An Overview of Artificial Neural Network in the Field of Pediatric Dentistry

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Abstract

Artificial intelligence (AI) has been used in a variety of ways in healthcare. AI is a development in the field of technology which is expeditiously advancing and has fascinated the minds of researchers across the globe. AI has also been utilized in the medical decision-making process, and nonprofessionals to get expert-level information. In medicine and dentistry, AI helped in the data acquisition and also in performing virtual surgeries in these fields. Currently, application of AI is rapidly utilized beyond text-based, image-based dental practice. Rapid pace for commercialization were resulted from machine learning based on artificial neural networks to dental treatment through analysis of dental magnetic resonance imaging, cephalometric radiographs and computed tomography. In addition to the diagnosis of visually confirmed dental caries and impacted teeth, studies applying machine learning based on artificial neural networks to dental treatment through analysis of dental magnetic resonance imaging, computed tomography, and cephalometric radiographs are actively underway, and some visible results are emerging at a rapid pace for commercialization. This paper reviewed the history, concept, and the latest application of AI in the field of pediatric dentistry.

Keywords: Artificial Intelligence, Application, Pediatric Dentistry, Machine learning, Neural Networks.

1. Introduction

Artificial Intelligence (AI) is the intelligence expressed by machines in comparison to the essential knowledge represented by humans and animals. Recently, there have been many studies on artificial intelligence and bioinformatics.[1] One approach is machine learning using a neural network system.[2] This emulates human knowledge in a situation that cannot be formalized or standardized. The human brain which transmit signals throughout the body composed of networks of interlinked neurons. Various inventions of field of science with the onset of technology for processing a model that can mimic the functioning of human brain. Lesions not diagnosed with human naked eyes are able to detect by computer based technology to diagnosis and giving path for holistic practice.[3]

An artificial neural network is a mathematical model that emulates the brain's operation. A typical neural network has an input layer (or level) consisting of one or more, which send data via synapses to the second layer or intermediate 'hidden'.[4] It consists of complex system with more layers of neurons.[5] Artificial neural networks, following training, can discriminate important patterns in input information and respond with an appropriate output.[6] Previously AI was applied to logistics, data mining, medical diagnosis and other areas. The various applications of AI in pediatric dentistry include Artificial Neural Networks (ANN), Genetic Algorithms (GA), and Fuzzy Logic.

2. History of Artificial Intelligence (AI)

AI has several internal tributaries in the history of formulation, research, and development. History dates back to as early as 400 BC when Plato envisaged a basic model of brain function.[5] First time in history, Aristotle presented the concept of AI, but did not advice the emergency of machinery could reinstate human thoughts. However, this forms a logic to become a source of replacement on human thinking mechanisms.[7] Ramon Llull, a 14 -century Catalan poet and great missionary theologian, devised remodel of human mind through logical concepts.[8] Alan Turing (1950), British mathematician created a machine to decode encrypted messages. The person who finally coined the term artificial intelligence in 1955 and is regarded as the father of AI is **John McCarthy**. The field of artificial intelligence research was founded as an academic discipline in 1956.[9] Dartmouth college researchers in 1956 introduced programs that could learn checker strategies and providing logical theorems and speaking English. Following this concept, in 1959 has witnessed various research using AI in the field of medicine and dentistry which involves the computational neural networks.[10] In the early 20th century, the concepts of AI was developed from the case of aviation technology.

3. Model of Artficial Neural Network (ANN)[5]

An artificial neural network is a mathematical model that emulates the brain's operation. It mainly contains many number of small elements (neurons), which will perform a single function. Each neuron has many input data as network from other neurons called synapses. This single data which are connecting with other neuron forms synapse can be exhibit by weight between 0 and 1. The aggregate of this input neuron is the total of these weighted inputs neurons which sums up the neurons at synapses. The neuron output (activity) is imitative by processing the sum neuron input through mathematical algorithm, this complete structure is called as 'architecture' (Fig. 1). Intermediate layers which send data through synapses that do not joins the input and output directly are called as 'hidden layer'. More layers of neurons involve with numerousinput

and output data, the more complex the system. Artificial neural networks, following training, can discriminate important patterns in input information and respond with an appropriate output.[4]
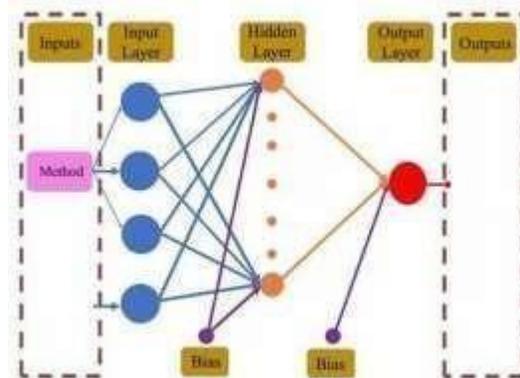
Figure 1. Topology of Neural Network Model.

3.1 Artificial neural networks and regression models[11]

Neural networks are similar to linear regression models in their nature and use. They are comprised of input (independent or predictor variable) and output (dependent or outcome variable) nodes, use connection weights (regression coefficients), bias weight (intercept parameters) and cross-entropy (maximum likelihood estimation) to learn or train (parameter estimation) a model.[12] ANN learn to perform tasks by using inductive learning algorithms requiring massive data sets. A working paper on the use of ANN in decision support systems states that the structure, quality and quantity of data used is critical for the learning process and that the chosen attributes must be complete, relevant, measurable and independent. The authors further observe that in business applications, external data sources (e.g. industry and trade databases) are typically used to supplement internal data sources

4. Application of ANN in Pediatric Dentistry

AI application technology in pediatricdentistry is advancing remarkably. AI involves the clinical decision system, which provide professional guide with computer programs. Pediatric dentists with the help of AI can help to diagnose specific

oral and dental problems, which helps in affordable, efficient treatment for the patient.[13] AI will guide the dentists to perform the treatment more effectively than human assistants and could avoid the communication gap.

Many researches have been conducted in the field of pediatric dentistry using AI, some of the researches includes:[9]

  i. Appointment bookings for the pediatric patients to their convenience and coordinating regularly

  ii. Dentist can perform various tasks easily with the help of software consists of voice recognition and interactive interphases.

  iii. Compared to humans, AI can document all required data and provides to the pediatric dentist much rapidly and more efficiently.

  iv. For early detection of oral cancer in children.

  v. Unerupted teeth sizes can be predicted by more promising with higher accuracy in the mixed dentition.[14]

  vi. Helps in cephalometric diagnosis with precise location of landmarks in radiographic tracing.

  vii. Minor apical foramen can be accurately detected, thereby playing an important role in working length determination.

  viii. Investigating the properties of dental materials such as chemical stability, wear resistance, and flexural strength.

  ix. Dental prostheses design can be make chairside with precision to its design based on the digital imaging following tooth cusps

  x. Precision for the design and chairside manufacturing of dental prostheses, based on digital image acquisition following tooth cusps estimation.

  xi. To classify patients into aggressive periodontitis and chronic periodontitis group based on their immune response profile.

  xii. Orthodontic problems in children, the software can perform number of space analysis, helps in diagnosis and treatment planning.[15]

  xiii. For diagnosis of recurrent aphthous ulcer with multifactorial aetiology.

  xiv. Helps to create toothache prediction model in children.[16]

  xv. Detection of dental caries in an extracted tooth by ANN.[17]

  xvi. Diagnosis for arch form qualitatively using artificial neuron network from tooth size and arch dimension variables on the scanned-dental cast from patients with class I malocclusion treated orthodontically.

  xvii. Convolutional neural network features (faster R-CNN) in the TensorFlow tool package to detect and number teeth in dental periapical films.[18]

  xviii. Applying deep artificial neural network approach to maxillofacial prostheses coloration.[19]

  xix. AI helps in detection of vertical root fracture along with evaluation of chemical resistance of dental ceramics.[4]

  xx. Artificial neural network (ANN) modelling and analysis for the prediction of change in the lip curvature following the extraction and non-extraction orthodontic treatment.[20]

  xxi. Automated Diagnosis and Severity Measurement of Cysts in Dental X-ray Images Using Neural Network.[21]

  xxii. The Application of an Artificial Neural Network to Support Decision Making in Edentulous Maxillary Implant Prostheses.[22]

4.1 Advantages of AI[10]

  i. Efficiency in diagnosis and treatment planning

ii.   Standardisation of programs
iii.   Conserves time

4.2 Disadvantages of AI[10]
i.   Mechanism of AI is very complex in nature
ii.   Expensive in setting up

Deep learning which increasingly refine the results from data along with computational power. Due to this advance in the field of AI, it has been employed in the real-life problems across all parts of society. Diagnosis of dental problems in the dental field with the help of AI is reaching levels of human competence. Changing the role of computer-assisted diagnosis from a 'second-opinion' tool to a more collaborative one.[23] The development of AI applications in the field of pediatric dentistry is also remarkable.[24]

Currently, the use of AI is expanding in the dental field. However, the clinical accuracy of AI in the dental field must be verified with a variety of cases and imaging modalities. Furthermore, current AI algorithms function as black boxes, making it difficult for humans to identify or adjust the criteria used for diagnoses.[25] Radiographic methods of Age estimation is commonly used due to the availability of the pre and post treatment records and also the ease of the availability of the data that can be retrieved any time. With the advent of the artificial intelligence, there are several programming neural networks can train the computers to automatically to estimate the age.

Yu et al., have proposed Artificial Neural Network (ANN), to detect the tooth decay. By using the back-propagation (BP) neural network, the X-ray image of the patient's teeth is analyzed. The network attained considerable superior performance in making differential diagnoses between decayed as well as healthy teeth with inter-pixel autocorrelation coefficients as its input feature vector. In comparison with the other method, the tooth decay detection accuracy was significantly improved.[26] ANNs have proved extremely helpful in solving problems with high computational complexity, especially in the field of pattern recognition. Therefore, ANNs have been established as a promising alternative to

statistical discriminate analysis because they can synthesise a considerable amount of information (or variables) without requiring mathematical modelling of the problem.

Successful clinical practice requires accurate diagnosis. AI is boon in diagnosing a disease involving multifactorial aetiology. In a study, data from 86 participants were used to construct and train a neural network to predict the factors appearing to be related to the occurrence of recurrent aphthous ulcers.[27] When this was further tested using untrained data of 10 participants the results revealed most accurate predictions such as gender, haemoglobin, serum Vitamin B12, serum ferritin, red cell folate, salivary candidal colony count, frequency of tooth brushing, and the number of fruits or vegetables consumed to be related to recurrent aphthous ulceration and appropriate for use as input data to construct ANNs. Hence, when trained ANNs were tested and compared with the diagnosis of a surgeon, the results revealed high sensitivity and specificity of ANN, thereby insisting on the importance of AI in achieving correct interpretations and reducing human errors.[28]

In the field of implantology and surgery, AI software has assisted plan surgeries to the minute detail before to the actual surgery. Robotic surgery is one of the greatest applications of AI in field of surgery. A crucial challenge in the field of robotics is simulating human body motion and human intelligence.[29] Contemporary applications of AI is seen in the field of "bioprinting", where living tissue and even organs can be constructed in consecutive thin layers of cells which in the future may be used for reconstruction of oral hard and soft tissues lost due to pathological or accidental reasons.[30]

5. Conclusion

The current review paper has established the concept, history, and present application of AI in pediatric dentistry. Dentists have always been at the leading edge in implementing the new innovative AI technology. The field of artificial intelligence has increasingly utilized in the last decade. Dentists will be able to pinpoint specific problems thereby speeding the recovery. It may

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not save time but can provide patients with an accurate diagnosis. AI-enabled tools for dentistry. Incorporation of AI in the teaching and learning process can dramatically improvise the way student perceive knowledge. Future AI-based dental education can significantly reduce the cost of education and the burden on educators. Furthermore, AI can only assist the pediatric dentist in performing the tasks efficiently, but in no way replace the intellect of the human knowledge, skill and treatment planning.

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