Artificial Intelligence in Dentistry: The Current Concepts and a Peek into the Future

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ABSTRACT

Introduction: Humans have recreated intelligence for effective human decision making and to unburden themselves of the stupendous workload. Artificial intelligence can act as a supplemental tool to improve diagnosis and treatment care but intelligent machines can never be 'human'. The field of artificial intelligence is relatively young but has still come a long way in the fields of medicine and dentistry. Hence, there is a need for the dentists to be aware about its potential implications for a lucrative clinical practice in the future.

Keywords: Artificial Intelligence, Neural Networks, Fuzzy Logic, Hybrid Intelligent Systems, Dentistry

INTRODUCTION

With an enormous increase in the documented patient data, intelligent software for its computation has become a necessity.[1] Computer-based diagnosis is gaining momentum due to its ability to detect and diagnose lesions which may go unnoticed to the human eye.[2] The conventional approaches have provided much information, but are subject to limitations.[3] The deed of the constant search has given rise to artificial intelligence (AI), which is a highly evolved system capable of mimicking functioning of the human brain.[2] This review will give an insight into the current concepts and uses of artificial intelligence in various fields of dentistry.

Artificial intelligence

Alan Turing, a young British polymath devised the Turing test to suggest that machines can use available information and reason to solve problems like humans. The term artificial intelligence was coined by John McCarthy in 1956[4] and it is defined as 'a field of science and engineering concerned with the computational understanding of what is commonly called intelligent behaviour, and with the creation of artifacts that exhibit such behaviour'.[5]

Common terminologies used in artificial intelligence

Machine learning (ML)

Machine learning is the subfield of artificial intelligence in which algorithms are trained to perform tasks by learning patterns from data rather than by explicit programming.[6] Machine learning techniques invariably involve parameter tuning with regards to the underlying technique, such as, the number of neurons, layers or epochs in a neural network technique; membership function selection in fuzzy logic; population size, selection strategy, mutation rate, crossover rate in genetic algorithms as well as in the hybrid techniques that use fuzzy logic or neural network or both.[7] Various machine learning models, such as the Genetic Algorithm (GA), the Artificial Neural Network (ANN) and the Support Vector Machine (SVM), can actually ``learn" and ``be trained" from the given data in order to execute many functions.[8]

Representation learning

Is a subtype of ML in which the computer algorithm learns the features required to classify the provided data. This does not require a hand labelled data like ML.[9]

Deep learning (DL)

The ML is a subset of AI, meanwhile, DL, in turn, is a subset of ML. That is DL is an aspect of AI; the term deep learning refers to artificial neural networks (ANN) with complex multilayers. The distinction between deep learning and neural networks (NNs) like feedforward NNs and feed backward NNs lies in their characteristic. Deep learning has more complex ways of connecting layers, also has more neurons count than other networks to express complex models, with more computing power to train and further has automatic extraction of the feature.[10] This algorithm uses multiple layers to detect simple features like line, edge and texture to complex shapes, lesions, or whole organs in a hierarchical structure.[9]

Clinical decision-support systems (CDSS)

CDSS actually is any computer system designed to help healthcare professionals make clinical decisions through managing clinical data or medical knowledge.[11] Most CDSS have four basic components: Inference Engine (IE), Knowledge Base (KB), Explanation Module and Working Memory. The Inference Engine (IE) is the main part of any such system, containing the knowledge about the patient from which to draw conclusions regarding certain conditions. The knowledge used by IE is represented in the knowledge base and tools that have been created to facilitate the acquisition and elicitation of this knowledge. The collected patient data may be stored in a database or may exist in the form of a message and is known as the working memory. The last component, the Explanation Module

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is not present in all CDSS. This module is responsible for composing justifications for the conclusions drawn by the IE in applying the knowledge in the KB against patient data in working memory.[12]

Artificial neural networks (ANNS)

Artificial neural networks are highly interconnected network of computer processors that are inspired by the biological nervous systems.[13] McCulloch and Pitts (1943) invented the first artificial neurone using simple binary threshold functions. The next important milestone came when Frank Rosenblatt, a psychologist, developed the Perceptron in 1958 which worked on a multilayer feed forward mechanism. Another breakthrough in this technology came when Paul Werbos in 1974 introduced "backpropagation" learning.[5] Today this ability of the computers programs is being used to "learn" from newer information to aid health care for data processing and knowledge representation.[1]

ANN consists of a variable number of artificial neurons or nodes connected in hierarchical layers: an input layer, one or more hidden layers, and an output layer. Each node, with the exception of the input neurons, receives multiple weighted inputs and produces an output that is usually a nonlinear function of the inputs.[14] A neural network 'learns' through repeated adjustments of these weights. Their ability to learn from historical examples, analyse non-linear data, handle imprecise information and generalise enabling application of the model to independent data has made them a very attractive analytical tool in the field of medicine. They have been used in the clinical diagnosis, image analysis in radiology and histopathology, data interpretation in intensive care setting and waveform analysis.[5]

Recent advances in neural networks

Recently, several variations of artificial neural networks gained attention like convolutional neural networks (CNNs) for image classification challenges and dilated convolutional neural networks (DCNNs) for sematic scene segmentation challenges. Two main classes of CNNs prevail for volumetric prediction in general: Tiramisu and dilated convolutional neural networks (DCNNs) data. Tiramisu based models such as U-net excel at predicting dose volumes that tend to be spatially consistent with respect to anatomy, such the dose volume to a prostate. Dilated convolutional neural networks (DCNNs) utilize convolutions that skip over information during their encoding stage, to help extend their field of view. DCNNs can be useful for predicting dose that can be mobile with respect to anatomy, as in head and neck cancer patients. It is likely that these methods will also soon become common in volumetric dose prediction for head and neck IMRT (intensity modulated radiation therapy).[15]

Fuzzy logic

Fuzzy logic is the science of reasoning, thinking and inference that recognises and uses the real world phenomenon – that everything is a matter of degree. Instead of assuming everything is black and white (conventional logic), fuzzy logic recognises that in reality most things would fall somewhere in between, that is varying shades of grey.[5]

Evolutionary computation

Evolutionary computation is a general-purpose stochastic global optimization approach under the universally accepted neo-Darwinian paradigm, which is a combination of the classical Darwinian evolutionary theory, the selectionism of Weismann, and the genetics of Mendel. Among all the evolutionary algorithms, Genetic algorithm (GA) is the most widely used. It was first introduced by Holland (1975). A simple GA consists of a population generator and selector, a fitness estimator, and three genetic operators, namely, selection, mutation, and crossover. It has been receiving increased attention due to a series of successful applications in different disciplines like biology, medicine and different branches of engineering.[16] It has better application in medical field where they work by creating many random solutions to the problem at hand.[5]

Hybrid intelligent systems

This synergetic system allows to accommodate common sense, extract knowledge from raw data, use human-like reasoning mechanisms, deal with uncertainty and imprecision, and learn to adapt to a rapidly changing and unknown environment. The advantages of these technologies can be combined together to produce hybrid intelligent systems which can work in a complementary manner. Many different hybrid systems available and the popular ones are ANNs for designing fuzzy systems, fuzzy systems for designing ANNs, and Genetic Algorithms for automatically training and generating neural network architectures.[5]

Applications in dentistry

1. In dental education: With the recent incorporation of artificial intelligence in intelligent tutoring systems like in the Unified Medical Language System (UMLS); there is a huge improvement in the quality of feedback that the preclinical virtual patient provides the students.[17]
2. ANN has sufficient precision for the design and chairside manufacturing of dental prostheses, based on digital image acquisition following tooth cusps assessment. It can have a great potential in investigating the properties of dental materials such as chemical stability, wear resistance, and flexural strength.[2]
3. Artificial Intelligence in Patient Management: - It can assist in coordinating regular appointments and alerts the patients and dentists about checkups whenever any genetic or lifestyle information indicates increased susceptibility to dental diseases (eg: periodontal screening for patients with diabetes and oral cancer screening for those who habitually use smoked or smokeless tobacco).[1]
    - It can also create a database about any relevant medical history or about any allergies that the patient may have. It can not only assist in clinical diagnosis and treatment but also provide emergency tele-assistance in cases of dental emergencies when the dental health care professional cannot be contacted.[1]
4. Artificial intelligence in Radiology: - It can be integrated

with imaging systems like MRI(magnetic resonance imaging) and CBCT (cone beam computed tomography) to identify minute deviations from normalcy that could have gone unnoticed to the human eye. This can also be used to accurately locate landmarks on radiographs, which can be used for cephalometric diagnosis.[1]

- ML algorithm can detect a lymph node in head and neck image as normal or abnormal provided it is trained Radiologist by analysing thousands of such images which are labelled as normal or abnormal.[9]
- ANN is found to act as a second opinion to locate the minor apical foramen, thereby enhancing the accuracy of working length determination by radiographs and in diagnosing proximal dental caries. It is also found to have sufficient sensitivity, specificity, and accuracy to be a model for vertical root fracture detection in digital radiography.[18]
- Wang et al. first presented an article that used DCNNs in the diagnosis and analysis of dental radiographs. In addition, Miki et al. conducted research that focused on classifying tooth types in dental cone-beam CT images via an automated method of DCNN.[19]
- Recently, Lee et al. studied DCNN using computed-assisted diagnosis (CAD) system for the detection of osteoporosis on panoramic radiographs. The DCNN CAD system was compared to experienced oral and maxillofacial radiologist and the results showed high agreement between the two.[19]

5. Dar-Odeh et al conducted a study to utilize ANN for the prediction of rather unclear entity of diseases termed as recurrent aphthous stomatitis.[20]
6. Artificial Intelligence in Prosthetic Dentistry:- In order to provide ideal esthetic prosthesis for the patient various factors like anthropological calculations, facial measurements, ethnicity and patient preferences has been integrated by a design assistant, RaPid for use in prosthodontics. RaPiD integrates computer aided design, knowledge based systems and databases, employing a logic based representation as a unifying medium.[4]
   - With the help of Artificial Intelligence, the computer can actually guide the dentist during the entire procedure of making a digital impression and aid in making an ideal impression.[1]
7. Artificial Intelligence in Orthodontics:- Diagnosis and treatment planning can be done by analysis of radiographs and photographs by intraoral scanners and cameras. This eliminates the necessity for making patient impression as well as several laboratory steps and the results are usually much more accurate compared to human perception. The tooth movement and final treatment outcome can be predicted by using algorithms and statistical analysis.[4]
   - It can also be used to provide orthodontic consultations to general practitioners for the alignment of crowded lower teeth.[2]
   - Seok-Ki Junga and Tae-Woo Kimb conducted a study to construct an artificial intelligence expert system for the diagnosis of extractions using neural network machine learning and to evaluate the performance of this mode. This study suggested that artificial intelligence expert systems with neural network machine learning could be useful in orthodontics.[19]
8. Pain assessment: Xiao-Su Hu et al conducted a study where artificial neutral network (3-layer NN) achieved an optimal classification accuracy at 80.37% for pain and no pain discrimination.[22]
9. Head and neck cancer: Ibragimov and Xing were the first to attempt the use of CNNs for segmentation of organs at risk from head and cancer CT images. Their results confirmed that CNNs well-generalize the intensity appearance of objects with recognizable boundaries whereas additional information may be required for CNN-based segmentation for the objects with poorly recognizable boundaries.[23]
   - Another study was conducted which showed that genetic programming (GP) performed the best in oral cancer prognosis when the features selected are smoking, drinking, chewing, histological differentiation of SCC, and oncogene p63. It was also found that the GP outperformed the SVM and LR in oral cancer prognosis. GP is also proved to be applicable in drug discovery.[8]
   - Fuzzy sets have been used to predict cervical lymph node metastasis in carcinoma of the tongue, for the prognosis of nasopharyngeal carcinoma, outcome prediction in esophageal cancer and for the prediction of oral cancer susceptibility.[24]
   - The neural network may be of value for the identification of individuals with a high risk of oral cancer or precancer for further clinical examination or health education.[2]
10. In periodontics: Lee et al. developed an architecture based on DCNN that consists of 16 convolution layers and two fully connected layers. The accuracy of their architecture in detecting periodontitis of premolars and molars was 81.0% and 76.7%, respectively.
    - Further, Rana et al. presented an autoencoder framework with convolutional layers to segment gingival diseases from oral images. This model successfully distinguishes between inflamed and healthy gingiva.[19]
    - ANN can also effectively be used in classifying patients into aggressive periodontitis and chronic periodontitis group based on their immune response profile. Therefore ANNs can be employed for accurate diagnosis of AgP or CP by using relatively simple and conveniently obtained parameters, like leukocyte counts in peripheral blood.[25]
11. Patcus. R et al conducted a study to evaluate facial attractiveness of treated cleft patients and controls by artificial intelligence (AI) and to compare these results with panel ratings performed by lay people,

orthodontists, and oral surgeons and found that the results were comparable with the average scores of cleft patients seen in all three rating groups (with especially strong agreement to both professional panels) but overall lower for control cases.[26]

12. Patcus. R et al conducted another observational study which illustrates that artificial intelligence (convolutional neural networks) might be considered to score facial attractiveness and apparent age in orthognathic patients.[27]
13. Forensic dental imaging: Personal Identification System Using Dental Panoramic Radiograph based on Meta_Heuristic Algorithm was reported to have an identification percentage approaching 97.7%.[28]
14. GAs and ANN are a promising tool for predicting the sizes of unerupted canines and premolars with greater accuracy in the mixed dentition period and can also be optimized for predicting the tooth surface loss which is a universal problem that involves an irreversible, multifactorial, non-carious, physiologic, pathologic, or functional loss of dental hard tissues.[2]
15. Another study was conducted with the objective of developing a decision support system for predicting the degree of color change after in-office tooth whitening by using colorimetric values. The patients' post-treatment color was largely close to the system prediction.[29]

Advantages of AI

1. Tireless performance of the tasks which saves time
2. Logical and feasible decisions without any involvement of human emotions which results in an accurate diagnosis
3. Standardization of procedures[2]

Disadvantages of AI

1. The complexity of the mechanism[2]
2. The cost involved in the setup[2]
3. Enormous data is required for training and precision and therefore is it is difficult to achieve accuracy in rare conditions or diseases.

CONCLUSION

There are so many techniques that are being used in artificial intelligence and it is still in its budding stage. The prevailing researches have provided sufficient evidence of its efficacy. There is a common notion that artificial intelligence will replace the clinicians, which is why they have been quite skeptical in embracing it. As a matter of fact, the incorporation of these techniques will not only increase the efficiency of the specialists but also help in better patient care. It needs to be understood that artificial intelligence has been given birth by humans, therefore, it will never be able to enslave them in unfamiliar situations unless trained to do so.

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