[8]

Many AI programs are developed and utilized to provide personalized network services (presenting and optimizing online behavioral forms such as search, shopping, and network management).

ARTIFICIAL INTELLIGENCE IN HEALTH CARE

With the ability to “train” a computer program to attain highly intelligent capabilities, NN s began emerging in health sciences. AI helps in better diagnosis and reduces errors in day to day practice.

1. Radiograph interpretation has been initiated from expert systems, through atlas-based models. They overcome the variability in the subjective individual examination and increases effective care while reducing the costs by eliminating routine tasks
2. Digital health data are extensively collected, while so far, these data are rather diverse; organizations are aiming to provide systematic and structured data
3. Research and discovery can be facilitated by adding silicon experimentation options to traditional research systems, complementing other researchers, and modeling strategies
4. AI streamlines the routine work and increases the patient to doctor face to face time. This saves the time of the doctors, by diagnostic assistance systems, voice, speech and text recognition, and translation
5. Health care can be made more participatory, especially if the patients provide their data actively. For example, using

- wearable technology with intelligence applications can predict a life-threatening crisis, like a stroke may occur in a patient, giving an opportunity to provide early treatment
6. By continuously collecting data, the disadvantages of “on-off medicine” can be overcome, where seen only for a few minutes, while most of the health conditions are usually acquired over the years and are often escalating (e.g., periodontal disease)
 7. Continual noninvasive observation of health and behavior will facilitate extensive, individual understanding of the etiology and processes underlying the disease outcome
 8. Diagnostic and treatment costs may be decreased, thereby relieving the burden on the health-care systems caused by the aging society with an increasingly high number of complex, chronically ill cases.^[9,10]

ARTIFICIAL INTELLIGENCE IN DENTISTRY

The quality of AI is that these machines can be trained to evaluate and memorize the data to impart the most favorable diagnoses. Virtual dental assistants based on AI can perform different tasks with less manpower and great precision compared to humans. Apart from assisting in diagnosis and treatment planning, it also guides in appointment scheduling, executing insurance, and paper works.^[11] It also helps in alarming the dentist about the patient’s medical history and habits. AI has been transformed so that based on the voice command, chair position, light control, and water dispensing can be controlled, reducing the risk of cross-contamination.^[12]

AI can be used to diagnose, screen, and treat the lesions of the oral cavity. Pictures of the lesions can be uploaded in the application, and diagnosis can be made from the vast data available around the world. The data input helps to diagnose suspicious oral lesions into premalignant and malignant lesions.^[13]

AI provides an advantage in head and neck imaging modalities due to its exclusive ability to learn and can be assimilated with all the imaging modalities such as cone-beam computed tomography (CT), MRI, and CT scan to determine indiscernible variations from normality that could have gone unrecognized by the human eye.^[14]

AI helps the prosthodontist to design an ideal and esthetic prosthesis taking into account the factors such as facial measurements, shade matching, patient’s desire, optimal function, ideal occlusion, contacts, and margins suitable for each case. In implantology, AI aids in identifying the type and thickness of bone for the fabrication of precise surgical guides [Figure 3]. These guided stents help the practitioner have shorter operation time, safer approximation around delicate structures, and high accuracy.^[15]

With the advancements in CAD-CAM technologies, which creates three-dimensional (3D) models, the time-consuming and tedious process of crown and bridgework can be eliminated, reducing human errors [Figure 4].^[16]

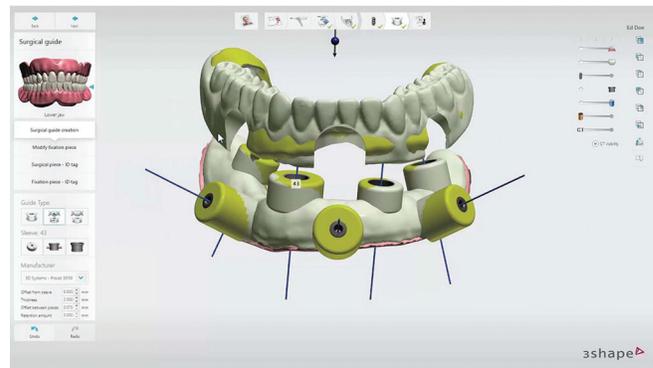


Figure 3: Fabrication of implant guide using artificial intelligence

Posttreatment facial profile can be simulated using virtual reality simulation technology, which not only enables the dentist in designing a prosthesis but can also be used in motivating the patient.^[17]

The application of AI in oral and maxillofacial surgery is the advancement of robotic surgery, where human body motion and intelligence is simulated.^[18] AI plays an important role by assisting the surgeon in planning surgeries, removal of the tumor and foreign bodies, temporomandibular joint surgeries, and biopsy with reduced operation time and high intraoperative accuracy.^[19] Accurate image-guided surgery is possible with this technology, reducing the need for revision procedures.

Oral hard and soft tissues that are lost due to pathological or accidental reasons can be formulated in successive thin layers of cells with bioprinting for regeneration.^[20]

The recent innovation is AI-driven orthodontic treatment. AI analyses the radiographs and photographs of the patients, thereby aiding in diagnosis, treatment planning, and monitoring the progression of treatment.

In orthodontics, it is of prime importance to note that different orthodontists have different treatment plans for a specific case. Neural networks are used to predict treatment plans, including the determination of extraction – non extraction, extraction patterns and anchorage patterns. Also identifies the craniofacial growth and helps in deciding whether or not to utilize growth during treatment. Therefore, the AI software can output the feasibilities of several applicable treatment plans, offering flexibility in making decision. With the use of 3D intraoral scanners and printers, it is easy to 3D print the aligners with the customized treatment plan.^[21,22]

AI helps in detecting and highlighting carious lesions [Figure 5],^[23] minor apical foramen,^[24] vertical root fractures,^[25] accuracy of working length determination,^[23,26] etc., all of which would help for better patient care.

This software can be used for patient awareness, thereby increasing treatment acceptance.^[27]

AI using radiographs assist in diagnosing and treatment planning of periodontal diseases by early detection of periodontal changes,

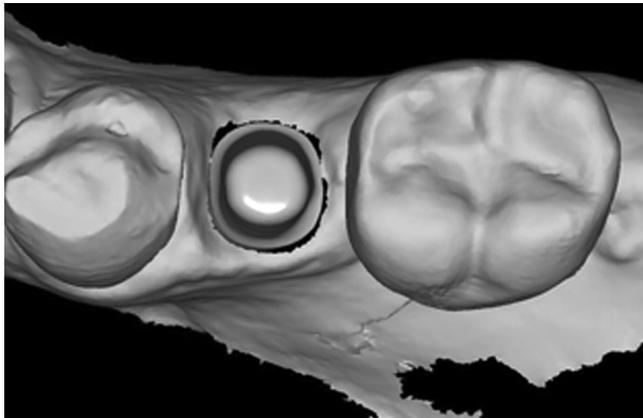


Figure 4: Margins of prepared tooth analyzed using artificial intelligence

bone loss, and changes in bone density. Peri-implantitis can also be detected, leading to early intervention.^[28,29]

Age estimation is a major aspect of forensic odontology. Research is being carried out for age estimation using facial images.^[30] Dental age can be observed on the radiograph based on the stages of tooth formation and eruption. With the advances in dental imaging and AI, NNs can train computers to estimate the age automatically.^[30]

Clinical procedures are essential in dental practice for learning the skills to enhance patient care. AI can be used in the education system, to create virtual reality, where the students can perform their preclinical work on virtual patients instead of phantom heads.^[31] This helps the students, reduce the risk of iatrogenic damage in clinical cases.^[32]

PATIENT COMMUNICATION THROUGH ARTIFICIAL INTELLIGENCE

AI helps the doctor in patient communication. Queries of the patient can be answered by AI if complicated, can be directed to the doctor. It helps in providing a relevant medical history or allergies the patient has before the appointment.^[11]

For patients, AI helps to set up regular reminders who are on tobacco or smoking cessation programs. In an emergency, when the doctor is not available, the option of emergency teleassistance would assist the patient.^[33]

Advantages of AI:

1. Accurate diagnosis
2. Time-saving
3. Reduces human errors
4. Standardization of procedures
5. Smart patient communication.

Disadvantages of AI

1. Complex mechanism
2. Expensive setup

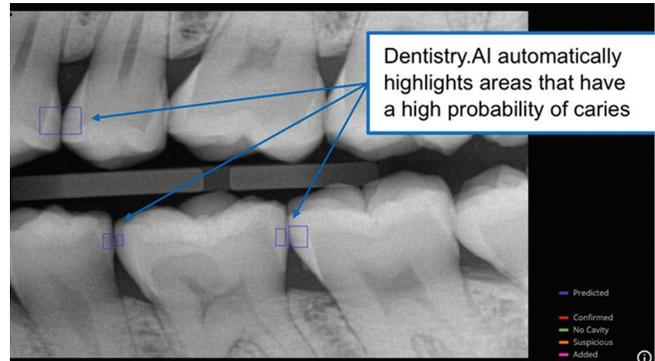


Figure 5: Caries detection using artificial intelligence technology

CONCLUSION

With the advancements in technology, AI has transformed the health-care industry and has led the researchers and enterprises to invest in the medical field. The continuous development of AI in dentistry will help practitioners and researchers harmonize different fields of knowledge and improve patient care. Nevertheless, it is also important to be aware of the possible errors in the interpretation of data through AI programs. By combining AI technology with conventional methods, it is possible to minimize output errors.

Although AI in dentistry is a great asset, the human biological system is involved; it is not the only diagnosis, but relating it to clinical findings and personalized care is essential.

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Conflicts of interest

There are no conflicts of interest.

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