

- 1 Introduction (5-6 pages, at most 10 pages)
 - 1.1 Motivation
(Introduce the procedure of the endodontic treatment- Open->Clean->Fill)
 - 1.2 Previous Work and Problem Definition
(Briefly mention some dental robots)
(Focus on cleaning procedure)
(Two problem definition: prevent breakage of file, clean thoroughly)
 - 1.3 The Prospect and Challenges of this Project
(Move to the infected teeth -> Root canal searching -> Repetitive drilling -> Apex Detection)
(Challenges: root canal is small, risk of file breakage)
 - 1.4 Main Contributions of the Thesis
 - Robot-Assisted System Design
 - Self-Alignment of Root Canal Direction for Automatic Navigation
 - Precaution against Endodontic File Fracture
 - 1.5 Organization of the Thesis
- 2 Related Work and Literature Review
(Elaborate more details of NCTU paper, YOMI and even other dental robots)
(Why not Image processing and why force feedback?)
- 3 Robot-Assisted System
 - 3.1 System Architecture
 - 3.1.1 Requirement and Specification
(Payload, resolution and workspace)
(Why not RCM mechanism)
 - 3.1.2 The DentiBot
(Why Robot Arm - Meca500, F/T sensor - Mini40, Customized Handpiece)
(DOF discussion)
- 4 Kinematics Analysis and Admittance Control (Tutorial, only variables without numbers and data) (cite some technical papers)
 - 4.1 Kinematics Analysis
 - 4.1.1 Coordinate Definition
(0~6 robot frame, Sensor frame, and tool frame)
 - 4.1.2 Forward and Inverse Kinematics
 - 4.1.3 Jacobian matrix (variables are shown in appendix because they are too long)
(How to obtain Jacobian matrix in frame 6 by Jacobian matrix in frame 0)
 - 4.1.4 Tool Center Point
(How to find RCM by four-points-method)
 - 4.2 Admittance Control
 - 4.2.1 Gravity Compensation
 - 4.2.2 Admittance Control based on F/T sensor
 - 4.2.2.1 Control Scheme
(Block diagram, robot command choice)
 - 4.2.2.2 Discussion about Affection of Parameter Setting
(K, Bi, Mi)
 - 4.2.3 Reference Frame Changing of F/T sensor
(How to find the direction vector of the tool)
(From sensor frame to tool tip frame)
- 5 Self-Alignment of Root Canal Direction for Automatic Navigation Based on Force and Torque Feedback
 - 5.1 Problem Definition
(Main cause of surgical failure)
 - 5.2 The Proposed Method
(Peg-in-hole method based on F/T feedback)
 - 5.3 The Implementation of the method
(What functions should we used to implement this method)
(Admittance control + Transformation from robot to tool + Transformation from sensor to tool + Motion Planning: based on admittance control)
 - 5.4 Parameters Setting (get reasonable and suitable parameters first)
(Modes: Doctor Dragging and Auto navigation)
- 6 Precaution of Endodontic Files Fracture Based on Current Feedback
 - 6.1 Problem Definition
(Main cause of Files Fracture)
(File property)
 - 6.2 The Proposed Method and Theorem
(CACS2020)(Prototype 1)
(Motion Planning: sections)(Current threshold setting)

- 7 Preliminary Experiment Result
 - 7.1 Experimental Setup
 - (Communication protocol – EtherCAT, RTOS – NI target)
 - For 7.2 experiment: (Stewart-Platform + PhaseSpace + markers)
 - For 7.3 7.4 experiments: (Acrylic root canal model + truth tooth)
 - 7.2 Admittance Control
 - (Metrics: position comparison between the target and the robot)
 - 7.3 Automatically Direction Changing
 - (Metrics: time, completeness and file breakage)
 - (Completeness definition: comparison of pixel area before and after experiment via image)
 - 7.4 Repetitive Experiment
 - (Metrics: file breakage, compare with and without reverse)
- 8 Conclusions and Future works
 - (Patient move tracking via cable, root canals searching)