

CHAPTER 1

INTRODUCTION

This chapter presents a brief overview of dental imaging modalities and dental image segmentation. Further, the motivation behind the present work, an introduction to the problem statement and the research objectives of the thesis are also discussed. Finally, the chapter concludes with a list of contributions of this thesis in the field of dental image segmentation.

1.1. Background

In the field of medical imaging, dental image analysis is a rapidly growing field of research that involves the use of advanced imaging techniques and computer-based algorithms to extract clinically relevant information from dental images. Dental image analysis involves a range of techniques, including image segmentation, feature extraction, pattern recognition, and machine learning. These techniques can be applied to a variety of dental imaging modalities, including two-dimensional (2D) and three-dimensional (3D) images. The analysis results provide critical information about dental conditions, such as cavities, periodontal disease, and oral cancers, as well as aid in the planning and monitoring of dental procedures such as implantology, surgeries, and orthodontics[1].

There are various types of dental image modalities, such as radiographs, endoscopic images, 3D intra-oral scans and 3D dental models or structures. The radiographs are roughly categorized into X-rays and Cone-Beam Computed Tomography (CBCT). X-rays are further divided into panoramic, bitewing and periapical images[2][3]. These images are the most comprehensive source used in dentistry because of their low price and assist in checking the condition of impacted teeth, gums and alveolar bone

resorption. Panoramic X-rays are taken from the outside of the mouth and cover the overall tooth structure. Periapical X-rays are taken from the inside of the mouth and contain information about three or four teeth with their roots and bone areas surrounding them. Bitewing images are also captured from the inside and represent the upper and lower jaws with half of their roots. These are used to detect decay and cavities between teeth. It also ensures that restoration is done precisely. CBCT are 3D images unlike traditional dental X-rays, which provide 2D images, CBCT scans provide a more comprehensive view of the teeth, roots, bones, and soft tissues. This makes CBCT images particularly useful for a range of dental procedures, including implant placement, orthodontics, endodontics, and oral surgery. CBCT scans are also helpful for diagnosing complex dental conditions and planning treatments that require precise measurements and accurate anatomical information. 3D intraoral scans are a type of digital imaging technology used in dentistry to create high-quality, detailed images of a patient's teeth and oral structures. Intraoral scanners use a small handheld wand to capture thousands of images of the teeth and gums, which are then compiled by specialized software to create a 3D model of the patient's mouth. This technology is useful in locating exact teeth. Compared to traditional dental impressions, 3D intraoral scans are faster, more comfortable, and more accurate, making them an increasingly popular option in modern dental practices. 3D dental models or structures are virtual representations of a patient's teeth, gums, and oral structures created using digital imaging technologies and are used for precise and reliable tooth segmentation. Endoscopic images are high-resolution images captured using an endoscope, a medical device designed to visualize the interior of the oral cavity[4]. These are generally used to diagnose dental plaques.

1.2 Dental Image Segmentation

Dental image segmentation is a critical task in dental image analysis. It is the process of dividing a dental image into multiple regions or segments for further analysis. This technique is essential for various dental applications, including diagnosis, treatment planning, and image-guided interventions[5]. Dental image segmentation can be categorized into semantic segmentation and instance segmentation. Semantic segmentation is pixel-wise classification in which images are roughly segmented into different regions, generally foreground (teeth region) and background (irrelevant region). On the other hand, the focus in instance segmentation is to extract individual teeth. Dental image segmentation helps to identify and isolate specific structures of interest within an image, such as teeth, gums, bones, or other dental structures.

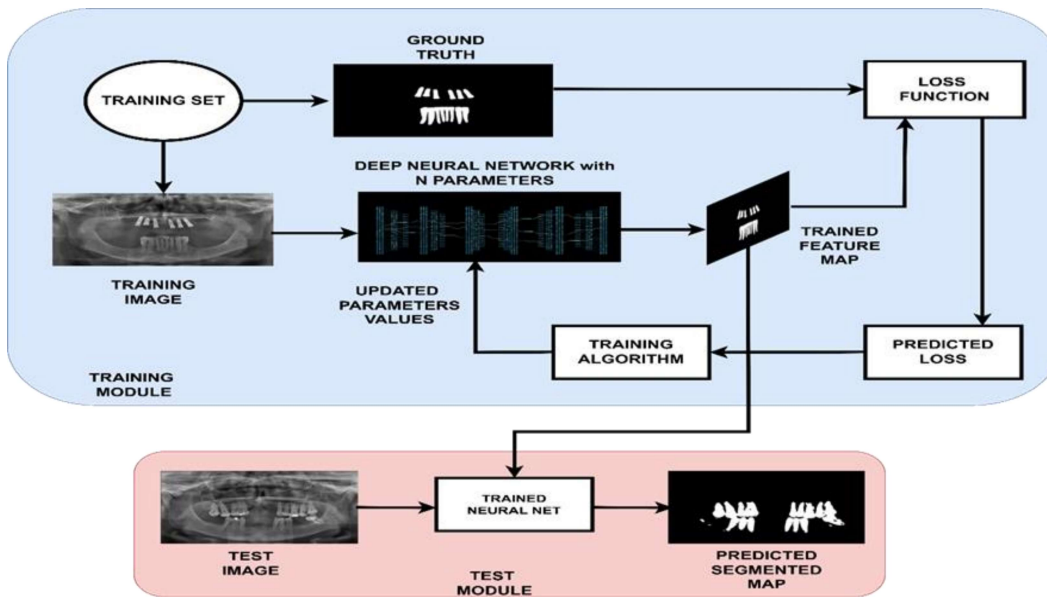


Figure 1.1 General deep learning framework for dental image segmentation.

A general framework for segmenting dental images using deep learning is shown in Figure 1.1. The framework is divided into two modules training and testing module. In

the training module the dental images are passed to the deep neural network which generates a trained feature map. A loss function is used to calculate the loss between generated feature map and ground truth of the related dental images. The predicted loss is then passed to training algorithm to update the parameter values for neural network. The process is repeated till the loss is minimized and network cannot be further trained. After training of the network, the unseen image from the test set is fed to the trained neural network to predict the segmented map of dental image.

1.3 Motivation

Nowadays, there are many people who have started obsessively pursuing high-quality diets. However, due to inappropriate eating habits and inadequate dental cleanings, the situation of oral health of the population is not promising resulting in rising of oral diseases. The rate of advancement of dental treatment cannot keep up with the rate of rising oral diseases resulting in lacking of treatment and diagnosing of person's dental problem.

Also, the dentists can only see the crown region of the tooth from the naked eyes. To locate the diseases in tooth root and neck, dental images are of significant importance. The dentist analyses these images to detect the disease and plan further treatment. However, to analyse dental images manually is time consuming and requires the expertise knowledge of the doctors which are prone to errors. Therefore, it becomes essential to employ computer-guided diagnosis and treatment for several common dental issues in order to enhance the efficacy of dentist diagnosis.

The advancement of computer vision and deep learning in the realm of medical imaging, it is now viable to use them in dental imaging automated segmentation. Thus, the motivation for the research work can be summarized as follows:

- Automated and accurate dental image segmentation can help dental professionals in making decisions related to prevention, diagnosis and treatment planning.
- It saves valuable time for the dentist and reduces stress and fatigue during daily practices.
- It ensures consistency in results across different dental professionals.
- It helps streamline the routine work and increase face time between patient and dentist.
- It can be a valuable tool for young practitioners as interns can visualize the fundamental dental morphology and structure which is convenient to learn during training stage.
- The traditional approaches are either semi-automatic or suffer in terms of segmentation accuracy.

Thus, such issues are the motivations to propose novel deep-learning solutions to find better methods and models to accomplish the important task of dental image segmentation.

1.4 Problem Statement

This thesis addresses some critical challenges and issues of dental image segmentation using deep learning approaches. The problem statement of the thesis can be defined as.

“Design and Development of Some Methods and Models for Dental Image Segmentation using Deep Learning Approaches.”

1.5 Research Objectives

The research objectives are as follows:

- I. An extensive study of the existing state-of-the-art methods for dental image segmentation using conventional as well as deep learning approaches to identify the research gaps.
- II. Design and development of a novel deep learning approach for dental image segmentation by exploiting enhanced spatial features.
- III. Design and development of a novel deep learning approach by providing attention to teeth boundaries using enhanced features for dental image segmentation.
- IV. Design and development of deep learning architecture to preserve semantic features and structural information of teeth in dental image segmentation.
- V. Design and development of the deep learning architecture for dental image segmentation based on the capsule network.
- VI. Design and development of the deep learning method utilising the transformer to segment dental images.

1.6 Contributions to the Thesis

The contributions to the thesis are summarised as follows:

- I. Performed an extensive study of the existing state-of-the-art methods for dental image segmentation using conventional as well as deep learning approaches to identify the research gaps.
- II. Proposed a Multimodal CNN architecture to exploit enhanced spatial features from panoramic X-ray images for dental image segmentation.

- III. Proposed an Attention-guided cascaded deep network for dental image segmentation.
- IV. Proposed a novel deep multi-fusion neural network to preserve teeth's semantic features and structural information in dental image segmentation.
- V. Proposed a novel deep-learning architecture based on the Capsule network for dental image segmentation.
- VI. Proposed a novel deep neural network based on transformers for segmenting dental images.
- VII. Implementation, performance analysis of the proposed models on the chosen datasets and their comparative studies with state-of-the-art methods in literature.

1.7 Thesis Organization

The thesis is organised into seven chapters as follows:

Chapter 1 briefly discusses the background of dental image segmentation and the need for dental image segmentation. Further, the motivation for the research, problem statement, and research objectives are also explained. This chapter also points out a list of contributions to the thesis and concludes with thesis organisation.

Chapter 2 presents a brief literature review of state-of-the-art methods for dental image segmentation. The research gaps identified have also been discussed. This chapter also discusses the details of the datasets and performance metrics used in the thesis.

Chapter 3 explains two proposed methods for dental image segmentation: “Exploiting Multimodal CNN architecture for automated teeth segmentation on dental panoramic X-ray images” and “Attention guided cascaded deep network for teeth segmentation on dental panoramic X-ray images. This chapter discusses experiment details and comparative results analysis with state-of-the-art methods available in the literature. The proposed models have been implemented and tested on UFBA_USEC

dataset and it can be observed that the proposed models perform better than the state-of-the-art approaches mentioned in the literature.

Chapter 4 presents and discusses the proposed model, “Enhancing teeth segmentation using multi-fusion deep neural net in panoramic X-ray. Extensive experiments and comparative results analysis with state-of-the-art methods have been done. The proposed model has been implemented and tested on two dental datasets. It has been observed that the proposed models perform better than the state-of-the-art approaches.

Chapter 5 discusses the proposed model “TeethCaps: A dental image segmentation model based on capsule network”. The chapter explains experiment details and comparative results analysis with state-of-the-art methods available in the literature. The proposed has been implemented and evaluated on two dental datasets. The proposed model has been observed to perform better than the state-of-the-art approaches mentioned in the literature.

Chapter 6 discusses the proposed model, “Investigation of dental image segmentation using transformers”. The chapter explains experiment details and comparative results analysis with state-of-the-art methods available in the literature. The proposed model is implemented and evaluated on two dental datasets. The proposed model has been observed to perform better than the state-of-the-art approaches mentioned in the literature.

Chapter 7 presents the summary of findings, conclusion of the thesis and future research scopes in dental image segmentation.