JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

An overview into the world of Artificial Intelligence and Machine learning in Dentistry – A beginner's perspective

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Abstract

Artificial Intelligence is a technological advancement in day-to-day life. With recent progress in digitized data acquisition, computing infrastructure and machine learning, AI applications are expanding into areas that were previously thought to be reserved for human experts. AI has tremendous potential to improve patient care and revolutionize the health care field coming to its application in medical and dentistry. In dentistry, AI is being used for a variety of purposes, specifically identification of normal and abnormal structures, diagnosis of diseases and prediction of treatment outcomes. As well as machine learning is being increasingly employed in dental research and application. This paper focuses on brief description about machine learning models and artificial intelligence which can be used in dentistry for various purposes. This article aims to make the beginners in dentistry more aware about machine learning and artificial intelligence in dentistry so that it is more useful for future endeavors.

Keywords: Artificial Intelligence, Machine learning, algorithm, Model

INTRODUCTION :

Dentistry is a technologically driven field in the healthcare sciences that help improve overall patient care. Earlier dental charting [1] was manual and it was a tedious process. The maintenance of records and treatment plans for patients was done manually in files. With the advent of computers this task has become quicker, more reliable and simpler in modern-day scenarios. Though this seems more tedious but new technologies are there in the market which helps the dentist to chart down through intraoral scanners and plan the treatment with the help of software like pearl.ai [2] and overjet.ai [3] as these software work primarily on machine learning models [4] which are getting better and better with thousands of data points and images in its processing code.AI has been adopted in many fields of industry, such as robots, automobiles, smart city, and financial analysis. Etc. It has also been used in medicine and dentistry, for example, medical and dental imaging diagnostics, decision support, precision and digital medicine, drug discovery, wearable technology, hospital monitoring, robotic and virtual assistants. AI can be regarded as a valuable tool to help dentists and clinicians reduce their workload.[5]

A basic computer program is based on an input, function, and output.[6] It means that a computer programmer or a coder knows the input and output that will be achieved based on set rules with manual efforts.[7] Whereas machine learning is based on complex functions which are difficult to code. The input and output need to be related to statistical data points and the computer itself creates a function which can create input and output pairs, the machine learning works on model training the more amount of correlated data is put forward into the system the more reliable or accurate it gets.[8]Through complex calculations capable of only by computer.[9]The basic difference between traditional computing and machine learning is that traditional computing is written or coded with a set of rules with knowledge of input and output whereas the latter depends on function learning based on data sets.[10] Machine learning is the backbone of artificial intelligence or vice versa. Both terms are often used interchangeably.[11]Whereas artificial intelligence refers to developing machine learning capabilities.[12]Machine learning is the statistical and mathematical modelling process which doesn't require a lot of coding to achieve a result or target by automatic learning and predictive analysis, there's a huge difference between computer programming and machine learning. [13]

When we come to the basics of machine learning. It is based on three models:

1-Supervised learning

2-Unsupervised learning

3-Reinforcement learning

Supervised learning means that the system takes up the input and output pairs and relates them to function the more correct function it gets in relation to the input and output the better the model (input and output with functional relationship). [14] It is synonymous with the function approximator as it approximates the function between input and output pairs.[15] Machines learn by categorically creating label types that are based on problems it can be regression problems or classification problems.[16] It more relies on the model training which is again based on data sets of labels each data set is divided into training, validation, and test dataset.[17] Traditional machine-learning algorithms employed in supervised learning are decision trees, random forests, support vector regression etc.[18]

Unsupervised learning is the process of finding correlations between unstructured data sets. Structured and unstructured data sets stand for statistical data like age, gender, height, weight etc., whereas the latter unstructured data set contains images and text embeddings.[19]

These are the traditional concepts of machine learning. The more currently used and employed machine learning models are based on deep learning, deep learning is based on the hierarchical ordering of the data or parameters into layers as shown in figure 1. Thus, features are repeatedly added and multiplied together with the outputs from one layer and fed to the next layer before any prediction can be made.[20]This increases the features and prediction relation between the layers and makes the model more complex.

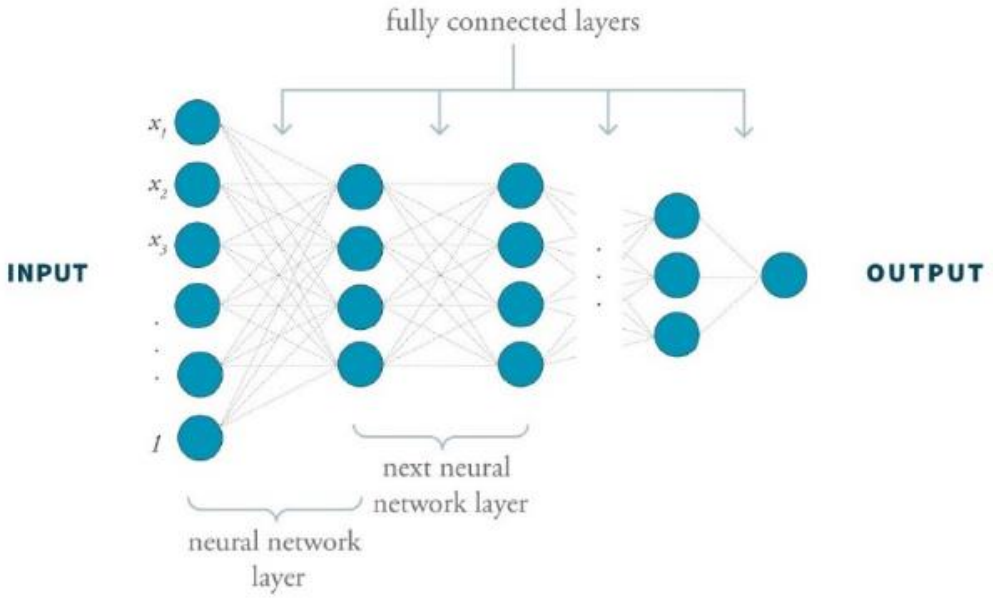

Figure 1- A diagram of a network structure

In deep learning, there are various important concepts which are

- Cross-entropy loss the function determines the difference between prediction and probability.[21]

The function is simple– you sum the negative log of the model's predicted probability for the ground truth class. Because probabilities are between 0 and 1, the log value is some negative number.

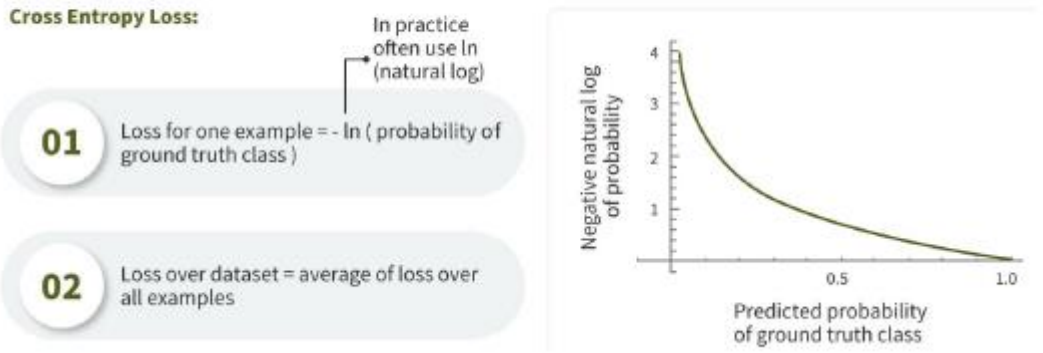

Figure 2-A graph and diagram of a log value

- Gradient descent is the optimization of the algorithm to find good model parameters with minimizing the loss function.[22]
- Backpropagation it is the key technique of deep learning models in machine learning that breaks down the gradient computation into parts rather than a combined structure.[23]

In deep learning, "loss function" and "cost function" are often used interchangeably. They both refer to the same concept of a function that calculates the error or discrepancy between predicted and actual values. The cost or loss function is minimized during the model's training process to improve accuracy.Loss informs how much the machine learning algorithm is close to the true label and estimated label.[24]The goal of any machine learning algorithm is to reduce the loss as much as possible to achieve better results and prediction rates.

There are various type of deep learning neural networks. Some of them and their applications are mentioned below.

CNNs (Convolutional Neural Networks) - Designed for an unstructured data set which has Image sets for detection. CNNs work by dividing the image into pixels and correlates them with the neural network in layers and achieves the results.[25] Its uses in dentistry are as follows :-

- Histopathology: Detection of abnormal cells in a histopathologic section in relation to diseases [26]
- Clinical diagnosis: Detection of any oral Lesion
- Radiology: caries Detection, bone loss, unknown Radiolucency and Radiopacities.[27]

ImageNet, Resnet And Google Lens are few CNNs which are based on semantic segmentation and object detection.[28]

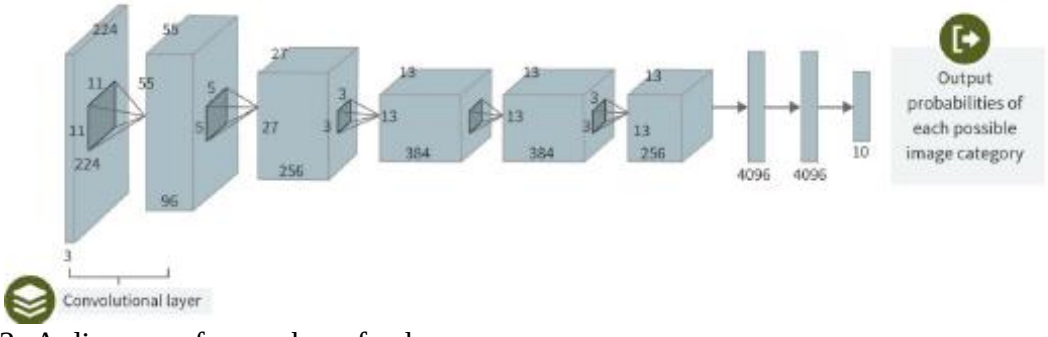

FIGURE 3- A diagram of a number of cubes

NLP or Natural Language Processing Algorithm understands human languages and organizes them, it not only recognizes the vocabulary but also the context behind the words.[29]

Reinforcement Learning [30]:

It is a Comparatively Less explored field in terms of healthcare as the model is designed to predict the results with external agents as well as there is no correct way to stimulate the environment in real-world situations.

PRECISION DENTISTRY

The amalgamation of precision dentistry and AI is where innovation occurs. AI's ability to analyse and interpret huge datasets complements precision dentistry's focus on individualized care. Together, they create a symbiotic relationship that amplifies the potential for improved patient outcomes.

1. Improved diagnostics

AI algorithms excel in pattern recognition based on CNN and RNNs, making them ideal for identifying subtle anomalies like dental caries in dental images and radiographs [31] that might be missed by the human eye. This aids in the early detection of dental issues, enabling timely intervention and prevention of disease progression.

2. Personalized Treatment Plans

Precision dentistry is based on the concept of tailoring treatment to each patient's unique characteristics. AI improves this by analysing large databases of patient information to recommend the most effective treatment plans based on factors such as genetics, medical history, and lifestyle. A chatbot can be introduced for more precise results based on NLP and LLMs models.

3. Predictive maintenance

Incorporating AI into dental practice management systems can lead to more efficient clinical operations. AI algorithms can predict equipment maintenance needs and ensure that dental tools are in optimal working condition. This predictive maintenance prevents unexpected breakdowns and minimizes disruptions in patient care.

4. Big Data

This term is used to describe data that is large and unmanageable. In order to meet our present and future social needs, we need to develop new strategies to organize this data and to extract the information contained and transform the raw data into knowledge and derive meaningful information. Biomedical Big Data includes data from different sources such as electronic health records, health research, wearable devices, and social media. AI can be incorporated to manage this Big Data.

5. Patient engagement

AI-powered gadgets can provide control over oral health. Mobile apps (such as the Oral B iO app [32] and virtual assistants can provide individualized oral hygiene advice, track brushing and flossing habits, and remind patients of impending appointments [33]This level of participation develops a sense of ownership and alertness toward oral health.

6. Research and development

Artificial intelligence-driven dentistry research is accelerating the development of new materials, treatments, and technologies. AI accelerates the process of uncovering innovations that can transform the future of dental care by evaluating vast data sets and modelling treatment results.

CHALLENGES AND CONSIDERATION

Several challenges and considerations need to be addressed as promising as the fusion of precision dentistry and AI.

1. Data privacy and security

The integration of AI requires access to enormous amounts of patient data. Ensuring the privacy and security of such data is paramount. Striking a balance between data use to improve patient care and safeguarding patient confidentiality is crucial [34]

2. Compliance with law and regulations

Dental practice must navigate through a maze of regulations when implementing AI systems. These systems must comply with standards set by medical and dental regulatory bodies to ensure patient safety and ethical use following HIPAA laws [35.]

3. Education and training
Dental professionals must be trained to effectively use AI-powered tools and interpret their outputs. Incorporating AI into dental curricula and providing continuous training opportunities will be vital to harnessing its full potential [36].

4. Cost implications
Integrating AI systems can involve significant upfront costs from acquiring technology to the training staff. Dental practices, especially smaller ones, must carefully evaluate the return on investment to justify these expenses.

CONCLUSION:
Machine Learning is exploration and finding out new possibilities and outcomes with the underlying data that is present and creating new pathways for traditional methods that may be cumbersome. Huge amount of data is available in dentistry which can be harnessed to create models of prediction and can be deployed worldwide with a user interface and can be used in less accessible settings. Best options can be delivered with data backed knowledge.

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