BUILDING AN ASSURANCE CASE FOR AORTAGEOMRECON SOFTWARE

BUILDING AN ASSURANCE CASE FOR AORTA GEOMETRY RECONSTRUCTION SOFTWARE

BY

JINGYI LIN, M.Eng.

A REPORT

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AUTHOR:	Jingyi Lin M.Eng. (Computing and Software CRP), McMaster University, Hamilton, Canada
SUPERVISOR:	Smith Spencer
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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

Optional second line

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

AI	Artificial intelligence

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 project.

1.1 Objective

The main goals of this project starts with 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.

1.2 Background

Aorta

The largest artery that carries blood from the heart to the circulatory system.

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

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

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 with very complex software, with a minimum of 10 minutes of human operator, who is a medical domain expert.

The implementation till the date of this report can let the users who have the user characteristics described in SRS get the Aorta 3D geometry with only a few hyper-parameters and 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.

  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. 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). 3D Slicer read the pixels' intensity of the surrounding area, and segment based on the intensity. Any pixels's intensity that are 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.

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), in order to know the starting voxel and the size crop the volume, and get the index of the aorta seed. This Figure 2.1 shows an example of the aorta seeds.

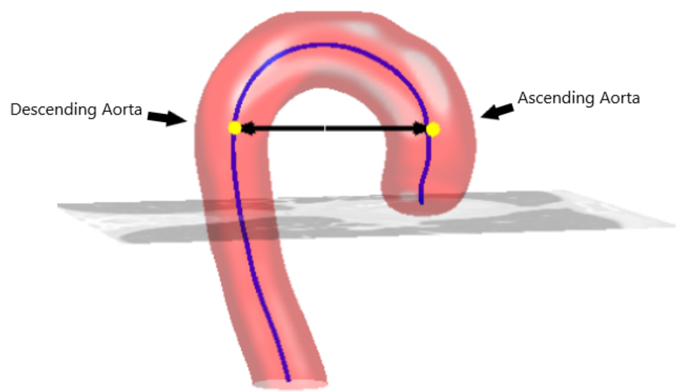

Figure 2.1: The aorta seeds (Kurugol et al., 2012)

In order 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 useful UI.

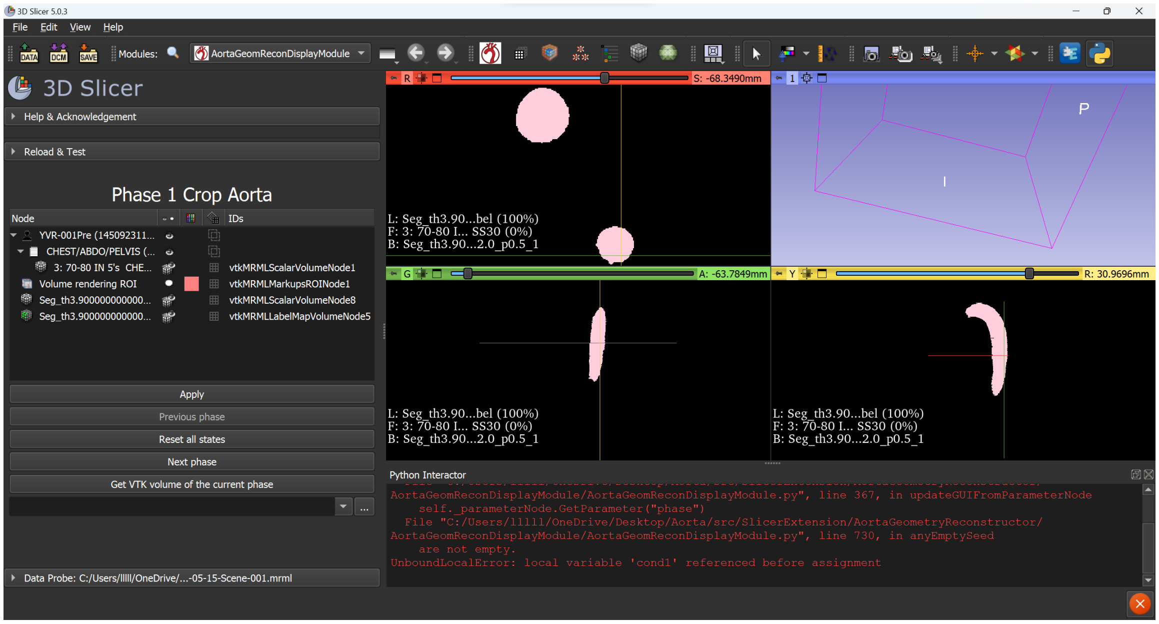

Figure 2.2: AortaGeomRecon UI phase 1

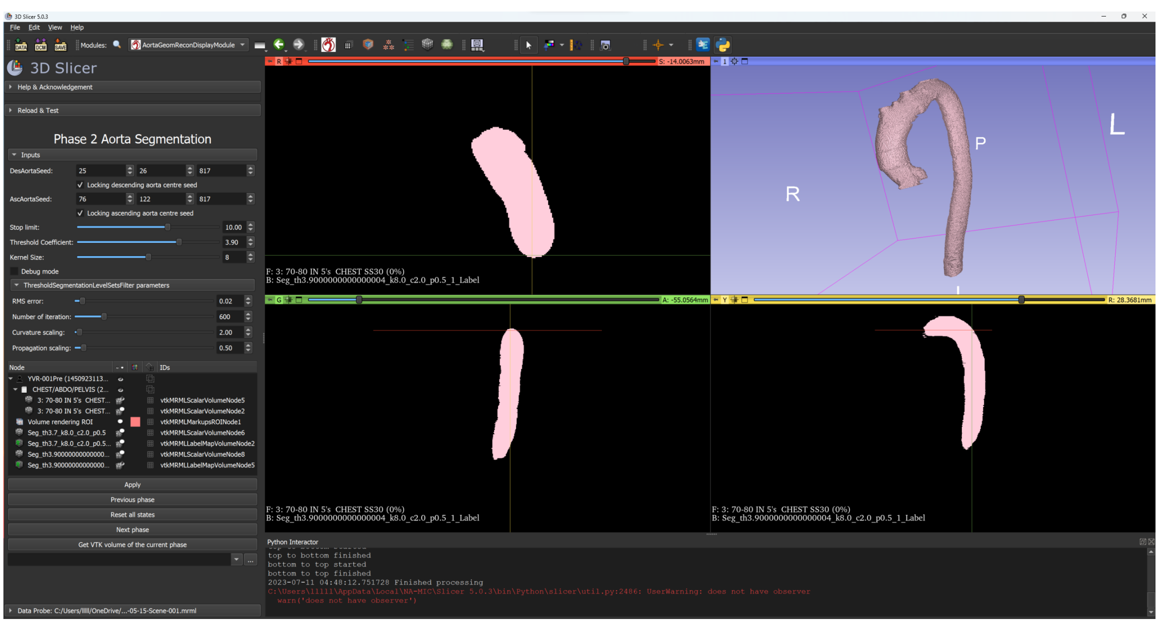

Figure 2.3: AortaGeomRecon UI phase 2

- 3D Slicer Data Structure

- 3D Slicer Widget Class
- 3D Slicer Logic Class

2.4 Segmentation Algorithm

- Inputs Parameter
- 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.

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Bibliography

Sila Kurugol, Raul San Jose Estepar, James Ross, and George R. Washko. 2012. Aorta segmentation with a 3D level set approach and quantification of aortic calcifications in non-contrast chest CT. In *2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. 2343–2346. https://doi.org/10.1109/EMBC.2012.6346433

Jingyi Lin. 2023. System Requirements Specification. https://github.com/smiths/aorta/blob/main/docs/SRS/SRS.pdf.