Software Requirements Specification

Team Aura
Virtual Surgery

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Abstract

This Software Requirements Specification (SRS) specifies the requirements for the system produced by this project. Firstly, this document contains background information on temporal bone surgery, including the surgical procedures and tools used, and an overview of the existing system.

Secondly, the SRS outlines the proposed system to be developed. The proposed system is detailed in terms of functional and non-functional requirements. The document also provides examples of behaviour of the system and prototypes (guides) for the graphical user interface.

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1 Introduction

1.1 Overview of Project

The aim of this project is to create a software system which enables surgeons to simulate temporal bone surgery. To create a *Virtual Surgery* environment, the system displays the structure of the bone and enables the user to drill the bone. The project does not deal with other aspects of surgery such as making the incision, or closing up the wound of a patient.

The system can be divided into three sections:

1. Generation of a 3D model: Using data provided by CT scans, a 3D model is created. Only a small section of the skull is represented for virtual surgery.
2. Simulation of Bone drilling: The surgeon interacts with the model, and performs a virtual surgery.
3. Augment 3D model with landmarks: Allow surgeons to represent on the 3D model where the landmarks exist.

1.2 Scope of Document

This document (Software Requirements Specification) provides background information regarding the nature of the virtual surgery being simulated. Based on the IEEE Software Engineering Standards, this document lists the functional requirements according the features of the system (a *features* structure — see IEEE. Std 830-1993 SRS A.5 Template).

The SRS also covers the non-functional requirements, including issues such as performance constraints, hardware constraints, nature of users, external interfaces, implementation requirements and the software system attributes. The document prototypes of the graphical user interface, and some examples of behaviour for the system.

1.3 Purpose of Document

The aim of this Software Requirements Specifications (SRS) is to list all of the requirements that the final product must satisfy. The intended audience of this document includes Team Aura, the project's clients, and any software developers who may be further developing this project in the future.

The aim of this document is to enable Team Aura and the clients to reach a common understanding of the software system to be built and the product acceptance criteria. This document will also be used by the team in planning the system architecture (Software Architecture Design Document) and developing the detailed design (Software Design Document).

Finally, this document will also serve as a basis for further improvements on the software in the coming years. This will include any of the non-core requirements, and any other further technological developments.

1.4 Client Details

Omitted to preserve anonymity.

1.5 References

- "IEEE Standards Collections, Software Engineering", 1997, The Institute of Electrical and Electronic Engineers.
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- R. Robb, D. Hanson, M. Stacy and J. Camp. Biomedical Imaging Resource.
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2 Background On Temporal Bone Surgery

Temporal bone surgery refers to any surgical procedure involving the complex bone situated around the side of the skull (near the temples).

The types of surgery which fall into this category include:

- Bionic ear implant surgery — drilling sufficient cavities to implant the bionic ear package (further background available at the website: `http://www.medoto.unimelb.edu.au/cic/`);
- Exploration of temporal bone for the removal of disease;
- Approaches to the skull base — methods of drilling the bone to reach the brain.

2.1 Hazards and Landmarks in Surgery

When performing the bone removal procedure, there are certain landmarks surgeons need to be aware of, and hazards they should avoid, when drilling.

Some key landmarks in temporal bone surgery include:

- Dura mater (including the sigmoid sinus, which is a localized area of the dura mater);
- Facial nerve;
- Ossicles and the ear drum;
- Inner ear and internal auditory meatus.

For example, it is dangerous to penetrate the dura mater, as it will cause the brain to be flooded with fluid (known as a CFS leak), and put the patient at risk of meningitis.

2.2 Types of Cavities to Drill

During temporal bone surgery, cavities of different shapes and sizes may be drilled.

For example, a surgeon operating to implant the bionic ear would be required to drill the following holes:

- Large cavity (shaped like a flowerpot, cone or pyramid) - starting wide from the outer bone, and narrowing in as it gets closer to the inner ear
- Medium cavity connecting mastoid to the middle ear (posterior typamotomy)
- Very small cavity around 0.6 mm near the inner ear so that the electrode of the bionic ear package can be inserted into the spaces in the cochlear

Figure 1: Photo of a 3 mm cutting burr

2.3 Tools Used in Drilling

The drilling tool consists of a "burr", driven by an electric motor. The burr can also be used manually. Refer to Figure 1 for a photo of a 3 mm cutting burr.

There are four properties related to the burr and its use:

1. Texture: There are two main types of burrs —
   (a) Cutting burr (diamond head) — used to remove large parts of the bone;
   (b) Polishing burr — used to remove small, finer parts of the bone.
2. Size: The burrs come with different sized heads. Different sized burrs (from 0.6 mm – 7 mm) are used to remove different quantities of bone. A larger burr size would remove more quantities of bone.
3. Torque / Speed: By using a foot pedal, the surgeon can vary the rotating speed of the burr. A faster speed would provide more torque, which removes more quantities of bone.
4. Pressure: By placing more pressure on the burr, the surgeon can remove more quantities of bone, provided there is sufficient torque

During the drilling process, bone fragments are created. A "surgical irrigator" runs fluid through the area of bone being drilled, to ensure that bone fragments can be easily removed by the sucker.

3 Existing System

This section provides an overview of the existing system. The clients currently have aids which allow them to examine the temporal bone area. These include:

1. CT scans — provide 2 dimensional (2D) slices of the skull;
2. 3D modelling software: AnalyzeAVW — reconstructs 2D and 3D models of the skull from the CT scans.

3.1 CT scans

CT scans are otherwise known as computed tomography, or computed axial tomography scans.

3.1.1 How CT Scans are Produced

They are produced by a special radiographic technique which uses a computer to assimilate multiple X-ray images into a 2D cross- sectional image. The machine rotates around the patient's body, sending out a pencil-thin X-ray beam at 160 different points to take an X-ray of the patient's head.

This project will deal with CT scans that are sliced at intervals of 0.1 mm up to 2.0 mm. They can be sliced in an axial or coronal plane. The slices are presented as a series of pictures on X-ray films, or saved into the DICOM file format.

3.1.2 Uses

Using the X-ray films, surgeons can examine the series of pictures and determine the cavity (or cavities) that need to be made. They are used to identify variation in the anatomy, pathology (areas of disease) and also to plan the surgical procedure.

The CT scans saved in DICOM file format is used by the existing software (see below) to generate 3D models. They will also be used in this project as the source of raw data from which 3D models are generated (See Section 4).

3.2 3D Modelling Software: AnalyzeAVW

AnalyzeAVW is a proprietary software used by surgeons and other medical professionals to model the anatomy of the head. The software uses the CT scans, saved in DICOM file format, to reconstruct 2D and 3D models of the head.

3.2.1 Main Features

The main features of the software include:

1. Retrieval and management of image data from many file formats including DICOM;
2. Generation and display of 2D and 3D images;

3. Image processing, registration and segmentation using image algebra (e.g. 3D matrix operations and geometric transformations);
4. Selection and sampling of regions of interest (e.g. 3D model limited using a threshold density of the head — narrow range of 220–240 represents dense parts, wide range of 20–200 produces 3D model including most parts of the head's tissue);
5. Ancillary features including screen capture tools, editor for session notes, hard copy printing of text, labels and graphics.

3.2.2 Limitations

The software does not allow a virtual surgery environment to be simulated. In particular, the software is unable to:

1. Represent the actual cavity to be drilled;
2. Allow users to interact with the 3D model and simulate drilling;
3. Allow the landmarks and hazards marked in by the users to be represented in the 3D model.

More information regarding this software may be located at the official website of the AnalyzeAVW developers: `http://www.mayo.edu/bir/`.

4 Proposed System

The proposed system creates an environment to simulate temporal bone surgery. The major element in the environment will be a 3D model of the skull obtained from a CT scan. The system will enable users to interact with the 3D model to simulate drilling during a surgical operation. It is intended that the virtual environment will be used for teaching and training purposes for both trainee and experienced surgeons.

The system to be developed is seen as the first stage in the development of a sophisticated virtual surgery tool. To this end much of the development in this stage will consist of research and prototyping to find the most effective and efficient methods of implementing the 3D model and interactive tools.

The functionality of the proposed system has been divided into two sections, core and non-core. This is due to the experimental nature of the project where the feasibility of many of the requirements is dependent on the results of research and prototyping.

4.1 Core Requirements

These are the essential requirements of the system which need to be implemented before the product can be accepted. The requirements are described using the features that the system must be able to offer a user.

1. Convert a CT scan to a 3D model;
2. View and rotate the 3D model;
3. Interact with the 3D model using an input device to drill away portions of the 3D model.

4.2 Non-Core Requirements

These requirements have been sourced from the clients as an indication of the features they highly desire but are not necessary for the acceptance of the software. After the core system has been built according to the requirements as detailed in Section 4, the team will move on to develop these highly desirable features for the system.

It is anticipated that at least some of these features will be able to be implemented. It is also intended that some of these features will be extended or will be implemented by future developers of the system. Below is an outline of which requirements fall into the non-core requirements.

1. Extended functionality to view and rotate the 3D model;
2. Extended functionality to interact with the 3D model.
3. Augment the 3D Model with hazards (allow surgeons to represent on the 3D model any hazards that my exist).

5 Functional Requirements

5.1 Core Requirements

These are the essential requirements of the system which must be implemented before the product can be accepted. The requirements are described using the features that the system must be able to offer a user.

The following discusses each of the features in further detail.

5.1.1 Convert a CT Scan to a 3D Model

To convert the data provided by the CT scans into a 3D model, the system implements the following features:

1. Input Data Format — Read in CT scans provided in DICOM 3 format;
2. Input Data Resolution — Represent the 3D image using slices made at a minimum of 0.5 mm intervals (refer to Figure 2);

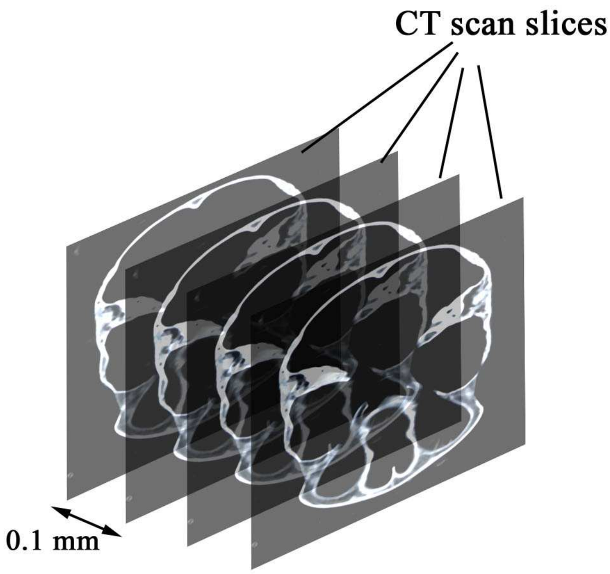

Figure 2: CT Scans sliced at 0.1 mm intervals

3. Limited tissue — Limit the 3D model to representation of the bone only (no other tissue such as veins, nerves, skin) where the density of the tissue to be represented is provided by the client;
4. Limited volume — Automatically limit the 3D model to a small 40 mm x 40 mm x 40 mm region, which is the maximum amount of volume the surgeon will deal with when performing temporal bone surgery (where the exact volume to limit is provided by the client);
5. Resolution of 3D model — Represent the 3D model with a minimum resolution of 1 voxel per 0.5 mm x 0.5 mm x 0.5 region.
6. CT Scan Threshold Control — Allow the user to control the thresholds of the CT scan used to construct the 3D model.

5.1.2 View and rotate a 3D model

To enable the user to view a 3D model, the system implements the following features:

1. View — View the 3D model at a minimum size of 1 voxel corresponding to 0.5 mm x 0.5 mm x 0.5 mm region (original size);
2. Rotate — Rotating the 3D model in any direction required, where the rotation need not be smooth or continuous, i.e. the screen need only represent the rotated 3D model and not any other positions in between;
3. Zoom in — Zoom into the 3D model to view it closer, but the data is not processed in any way to provide better resolution than the CT scans where a high level of magnification may produce rough edges;
4. Zoom out — Zoom out of the 3D model to the original size;
5. Traverse — Traverse into the bone cavities, e.g. inside a cavity that has been drilled by the user;
6. Save — Save the 3D model produced into a file format using a user specified name.

Note that in this document, any reference to (or interaction with) the 3D model refers to the model which represents the bone tissue of the CT scans, and not any other items which may constitute part of the 3D model (such as empty space surrounding the bone tissue).

5.1.3 Interact with a 3D Model

This is a critical part of this project. The system provides a virtual surgery environment where a user can drill away bone (portions of the 3D model) using an input device. A solid volume of the bone (3D model) is eventually drilled away.

To enable the user to interact with the 3D model, the system implements the following features:

1. Screen — Represents the 3D model on the screen, with the cursor moving on the screen corresponding to the user's movement of the input device;
2. Virtual Burr — Implements the mouse as an input device to simulate the drilling tool (burr);
3. Virtual Burr Specifications — Models a 3mm burr where the volume drilled away per drill is one *drill unit*. No other characteristics (or use) of a real burr are implemented (e.g. texture, size, torque and pressure);
4. Drill Unit — Where one drill unit is 2.5 mm wide x 2.5 mm long x 1.0 mm depth (refer to Figure 3 and Figure 4);
5. Screen Refresh — Updates the screen at a rate of at least 1 second per drill unit removed;
6. Limited drilling area — Limits the drilling area to the 3D model — and placing the cursor at any other points on the screen will not cause the screen to refresh or perform any action;

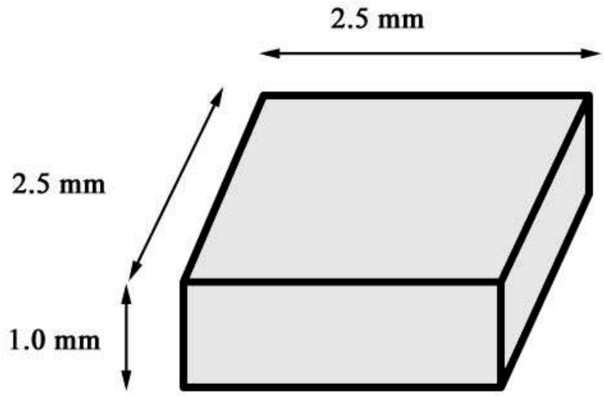

Figure 3: Size of one drill unit

7. Sense of depth — Represents a sense of depth;
8. Saving — Saves the 3D model resulting from the interaction into a file format using a user specified filename. Allows 3D model to be loaded and viewed as per Section 4.1.2. and interacted with as per Section 4.1.3;
9. Bone fragment removal — Assumes when the bone is drilled, the bone disappears. Does not represent the surgical irrigator and the sucker's removal of the bone fragments.

5.2 Non-Core Requirements

These requirements have been sourced from the clients as an indication of the features they highly desire but are not necessary for acceptance of the software.

5.2.1 Convert CT Scan to 3D Model

In addition to the features described in Section 4.1.1, the non-core system includes the following features —

1. Input Data Resolution — Represent the 3D image using slices made at 0.1 mm intervals (refer to Figure 2);
2. Input Data Resolution — Represent the 3D image using slices made at per 0.033 mm intervals (3 slices per 0.1 interval);
3. Resolution of 3D model — Represent the 3D model with a minimum resolution of 1 voxel per 0.1 mm x 0.1 mm x 0.1 region.

5.2.2 View and rotate a 3D model

In addition to the features described in Section 4.1.2, the non-core system includes the following features -

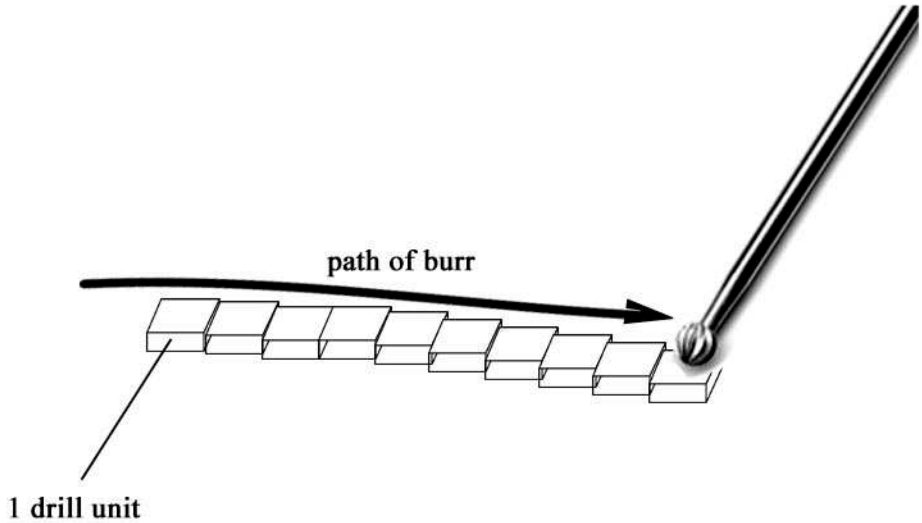

Figure 4: Path of a burr and portions of 3D models drilled

1. Zoom in — Zoom in and view the 3D model at magnifications of:
   (a) 1000% (x10)
   (b) 2000% (x20)
   (c) 3000% (x30)

   where the image still appears smooth and continuous (not pixelated) at the maximum magnification;
2. Densities — View bone of two varying densities: honeycomb or hard, where the amount of removed by the drill is proportional to the density of the bone and the densities are provided by the client;
3. Translucent 3D model — Generates a translucent 3D model, such that the inner parts of the 3D model can be viewed from the outside;
4. Illumination — Allows the 3D model to be viewed as if the 3D model is illuminated by different light sources from various points.

5.2.3 Interact with the 3D model

In addition to the features described in Section 4.1.3, the non-core system offers the following features to users -

1. Virtual Burr
   (a) Texture of burr — Represents two different burr textures including:
      i. a diamond polishing burr; and
      ii. a cutting burr;

      where each tool produces a different effect when used to drill away portions of the 3D model where the effects of the tools are specified by the clients;

(b) Size — Provides different sizes of burrs ranging from 0.6 mm to 7 mm where the size of the burr affects the size of the drilling unit (refer to Section 4.1.3) and portion of the 3D model removed where the effects of the sizes are specified by the clients.

(c) Torque or Speed — Select the speed at which the burr is rotating (simulation of the foot pedal) - which is from 0 — 6,000 revs/sec where the effect of the speed is specified by the clients;

(d) Pressure — Simulates pressure by using the amount of pressure the user places on the input device, affecting the number of units of the 3D model being drilled, where the quantitative effect of the pressure is specified by the clients.

2. Removal of bone

   (a) Fast screen refresh (10 frames / sec) — The screen refreshes at a rate of 10 frames per second, to allow minimum lag time and a smooth and continuous drilling process (i.e. surgeon is able to instantaneously see the effects of the burr on the 3D model);

   (b) Auditory response with the burr — The system produces a sound which is similar to the sound produced by real burrs when drilling. The sound varies depending on:

      i. whether the burr is in contact with the 3D model;
      ii. the amount of pressure on the bone when the bone is being drilled;
      iii. the density of the bone of the bone being drilled;
      iv. the thickness of the bone of the bone being drilled.

      The effects of the above factors on the sound are specified by the client.

3. AutoSave — The system will automatically save the changes made by the user in drilling the bone at a regular time interval as specified by the user.

5.2.4 Augment the CT scans

This is a new feature not previously detailed in the core system. The 3D model created by the core system only includes the bone structure. This feature enables the user to augment the CT scans with other types of tissue or landmarks (refer to Section 2) which the user needs to be aware of and possibly avoid when drilling the bone.

As there are currently other packages which will allow users to augment the CT scans, the client feels that this requirement is of low priority.

The representation of the landmarks involves the following process (and the features offered by the system to facilitate each step):

1. Represent the CT scans as 2D slices on the screen

   (a) View one slice — View each of the 2D slices separately where each slice closely represents the CT scan slices as viewed by surgeons on an X-ray;

   (b) View two slices — View an unmarked 2D slice placed on top a marked 2D slice so that the latter can be used as a guide for the former.

2. User marks all or some of the 2D slices using the tools provided

(a) Drawing tools — Provides tools such as paint brushes, marquee tools, pens, straight lines, paint buckets to enable the user to mark any 2D shape on a CT scan slice;

(b) Colour Palette — Select from a colour palette of up to 24 colours;

(c) Limitation of colour — Each landmark can only be marked in one colour, e.g. the Dura Mater may be represented by red, and the sigmoid sinus in green.

3. Marked 2D slices are converted into a 3D model

   (a) Join landmarks in slices — The user may choose to mark some or all of the slices. If not all slices are marked, the system joins up the marked regions as a straight line to fill in the missing gap where some slices have not been marked;

   (b) Generate 3D model — A 3D model with the original CT scan data and the newly added landmarks is produced;

   (c) Save — Save the 3D model generated into a file format with a user specified filename, which can be loaded to be viewed as per Section 4.1.2 and interacted with as per Section 4.1.3.

6 Non-functional Requirements

6.1 Nature of Users

The following section details the nature of the users of the software, including their level of technical expertise and purpose for using the software.

6.1.1 Users of the system

1. Trainee surgeons
   - To plan and practise temporal bone surgical procedures;
   - To gain an understanding of the bone structure and drilling process by viewing the 3D model and the sample cavities drilled by the experienced surgeons.
2. Experienced surgeons
   - To perform Virtual Surgery for as a rehearsal for the management of an unusual problem;
   - To augment the CT scans with appropriate landmarks for the benefit of trainee surgeons;
   - To drill different types of cavities as samples for trainee surgeons;
   - To replay sections of performed surgery for analysis.
3. Diagnostic Personnel (e.g. radiologists) — may find it useful to use the software as a tool for examining the bone structure and CT scans of a patient;
4. Matching information acquired from X-rays and magnetic reasonance imaging.

6.1.2 Hardware competence

The users will have some basic computer knowledge, including the use of hardware such as mouse and keyboard. Any non-standard hardware (especially Virtual Reality Tools) will be accompanied with appropriate training material to allow users to adapt to them quickly and effectively.

6.1.3 Software competence

The users will be familiar with Windows 98 and the basic functions such as opening an application and closing an application. The software shall be sufficiently user friendly to allow users with basic computer literacy to use the basic functions of the software effectively. There shall be accompanying documentation to assist users with using the more advanced functions of the software (refer to *Section 5.2* below).

6.2 User Documentation

Documentation will be supplied with the final software product. The user documentation shall specify and describe the required data and control inputs, input sequences, options, program limitations, and other activities or items necessary for successful execution of the software. All error messages will be clear and appropriate corrective actions described.

There will be two user documentation produced: a brief Setup guide, and a complete Reference and Troubleshooting Guide.

6.2.1 Setup Guide

Target Audience: Users of the software.

Purpose: A brief guide to assist users with the technical aspects setting up the custom software provided.

Contents: The contents shall include —

1. Instructions for installing and setting up the custom software;
2. Instructions for setting up and configuring the associated hardware.
3. Explanation for the specification of each of the burrs and an explanation for the limits of resolution and torque.

6.2.2 Reference and Troubleshooting Guide

Target Audience: Users of the software.

Purpose: A reference guide for users of the software to use and understand the functionality of the software.

Contents: The contents shall include —

1. Users Reference, which
   (a) Is reference guide for users of the system;
   (b) Provides a functional description of the software;
   (c) Describes the required data and control inputs, input sequences;
   (d) Describes the options and functions available in the software;
   (e) States the program limitations;
   (f) Provides all the information required for user to use all the features available in the software effectively and efficiently.
2. Troubleshooting
   (a) Identifies the error messages given by the system during system failure;
   (b) Identifies any other problems which do not result in error messages;
   (c) Provides a description of the problem in a language understandable for general users (non-programmers);
   (d) Provides possible corrective actions (solutions) for the error.

The user documentation will be provided as both Online Help and as a hard copy.

6.3 Hardware constraints

There are no hardware constraints for the system this software must run on. The clients are willing to consider software which requires extremely fast and/or expensive hardware resources to run properly.

6.4 Performance requirements

The performance of the system is important. It would be ideal for the system to refresh quickly and provide real-time performance especially while the user is drilling the bone.

Performance is of equal priority with the production of an accurate and high resolution 3D model of the bone, and a user friendly interface.

It is difficult to ascertain the exact performance requirements given there are no hardware constraints given by the clients and insufficient prototype results / research to precisely state what the performance would be.

It is worth noting again that the acceptable frame rate for screen refresh for the core and non-core requirements are 1 frame / sec per unit drill and 10 frame / sec per unit drill respectively.

6.5 Design Constraints

A critical requirement is for the design to be easily extendible. Future developers of the software must be able to make improvements and add functionality to the software without much difficulty. Hence, the design should be as modular as possible, with the design of each module sufficiently documented.

The client has not indicated a preference for a particular programming language. The only requirement is for the language used to be sufficiently common and understandable that software developers can easily develop the software in future to make improvements.

6.6 Implementation Constraints: Technical Resources

There is no specification for the development hardware. The prefered system is a Pentium 3 with 256MB RAM and a Graphics Accelerator Card with at least 32MB RAM. The operating system to be used has also not been specified. The prefered operating system is Windows (95/98/2000).

6.7 External Interfaces

The DICOM 3 file format is the main file input interface where the input file is derived either from the CT scan or from the previous saved output.

The standard peripheral inputs to the system are a keyboard, a mouse and a device to interact with the image that simulates using a drill during surgery. The exact device that simulates the function of a drill is under review but is likely to be some form of pen and tablet.

All output responses are to be displayed on a monitor where the output displayed can be printed out via any standard printer.

6.8 Error handling

The following outlines the requirements for handling errors:

1. Surgery is a continuous process, and it would be ideal that no errors occur in the system that would interrupt the simulated operation;
2. Error handling in system must be formal, stating the type of error, cause of error, and a note as to how to fix the error or avoid the error in future;
3. All GUI items must be clearly visible, and if the wrong function is chosen, an appropriate error message must be displayed;
4. If an error occurs that interrupts the simulated operation the system should allow the user to continue their interaction from the point before any error occurred.

6.9 Software System Attributes

6.9.1 Reliability

The reliability of the system is of high priority. There should be mininal system failure during normal use of the system. Team Aura will make the utmost attempt to ensure the reliability of the system.

6.9.2 Security

The name and identification details of the patient which are on the CT scans need to be removed before the 3D model is generated. There are no other security concerns with the software.

6.9.3 Maintainability

It is not anticipated that the software will be routinely maintained after each stage of completion, but the software needs to be able to be improved on by software developers in future years.

There is no particular concern with the choice of language, as long as it is standard and allows for extensibility.

6.9.4 Portability

There are no portability requirements.

7 Graphical User Interface

This section details the proposed graphical user interface of the system based on the functional requirements outlined in Section 5. The graphical user interface is to be used as a guide for design purposes.

The user interface is separated into the following sections:

1. Core Requirements
   (a) 3D Virtual Surgery Screen.
2. Non-Core Requirements
   (a) 3D Virtual Surgery Screen;
   (b) Augment Screen — One Slice View;
   (c) Augment Screen — Two Slice View.

7.1 Core Requirements

This user interface encompasses all the core requirements defined in Section 5.1.

7.1.1 3D Virtual Surgery Screen

The interface outlined here is the Core 3D Virtual Surgery screen. It allows the user to view the 3D model, perform drilling at the basic level, image control — have the ability to zoom-in, zoom-out (maximum of real size 1:2) and rotate the 3D model in any angle. This screen is depicted in Figure 5.

1. Menu Bar — The menu bar is located at the top of the screen. The menu bar consists of 3 drop down menus: File, View and Help. These allow the user to import file, save file, select view, and read help documentation.
   (a) File: This drop down menu allow access to the following options:
      i. Open CT Scan: To open a CT scan. A dialog will appear to allow user to browse and select the required CT scan. The CT scan will be automatically constructed into a 3D model.
      ii. Open: To import a file. A dialog will appear to allow user to browse and select the required file;
      iii. Close: To close a current working file;
      iv. Save: To save a current working file. Overwriting the existing file;
      v. Save As: To save a current working file under a different name;
      vi. Exit: To exit the program.
   (b) View: This menu allows the user to choose to view or hide the following parts:
      i. Burr Controller;
      ii. Image Controller.
   (c) Help: This menu provides the user with:
      i. Contents and index: To search the User Manual of the system;
      ii. About: Displays the version number of the system.

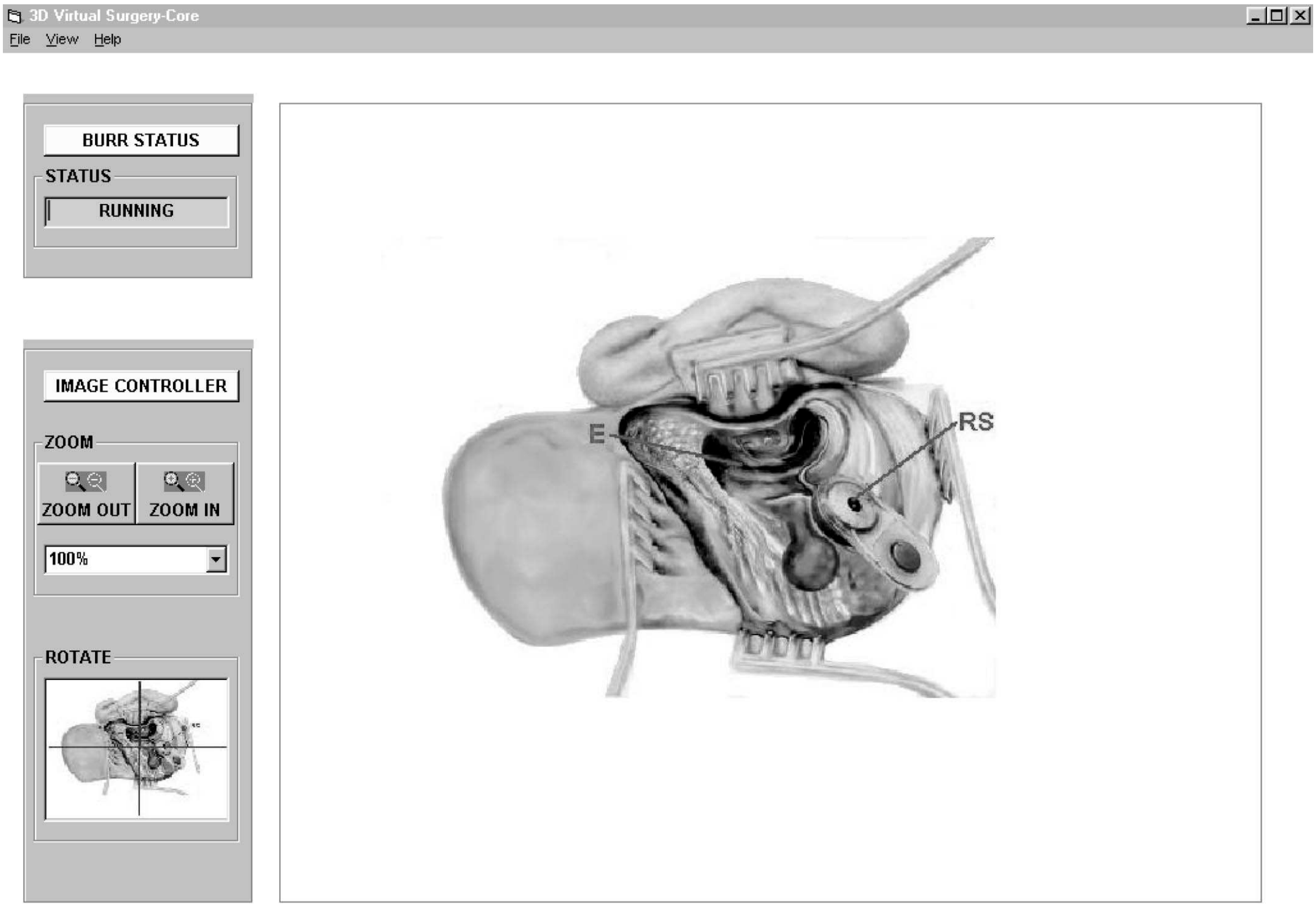

Figure 5: 3D Virtual Surgery Screen — Core

2. Burr Status - The burr status shows the status of the burr
   (a) Status box: Shows whether the burr is running or has stopped.
3. Image Controller - The image controller is used to control the 3D model on the screen including rotation and zooming.
   (a) Zoom In/Out Buttons: The user can zoom in or zoom out of the 3D model by selecting zoom in or zoom out button respectively. This activates the zooming mode. Then clicking on the 3D model where it needs to be zoomed;
   (b) Zoom Control Box: User can specify the percentage of zooming needed by selecting a value of the magnification between 0-200% range from the control box;
   (c) Image Rotation: The angle of rotation is represented by 4 quadrants. Rotation of the 3D model is performed when user clicks on a point within a quadrant.

4. Image Frame - The image frame contains the 3D model of the bone where the drilling process will be performed. User can start the drilling operation by keeping the left button of the mouse down causing the burr to run and then dragging the mouse around the area where the bone is to be removed.

7.2 Non-Core Requirements

The following user interfaces incorporate both the core and non-core requirements. Allowing the user to select/adjust features of the burr and augment the CT scans.

7.2.1 3D Virtual Surgery Screen

The user is able to modify the type, size, torque and pressure level of the Burr. In addition, the user can select to view a translucent 3D model. This screen is depicted in Figure 6.

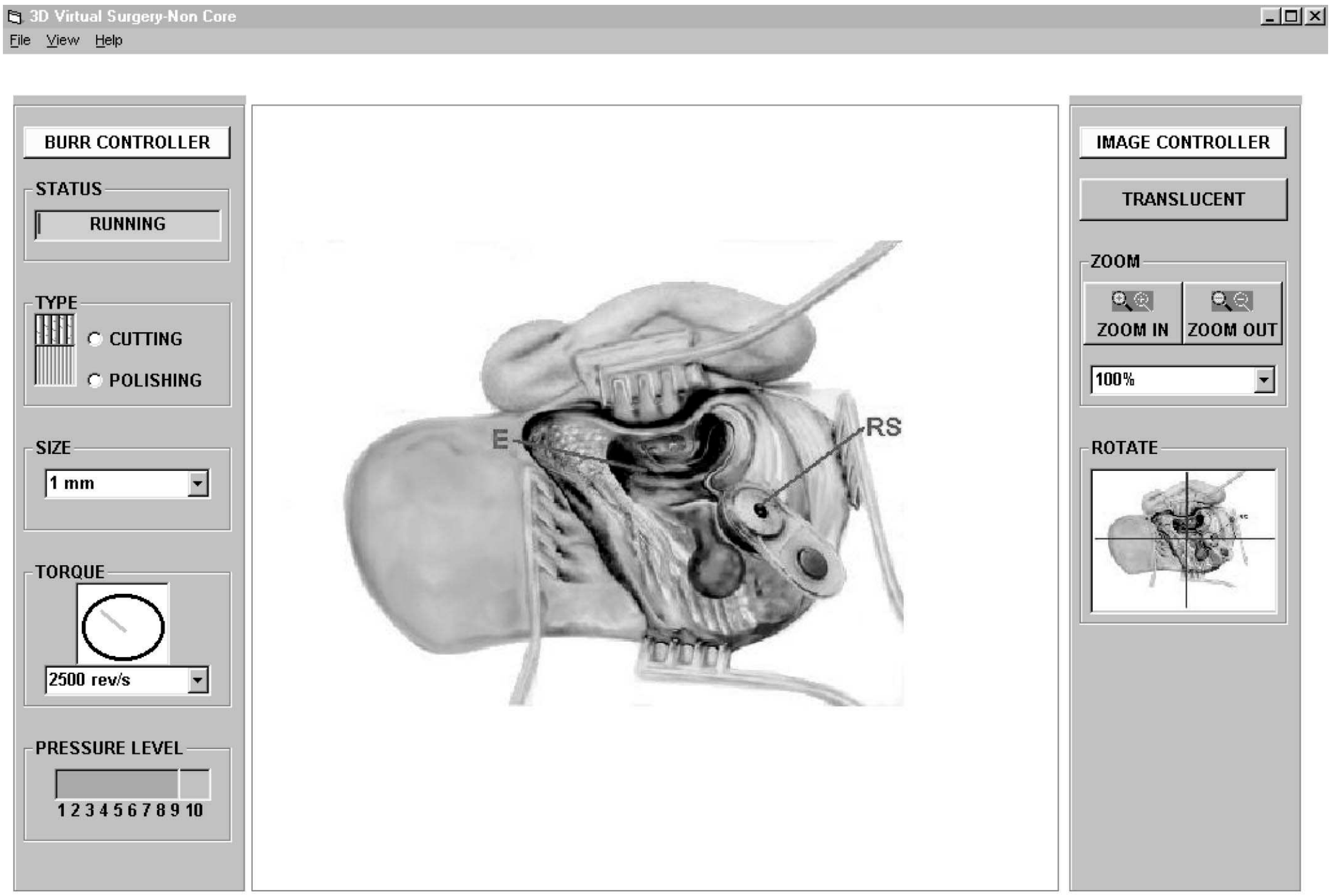

Figure 6: 3D Virtual Surgery Screen — Non Core

1. Menu Bar - The menu bar is located at the top of the screen. The menu bar consists of 4 drop down menus: File, View, Window and Help. These allow the user to import file, save file, select view, switch between the 3D Virtual Surgery Screen and the Augment Screen and read help documentation.
   (a) File: refer to the 3D Virtual Surgery-Core Screen;
   (b) View: refer to the 3D Virtual Surgery-Core Screen;
   (c) Window: This menu allows the user to switch between the 3D Virtual Surgery Screen and the Augment Screen;
      i. 3D Virtual Surgery Screen;
      ii. Augment Screen.
   (d) Help: refer to the 3D Virtual Surgery-Core Screen.
2. Burr Controller
   (a) Type: Allows the user to select the type of burr by choosing a burr type in one of the option box;
   (b) Size: Allows the user to select the size of burr by selecting a burr size in the drop-down list box;
   (c) Torque: Allows the user to specify the torque at which the burr is rotating by using the incremental box to increase or decrease the torque;
   (d) Pressure: The pressure box will be activated if the burr is running. The pressure applied to the bone can be determined by selection of a pressure level within the 1 to 10 scale.
3. Image Controller
   (a) Zoom Control Box: The user can specify specific percentage of zooming by selecting a discrete range of value of magnification (from 0 up to 30 times) from the control box;
   (b) Translucent Button: By Clicking on this button the user can view the translucent 3D model. Re-clicking, reverts the translucent 3D model to the normal 3D model.
4. Image Frame — The image frame contains the 3D model of the bone where the drilling process will be performed. It can also be used to control the 3D model.
   (a) Drilling: User can perform the drilling operation by using the input device;
   (b) Controlling Image: Allows the user to rotate, zoom in or zoom out of the 3D model. To rotate, the user left-clicks outside the 3D model in the desired direction of rotation. The user left-clicks the mouse in the desired position of zooming within the 3D model to zoom in and right-clicks to zoom out.

7.2.2 Augment Screen — View One Slice

This user interface enables the user to represent tissues or landmarks, which the user needs to be aware of and possibly avoid when drilling the bone. The Augment screen provides the user with drawing tools and a colour palette. Under this One Slice View, the user can work on one slice at a time and then move to the next slice. This screen is depicted in Figure 7.

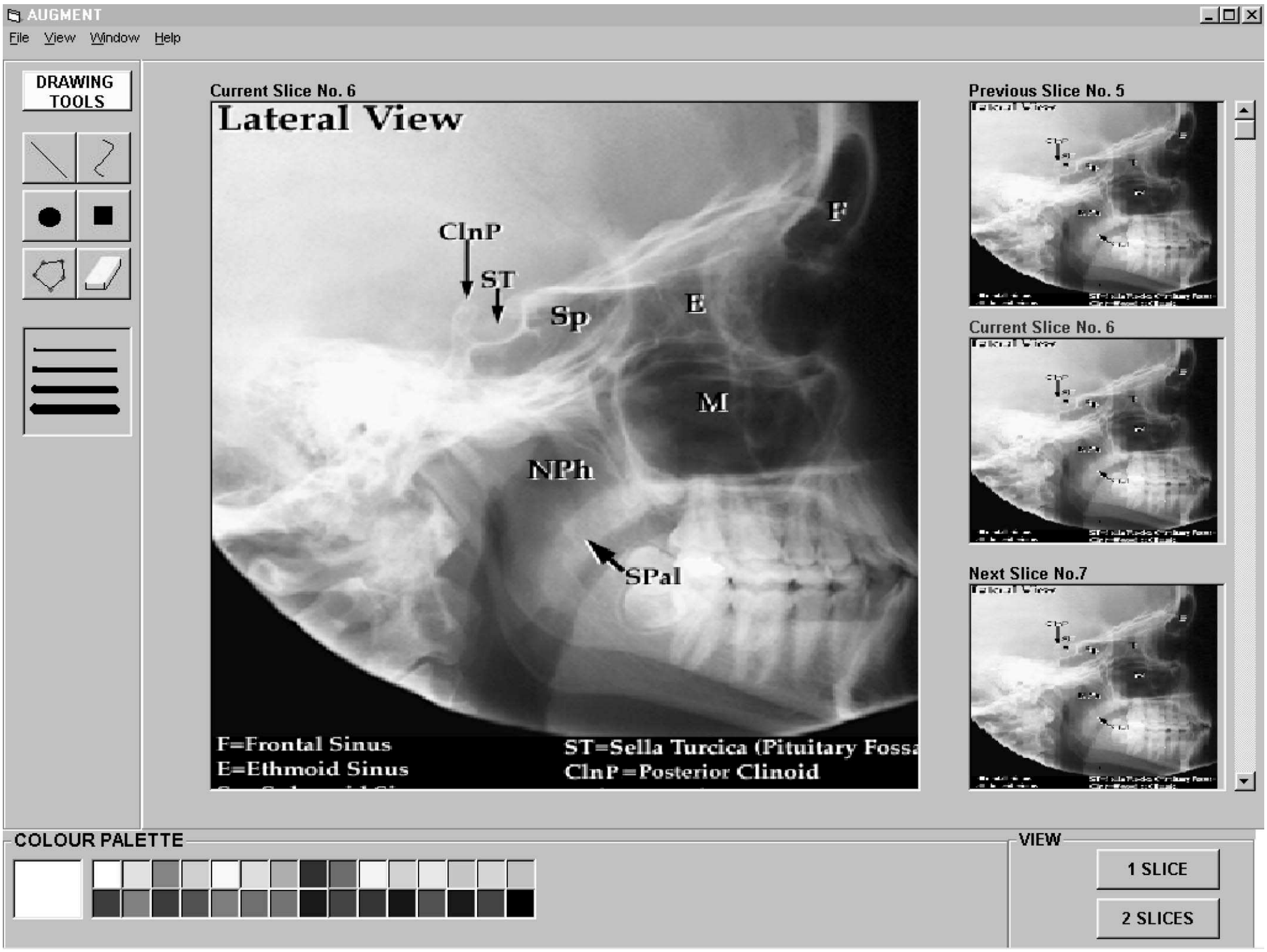

Figure 7: Augment — View One Slice

1. Menu Bar - The menu bar is located at the top of the screen. The menu bar consists of 4 drop down menus: File, View, Window and Help. These allow the user to import file, save file, select view, switch between the 3D Virtual Surgery Screen and the Augment Screen and read help documentation.
   (a) File: refer to the 3D Virtual Surgery-Core Screen;
   (b) View: This menu allows the user to choose to view one slice or two slices:
      i. View one slice;
      ii. View two slices.
   (c) Window: refer to the 3D Virtual Surgery-Non Core Screen;
   (d) Help: refer to the 3D Virtual Surgery-Core Screen.
2. Drawing Tools - The drawing tools panel provides the user with a range of line shape and type selections:
   (a) Straight Line Button: Allows the user to draw a straight line when the button is selected. To draw the line, drag the pointer;

(b) Free-formed Line Button: Allows the user to draw a free-formed line when the button is selected. To draw the line, drag the pointer;

(c) Circle Button: Allows the user to draw an ellipse or circle. Circle is drawn by dragging the pointer diagonally;

(d) Rectangle Button: Allows the user to draw a rectangle or square. To draw a rectangle, drag the pointer diagonally in the direction desired;

(e) Erase Button: Allows the user to erase an area of drawing. To erase, select button and drag pointer over the area to be erased. The erase button will not erase the original 2D image data;

(f) Adjoining Points Button: Allows the user to draw a shaped line by placing points on the 2D image. Then a shaped line will be formed by joining one point to the other point at a time;

(g) Thickness Panel: Allows the user to adjust the thickness of line drawn.

3. Colour Palette - Allows the user to select from a colour palette of up to 20 colours. The colour palette is located at the bottom of the screen.

4. Main Slice Viewer - Displays the current slice in the viewer window with the slice number is displayed on top of the viewer window.

5. Slice Previewer - Allows the user to preview the last, current and next slices. The slices are presented in mini viewer windows. The user can change slices by moving the slider.

6. Viewer Buttons - Allows the user to view one slice or view two slices by a selection of the buttons.

7.2.3 Augment Screen — View Two Slices

The View Two Slice screen allows the user to view two slices at one time for comparison purposes so that a previously marked slice can be used as a guide for the next slice. This screen is depicted in Figure 8.

The View Two Slice window is essentially the same as the View One Slice window, in which both contain the drawing tools, colour palette, and the change of view buttons. The difference between them is that instead of having one main viewing window and preview slices, there are two main viewing windows of the 2D slices allowing the user to work on two 2D slices at a time.

By clicking on any part of the 2D image on either main window activates a set of axes to be displayed on both images. The axes correspond to the same position. The axes can be moved by dragging the pointer.

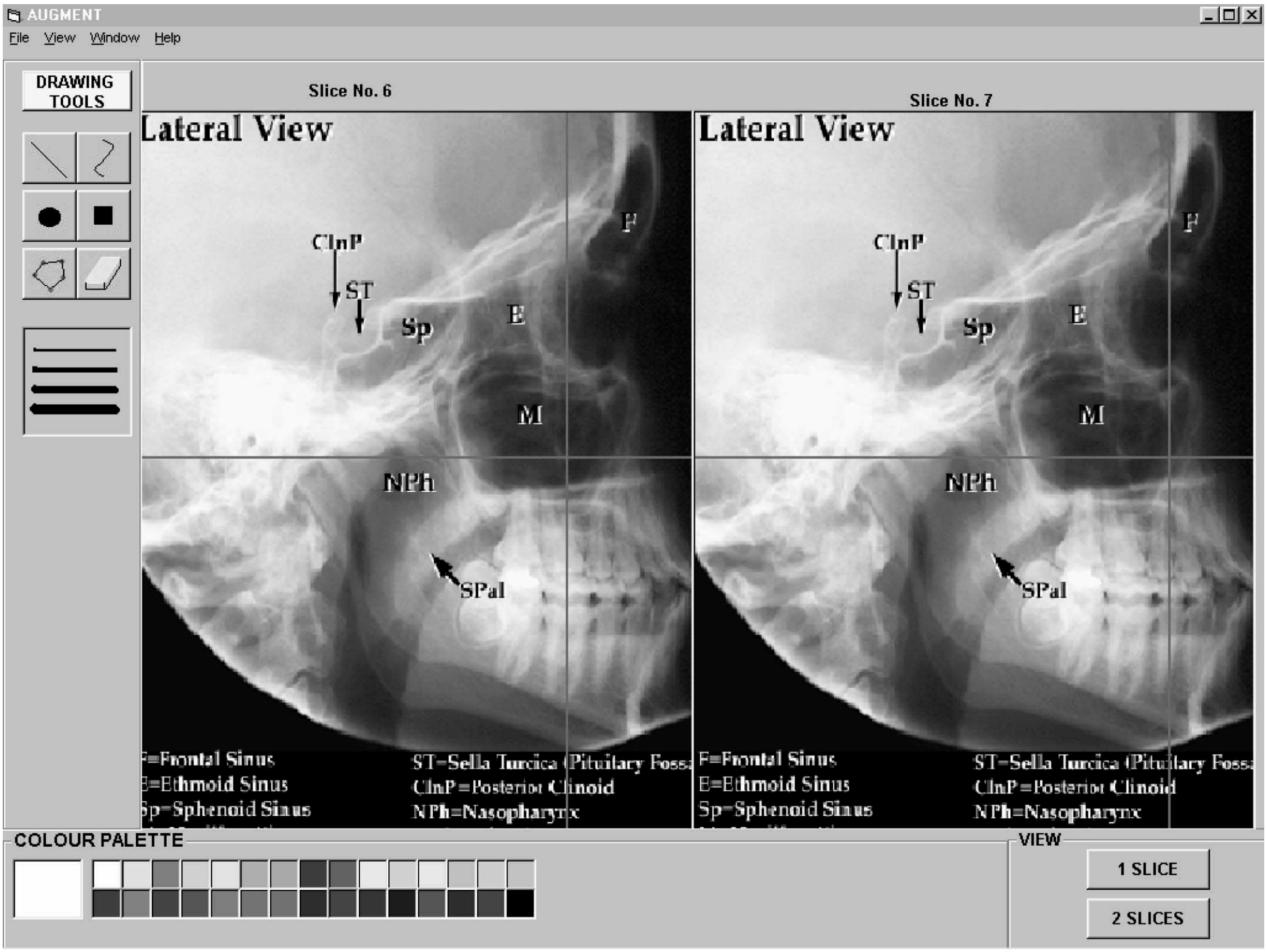

Figure 8: Augment — View Two Slices

8 Examples of Behaviour

This section outlines examples of user interaction with the system. It is classified into core requirement and non-core requirement behaviour which are based on the functional requirements outlined in Section 5. The examples of behaviour are provided to help the reader to gain a general understanding of the system.

8.1 Core Requirement Behaviour

1. Load a CT scan file;
   (a) The user selects a file containing the required CT scan to load;
   (b) The system loads and converts the CT scan to a 3D model;
   (c) The system displays the 3D model onto the screen.
2. Rotate a 3D model;
   (a) The user specifies the desired direction of rotation;
   (b) The system rotates the 3D model;
   (c) Steps a and b are repeated until the user is satisfied with the displayed 3D image.
3. Zoom or Traverse a 3D model;
   (a) The user enables the zoom mode;
   (b) The user selects the required zoom value;
   (c) The user selects a zoom value of 100% for traverse;
   (d) The user selects the zoom target from the 3D model;
   (e) The system displays the 3D model at the selected zoom value.
4. Perform drilling operation;
   (a) The user activates the burr;
   (b) The user sweeps the cursor through the area within the 3D model which is to be removed;
   (c) The system updates the 3D model;
   (d) Steps a, b and c are repeated until the user is satisfied with the displayed 3D image.
5. Save the 3D model.
   (a) The user specifies the file name in which the 3D model is to be saved in;
   (b) The system saves the 3D model under the name specified by the user.

8.2 Non-Core Requirement behaviour

8.2.1 Augment the CT scan

1. Load a CT scan file;
   (a) The user selects a file containing the required CT scan to load;
   (b) The system displays a 2D slice of the scan onto the screen.

2. Customise the drawing tool;
   (a) The user selects a type of drawing tool from the menu or tool bar;
   (b) The user selects a colour from the menu or tool bar with which the landmark is to be represented.
3. Marking the landmark;
   (a) The user marks the landmark on the displayed 2D slice;
   (b) The user selects the next slice to be displayed when the marking of the displayed slice is finished;
   (c) Steps a and b are repeated until a satisfactory number of slices are marked;
   (d) An undo function will be provided in the event the user makes an error.
4. Save the CT scan file.
   (a) The user specifies the file name in which the marked CT scan file is to be saved in;
   (b) The system saves the marked the CT scan file under the name specified by the user.

8.2.2 Perform the Virtual Surgery Operation

1. Load a CT scan file — refer to the core requirement behaviour;
2. Rotate a 3D model — refer to the core requirement behaviour;
3. Zoom or Traverse a 3D model — refer to the core requirement behaviour;
4. Customise the burr.
   (a) The user chooses the type of the burr;
   (b) The user selects the size of the burr;
   (c) The user specifies the torque at which the burr is to be rotated.
5. Perform drilling operation;
   (a) The user activates the burr;
   (b) The user sweeps the cursor through the area within the 3D model which is to be removed;
   (c) While the user is sweeping the input device, the system activates the burr and shows the amount of pressure placed on the input device;
   (d) The system updates the 3D model;
   (e) Steps a, b and c are repeated until the user is satisfied with the displayed 3D model.
6. Save the 3D model — refer to the core requirement behaviour.

9 Product Acceptance Criteria

The product will be accepted if the requirements listed under Section 5.1 Functional Requirements (Core) are completed, and the requirements listed under Section 6 Non-functional Requirements are satisfied.

10 Delivery Plan

At the end of the project the final product will be delivered. The delivery includes the following:

1. Software System
   (a) All core functional requirements detailed in Section 5.1; and
   (b) Any non-core functional requirements detailed in Section 5.2 (which are developed within the time frame).
2. User Documentation
   (a) The Setup Guide detailed in Section 6.2.1, and
   (b) The Reference and Trouble Shooting Guide detailed in Section 6.2.2.

The product is scheduled to be delivered on October 30th 2000.

11 Glossary

The following includes basic explanations of medical terms. For more complete explanations, please refer to medical dictionaries or textbooks.

2D: Two dimensional.

3D: Three dimensional.

Axial: Axial means an object's position as it relates to an axis. For CT scans, axial refers to slices made using the Central Nervous System as an axis.

Cavity: A hollow space within a solid body.

CT Scan: CT stands for computed tomography. This is a special radiographic technique that uses a computer to assimilate multiple X-ray images into a 2 dimentional cross-sectional image.

DICOM 3: DICOM stands for Digital Imaging and Communications in Medicine. It is a standard used for the communication of medical images and associated information. DICOM 3 refers to the third version of this standard.

Dura Mater: The outermost, toughest and most fibrous of the three membranes (meninges) covering the brain and spinal cord.

IEEE: Institute of Electrical and Electronic Engineers.

Meningitis: Inflammation of the meninges (refer to dura mater).

Ossicles: The tiny bones of the middle ear.

Pathology: The branch of medicine concerned with disease, especially its structure and its functional effects on the body. Pathology is sometimes used as a noun to refer to diseases.

Sigmoid Sinus: The vein draining blood from the brain to the neck. It is enclosed in the dura mater behind the temporal bone.

Sucker: A small pipe used during temporal bone surgery through which bone and water is drawn away.

Surgical Irrigator: A small pipe, through which water is run to moisten the temporal bone area being drilled.

Team Aura: The University of Melbourne 4th Year Advanced Software Engineering development team for Virtual Surgery. The team consist of 17 members.

Temporal: Of or pertaining to the temple or temples.

Temporal Bone: A very complex bone situated in the side of the skull of humans.

Voxel: A minimal cubic volume element in a 3D volune. Each 3D volune contains thousands or millions of voxels.

12 Client Sign-off

We, the clients of the Virtual Surgery project, have read and understood the requirements specified in this document. We agree to accept the delivered product if it satisfies the requirements as specified in the Section 7 Product Acceptance Criteria.

Client name Client

Client name Client

We, the developers of the Virtual Surgery project, have read and understood the requirements specified in this document. We agree to develop and deliver a product which satisfies the requirements as specified in Section 7 Product Acceptance Criteria.

Project manager name Project Manager
representing Team Aura