BIG DATA AND MACHINE LEARNING WITH APPLICATIONS

This book presents a collection of studies related to Big Data (BD) and Machine Learning (ML) in its various real-world applications. The presentation starts with an introduction and overview of BD and ML. Not only limited to marketing strategy, ML is also very affective in many areas, such as heritage property, construction, water quality, classification, crime analysis, dentistry, Covid-19 and healthcare. Different modelling techniques and mechanisms are developed by the authors for a reliable and sustainable prediction strategy based on BD. Besides that, a comprehensive analysis of traditional and modern analysis is also discussed in this book. Based on the experimental results from the chapters, it is observed that ML can generate promising results and help the development of related areas. Hence, this book covers the execution of BD and ML that brings beneficial in term of time, cost, and quality.

UTM UNIVERSITI TEKNOLOGI MALAYSIA Penerbit UTM Press

ISBN 978-983-52-1857-6

9 789835 218576

RM60.00

Edited by Yusliza Yusoff Sarina Sulaiman

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UTM UNIVERSITI TEKNOLOGI MALAYSIA Penerbit UTM Press
www.penerbit.utm.my
2022

First Edition 2022

Perpustakaan Negara Malaysia Cataloguing-in Publication Data

BIG DATA AND MACHINE LEARNING WITH APPLICATIONS / Edited by Yusliza Yusoff, Sarina Sulaiman
ISBN 978-983-52-1857-6
1. Big data.
2. Machine learning.
3. Application software.
4. Government publications--Malaysia.
I. Yusliza Yusoff.
II. Sarina Sulaiman.
005.7

Editor: **YUSLIZA YUSOFF & SARINA SULAIMAN**
Editor Penyelaras/ Acquisition Editor: **NUR'AINA OSMAN**
Pereka Kulit / *Cover Designer:* **NORIZAN YAACOB**

Diatur huruf oleh / *Typeset by*
YUSLIZA YUSOFF
School of Computing, Faculty of Engineering
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Diterbitkan di Malaysia oleh / *Published in Malaysia by*
PENERBIT UTM PRESS
Universiti Teknologi Malaysia
81310 UTM Johor Bahru
Johor Darul Ta'zim, MALAYSIA
(PENERBIT UTM ahli MAJLIS PENERBITAN ILMIAH MALAYSIA (MAPIM) dan anggota PERSATUAN PENERBIT BUKU MALAYSIA (MABOPA) dengan no. keahlian 9101)

Dicetak di Malaysia oleh / *Printed in Malaysia by*
JASAMAX ENTERPRISE
No. 16, Jalan Kebudayaan 2, Taman Universiti
81300 Skudai, Johor, MALAYSIA

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Preface

Big Data and Machine Learning are two focus areas of Data Science and have become significantly influential as many organizations and industries have been collecting and generating huge amounts of in-house data and information.

The use of Big Data technology is becoming very significant these days as recent smart devices are producing very large amounts of data at one time. The diversity of data formats and types has resulted in manual and traditional data analysis is no more longer being competent. These days, the use of advanced tool and software in data analyzing is a necessity in any organization especially in predicting the future trend and business.

Big Data is use with Machine Learning applications in a variety of areas such as policy, crime, healthcare, and pollution. Machine Learning involves high level and complex algorithms through hierarchical training and learning processes. The capabilities of Machine Learning in analyzing massive unstructured data are undeniable, making it a valuable tool to be utilized in addressing problems in Big Data era.

In line with the Fourth Industrial Revolution, it is observed that the evolution of Big Data and Machine Learning is increasingly important. Due to that reason, this book highlights the trends and issues related to Big Data and Machine Learning to expose the current needs and challenges in various real-world applications.

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2022

CHAPTER 9

Current Applications of Machine Learning in Dentistry

Ahmad Badruddin Ghazali, Nor Hidayah Reduwan, and Roliana Ibrahim

9.1 INTRODUCTION

Artificial intelligence (AI) is the general description given to computer systems that can perform tasks and mimic the requirement of human intelligence input (Pesapane *et al.*, 2018). Machine learning (ML), a subset of AI was described as an algorithm with the ability to "learn" by identifying patterns in a large dataset (Rowe, 2019). ML programs can improve from experience automatically, unlike traditional computer programming, where every step of the program requires a written code (Mayo & Leung, 2018). The process is similar to a human expert that can learn by repeated training (Hung *et al.*, 2019). The quality of the output depends on the quality of data used to train and validate the algorithm (Rowe, 2019). Additionally, deep learning (DL), which is a subset of ML, was inspired by the structure and function of the human brain called artificial neural network (ANN). ANN contains multiple layers of the network that receives the output of the previous layer, computing a task and sending it to another layer, and the structure is able to teach itself by reviewing a large amount of data (Mayo & Leung, 2018). Convolutional neural network (CNN) is commonly applied in computer vision research. The difference between ANN and CNN is that in CNN, only the last layer is fully connected, but in ANN, each neuron is connected with the other (Kumar, 2017).

Most mathematical models were developed to find the relationship between input data and output data. However, a complex real-world phenomenon cannot be described easily from a closed-form input-output relationship. Thus, ML is an automated process to build a computational model of these complex relationships (Bastanlar & Özuysal, 2014).

This chapter is organized by firstly presenting potential use of ML in dentistry in Section 9.2. Section 9.3 describes the methodology for ML research while Section 9.4 explains the applications of ML in dentistry. Section 9.5 discusses the available ML products and studies in the field of dentistry. Section 9.6 of this chapter provides the limitation and ethical consideration of ML research in dentistry, and finally Section 9.7 concludes the chapter.

9.2 POTENTIAL USE OF ML IN DENTISTRY

Dental radiology is most benefited from the advancement in ML due to the digitization of radiological images in the current practice. The digital images offer direct access and easily be translated into computer language (Hung *et al.*, 2019). Incorporating ML technology into a radiological service can help improve the

radiologist's performance, reduce the time for interpretation, smooth integration with current workflow, and be cost-effective for the initial start (Mayo & Leung, 2018).

Uses of ML in dental radiology includes tooth classification, segmentation, automated tooth numbering, radiographic landmark identification, detection of osteoporosis, classification of cysts, identification as well as measurement of alveolar bone resorption, and detection of dental diseases (Hung *et al.*, 2019). Other than that, it could be used for prediction of medication-related osteonecrosis of the jaw (MRONJ) (Chen *et al.*, 2020), age estimation (Bunyarit *et al.*, 2020; Mohammad *et al.*, 2021) and many more.

The number of available Oral and Maxillofacial Radiologists specialists is very limited to interpret all radiographs taken in the clinical practice. Thus, the development of ML algorithm for the interpretation of radiographs can ease the burden of the radiologist. However, the final interpretation still depends on the clinician as the output from ML algorithm is not fully reliable for clinical practice at the moment (Heo *et al.*, 2020).

9.3 METHODOLOGY FOR ML RESEARCH IN DENTISTRY

9.3.1 Steps

The first step in developing ML technique is to gather a large amount of training data and store it in a suitable, computable form. Commonly, there is more than one computational model that can be used for each problem. Each model depends on the quantity and quality of the training data and the complexity of the relationship of the input-output data. This means that a researcher should try multiple models to find the most suitable one (Bastanlar & Özuysal, 2014).

The training dataset can be divided into supervised learning, unsupervised learning, and reinforcement learning. Regarding supervised learning, one or more experts in the field (oral radiologist) will label or annotate the training data. Unsupervised learning means that the system will learn to recognize the unlabeled data automatically. Reinforcement learning is commonly used in gaming and robotics and learn from positive and negative feedback (Heo *et al.*, 2020).

All of the collected patient data need to be anonymized, and the data's representativeness needs to be validated, the area of interest will later be segmented, and the data will be annotated by the experts (Do *et al.*, 2020).

Data labeling from the radiographic study can be done in two methods: having an expert or radiologist label each of the radiographs or taken from the radiology report. Despite these two methods have their own strengths and weaknesses, both were aimed at having a ground truth to be used as a reference (Do *et al.*, 2020). Labeling by an expert is time-consuming and may lead to observer's disagreement. Thus, having an acceptable intra and inter observers' agreement is crucial to get an adequate ground truth (Heo *et al.*, 2020).

The data are then divided into training, validation, and test dataset after the labeling process is done. The parameter can be altered during the training phase accordingly. The performance of the model can be assessed during the validation phase, and the best model can be chosen that suits the objective of the study. Then, the final assessment of the model can be evaluated during the test phase. Clear division between validation and test data is needed, and the number of data needed for each phase depends on the difficulty of each task. Cross-validation can be used in a study with a small dataset. However, some studies removed the validation phase, and the data is divided only into training and test sets (Heo *et al.*, 2020).

9.3.2 Test of Performance

Few methods are used to test the performance of a developed ML algorithm. One method is by doing a validation test. Several types of validation tests were described in the literature such as multiple fold cross validation, independent sample validation, or combining multiple validation methods (Hung *et al.*, 2019).

Another method of testing the algorithm performance is by calculating the mean, median and deviation of the measurement, accuracy, specificity, positive and negative predictive value (PPV/NPV), area under curve (AUC), mean difference and/or correlation against the reference standard (Hung *et al.*, 2019). Each study may require different sets of tests to measure the performance of the developed algorithm.

9.4 APPLICATIONS OF ML IN DENTISTRY

9.4.1 Classification, Detection and Segmentation

Machine learning through CNN in dentistry can perform several tasks such as classification, detection, and segmentation on a dental radiograph (Heo *et al.*, 2020). Detection method can recognize and isolate and comparatively have similar fundamental to the classification method. In the segmentation method, the area of interest can be identified and segmented from the radiographic image- an example of three methods in caries detection presented in Figure 9.1.

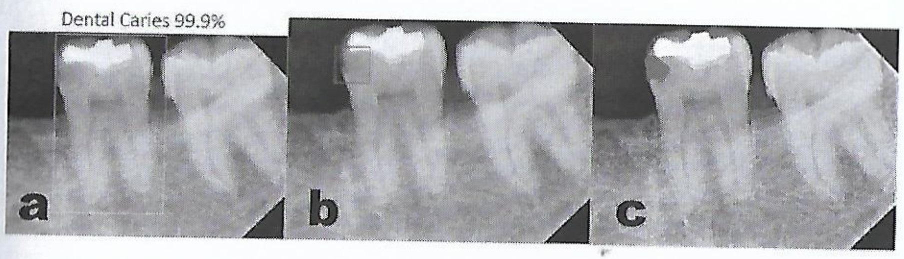

Figure 9.1 Caries detection by several methods. a. classification b. detection c. segmentation

A systematic review by Prados-Privado *et al.* (2020) compiled seven studies of caries detection from dental radiograph based on classification, detection, and segmentation neural network task.

9.4.2 Improving the ML Data Quality

Several methods were used to increase the training data quality and reduce the time of the training phase. Data augmentation, using a pre-trained deep learning network such as GoogLeNet Inception V3) or a pre-trained model of AlexNet Network can be used to achieve these objectives (Chen *et al.*, 2020; Heo *et al.*, 2020; Mohammad *et al.*, 2021).

Data augmentation is a commonly used method to boost the capability of neural networks. It plays a crucial role when ground truth data is deficient, and acquiring new images is not easy due to time or cost constrain. The image can be rotated, flipped, translated, scaled, cropped, or sheared to increase the number of the available image from one original medical image (Nalepa *et al.*, 2019).

Image classification of medical images can be enhanced by using a pre-trained network such as ImageNet. It is a non-medical image of over 1.2 million scenery images that can be used to train medical images. Shallower network AlexNet has higher accuracy of image classification when compared with deeper network VGGNet-16, and both networks were trained with ImageNet (Alebiosu & Muhammad, 2019). Utilizing AlexNet trained with ImageNet can improve the flow of training image classification in dental radiographs, too (Mohammad *et al.*, 2021).

9.4.3 Performance

The expected outcome for accuracy in clinical practice is 98–99% (Hwang *et al.*, 2019). The performance of each model is not equal. Recent models have shown improvement with score of at least 95% for accuracy, specificity, and sensitivity. Thus, the models could be used for clinical applications in the future (Hung *et al.*, 2019). However, the dataset and performance from each research confined in-house, so comparing each result are not possible. A call for a

publicly available, anonymized dataset to develop ML algorithm was suggested (Hwang *et al.*, 2019).

9.5 CURRENT APPLICATIONS

9.5.1 Available Products

Several products are available in the market especially by startup companies, by using the ML technology to aid the clinician's work. Diagnocat, can detect pathologies from intraoral, panoramic, and cone beam computed tomography (CBCT) images. Dentalxr.ai, also have the capability to detect, and classify individual tooth, and detect caries, restorations, and apical pathosis, then convert the findings into a radiographic report. Similar automated radiographic interpretation can also be seen in Denti.ai. These programs utilize machine learning algorithms to identify and classify tooth structures and any pathologies and develop a treatment plan for each specified problem. A dentist's input is still needed to approve the proposed diagnosis and treatment plan specified by the software. Sample CBCT radiographic report by Diagnocat is presented in Figure 9.2 and Figure 9.3.

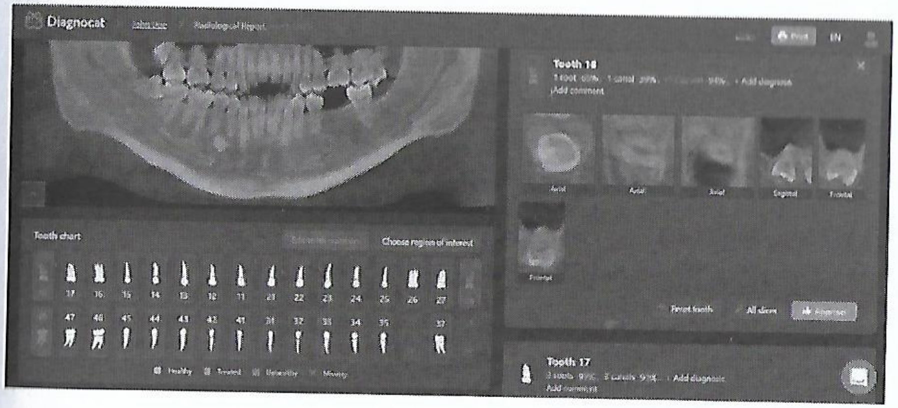

Figure 9.2 CBCT Radiographic report interface by Diagnocat

Cephalometric analysis is more widely used, and the technology is more matured. Software such as CephX by Orca Dental AI and Audax CephX can do the automated lateral cephalometry tracing effortlessly and instantaneously using machine learning algorithms. Radiographic software from industrial giants like Newtom and Dentsply Sirona can be integrated with CephX to get the automated tracing done. The automated cephalometry tracing is also available in the Planmeca Romexis software.

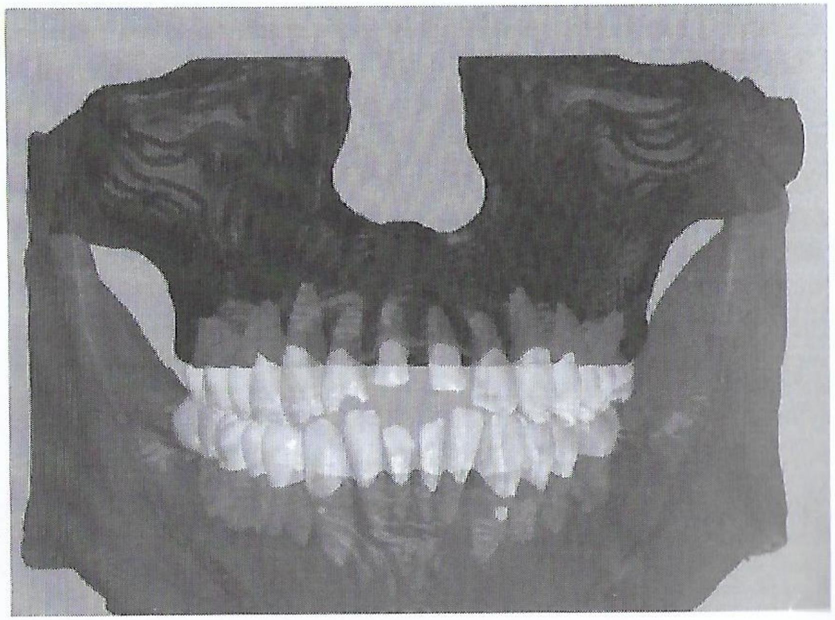

Figure 9.3 Jaw, individual tooth and inferior alveolar nerve canal (IAC) segmentation by Diagnocat from a raw CBCT data

9.5.2 Current ML Studies in Clinical Dentistry

A summary of current applications of studies of ML applications in clinical dentistry presented in the Table 9.1.

Table 9.1 Current applications of studies of ML applications in clinical dentistry

Year	Study	Data type	Detail
2021	Bayrakdar *et al.*	Bitewing radiograph	Caries detection and segmentation
2021	Başaran *et al.*	Panoramic radiograph	Dental charting
2021	Mohammad *et al.*	Panoramic radiograph	Age estimation
2021	Lee *et al.*	Bitewing radiograph	Caries detection
2020	Kise *et al.*	Ultrasound	Sjogren's syndrome diagnosis
2020	Lee *et al.*	CBCT	Cyst diagnosis
2019	Ekert *et al.*	Panoramic radiograph	Detection of apical lesion
2019	Hiraiwa *et al.*	Panoramic radiograph	Root morphology assessment

9.6 LIMITATION AND ETHICAL CONSIDERATION

The ML study in dentistry is still considered on a small scale and fragmented (Heo *et al.*, 2020). Large training datasets are required for the clinical application of ML (Hwang *et al.*, 2019). The majority of ML research in dentistry is using a small number of the training dataset. 90% of the studies are using less than 500 images, and many studies are using around 50 to 100 images to develop the algorithm (Hung *et al.*, 2019). The trend of increasing the number of training images is seen from 100 to 1000 images in the year 2018 (Hwang *et al.*, 2019). The process of getting a large number of data annotated by an expert, i.e., an Oral and Maxillofacial Radiologist, is very laborious (Heo *et al.*, 2020). Several points discussed in Section 1.4.2 could be used to increase the number of training images when the novel number of data is limited.

There are few limitations associated with ML. It can only excel in one task, and dependent on the quality of the training data. Supervised learning with the labeling of the ground truth by an expert radiologist is time, cost, and resource-consuming, while semi-supervised and unsupervised learning methods cannot achieve the same power (Noguerol *et al.*, 2019). Collaboration between multiple academic specialties such as an oral radiologist and the dental clinic to get the data, and data scientists and computer engineers are needed to produce a good ML model that suits clinical application (Chen *et al.*, 2020).

A multi-society joint statement by various radiology and medical physicist associations divided the ethical issues in AI in radiology setting into three categories: ethics in data, ethics in algorithm and trained models, and ethics of practice (Geis *et al.*, 2019).

Radiologists are responsible for using the collected data for the greater good of the patients. Bias should be reduced to the minimum level regarding the patient's gender, ethnicity, and socio-economic factors. Due to the fact that the patient's radiographic images can be used to develop a commercial program, the value of the images could increase tremendously. Thus, the access and management of the data should be lined beforehand (Geis *et al.*, 2019).

9.7 CONCLUSION

This chapter presented that there are many potential applications of ML in the field of dentistry. It can help clinicians' burden by automatically classifying, detecting, and segmenting an area of interest and providing diagnosis from a radiograph at a high level of accuracy, specificity, and sensitivity. However, a final human input is still needed when we are dealing with a patient, especially regarding the diagnosis and treatment planning.

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