Software Requirements Specification for AortaGeomRecon

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Contents

Revision History

Date	Version	Notes
2023-02-12	1.0	Notes
2023-03-01	1.01	Modified system context image, coordinate systems, and goal statements.
2023-04-29	1.02	Added requirements, instance models, data definitions
2023-06-05	1.03	Added Traceability Matrices and Graphs

1 Reference Material

This section records information for easy reference.

1.1 Table of Units

Throughout this document SI (Système International d'Unités) is employed as the unit system. In addition to the basic units, several derived units are used as described below. For each unit, the symbol is given followed by a description of the unit and the SI name.

1.2 Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The choice of symbols was made to be consistent with existing documentation for 3D Slicer program. The symbols are listed in alphabetical order.

symbol	**type**	**description**
LOW	$\mathbb{N}$	A low intensity values means 0 on a scale of 0 and 1, or 0 on a scale of 0 to 255.
$HIGH$	$\mathbb{N}$	A high intensity values means 1 on a scale of 0 and 1, or 255 on a scale of 0 to 255.
$slice$	$\mathbb{R}^{m \times n}$	A slice is a 2 dimensional image view from the superior to inferior direction.
$Start$	$\mathbb{N}^3$	A coordinate indicates the indexes of a starting voxel.
v	$\mathbb{R}$	A voxel reports the intensity of a single point on a grey-scale 3 dimensional image.
m	$\mathbb{N}$	The first dimension of the segmentation volume
n	$\mathbb{N}$	The second dimension of the segmentation volume
p	$\mathbb{N}$	The third dimension of the segmentation volume
m_i	$\mathbb{N}$	The first dimension of the input volume for region of interest
n_i	$\mathbb{N}$	The second dimension of the input volume for region of interest
p_i	$\mathbb{N}$	The third dimension of the input volume for region of interest
m_o	$\mathbb{N}$	The first dimension of the output volume for region of interest
n_o	$\mathbb{N}$	The second dimension of the output volume for region of interest
p_o	$\mathbb{N}$	The third dimension of the output volume for region of interest

Table 1: Table of Symbols

1.3 Abbreviations and Acronyms

symbol	**description**
A	Assumption
AortaGeomRecon	Aorta Geometry Reconstructor
DD	Data Definition
DICOM	Digital Imaging and Communications in Medicine
GD	General Definition
GS	Goal Statement
IM	Instance Model
LC	Likely Change
PS	Physical System Description
R	Requirement
SRS	Software Requirements Specification
T	Theoretical Model

2 Introduction

This document provides an overview of the Software Requirements Specification (SRS) for the AortaGeomRecon. AortaGeomRecon provides a highly customizable aorta segmentation module, and an interactive user interface to apply the segmentation workflow.

2.1 Purpose of Document

The main purpose of this document is to provide sufficient information to understand what AortaGeomRecon module does. The goals and theoretical models used in the AortaGeomRecon segmentation module implementation are provided, with an emphasis on explicitly identifying assumptions and unambiguous definitions.

2.2 Scope of Requirements

The scope of requirements only covers for the segmentation of the organ, more specifically the ascending aorta, the aortic curvature and the descending aorta. The requirements assumes that the source of the data is accurate, and the user can manipulate (read, change dimensions) the data.

2.3 Characteristics of Intended Reader

The readers of the SRS have taken the university level introduction to computational mathematic course, and is capable of understand the mathmatical notation in the instance model section. The readers might have taken the university level introduction to software engineering course, have learned at least the waterfall software development model, and understands the purpose of the software specification requirement document, and other documents.

2.4 Organization of Document

The organization of this document follows the template for an SRS for scientific computing software proposed by Koothoor (2013) and Smith and Lai (2005). The presentation follows the standard pattern of presenting goals, theories, definitions and assumptions. The goal statements are refined to the theoretical models, and theoretical models to the instance models. For readers that would like a more bottom-up approach, they can start reading the instance models in Section 4.2.6 and trace back to find any additional information they require.

3 General System Description

This section provides general information about the system. It identifies the interfaces between the system and its environment, describes the user characteristics and lists the system constraints.

3.1 System Context

Figure 1 shows the system context. A circle represents an external entity outside the software, the user in this case. A rectangle represents the software system itself. Arrows are used to show the data flow between the system and its environment.

- User Responsibilities:
  - Provide the input data to the system
  - Ensure the input meets the necessary assumptions
  - Verify the result meets their requirements, otherwise repeat the process with a different seed values.
- AortaGeomRecon Responsibilities:
  - Provide DICOM data reader which can take a path to a folder containing DICOM files.
  - Provide crop functionality to easily select a region of interest.

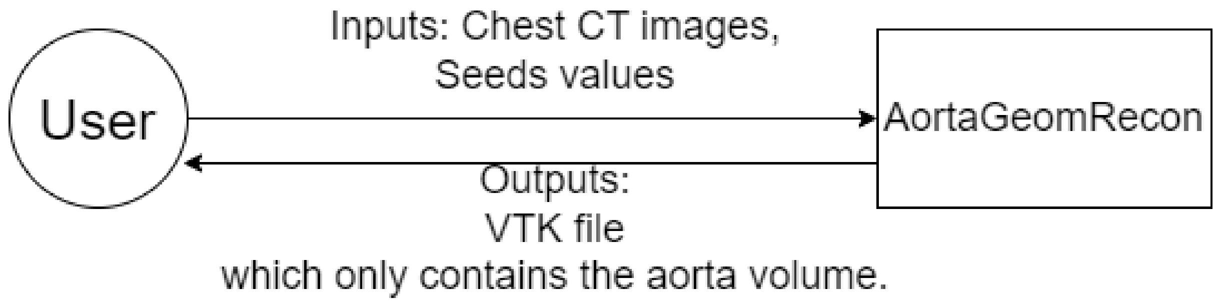

Figure 1: System Context

- Provide simple interactions to obtain and store the users' inputs. This includes a data probe to read voxel location which stored as a coordinate, and text inputs for real numbers.
- Provide visualization on the result data.

3.2 User Characteristics

The end user of AortaGeomRecon have taking the university level anatomy introduction course, and is capable to point out the center of the descending aorta and the ascending aorta.

3.3 System Constraints

4 Specific System Description

This section first presents the problem description, which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification, which presents the assumptions, theories, definitions and finally the instance models.

4.1 Problem Description

The main purpose of AortaGeomRecon is to semi-automatically segment a 3D aorta geometry from a chest CT scan.

4.1.1 Organ Segmentation

The organ segmentation or the organ boundary is useful for orientation and identification of the regions of interests inside the organ during the diagnostic or treatment procedure.

The aorta segmentation is important for aortic calcification quantification and to guide the segmentation of other central vessels.

4.1.2 Coordinate Systems

This subsection provides a list of terms that are used in the subsequent sections and their meaning, with the purpose of reducing ambiguity and making it easier to correctly understand the requirements. The sections below **?**

While working with medical images, it is necessary to be familiar with the different coordinate systems of the medical literarure and how data (voxels' orientation) is interpreted in different medical and non-medical software. Each coordinate system uses one or more numbers (coordinates) to uniquely determine the position of a point (in the medical context, we refer to each point as a voxel). The purpose of this section is to introduce some of the coordinate systems related to the medical imaging. There are different coordinate systems to represent data. A knowledge of the following coordinate systems is needed to work with the medical images.

Cartesian Coordinate System A Cartesian coordinate system is a coordinate system that specifies each point uniquely in a 2D plane by a pair of numerical coordinates or in a 3D space by three numerical coordinates. We assume a right-hand Cartesian coordinate system throughout this document.

World Coordinate System World Coordinate System (WCS) is a Cartesian coordinate system that describes the physical coordinates associated with a model such as an MRI scanner or a patient. While each model has its own coordinate system, without a universal coordinate system such as WCS, they cannot interact with each other. For model interaction to be possible, their coordinate systems must be transformed into the WCS. Figure 2 shows the WCS corresponding space and axes.

Anatomical Coordinate System Anatomical coordinate system, also known as patient coordinate system, is a right-handed 3D coordinate system that describes the standard anatomical position of a human using the following 3 orthogonal planes:

- Axial / Transverse plane: is a plane parallel to the ground that separates the body into head (superior) and tail (inferior) positions.
- Coronal / Frontal plane: is a plane perpendicular to the ground that divides the body into front (anterior) and back (posterior) positions.
- Sagittal / Median plane: is a plane that divides the body into right and left positions.

Figure 3 shows this coordinate system.

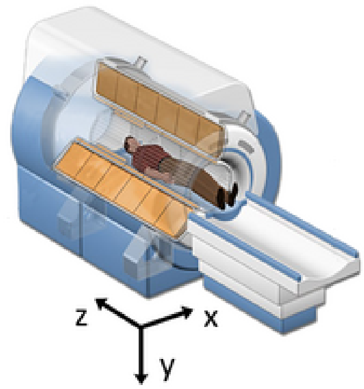

Figure 2: World Coordinate System Space and Axes sli (2014)

Medical applications follow an anatomical coordinate system to store voxels in sequences. Depending on how the data is stored, this coordinate system can be divided into different bases. The most common ones are:

- LPS Coordinate System:

  The LPS coordinate system is used in DICOM images and by the ITK toolkit. In this system, voxels are ordered from left to right in a row, rows are ordered from posterior to anterior, and slices are stored from inferior to superior. LPS stands for Left-Posterior-Superior which indicates the directions that spatial axes are increasing.

- RAS Coordinate System:

  The RAS coordinate system is the preferred basis for Neurological applications such as 3dfim+, and 3D Slicer. RAS stands for Right-Anterior-Superior is similar to LPS with the first two axes flipped.

Image Coordinate System To specify locations in an image we need to know to which coordinate system it is referenced. Different software may use different orders as their index convention.

4.1.3 Physical System Description

4.1.4 Goal Statements

Given the DICOM image that includes patient's chest, the descending aorta center voxel coordinate, and the ascending aorta center voxel coordinate, the goal statements is:

GS1: Extract the three dimensional segmentation of the aorta.

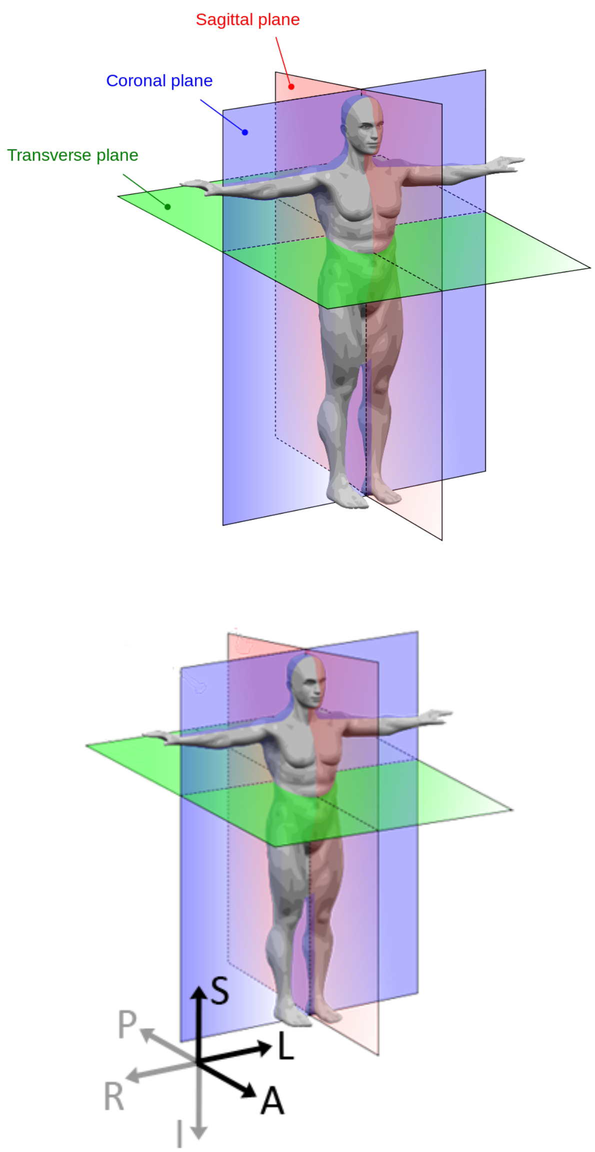

Figure 3: Anatomical Coordinate System Space and Axes sli (2014)

4.2 Solution Characteristics Specification

4.2.1 Assumptions

This section simplifies the original problem and helps in developing the theoretical model by filling in the missing information for the physical system. The numbers given in the square brackets refer to the theoretical model [T], general definition [GD], data definition [DD], instance model [IM], or likely change [LC], in which the respective assumption is used.

A1: The 3D image provided by the user must contains a visually distingushable aorta volume [DD2].

4.2.2 Theoretical Models

4.2.3 General Definitions

4.2.4 Data Definitions

This section collects and defines all the data needed to build the instance models. The dimension of each quantity is also given.

Number	DD1
Label	**Voxel**
Symbol	v : $\mathbb{R}$
SI Units	-
Equation	-
Description	A slice (DD2) consists of n × n voxels. A real number is assigned to each voxel to reports the intensity on a grey-scale image.
Sources	
Ref. By	DD2

Number	DD2
Label	**Image/Slice**
Symbol	slice : $\mathbb{R}^{m\times n}$
SI Units	-
Equation	-
Description	A visual representation of something that is represented using only two spatial dimensions with a sequence of arrays where a voxel (DD1) represents the color or intensity. Each move in the Z plane is considered as one slice
Sources	
Ref. By	DD3

Number	DD3
Label	**Volume**
Symbol	volume : $\mathbb{R}^{m\times n\times p}$
SI Units	-
Equation	-
Description	A three dimensional image is a sequence of some images/slices (DD2).
Sources	
Ref. By	IM1

4.2.5 Data Types

4.2.6 Instance Models

This section transforms the problem defined in Section 4.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 4.2.4 to replace the abstract symbols in the models.

The goals GS1 are solved by finding IM1 and perform IM2 on the aorta.

Number	IM1
Label	**Region of interest**
Inputs	$\mathrm{V_{in}} : \mathbb{R}^{m_i \times n_i \times p_i}$, Start : $\mathbb{N}^3$, $m_o, n_o, p_o : \mathbb{N}$, with the following constraints: $$\begin{gathered} 0 \leq start[0] \leq (m_i - 1) \\ 0 \leq start[1] \leq (n_i - 1) \\ 0 \leq start[2] \leq (p_i - 1) \\ 0 < m_o < (m_i - start[0]) \\ 0 < n_o < (n_i - start[1]) \\ 0 < p_o < (p_i - start[2]) \end{gathered}$$
Output	$\mathrm{V_{out}} : \mathbb{R}^{m_o \times n_o \times p_o}$ such that $$\begin{gathered} \forall (i, j, k : \mathbb{N} \mid \\ i \in [start[0]..start[0] + m_o] \wedge \\ j \in [start[1]..start[1] + n_o] \wedge \\ k \in [start[2]..start[2] + p_o] : \\ V_{out}[i][j][k] = V_{in}[i][j][k]) \end{gathered}$$
Description	The regions of interest is a subset (shaped like a box) of the 3D Vout. This subset contains the anatomical structure that the users wants to read, process or extract.
Sources	
Ref. By	IM2

Number	IM2
Label	**Segmentation**
Input	$\mathrm{V_{in}} : \mathbb{R}^{m \times n \times p}$
Output	$\mathrm{V_{out}} : \mathbb{R}^{m \times n \times p}$ such that $$\begin{gathered} \forall(i,j,k : \mathbb{N} \mid \\ i \in [0..m-1] \wedge \\ j \in [1..n-1] \wedge \\ k \in [2..p-1] : \\ (V_{in}[i,j,k] \in \text{structure} \implies V_{out}[i,j,k] = HIGH/) \\ V_{in}[i,j,k] \notin \text{structure} \implies V_{out}[i,j,k] = LOW)) \end{gathered}$$
Description	The process of extract an anotomical structure from the original 3D volume. The extracted anotomical structure is represented with high intensity pixel value. The rest of the image should have a lower intensity pixel value. A seed is what the algorithm needed as the inputs to perform segmentation, the type of a seed is different among different algorithm.
Sources	
Ref. By	R3, LC2

4.2.7 Input Data Constraints

Table 2 shows the data constraints on the input output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable. The column for software constraints restricts the range of inputs to reasonable values. The software constraints will be helpful in the design stage for picking suitable algorithms. The constraints are conservative, to give the user of the model the flexibility to experiment with unusual situations. The column of typical values is intended to provide a feel for a common scenario. The uncertainty column provides an estimate of the confidence with which the physical quantities can be measured. This information would be part of the input if one were performing an uncertainty quantification exercise.

The specification parameters in Table 2 are listed in Table 3.

(*) [you might need to add some notes or clarifications —TPLT]

4.2.8 Properties of a Correct Solution

A correct solution must exhibit [fill in the details —TPLT]. [These properties are in addition to the stated requirements. There is no need to repeat the requirements here. These

Table 2: Input Variables

Var	**Physical Constraints**	**Software Constraints**	**Typical Value**	**Uncertainty**
L	$L > 0$	$L_{\text{min}} \leq L \leq L_{\text{max}}$	1.5 m	10%

Table 3: Specification Parameter Values

Var	**Value**
L_{min}	0.1 m

additional properties may not exist for every problem. Examples include conservation laws (like conservation of energy or mass) and known constraints on outputs, which are usually summarized in tabular form. A sample table is shown in Table 4 —TPLT]

Table 4: Output Variables

Var	**Physical Constraints**
T_W	$T_{\text{init}} \leq T_W \leq T_C$ (by A**??**)

[This section is not for test cases or techniques for verification and validation. Those topics will be addressed in the Verification and Validation plan. —TPLT]

5 Requirements

This section provides the functional requirements, the business tasks that the software is expected to complete, and the nonfunctional requirements, the qualities that the software is expected to exhibit.

5.1 Functional Requirements

R1: Input the following functions, data and parameters:

symbol	**description**
volume	CT Scans volume (DD3)
Seed	Any inputs neede by the segmentation algorithm (IM2)

R2: Use the volume in R1 to create a second volume, the region of interest (IM1) that contains all of the aorta.

R3: Perform segmentation (IM2) on the volume created in R2.

R4: Visualize a volume (DD3).

NFR2: **Usability** AortaGeomRecon can visualize the volume with 3D rendering.

- Other NFRs that might be discussed include verifiability, understandability and reusability.

6 Likely Changes

LC1: IM2 There are various segmentation algorithms, each has a different procedure and inputs.

7 Unlikely Changes

LC2: IM2 There are various segmentation algorithms, each has a different procedure and inputs.

8 Traceability Matrices and Graphs

The purpose of the traceability matrices is to provide easy references on what has to be additionally modified if a certain component is changed. Every time a component is changed, the items in the column of that component that are marked with an "X" may have to be modified as well. Table 5 shows the dependencies of theoretical models, general definitions, data definitions, and instance models with each other. Table 6 shows the dependencies of instance models, requirements, and data constraints on each other. Table **??** shows the dependencies of theoretical models, general definitions, data definitions, instance models, and likely changes on the assumptions.

	DD1	DD2	DD3	IM1	IM2
DD1					
DD2	X				
DD3		X			
IM1			X		
IM2				X	

Table 5: Traceability Matrix Showing the Connections Between Items of Different Sections

The purpose of the traceability graphs is also to provide easy references on what has to be additionally modified if a certain component is changed. The arrows in the graphs represent

	IM1	IM2	R1	R2	R3	R4	NFR1	NFR2
IM1				X				
IM2					X			
R1								
R2	X							
R3		X						
R4								
NFR1								
NFR2								

Table 6: Traceability Matrix Showing the Connections Between Requirements and Instance Models

dependencies. The component at the tail of an arrow is depended on by the component at the head of that arrow. Therefore, if a component is changed, the components that it points to should also be changed.

9 Referance

References

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