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REVIEW ARTICLE

Artificial Intelligence and Maxillofacial Radiology: A review

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ABSTRACT:
Artificial Intelligence deals with the study and design of intelligent agents that perceives its environment and takes actions which maximize its chances of success. The present article highlights clinical applications and scope of intelligent systems such as machine learning, artificial intelligence, and deep learning programs in maxillofacial imaging.
Key words: Artificial Intelligence, deep learning, deep learning.

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Introduction

Artificial Intelligence (AI) term was coined by John McCarthy in 1956. He defined it as "the science and engineering of making intelligent machines." AI is the branch of computer science which deals with the study and design of intelligent agents that perceives its environment and takes actions which maximize its chances of success. AI may be defined as: "The ability to hold two different ideas in mind at the same time and still remain the ability to function". But AI must include the learning from past experience, reasoning for the decision making, inference power and quick response.[1]
Most popular AI analytic tool are used for image analysis inspired by the biological nervous system. This involves a network of highly interconnected computer processors that has the ability to learn from past examples, handle imprecise information, and generalize enabling application of the model to independent data has making it a very attractive analytical tool in the field of medicine. The various techniques of AI which are being applied in dentistry include artificial neural networks (ANN), genetic algorithms, and fuzzy logic.[2]

Components of AI

It has four main components 1. Expert systems: 2. Heuristic problem solving 3. Natural Language Processing 4. Vision Expert system handles the situation as an expert and gives performance. Heuristic problem solving is meant to evaluate small range of solutions, may involve some guesswork to find near optimal solution. Natural language processing provides communication between human and machine in natural language. Vision is the ability to recognize shapes and features etc. automatically.

Artificial Intelligence (AI)[3]

Machine learning
Learning to detect normal and abnormal from analyzing hand labelled images

Representation learning
Learning the features required to classify the provided data without the help of hand labelled

Deep learning
Learning the hierarchical normal representation of specific type of image from large number of normal exams

Machine learning (ML)
It is a part of research on AI that seeks to provide knowledge to computers through data and observations without being explicitly programmed. This allows a computer to correctly generalise a setting by tuning of parameters within the algorithm to optimize the goodness of fit between the input (ie, text, image, or video data fed into the algorithm) and output (ie, classification).

Representation learning
It 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.

Deep learning
It is a subfield of representation learning relying on multiple processing layers (hence, deep) to learn representations of data with multiple layers of abstraction. 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. Basis of any radiologic interpretation is logical elimination of possible diagnosis. In this context, deep learning can potentially excel by learning a hierarchical normal representation of a specific type of image from a large number of normal exams.[4]
Radiologists are primarily known for their image interpretation skills. Advanced breakthroughs in image recognition introduced by deep learning techniques, and media statements by researchers have portrayed artificial intelligence as the cause of demise of radiologists. However, the complex work performed by radiologists includes many other tasks that require common sense and general intelligence for problem solving tasks that cannot be achieved through AI. Understanding a case requires multiple basic medical and clinical specialities to provide plausible explanations for imaging findings. Also, advanced imaging modalities necessitate specialized intelligence for detection of anomalies, segmentation, and image classification.[5]

Applications
Adapting of AI in maxillofacial radiology its clinical applications can be divided into 3 types.[6]
1. Clinical workflow
2. Types of applications
3. Classes of use cases

Clinical workflow
These are the diagnostic tests inserted in existing clinical pathways. For example, when a patient requires a diagnostic imaging, radiologist is the one who decides the image selection and other protocols. Alternatively, AI applications can be applied using various scenarios to reduce the radiologist burden.
Different scenarios used in clinical work flow are triage, replacement and add-on which are based on the conceptual frame work developed by Bossuyt. et al.[7]

Triage scenario:- adapted from is used as a screening tool to sort examinations based on the probability of disease being positive or negative according to AI. For example, AI will assess the not interpreted x-rays for highest probability of disease determined by an algorithm according to the content of images or other data available and determine which examination should be interpreted first.

Replacement scenario:- AI may replace radiologists if results are consistently more accurate, rapid, reproducible, and easier to obtain. Most common application of it being estimation of bone age by an AI software. AI is found to consistently provide better performance than a radiologist in bone age estimation. Add-on scenario may use AI in a subgroup of patients where the existing clinical pathway is dependent on the radiologist interpretation. This tool is applied only if the imaging findings warrant a time-consuming application best left to ML algorithms.

Types of application
This can be divided into-

Detection: To identify an anomaly within an image (eg, a nodule);

Segmentation: To isolate a structure from the remainder of the study (eg, defining the boundary of an organ);

Classification: To assign an image or lesion within an image is assigned to a category (eg, is presence or absence of pulmonary embolism on a CT scan).[8]

Applications

Identification of radiographic landmarks
Convolutional neural networks use automated segmentation to detect and segment certain patterns in large-volume datasets. The U-net architecture is the most common convolutional neural network segmentation method used in medical specialties to differentiate osseous and soft tissue structures. The automated interpretation of radiographs enables the accurate localization of landmarks and could be used with CT and MRI to identify abnormalities in images that may go unnoticed by visual interpretation. Convolutional neural networks allow precise edge detection, and edge-based, region-based, and knowledge-based algorithms are used to locate cephalometric landmarks. These networks can locate the landmarks in partially hidden, low-contrast, overlapping areas that are not visible to the naked human eye. Convolutional neural network algorithms enable pixel-by-pixel elaboration, and knowledge-based algorithms help to locate new anatomic landmarks in a more robust and precise way.[9]

Evaluation of Periodontal diseases and bone density
Periodontists are being assisted by deep analysis tools are assisting in the early detection of alveolar bone loss, bone density changes, and areas of furcation involvement. Krois et al[10] found that a convolutional neural network showed higher diagnostic performance, with an accuracy of 81%, than individual examiners, who showed an accuracy of 76%, in the radiographic detection of periodontal bone loss.

Evaluation of periapical pathologies
Periapical lesions such as abscesses, granulomas and cysts are apparent on radiographs, but some may go unseen as images may have low contrast. Intelligent systems can accurately locate tooth areas prone to caries and complex periapical pathoses, use automated segmentation to define the boundaries of lesions in a more precise way, and enable their differentiation. In the future, these systems they may benefit implant dentistry by enabling the early detection of peri-implantitis with appropriate interventions.[11]

Determination of maxillary sinus pathologies
Maxillary sinusitis is characterized radiographically by mucosal thickening >4 mm, the air fluid level, and opacification. Paranasal sinus (PNS) views are used routinely for identification of maxillary sinusitis, and verification is made with CT scan, which is the preferred imaging modality for evaluating the air fluid level and sinus opacifications. These conventional radiographs create diagnostic difficulties due to overlapping of the maxillary sinus by facial bony structures, which may yield false-negative results. Deep learning programs increase the diagnostic ability of conventional radiographic views, thereby helping to avoid unnecessary referrals of patients for CT examinations, which have high radiation doses.[12]

Caries detection
Logicon Caries Detector™ program (Logicon Inc., USA) is designed to assist dentists in the detection and characterization of proximal caries.[13]

Automatic segmentation of mandibular canal
Gerlach reported accuracy of automatic segmentation of the mandibular canal by the AAM and ASM methods is inadequate for use in clinical practice.

Forensic dental imaging
Personal Identification System using dental panoramic radiograph based on Meta Heuristic Algorithm reported to have 97.7% precision. Bewes et al[14] found that neural networks showed a 95% accuracy in distinguishing sex in 900 anthropological skulls reconstructed from CT scans. Intelligent systems could also improve the accuracy of age estimation methods, although very limited studies have yet investigated the application of neural networks for age determination.

TMJ osteoarthritis
Osteoarthritis, which is the most common degenerative disease affecting the temporomandibular joint (TMJ), is characterized by destruction of the articular cartilage and subchondral bone resorption.
de Dumast et al[15] described a non-invasive technique that uses neural networks to classify morphological variations of 3D models of the mandibular condyle into 7 different categories (G1, normal; G2, close to normal; and G3-6, various stages of degeneration). A rainbow color-coded map on 3D models defined the exact

location of the morphological changes on the condylar surface. Categorization by neural networks will enhance the understanding of clinicians regarding the shape changes that occur in patients with TMJ osteoarthritis.

Assessment of Sjogren syndrome

Software algorithms have emerged as a promising approach for the analysis of big datasets obtained from large groups of patients affected by systemic autoimmune diseases. Kise et al[16] assessed cases Sjögren syndrome on CT with deep learning system and observed accuracy of 96%, sensitivity of 100% and specificity of 92.0%. The corresponding values of inexperienced radiologists (83.5%, 77.9%, and 89.2%) indicate that the diagnostic performance of the deep learning system was better than that of inexperienced radiologists. Authors suggested that deep learning systems may be used as diagnostic support for the interpretation of CT images Sjogren syndrome patients.

Headache

Migraine and tension headaches have a significant impact of the quality of life of individuals in the working population. Primary headaches have no associated underlying organic cause, whereas secondary headaches are usually the symptoms of an underlying disease process. Physicians diagnose patients with chronic headache symptoms on the basis of a clinical examination and imaging modalities such as MRI, and usually prefer medical management as an appropriate treatment intervention. Krawczyk et al[17] developed an automated 3-component system for classifying headache disorders by a decision tree algorithm. They found that automated techniques were highly accurate (97.85%) and reduced classification errors.

Advantages of AI

It is a powerful tool to identify patterns, predict behaviour or events, or categorize objects. Improvement of radiology departmental workflow through precision scheduling, identify patients most at risk of missing appointments, and empower individually tailored exam protocols.[18] Machine learning directly with medical data can help in preventing the errors due to cognitive bias.[19]

Shortcomings

It requires a very huge and sound data base of knowledge, if not may result in inappropriate answers when presented with images outside of their knowledge set. For example, when image techniques not appropriate or if there are any artefacts may result in faulty interpretation of image. It may not adapt with new imaging software or new machine immediately.[20]

Future scope

Radiologists should be familiar with AI terminology and hierarchy. Radiology programs should begin to integrate health informatics, computer science and statistics courses in their curriculum. Radiologist should be trained 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.

Conclusion

Intelligent systems play an significant role in dentomaxillofacial radiology in making diagnostic recommendations. They have been found to be effective in every field in dentistry as a way to obtain a quick diagnosis and treatment plan for complex problems unresolved by the human brain.

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