Artificial Intelligence in Oral Medicine and Radiology- Heralding A New Era

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ABSTRACT

Dentistry has progressed in leaps and bounds over the past few years. New technological advances and diagnostic aids have paved the way for the revolutionization of conventional dental treatment. 'Artificial intelligence', which is a highly evolved system capable of mimicking functioning of the human brain is one such breakthrough whose potential has recently been tapped into. Artificial intelligence (AI) is defined as a field of science and engineering concerned with the computational understanding of what is commonly called intelligent behavior and the creation of the artifacts that exhibit such behavior. Implementing artificial intelligence technology in dental applications could reduce cost, time, human expertise and medical error.

The applications of AI in dental sciences include diagnosis, differential diagnosis, imaging and management of head and neck diseases, dental emergencies as well as other specialties of dentistry. While artificial intelligence by no means can replace the role of a dentist, it is of prime importance to be aware of the possibilities to integrate this technology in the future. This can result in a rise in the standard of diagnosis and management of orofacial disorders. This overview of AI aims to provide an insight into the various techniques and applications of artificial intelligence in the field of oral medicine and radiology.

Keywords: Artificial Intelligence, Oral Medicine, Radiology, Heralding A New Era

INTRODUCTION

The human brain is a unique structure composed of networks of interlinked neurons which transmit signals throughout the body. This nonpareil nature of human brain has always made researchers and scientists inquisitive from time immemorial. The act of constant search has given rise to what is known as artificial intelligence (AI), which is a highly evolved system capable of mimicking the human brain function. AI is defined as a field of science and engineering concerned with the computational understanding of what's commonly called intelligent behavior and with the creation of artifacts that exhibit such behavior. Computer-automated diagnosis is gaining impetus due to its ability to detect and diagnose lesions which may go unnoticed to the human eye, thereby paving way for a comprehensible practice.

APPLICATIONS OF AI IN DENTISTRY

- Regularizing appointments according to the convenience of the patients and dentists.
- Foreshadowing the patients and dentists about checkups whenever any genetic or lifestyle information indicates increased susceptibility to dental diseases.
- Managing the paperwork and insurance
- Supporting the clinical diagnosis and treatment planning
- Portending the dentist before every appointment about any allergies that the patient may have
- Making the dental healthcare provider vigilant about any relevant medical history
- Setting up regular reminders for patients who are on tobacco or smoking cessation programs.
- Providing emergency tele-assistance in cases of dental emergencies when the dental health care professional cannot be contacted.

TECHNIQUES OF AI APPLIED IN ORAL MEDICINE AND RADIOLOGY

- Artificial neural networks (ANN)
- Clinical Decision Support System (CDSS)
- Principal Component Analysis (PCA)
- Data Mining technique
- Fuzzy Logic
- Belief Merging
- Genetic Algorithms (GA)
- Probabilistic and General Regression Neural Network
- Dynamic Bayesian Networks
- Atlas based techniques
- Deep Learning (DL)
- Machine Learning (ML)

Artificial neural networks (ANN)

AI technology in the form of ANN has been extensively used in assessing the degree of aggressive activity of cancers and has impressively supported to contrive unique approaches to predict the course of the disease and prognosis and thus providing prospective suggestions to treatment modalities. The structure and function of ANN largely mimic the brain. It is composed of perceptrons that functionally simulate the neurons. The basic concept

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in ANN is establishing a decision-making unit with interconnection of the perceptron units and this enables nonlinear analysis (Figure 1). There are two types of ANN. Among the most commonly utilized ANN formats are the multilayer perceptron (MLP). This represents a feed-forward network wherein a layer of input perceptrons connects to a number of hidden layers of perceptrons followed by an output layer. The MLP has been shown to be a well-grounded vehicle for exploring the predictive potential of biomarkers for oral cancer.[1]

Clinical Decision Support System (CDSS)

CDSS are interactive computer programs, which are designed to help health professionals with decision-making tasks. The basic components of a CDSS include a dynamic knowledge base and an inferencing mechanism, implemented through medical logic modules based on a language such as Arden syntax (Fig 2). These systems use embedded clinical knowledge to analyze patient data and make decisions regarding diagnosis, prevention, and treatment of orofacial disorders. CDSS applications may be standalone systems, or they may interact with other tools such as an electronic dental record, an order entry system, or a radiology system. CDSS may also portend dentist regarding potentially dangerous conditions for a patient (drug allergies), or they may remind clinicians of routine tasks such as more frequent screening for oral cancer in a smoker, for periodontal disease in a patient with diabetes, or even perform tasks such as the use of prophylactic antibiotics when appropriate. The varied applications include radiology systems and patient education tools which may provide dentists with additional support. By ranking and weighting the related parameters, this intelligent system has the potential to help experts to make the final decision in the differential diagnosis of diseases when there are several possible alternatives as well as in multi-diagnosis when dealing with patients with multiple illnesses at the same time. This system intelligently provides specialists with the necessary prognoses including the prediction of lesion's susceptibility to malignancy and proposes the necessary measures to the specialists. A clinical decision support system is used for the detection and diagnosis of oral cancer.[2]

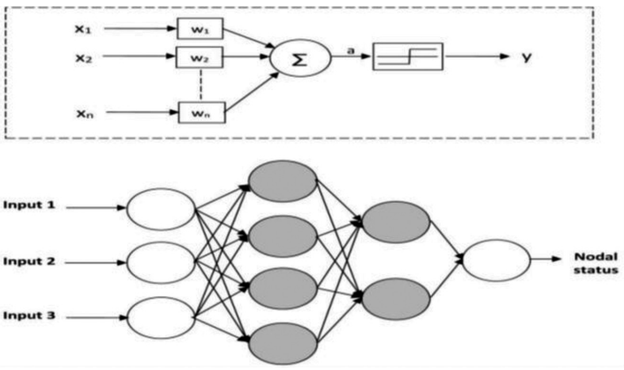

Figure-1: Feed-forward network wherein a layer of input perceptrons connects to a number of hidden layers of perceptrons followed by an output layer

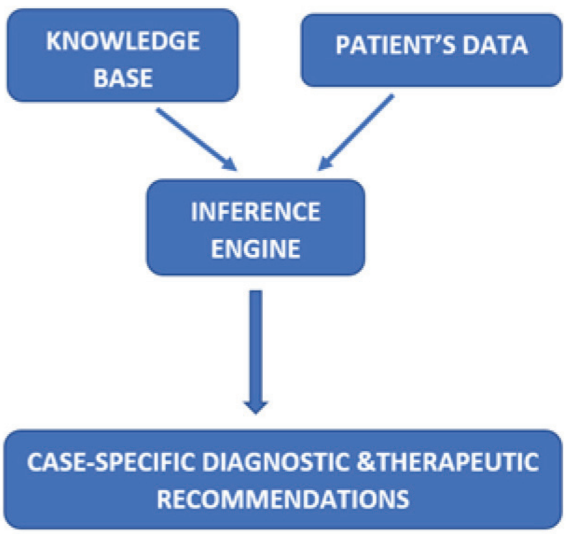

Figure-2: Components of CDSS

Principal Component Analysis (PCA)

The laser-induced fluorescence (LIF) spectroscopy and fluorescence imaging is a noninvasive diagnostic tool for differentiating normal and neoplastic oral tissues that involves illumination of tissue with monochromatic light and recording the fluorescence spectrum & utilize tissue fluorophores (autofluorescence) or exogenous fluorophores and classification is made using both PCA and artificial neural network (ANN).[3]

Advantages are

- Technique is fast,
- Uses cheap, portable equipment, and that can objectively evaluate in a community screening program
- Low-cost equipment like an LIF system can be acquired even by small clinics in rural areas.
- Examination with such equipment using certified calibration sets provided can reduce the chances of a pre-malignant/ malignant situation being missed.

Data Mining technique

It is a Computational process of discovering patterns in large data sets. It extracts information from a data set and converts it into a fathomable structure for further use. It is the analysis step of the "knowledge discovery in databases" process or KDD. It involves anomaly detection, association rule mining, clustering, classification, regression, and summarization.[4] Implemented to create a novel method to diagnosis and prognosis of oral cancer. Genetic based ID3 algorithm is the very simplest algorithm for diagnosis and prognosis of cancer.

Fuzzy logic

Fuzzy logic is a superset of the conventional logic coined in 1965 and used in mathematics in the name of "fuzzy" set. A fuzzy logic system (FLS) can be defined as the nonlinear mapping of an input data set to a scalar output data. An important advantage that can stand alone in justifying the use of fuzzy logic in medicine is the ability of this machine algorithm to introduce into the process of decision linguistic terms, easier for human users to understand and communicate with. A FLS consists of four main parts: fuzzifier, rules,

Figure-3:

inference engine, and defuzzifier (Fig 3).[5] Used for detection and diagnosis of oral cancer, prediction of oral cancer risk assessment, and for diagnostic accuracy.

Belief merging

Belief merging looks at strategies for combining symbolic information, expressed in propositional logic, coming from different sources. Every source is coded as a set of propositional formulae and known as a belief base, where the group of belief bases in conjunction may be inconsistent; the strategies aim at obtaining a consistent belief base representing the group. In particular explains in detail the works on belief merging of propositional bases and logic-based merging with relevant strategies known as merging operators. Used in diagnosis of oral cancer.[6]

Probabilistic and General Regression Neural Network

(PNN/GRNN) models are helpful for the following decisions: To diagnose patients with malignancy and the type of malignancy based on demographic information, clinical symptoms, medical and personal history, and gross examination.

To predict the stage and extent of oral cancer based on symptoms which are confirmed with the help of relevant tests and investigations.

To predict the survivability of patients after appropriate treatments and follow-ups.[7]

Deep learning

DLS Can learn to extract relevant image features and perform image classification simultaneously, without the requirement of manual input of the image features. When image data are input into the top layer, learning of the correct classification occurs through the transmission of information through the layers, with the model performing output of the proposed classification in the final layer. Will greatly assist in alleviating the heavy workload of radiologists and physicians in fields such as molecular imaging for early diagnosis of cancer. Can evaluate cervical lymph node metastases from oral cancers.

Machine learning

Machine learning is a subset of artificial intelligence (AI) that enables computers to learn from historical data, gather insights and make predictions about new data using the information learned. Have high degrees of accuracy and precision. Statistics is primarily focused on inference and describes how a system of components relate to one another. For example, in one study, tumor depth of invasion>4mm was associated with an odds ratio of 8.3 of nodal metastasis.[8] On the other hand, machine learning focuses on making predictions about an unknown variable based on past experiences using large sets of patient data.

Artificial intelligence in the IMRT planning process

Dose prediction

Prior knowledge of the volumetric dose of a prospective patient undergoing radiotherapy would have a substantial impact on clinical workflows involved in IMRT treatment planning since it would provide dosimetric expectations which could be used to help identify outliers and planning cutoff criteria.

Three main types of volumetric dose prediction techniques are:

1. Atlas-based

Atlas-based dosimetry relies on three sub-steps: the reduction of a set of imaging and contouring data into a subset of descriptive data points, the machine learning algorithm that relates the subset of descriptive data points to a corresponding patient, and a deformable image registration algorithm that warps a past dose volume to a novel patient geometry

2. Fully connected neural networks

One alternative to atlas-based methods is to directly predict dose by learning a set of hierarchical features using artificial neural networks. Shiraishi et al. utilized ANNs for IMRT treatment planning assistance focused on utilizing a semi-unstructured approach.[14,15]

3. Convolutional neural networks

CNN-based architectures have been used to as an alternative to fully connected ANNs to predict volumetric information. While CNN based dose prediction methods are still in the developmental stage, they tend to prevail in industry, and thus it is likely that these methods will also soon become common in volumetric dose prediction for head and neck IMRT.

Planning support

IMRT planning is a lengthy process involving many iterations between the dosimetrist, physician, and treatment planning system.[9]

1. Dosimetrist mimicking: An auxiliary program that mimics treatment planning actions of a dosimetrist during the construction of an IMRT plan for a novel head and neck cancer patient.

2. Treatment planning system hyper-parameter optimization: Utilize hyper-parameter tuning algorithms to reduce the clinical burden of the treatment planning process through automation.[10]

3. Normal tissue complication prediction: Mucositis is a common acute toxicity following IMRT. Using a random forest-based classifier, machine learning can accurately predict the probability of onset of mucositis from dose-volume, spatial dose metrics, and clinical data in patients undergoing IMRT.

Genetic Programming

GP reformulated the process of solving the problems of other machine learning methods by searching a highly fit individual program in a population of candidate programs. This space of searching consists of many functions and terminals, relevant to the problem domain. GP functions by searching for the fittest individuals in the program. GP breed populations of hundreds or thousands of computer programs using the Darwinian principle of survival and reproduction of the fittest, together with genetic operations during the process of evolution, namely, mutation and crossover. Thus, in general, GP solves the problems given by the combination of natural selection and genetic operations. Used in assessing the prognosis of oral cancer.[11]

Dynamic Bayesian Networks

The dynamic Bayesian networks take into consideration time-series gene expression data collected at the follow-up study of patients that had or had not suffered a disease relapse. Based on that knowledge, to infer the corresponding dynamic Bayesian networks and subsequently conjecture about the causal relationships among genes within the same time-slice and between consecutive time-slices.

This program aims to

- Assess the prognosis of patients regarding oral cancer recurrence
- Provide important information about the underlying biological processes of the disease.[12]

Applications in oral radiology

- Interpretation of radiographic lesions and automated interpretation of dental radiographs
- Using the radiologist's work as data, AI may enable programs to identify details of individual radiologists' practice pattern and categorizing them to create a sophisticated radiology report card.
- Caries detection: Logicon Caries Detector™ program is designed to assist dentists in the detection and characterization of proximal caries.
- Diagnosis of vertical root fractures on CBCT images of endodontically treated and intact teeth.
- To stage tooth development.
- Computer based digital subtraction imaging.
- Computer-assisted image analysis is useful to visualize and evaluate the bone architecture directly from the dental panoramic radiograph.
- 3-dimensional orthodontics visualization using patient models and OPGs.
- Bone density evaluation to predict osteoporosis using OPGs.
- Automatic segmentation of mandibular canal.
- Forensic dental imaging: Personal Identification System Using Dental Panoramic Radiograph based on Metaheuristic Algorithm.
- Dental biometrics.

Advantages of AI

1. Accuracy in diagnosis
2. Standardization of procedures
3. Saves time.

Disadvantages of AI

1. The complexity of the mechanism
2. The cost involved in the setup.

Future recommendations

To be familiar with AI terminology and hierarchy.

Radiology programs should begin to integrate health informatics, computer science and statistics courses in their curriculum.

To train the radiologist for logic, statistics, and data science and be aware of other sources of information such as genomics and biometrics, insofar as they can integrate data from disparate sources with a patient's clinical condition.[13]

CONCLUSION

Applications of AI in everyday life are growing by leaps and bounds. Dental surgeons have always been at the forefront of implementing technology. The knowledge of various concepts and the techniques involved will have a clear advantage in the future when in a moment to adapt to the change with redefined roles for a rewarding practice. Artificial intelligence has already had a profound impact on the world of medicine and is expected to continue to play a major role, particularly as the pressure on health care institutions to provide high-quality cost-effective care to an expanding patient base increase. By no means there exists a doubt in the ascendancy of integrating AI into practice, it can never replace the role of a dentist since clinical practice is not only about diagnosing but also correlating with clinical findings and providing personalized patient care.

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