BUILDING AN ASSURANCE CASE FOR AORTAGEOMRECON SOFTWARE

BUILDING AN ASSURANCE CASE FOR AORTA GEOMETRY RECONSTRUCTION SOFTWARE

BY

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A REPORT

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TITLE: Building an Assurance Case for Aorta Geometry Reconstruction Software

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Abstract

Assurance cases has been proven to be effective developing a real-time system software.

Another domain that requires the high standard correctness, completeness is medical software.

Throughout the development of the Aorta Geometry Reconstruction software, we implicitly listed the evidences that are essential to build our confidence in the software for assurance cases, build the artifact and the evidences simultaneously.

Finally, we present this software with the list of the evidences built for assurance cases, to show that the assurance cases can apply well on the medical software

Your Dedication

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Acknowledgements

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Notation, Definitions, and Abbreviations

Notation

$A \leq B$	A is less than or equal to B

Definitions

Challenge With respect to video games, a challenge is a set of goals presented to the player that they are tasks with completing; challenges can test a variety of player skills, including accuracy, logical reasoning, and creative problem solving

Abbreviations

AortaGeomRecon
3D Slicer's extension module, Aorta Geometry Reconstruction

SRS Software Requirements Specification

MG	Module Guide

Declaration of Academic Achievement

The student will declare his/her research contribution and, as appropriate, those of colleagues or other contributors to the contents of the thesis.

Chapter 1

Introduction

This chapter includes an introduction for AortaGeomRecon assurance cases study. In section 1.1, we are dicussing the objective of this case study, and this documentation. In section 1.2, we are explaning some terms and definitions used throughout this document. Section 1.3 discussed about the problem statement, and finally section 1.4 gives the brief outline for this document.

1.1 Objective

In this study, we present the result of applying of assurance cases in a developing medical software to build the stakeholders' confidence in this software.

1.2 Background

Aorta is the largest artery that carries blood from the heart to the circulatory system. It has a cane-liked shape with Ascending aorta, Aortic arch and Descending aorta.

Unlike the real cane stick, the descending aorta might not be straight for each patient.

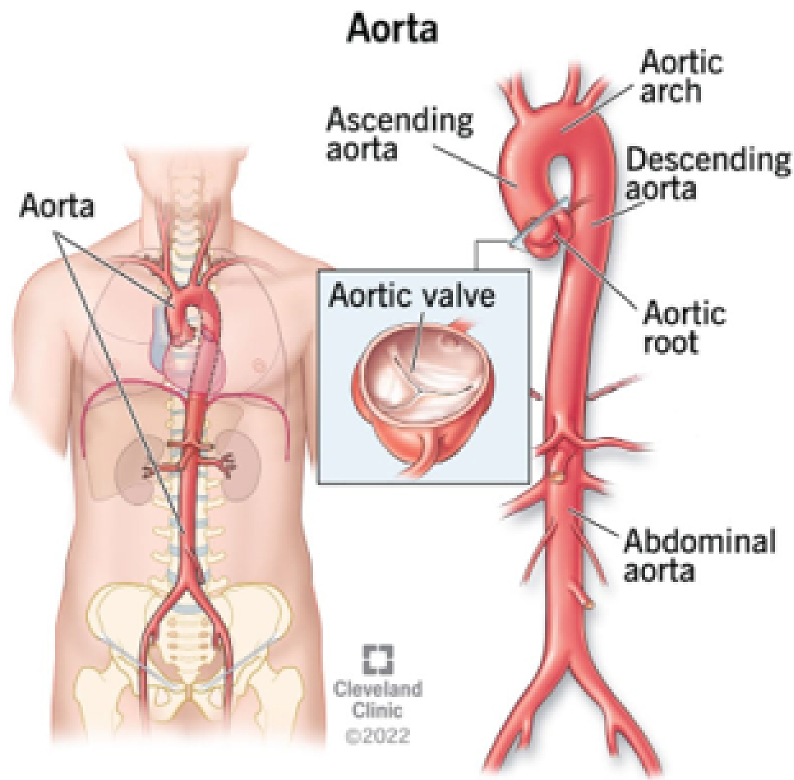

Figure 1.1: Aorta

Aorta segmentation in CT scans is important for:

- Coarctation of the aorta
- Aortic calcification quantification
- To guide the segmentation of other central vessels.

Assurance cases

3D Slicer

Image Processing

1.3 Problem Statement

The main goals of this project is building a software that can quickly build the 3D geometry of the Aorta from CT Chest scans, while applying the assurance cases for this academic medical software. This project shows the assurance cases can indeed help build up our confidence in the medial software in general, because medical software like real-time system software, needed completeness and correctness.

Build Software and Assurance cases for this software. Start with a list of Functional and Non-Functional requirements.

1.4 Thesis Outline

Chapter 2

AortaGeomRecon Research and Development

This chapter will discuss about the research and development of the AortaGeomRecon.

AortaGeomRecon stands for Aorta Geometry Reconstruction. The main objective of this software is to semi-automatically build 3D geometry of the Aorta from the patient's chest ct scans. The existing methods are often involved of extensive manual works by using a software with many steps. An experienced user, who might be a medical domain expert, needs to do a minimum of 10 minutes of manual works.

The implementation till the date of this report can let the users who have the user characteristics described in SRS (Lin, 2023) get the Aorta 3D geometry with only a few hyperparameters which can be set within half a minute, and the result requires maximum 2 minutes of execution time.

2.1 Existing Methods

There are many segmentation software available to the users, we will discuss the two main methods on two softwares.

- ITK-Snap

  ITK-Snap provides a segmentation method that first let user to select multiple voxels with a custom intial size and expanding size within any volume. We refer this method as "bubble method".

  Through many iterations, the voxels expand to fill the entire volume, finally user will need to cut the extra part of the volume. This Figure 2.1 shows the ITK-Snap UI executing the segmentation.

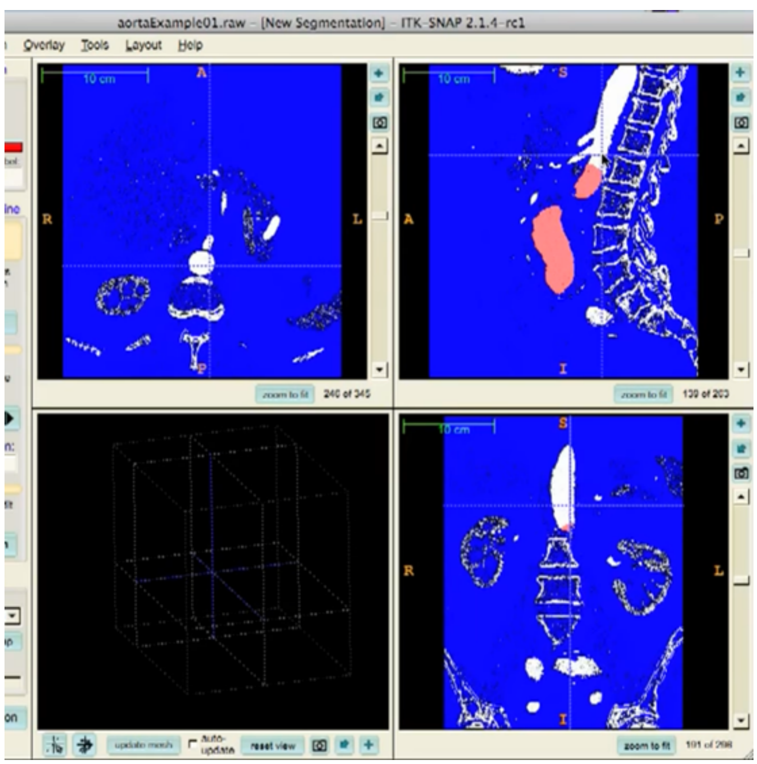

Figure 2.1: ITK-Snap's Bubble segmentation method

The advantages of the bubble method is that it guarantes to produce a correct the segmentation result. A medical domain expert can manually control the wanted area, and visually observing the segmentation result expanding, shrinking and the user can erase the unwanted part.

The disadvantages of this method is that the operations described above are complicated. Eeasier to say then do, an opeartor who has previous experience building the geometry with this method still needed 20 minutes of manual work building a new aorta geometry. Plus, ITK-Snap software can only read VTK file, therefore the chest CT scans are usually DICOM needed a manual conversion before using this software and its segmentation method.

- 3D Slicer

  3D Slicer is another well-known medical image processing software for academic. 3D Slicer provides multiple segmentation methods, and one of the quickiest and easiest to use is the intensity based segmentation.

  This method first let user select a small area that belongs to the wanted area on a 2D plane (Axial, Sagittal, and Coronal). 3D Slicer read the pixels' intensity of the surrounding area, and segment based on the intensity. Any pixels's intensity that is within the range will be segmented as the segmentation result.

  Like the bubble method, this method often reads extra volume, and requires user to cut the unwanted parts. A Youtube video shows an experience user who gets the aorta 3D geometry with 10 minutes of manual works.

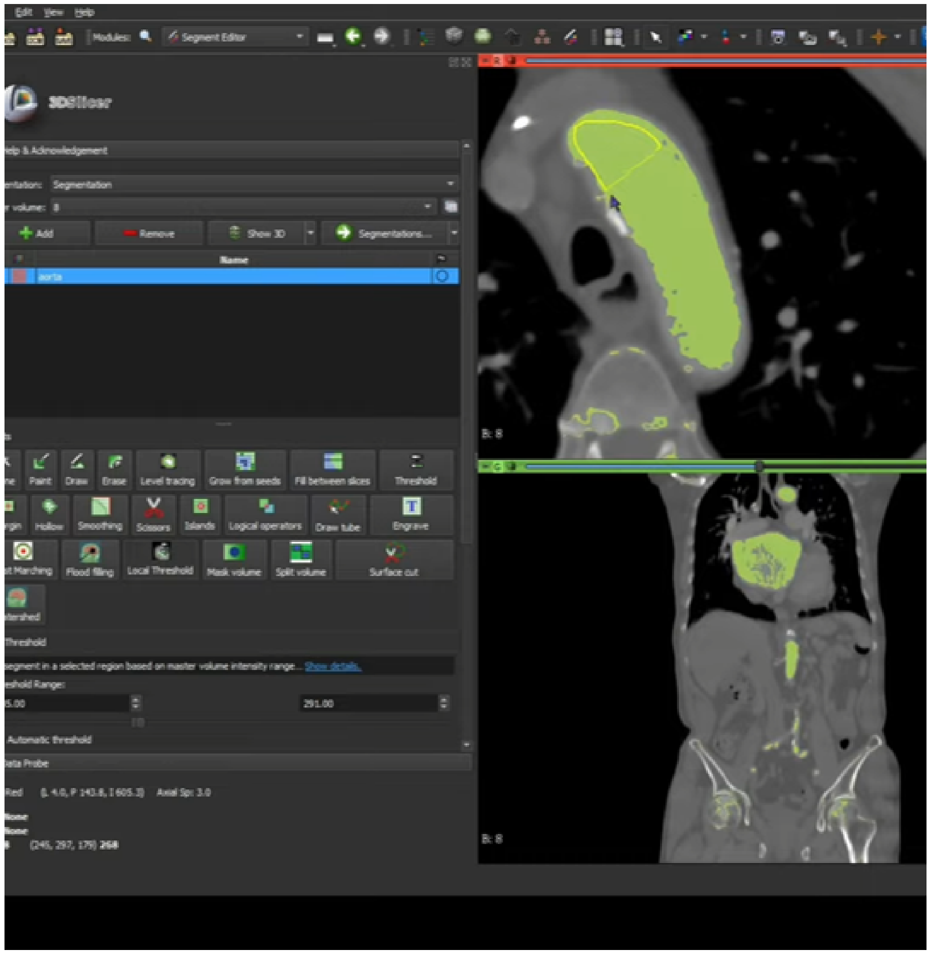

Figure 2.2: 3D Slicer BuiltIn Segmentation Method

2.2 GitHub and Workflows

This project uses GitHub for version control.

GitHub issues tracker use to keep track the items to work on throughout the development of the project

GitHub Project is used for dividing a large issue into smaller tasks, expected date of the completion. This is useful for project management.

GitHub Workflow is a great tool for Continuous Integration tests.

We uses GitHub Workflow for Linter and Continuous Integration tests.

2.3 3D Slicer Extension Development

The project has started with the a simple segmentation algoritm build on the jupyter notebook. When getting a new patient's data, the user will need to investigate the chest ct scans using another software (3D Slicer, ITK-Snap), to get the readings of the starting voxel and the size crop the volume, and get the index of the aorta seed. This Figure 2.3 shows an example of the aorta seeds.

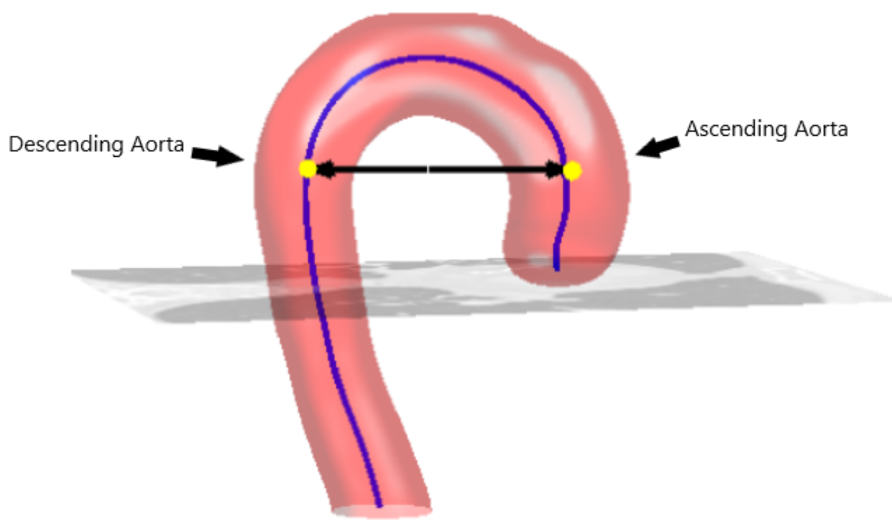

Figure 2.3: The aorta seeds (Kurugol et al., 2012)

To improve the usability of the AortaGeomRecon (reduce the amount of time for user inputs and execution), we implemented an extension module on 3D Slicer.

3D Slicer is a open-sourced medical image processing software for research. 3D Slicer provides useful modules such as Crop Volume module and Volume Rendering module, and it's highly modulizable with Python Scripting to control the extension module sequence, and QT designer to generate Graphical User Interface.

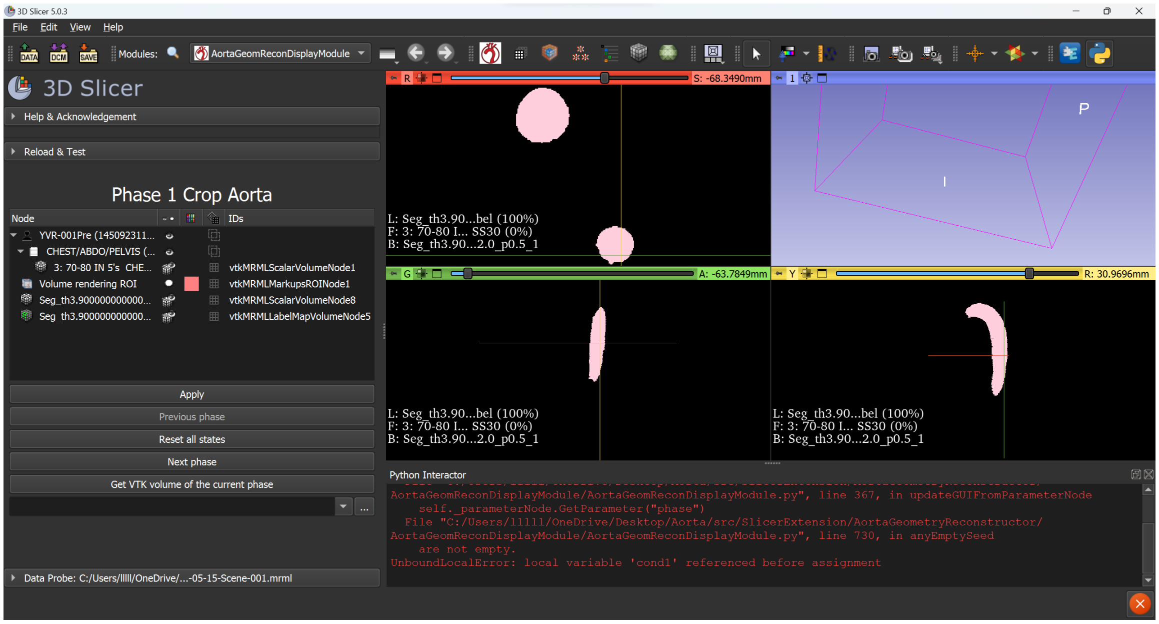

Figure 2.4: AortaGeomRecon UI phase 1

3D Slicer supports modulization with an extension. An extension is a software bundle that includes every modules to solve a specific medical image problem. An extension can compose multiple module, where each module is dedicated to solve a sub-problem.

3D Slicer's Data Structure can be divided into two categories: Node for storing large data such as DICOM with a Volume Node, Volume rendering Region of Interest Node, Label Map Volume Node, and parameters are read from extension's module UI and are stored as string. Every data stored in 3D Slicer can be accessed by the 3D Slicer's Widget Class and Logic Class for further processing.

On a higher level, 3D Slicer stores all the above data in a scene object. 3D Slicer can load any MRMLscene file, this allowed user to retrieve all the data nodes and

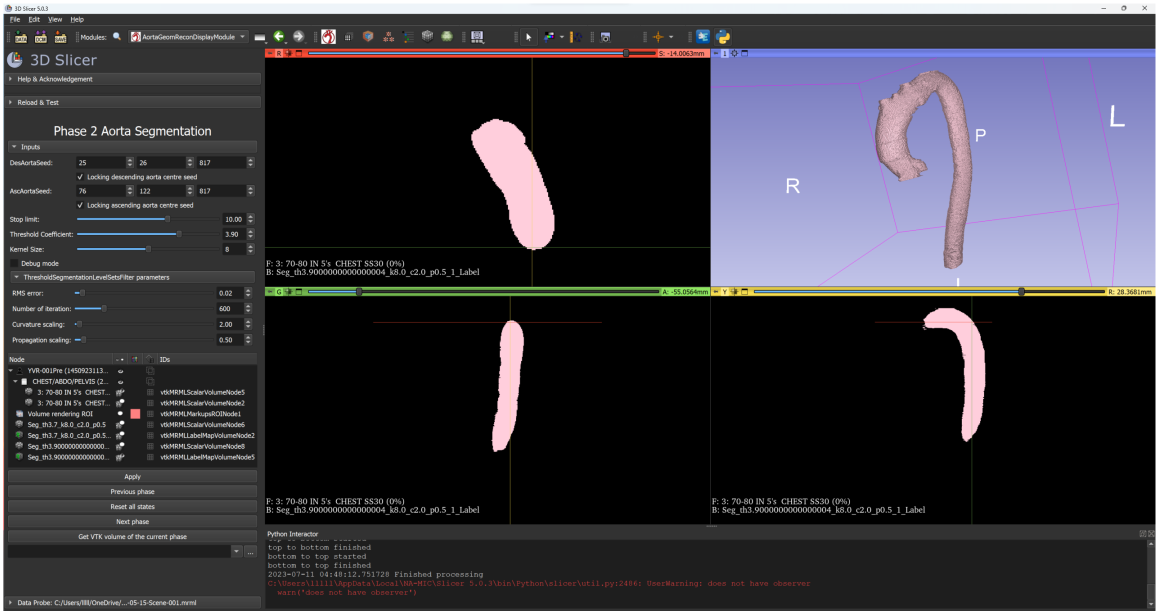

Figure 2.5: AortaGeomRecon UI phase 2

parameters. On the other hand, 3D Slicer has a special input module, the DICOM database allowed user to store DICOM metadata in 3D Slicer.

Every ScriptLoadableModule in 3D Slicer have a Widget Class and a Logic Class. The Widget Class is used to initialize the extension module's UI component, and the parameters tied to the UI compoenent. The module's Logic Class is used to perform the processing of the data. In the Logic Class, we initialize an AortaGeomRecon Segmenter object with the attributes set to the parameters reading from UI component, which are inputs by the user. After completing the segmentation with Segmenter object, we convert the SimpleITK image object to a volume node corresponding in 3D Slicer, which allow the user to visualize the segmentation result.

2.4 Segmentation Algorithm

The

- Inputs Parameter

  The parameters for AortaGeomRecon Segmenter class are passing the

- Threshold
- LevelSets
- Stop Condition

Chapter 3

Assurance Cases and Selected Evidence for AortaGeomRecon

3.1 Assurance Case Development

3.2 Assurance Case for Software Specification Requirements

- (Lin, 2023)
- Goals
- Assumptions
- Data Definitions
- Instance Model

- Functional Requirements
- Non-Functional Requirements
- Traceability Matrix Between Different Sections
- Traceability Matrix Between Requirements and Other Sections

3.3 Assurance Case for Implementation

- Design Document
  - Sphinx - Python Documentation Generator
  - Comments in the source code
  - Algorithm Overview - Explanation and Program Workflow
  - Glossary
- Module Guide
  - Traceability Matrix between Modules and Requirements
  - Traceability Matrix between Modules and Source Code
- Test Case
  - GitHub Workflow
  - Continuous Integration tests
    - build “Ground Truth Data”
    - Steps
    - Coverage

3.4 Algorithm Review

- Python Spyder IDE - Data Visualization and Debugging tool
- Algorithm Review with Kailin Chu
- Algorithm Review with Dr. Dean Inglis

Chapter 4

Conclusion and Future Works

4.1 Thesis Summary

4.2 Future Works

(Kurugol et al., 2012) discussed about a segmentation workflow that required less hyperparameters.

Appendix A

Your Appendix

Your appendix goes here.

Appendix B

Long Tables

This appendix demonstrates the use of a long table that spans multiple pages.

Col A	**Col B**	**Col C**	**Col D**
A	B	C	D
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