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Using virtual reality and augmented reality to teach human anatomy

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Using Virtual Reality and Augmented Reality to Teach Human Anatomy

by

Keerthi Kandikonda

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the Master of Science Degree in Engineering.

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An Abstract of

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As technology is advancing, biomedical engineering and computer engineering are merging to provide support for the various medical and health care applications. Virtual reality and augmented reality are two technologies in computer graphics which can be used to create applications to aid the teaching of the human anatomy. Using these two technologies, virtual 3D models of various parts of the human body can be created and interacted with. The present work addresses a case study of such technologies, their advantages and disadvantages in designing and interacting with virtual 3D models for teaching human anatomy. For this, I have created a 3D virtual model of the human spine and have performed basic interactions with it. I then showed an application in augmented reality using the 3D spine model and compared both the technologies.

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Chapter 1

Introduction

1.1 Motivation

Human-Computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them [1]. Virtual reality and augmented reality are two different technologies which use human computer interaction.

According to [2], virtual reality is a graphical two dimensional or three dimensional interface for interaction between the user and the computer. It applies to computer-simulated environments that can simulate places in the real world, as well as in imaginary worlds. Through virtual reality, a number of graphical applications can be developed. Example of such applications include both 2D and, 3D models, interactive and non interactive game engines, interactive web browsers, 3D simulations and a wide variety of other applications ranging from simple graphics to complex artwork for movies. Virtual reality has a limitation in a way that its scope is permitted only to the computer or system on which the user is working.

Augmented reality is a technology where virtual reality is combined with real world environments to make it look as if the virtual object is in real world. According to [3], augmented reality can be integrated into daily life and activity, and can be used for various purposes.

Health care and medicine are fields in which both technologies are being applied. Surgical simulation and planning, virtual endoscopy, medical education and teaching are examples of some domains that use these technologies [4].

In the area of teaching, human anatomy is mainly illustrative as it involves teaching through pictures, diagrams and real models for easier understanding, and the application of virtual reality and augmented reality to such activity has great potential. Through 3D visualization, students can understand human anatomy in a less complex way when compared to experimenting with real cadavers [4].

1.2 Objectives

In this work, I present a case study which addresses the use of both virtual reality and augmented reality as tools for the teaching of human anatomy. I compare the two technologies by analyzing 3D virtual models of the human body. The case study is supported by a set of experiments I have developed. In order to perform these experiments:

- I have used two virtual reality software's called Blender 3D and Maya 3D to create a 3D human spine model in virtual reality and I have performed basic interactions with the model. The 3D model is a replica of the human spine. For creating such a model, I have used reference pictures of the human spine that I have obtained from the internet to ensure the exact look.

- I have then described how augmented reality applications can be created using the 3D spine model.
- I have described in detail about using the 3D spine model in an augmented reality application using two different software's, the Adobe Flash professional CS5 and Google Sketchup.
- The referred 3D model I developed can be used in both virtual as well as augmented reality for teaching purposes. The model can be used to teach students about the human spine and its anatomy.

1.3 Thesis Organization

This thesis is organized into seven chapters. After introduction, the second chapter is a literature survey about human computer interaction, virtual reality and augmented reality. The third chapter is about how augmented reality works, the software's used to develop augmented reality applications and the process of creating an augmented reality application using a 3D model. A description of the code used to develop an augmented reality application is provided in this chapter. In the fourth chapter, I discuss how I have developed a two dimensional model of a human spine as the basis to designing a three dimensional model of the same. The fifth chapter discusses the construction of a three dimensional virtual model of a human spine and how I have used the software Maya 3D for developing it. The last chapter addresses conclusion and future work.

Chapter 2

Human Computer Interaction, Virtual Reality and Augmented Reality

This chapter is a literature survey of human computer interaction, virtual reality and augmented reality.

2.1 Human Computer Interaction

Human Computer Interaction is the study of interaction between people (users) and computers. It is often regarded as the intersection of computer science, behavioral sciences, design and several other fields of study [1]. Interaction between users and computers occurs at the user interface, which includes both software and hardware; for example, characters or objects displayed by software on a personal computer's monitor, input received from users via hardware peripherals such as keyboards and mice, and other user interactions with large-scale computerized systems such as aircraft and power plants [5]. The Association for Computing Machinery defines human-computer interaction as "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them [6]. The section that follows, discusses the architecture and general techniques used to develop interactive applications.

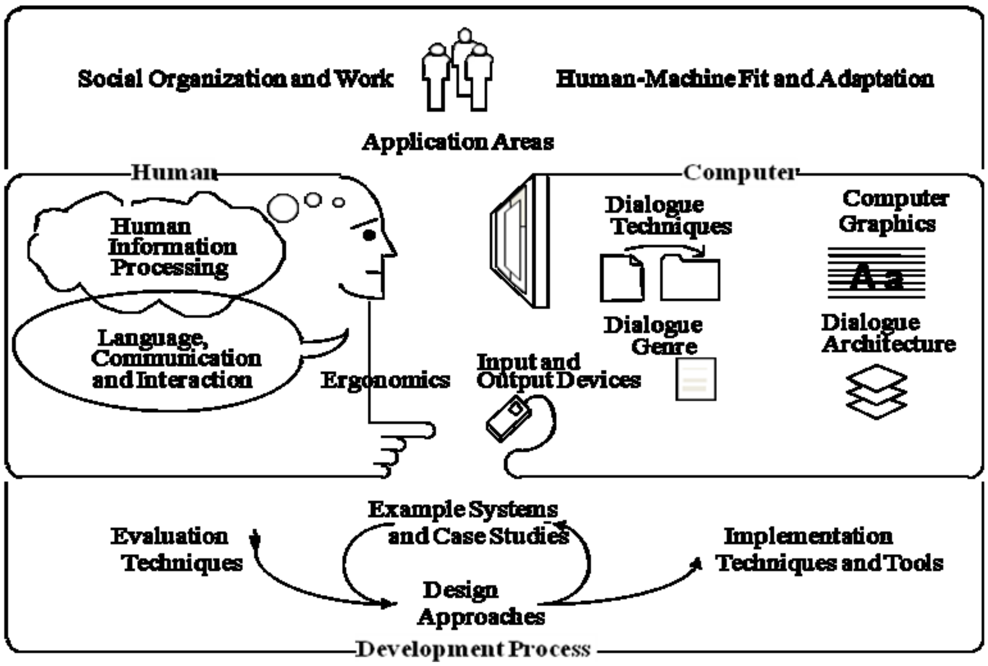

Figure 2-1: Map of Human Computer Interaction.

2.1.1 The Interface Architecture

According to [7], Figure 2-1 refers to specialized components computers have for interacting with people as described below:

Dialogue Techniques: These include the basic architecture and techniques for interacting with humans like dialog inputs and outputs, interaction styles like hand gestures and speech.

Dialog Genre: This includes the conceptual uses to which the technical means are put like interaction and content metaphors, transition management, style and aesthetics.

Computer Graphics: It includes the basic components from computer graphics that are especially useful to HCI.

Dialogue Architecture: The dialogue architecture includes the software architecture and standards for interfaces e.g., screen imaging, window managers, interface toolkits, multi-user architectures, look and feel, standardization and interoperability.

The Development Process: The steps involved in the construction and evaluation of interfaces are explained.

Design Approaches: The process of design is explained in this step e.g. graphical design basics (typography, color, etc), software engineering, task analysis, and industrial design.

Implementation Techniques and Tools: It involves the tactics and tools for implementation necessary in human computer interaction.

Evaluation Techniques: It involves the philosophy and specific methods for evaluation e.g. productivity, usability testing, formative and summative evaluation.

2.2 Virtual Reality

To be classified as virtual reality, an application should be interactive where users can interact with objects of the synthetic world [7]. In this section, I discuss the history of virtual reality and techniques used to design virtual objects.

2.2.1 History of Virtual Reality

According to [8], virtual reality came into picture as early as 1965. The first virtual environment was developed by Myron Krueger in 1983 and the virtual reality modeling language, which is very useful to create and interact with various virtual models, was introduced by silicon graphics in 1995 which state how rapidly virtual reality has been developing [8]. Table 2-1 presents the major advances in virtual reality from 1965 to 1999 [8].

Table 2.1: History of Virtual Reality.

Year	Person(s) Responsible	Why was it important?
1965	Ivan Sutherland	The beginnings of VR
1977	Dan Sandin, Richard Sayre and Thomas Defanti	Interaction through body movement
1982	Bonnie MacBird (Writer)	The first computer- generated movie
1983	Myron Krueger	First virtual environment
1984	William Gibson (His assistant)	The term ‘Cyberspace’
1987	Michael Piller (Writer)	The Holodeck, idea of immersive VR
1992	Stephen King (Official Website)	A look at the possible negative side of VR
1995	Silicon Graphics	Virtual Reality Modeling Language
1999	Larry and Andy Wachowski	Virtual Reality movie grosses $750M worldwide

2.2.2 Types of Virtual Reality

According to [8], virtual reality is classified as Immersive VR, Augmented VR, Text-based VR and Desktop VR. In Immersive VR, the user becomes immersed in a virtual world. It is also a form of VR that uses computer related components. Augmented VR is the idea of taking what is real and adding to it in some way so that user obtains more information from the created environment. When a reader of a certain text forms a mental model of this virtual world in his/her mind from the description of people, places and things, it is called text based virtual reality. Desktop VR refers to computer programs that simulate a real or imaginary world in 3D format that is displayed on screen as opposed to immersive virtual reality [8].

2.2.3 Modeling an Object in Virtual Reality

To model an object in virtual reality, the author in [10] has proposed a step by step process. The first step is creating a virtual environment that consists of virtual surroundings and a set of virtual objects that real people can manipulate in real time. In such an environment, virtual objects can then be used to demonstrate different kinds of skills and perform various actions. The next step is the multimodal interaction between virtual objects and users which includes speaking, eye contact, pointing at, gazing at and moving virtual objects. The last step is involves recording which records user‘s body movements including objects, eye gaze and speech acts in real time [10].

According to [10], the first two of the above steps come under virtual reality whereas the third and fourth steps come under interacting with virtual reality which is a form of human computer interaction. To interact with objects in virtual worlds, the objects have to be created first. According to [11], these objects can be created by specifying, modeling and evaluation. Specification discusses the techniques used to model an object. In modeling, an object is modeled using the techniques that have been specified in the specification. It is during the evaluation step that user studies are carried out with a small number of users to evaluate the model that has been created.

2.3 What is Augmented Reality

Augmented reality (AR) may be viewed as a variation of virtual reality. Virtual reality refers to the situation when the user is completely immersed inside a synthetic environment. While immersed in the environment, the user cannot see the real world around him/her. In contrast, AR allows the user to see the real world with computer generated objects superimposed upon the real world. Therefore, AR supplements reality rather than replacing it [12].

Augmented Reality focuses on both Virtual Reality and real-world elements together, while being interactive in real time. Instead of having programmers build the environment for interaction with the user, AR uses a person's own visual and spatial abilities, normally used for interaction with the real world, for interaction with an invisible computer [13].

The head mount systems are the most popularly used tools for viewing objects in augmented reality. Of these head-mounted displays (HMD's), there are currently two techniques used to create Augmented Reality [13]:

- Video See-through: With a video see-through head mounted display, the real-world view is captured with two miniature video cameras mounted on the head gear, as shown in Figure 2-2, and the computer generated images are electronically combined with the video representation of the real world.

Figure 2-2: Video See through.

- Optical See-through: With optical see-through HMDs, the real world is seen through half-transparent mirrors placed in front of the user's eyes, as shown in Figure 2-3. These mirrors are also used to reflect the computer-generated images into the user's eyes, thereby optically combining the real- and virtual-world views.

Figure 2-3: Augmented Vision optical see-through system

2.3.1 History of Augmented Reality

Even though augmented reality is a much newer technology, it can be considered to be available for more than 30 years now as it gradually emerged from virtual reality although the phrase 'Augmented Reality' was coined in 1992. A brief history of augmented reality, emphasizing its major advances are presented as follows [14].

- 1957-62: Morton Heilig, a cinematographer, creates and patents a simulator called Sensorama with visuals, sound, vibration, and smell.
- 1966: Ivan Sutherland invents the head-mounted display suggesting it was a window into a virtual world.
- 1975: Myron Krueger creates Videoplace that allows users to interact with virtual objects for the first time.
- 1989: Jaron Lanier coins the phrase Virtual Reality and creates the first commercial business around virtual worlds.
- 1992: Tom Caudell coins the phrase Augmented Reality while at Boeing helping workers assemble cables into aircraft.
- 1992: L.B. Rosenberg develops one of the first functioning AR systems, called Virtual fixtures, at the U.S. Air Force Armstrong Labs, and demonstrates benefit on human performance.
- 1992: Steven Feiner, Blair MacIntyre and Doree Seligmann present the first major paper on an AR system prototype, karma, at the Graphics Interface conference. Widely cited version of the paper is published in Communications of the ACM the following year.

- 1994: Julie Martin creates first Augmented Reality Theater production, Dancing In Cyberspace funded by Australian Federal Government, Australia Council For The Arts Features, dancers and acrobats manipulating full body sized virtual object in real time, projected into the same physical space and performance plane.
- 1998: Spatial Augmented Reality introduced at University of North Carolina at Chapel Hill by Raskar, Welch, Fuchs.
- 1999: Hirokazu Kato created ARToolKit at HITLab, where AR later is further developed by other HITLab scientists and it is demonstrated at SIGGRAPH that year.
- 2000: Bruce H. Thomas develops ARQuake, the first outdoor mobile AR game, and is demonstrated in the International Symposium on Wearable Computers.
- 2008: Wikitude AR Travel Guide launches on Oct. 20, 2008 with the G1 Android phone.
- 2009: AR Toolkit is ported to Adobe Flash (FLARToolkit) by Saqoosha, bringing augmented reality to the web browser.

2.3.2 Applications of Augmented Reality

Augmented reality applications have been developed to support other fields. Such fields involve teaching, medicine, gaming and mobile telephones. The subsections that follow present some of these applications.

Augmented Reality in Teaching

Augmented reality is being used in teaching and education in various sectors including student education in schools, colleges and universities. The Augmented Reality in School Environments (ARiSE) program, which is being funded by the European Union is an innovative teaching aid based on Augmented Reality technology. It enables teachers to develop, with moderate efforts, new teaching practices and curricula to bring scientific and cultural contents to school classes in an easy to comprehend way [15].

Developers and researchers in Switzerland have created a kind of AR virtual chemistry laboratory. Students can view and acquire simple atoms through a virtual drag-and-drop technique. This way, students can construct their own complex molecules while being bound by the subatomic rules that govern molecular interactions. This feature offers a clear advantage over traditional methods of building models [16].

Augmented reality is used in medical teaching. The visualizations created by augmented reality can be extremely useful tools for educating people about medicine. With the help of augmented reality projections of bones, muscles, nerves and other internal body parts, medicine students can practice procedures on mannequins in a somewhat real-world game of "Operation." Applications can also help teach kids about anatomy by allowing them to peer under the skin and reveal the inner workings of human bodies [17].

Figure 2-4: Augmented reality being used in chemistry and dance.

Figure 2-4 is illustrates how augmented reality is used in displaying models of molecular structures and how it can be used for teaching aerobics to students. The use of augmented reality in teaching has made the job easier for teachers and students can learn in a more interactive and interesting way.

Augmented Reality in Medicine and Surgery

Different medical AR prototype systems were built and tested in the late 90's like the semi transparent display for augmentation of orthopedic surgery [18]. Augmented reality is also used for surgery and birth simulations, virtual laparoscopy, tracking surgery tools, ultra sound projections and visualization of anatomical joints in motion [19].

Augmented Reality in Gaming and Entertainment

Augmented reality (AR), combining 3D real and virtual environments, makes new ways of interacting with games possible. It also allows an improved collaboration for this environment and stimulates a more direct interaction between players, even making it possible to eliminate avatars or text only chat interfaces within the game, extending its social aspect [20]. With AR, the game may be brought to the real world, and people can have a more physical, personal, and emotional interaction as in traditional board or card games [21]. In augmented reality, the player can influence a game with unique input and feedback devices. Furthermore, the user can move around in the real world and interact with other participants [22].

A very popular example would be the total immersion. A company called Total Immersion [23], has recently launched new software which works with baseball cards and applies augmented reality to it. It requires the user to download the Total Immersion software from the web and install it on his/her computer. Prior to begin playing, the user needs to hold his/her baseball card in front of the webcam. As the card is recognized by the software, it will create a 3-D image of the player on the computer screen. The user then needs to play the game and move his/her hands and the 3-D figure will automatically performing the action. Figure 2-5 shows how 3D image of a player is displayed on the card using augmented reality [23].

Figure 2-5: Augmented Reality game.

Mobile Augmented Reality

Augmented reality on mobile phones is a new technology. It is already making its way into masses through various applications available on mobile phones like iphone and other highly developed devices [23]. A list of such applications is provided as follows:

- Layar: With the help of applications like Layar, obtaining information of the surrounding area such as restaurants has become extremely easy. Layar works by gathering information on the surrounding area using the camera and GPS of the phone. Then it displays the information regarding all the restaurants available. Layar can also deliver to the user information such as jobs available amongst all the companies within a building. All the user is required to do is point the phone towards the building he/she is interested in [23].

- Yelp: Another application working on patterns similar to augmented reality is Yelp. Like Layar, Yelp too provides information about the restaurants available within the area, in addition to restaurant ratings and reviews as well [23].
- Car Locator: It is another augmented reality application on the iphone which is used to locate a particular car in the parking lot [23].

Apart from using augmented reality in specific fields, it can also be used in day to day lives to know more about people and society. The sixth sense, an application developed by students at MIT is an example of developing complex augmented reality. It uses a device which when used on a person scans the person and gets all information about the person such as his/her personal details, professional details, social networking details and a projector projects that information in front of the person [24]. The use of this application is to obtain more information about the person you meet without the need for to ask such details.

Augmented reality has potential in numerous different application areas. Its characteristics make it both an interesting and challenging subject from scientific and business perspectives.

Chapter 3

Working of Augmented Reality for Virtual 3D Models

As seen in the previous chapter, augmented reality can be generated using basic gadgets such as a web camera and head mount displays. Apart from them, specific software packages are required in order to generate an augmented reality application. This chapter discusses how augmented reality works and how a virtual 3D model can be used to develop an application in augmented reality.

3.1 How Augmented Reality Works

The first step is to capture video from the webcam. From a user's perspective, the video capture is similar to watching oneself while using Skype [25]. The augmented reality software then steps in. The software has three components: recognition, tracking and rendering. In the video stream, this software searches for a 'target,' which can be either a single user or a group of users. It then tracks the target and imposes a 3-D overlay by adding a virtual object, before rendering it back on the screen in real time [25].

For users, this means they see a virtual image on the screen i.e., having a virtual object on their faces. Variations of this technology include projecting the virtual object onto a custom screen such as large outdoor displays [25].

3.2 Augmented Reality Using a Webcam and Flash

Using Adobe Flash is one way to create applications in augmented reality. In this approach, a webcam will capture a marker image and the application will augment the webcam feed with a 3D model overlaid onto the marker's position. With Flash Player 10, developers have the most robust toolset yet for rich application development. All the developer is required to have is a webcam, a few open source libraries, and Adobe Flash CS4 [26].

3.3 Software Used to Develop an Augmented Reality Application Using Flash

To develop an augmented reality application in *flash*, there are various software packages that should be used. Below is the description of all the software to be obtained in order to make augmented reality work [26].

3.3.1 Flash Professional CS5

The main software to be obtained and installed is the flash professional CS5.With this software, developers have the most robust toolset yet for a rich application development. Through this software a user can integrate *flash* and other libraries into a project to create an augmented reality application [27].

3.3.2 Adobe Flash Player 10

Adobe Flash Player is the standard for delivering high-impact, rich web content. It is tool that can be used for viewing animations and movies using computer applications such as a web browser [28].

3.3.3 FLAR Marker Generator

The FLAR Marker Generator is a software used to generate a marker which is important to develop an augmented reality application. To generate a marker, the user can use any painting tools such as paint brush for instance to draw an image. This image must contain a pattern represented in black and must be surrounded by a thick black square border. After installing and opening the FLAR Marker generator, a window appears which automatically detects and opens the system's webcam. The printed version of the created image should then be placed such that the camera attached to the system captures it and the marker is saved. The saved marker is in the PNG (.png) format. The saved marker should then be printed again and used as a marker for the application [29].

3.3.4 Flex SDK Code library

The core Flex SDK library consists of the command-line compilers and the complete class library of user interface components and utilities necessary to develop the augmented reality applications [30].

3.3.5 FLARToolkit Library

FlarToolkit is an open source code library for Augmented Reality in Flash. It recognizes the marker from input image and calculates its orientation and position in 3D world [31].

3.3.6 Papervision 3D Code Library

Papervision 3D has complicated geometrical equations that basically enlarges, shrinks and warps objects in a scene which in turn makes them appear to be moving in a 3D space. Besides being a well crafted set of instructions to pull off the expanding, shrinking and warping effect of objects to make a scene appear 3D, it is also packed with classes and methods to help a user to pull off 3D effects [26].

3.3.7 Web Camera

A web camera should be installed to develop augmented reality applications.

3.4 Creating an Augmented Reality Application

According to [26], augmented reality applications can be created using flash and papervision 3D. As the first step, all the software's required to create the application have to be installed on to the computer.

The second step is to open the flash CS5 software and create a new project in it. This project has three files. A flash document (.fla) and a flash action script file (.as), which is the document file.

The action script file contains all the code for the augmented reality file. The code has all the libraries required to develop the application. There are three libraries to be imported into Adobe Flash CS5. They are the FLARToolkit library, the papervision 3D library and the flex library. These libraries are used to identify a marker on a paper and identify the graphics to be displayed on it, fetch the graphic which is the 3D collada (.DAE format) model and display it on the marker. The marker needed for the application is stored in another folder.

The action script file also has code to import the 3D collada model into the application. Flash accepts 3D models in collada (.DAE) format. I have converted the 3D model into that I have developed in Maya 3D into a collada (.DAE) model. Converting a Maya model into a collada model is simple because Maya has an option to directly export its models into collada format. Once all the required libraries are imported and the required code is written and modified, the project should be compiled. The compiled project generates a swiff file.

The third file in a CS5 project is a swiff (.swf) file which is a file format for multimedia, vector graphics and ActionScript in the Adobe Flash environment. Swiff is originally an abbreviation for "ShockWave Flash". It is the file where the augmented reality application is viewed. When this file is opened, the code from the action script file triggers the web camera connected to the system. Once we place the marker in front of the camera, the 3D model appears on the marker. Figure 3-1 shows the augmented reality folder setup after the project has been created.

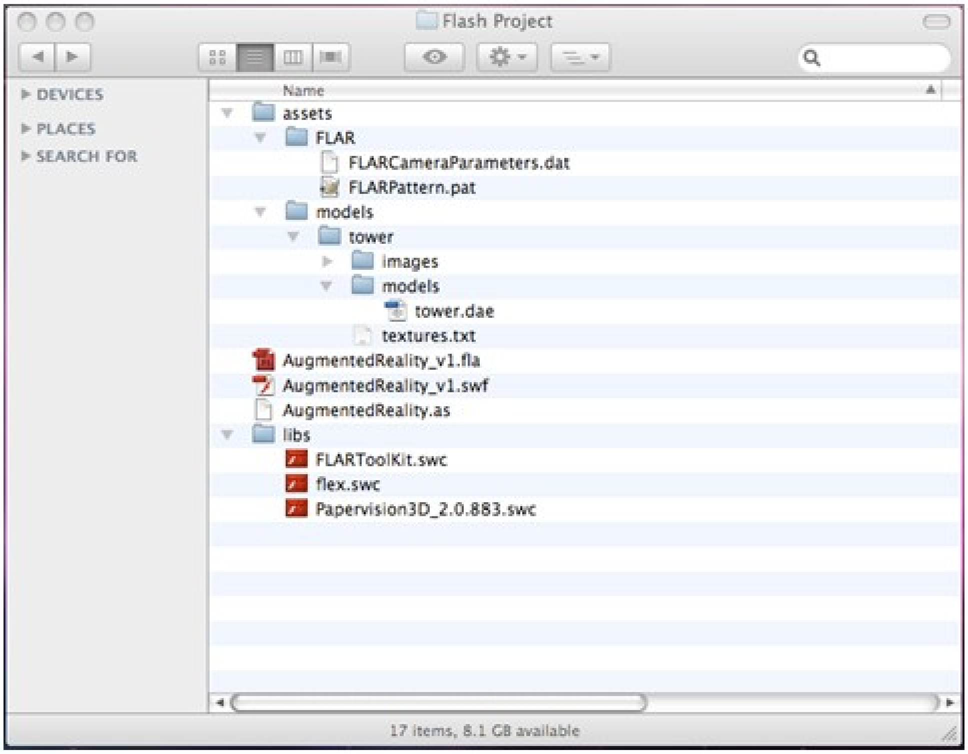

Figure 3-1: Augmented reality project folder using flash.

It is also possible to create an augmented reality application using a combination of Google Sketchup, an Augmented Reality plugin called AR-media and a web camera. Google SketchUp is a 3D modeling program marketed by Google to create and modify models. It is free software and can be easily downloaded from the internet [33]. With AR-media Plugin, Google sketchup users are allowed to visualize their 3D models using Augmented Reality directly in the real physical space which surrounds them. In a very precise sense, through AR-media Plugin, sketchup 3D models can be visualized out of the digital workspace directly on users' desktop, by connecting a simple webcam and by printing a suitable marker [34] .

I have imported the 3D spine model I have created in Maya, into Google Sketchup and have used the AR-media plugin to generate augmented reality. This process does not require writing any code as all the code is written internally by the software. The first step is importing the 3D spine model from Maya 3D into Google Sketchup as shown in Figure 3-2.

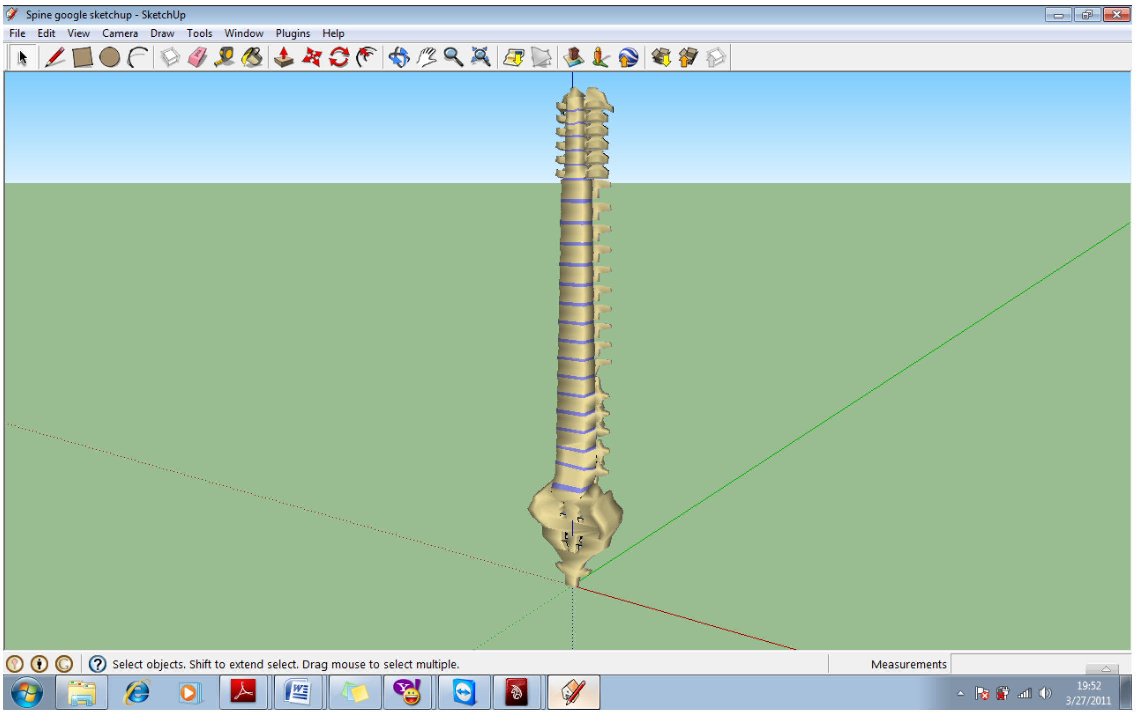

Figure 3-2: 3D spine model imported into Google Sketchup.

Now, the 3D spine model has to be configured with the AR-media plugin to generate augmented reality as shown in Figure 3-3

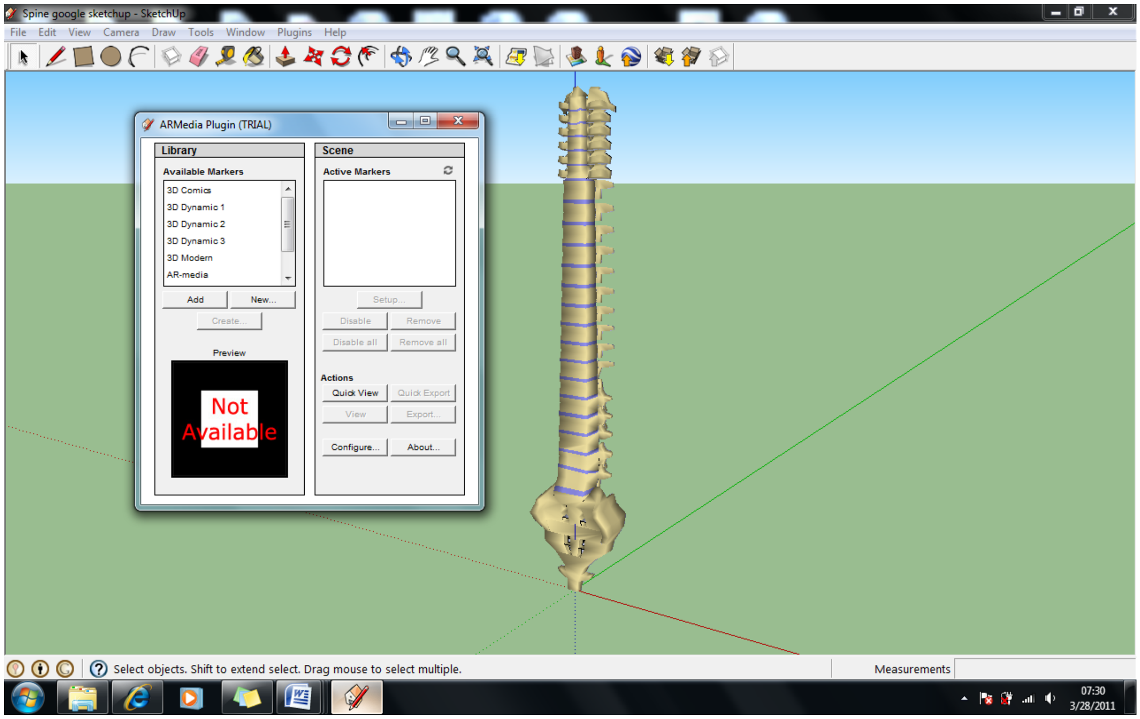

Figure 3-3: Configuring 3D model in Google Sketchup with augmented reality plugin.

A marker generator is automatically generated by the AR-media plugin. Once this setup is run, the web camera is enabled and it detects the marker in front of it, generating an augmented 3D spine. Figure 3-4 shows the augmented 3D spine model.

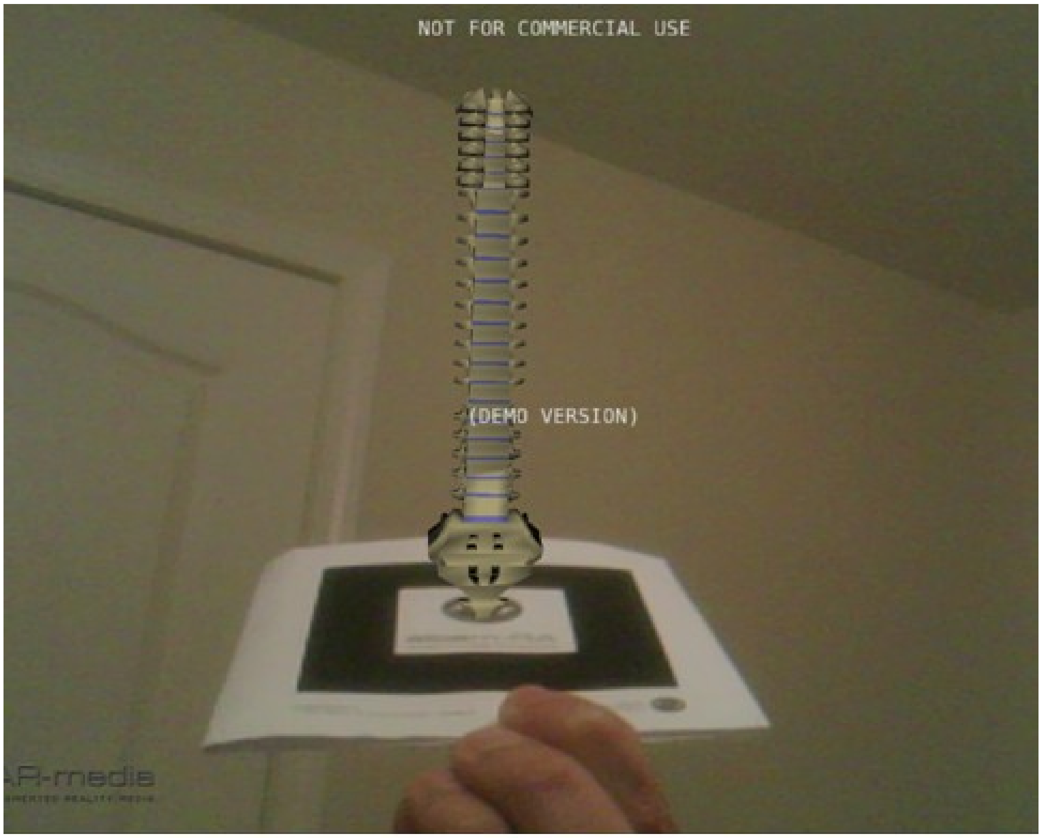

Figure 3-4: Augmented reality generated using the 3D spine model

In this way, 3D models of any part of the human body can be augmented. Using augmented reality has its own advantages in teaching or learning human-computer interaction. Traditional methods of using cadavers and heavy models of human body parts can be avoided. It is also easy to generate augmented reality and students can even interact with the augmented model. It is cost effective and anyone can use the basic computer at their home to learn about complex human anatomy.

.

3.5 Code for Generating Augmented Reality Application

- In this section, I will describe how the code actually works to generate an augmented reality application according to [32]. In the action script file, functions are created for different uses and variables are created for each function and are attached to the function.
- The first step is creating parameters for the SWF file. The SWF file is the compiled window of the action script file, where the output appears for the marker and the camera. This SWF command generates the size, framerate and color of the window.

```
[SWF(width="640", height="480", frameRate="30",
backgroundColor="#FFFFFF")]
```

- A function called ‘Create FLAR’ is created to have marker and FLAR parameters. The variables for FLAR and marker are created and are added to the function. This function sets up the FLAR marker file and webcam settings

```
public function createFLAR()
    {
        ar_params = new FLARParam //Parameters for project
        ar_marker =     new FLARCode(16, 16); //Marker for Project
        ar_params.loadARParam(new cam_params() as ByteArray);
        ar_marker.loadARPatt(new marker());
    }
```

- The next function is the ‘Create Cam’ function which is created to add the camera parameters. This function sets up a new camera that will project the images. The camera variables are created and added to the function. The action script file is then tested to see if the web camera setting is working and then we proceed to the next step.

```
private var ar_vid:Video;
private var ar_cam:Camera;
public function createCam()
        {
                ar_vid = new Video(640, 480); //video settings match the SWF
size
            ar_cam = Camera.getCamera(); //make a new project camera
                ar_cam.setMode(640, 480, 30); //camera setings match the video
and SWF
                ar_vid.attachCamera(ar_cam); //attach the camera to the video
                addChild(ar_vid); //attach the video to the project
        }
```

- A bitmap function is created for the bitmap data. This function sets up a new Bitmap canvas. For this, bitmap data variables and detection variables are created. These variables are added to the function specifying width and height and attach the video and marker.

```
public function createBMP()
			{
				ar_bmp = new BitmapData(640, 480);//create a new
Bitmap
				ar_bmp.draw(ar_vid); //draw the Bitmap canvas onto the
video
				ar_raster = new
FLARRgbRaster_BitmapData(ar_bmp);//Rasterize
				ar_detection = new
FLARSingleMarkerDetector(ar_params,
				ar_marker, 80); //Attach the marker file as the detection
point
			}
```

- Next, a papervision function is created to create a papervision object. The variables for Collada(.DAE) file, displaying the 3D scene, 3D camera, viewport and rendering the model are created. All these variables are added to the function and the 3D camera is setup. Then a DAE file is created and the collada model which has been imported into the action script file is loaded into it.

```
//This function creates a new PaperVision 3D object
public function createPapervision()
			{
				ar_scene = new Scene3D();//Create a new scene
```

ar_3dcam = new FLARCamera3D(ar_params);//Create a new 3D camera

var ar_materials:MaterialsList = new MaterialsList({all: new FlatShadeMaterial(ar_light)});

ar_dae = new DAE();

ar_dae.load("lrg_acorn.dae", ar_materials);

ar_dae.scaleX = 5;

ar_dae.scaleY = 5;

ar_scene.addChild(ar_basenode);//add the content box to the scene

ar_basenode.addChild(ar_dae); //Uncomment this section if you wish to use a DAE 3D file

addChild(ar_viewport);//Add the viewport to the project

}

- The last function is a loop which tells the project what to do whenever it shows the web camera. A Try Catch loop is created. The try loop has all the functions and if there is any error, the catch loop identifies the error. After the code is written, it is compiled and the augmented reality model is generated.

  private function loop(e:Event):void

  {

```
                    ar_bmp.draw(ar_vid);//attach the bitmap to the webcam
video
//                  ar_dae.rotationZ +=4; //Rotate DAE

                    try //This "try" clause catches any errors and prevents them
from locking up the program.
                    {

    if(ar_detection.detectMarkerLite(ar_raster, 80) &&
ar_detection.getConfidence() > 0.5)//Find marker
                        {

    ar_detection.getTransformMatrix(ar_transmat);//When the marker is
found, get the transformation matrix
    ar_basenode.setTransformMatrix(ar_transmat);//Place the content box
onto the transformatin matrix
    ar_renderengine.renderScene(ar_scene, ar_3dcam, ar_viewport);//Render
the scene
                        }
                    }
                    catch(e:Error){}//catch any errors
            }
```

After this code is compiled, an SWF appears and we can generate the augmented reality model using a marker.

Chapter 4

2D Spine Model

This chapter addresses the creation of a 2D model in Blender [35].

4.1 The Blender Interface

4.1.1 The Window System

At default, the Blender interface is separated into three windows. The main menu at the top, the large 3D Window also called The Viewport Window and the Buttons Window at the bottom. The viewport window allows users to see the image that they have imported, create a model from the image and allows them to view and manipulate the 3D objects created. It also allows the perform actions on the objects created such as rotate, pan and zoom the model that has been created. The Buttons Window is an important tool in Blender. When an object is selected after its creation, there will be a number of options in the buttons window through which the users can perform operations on the model [35].

4.1.2 The Default Scene

The default Blender scene in Figure 4-1 shows the screen that is available after starting blender for the first time [35].

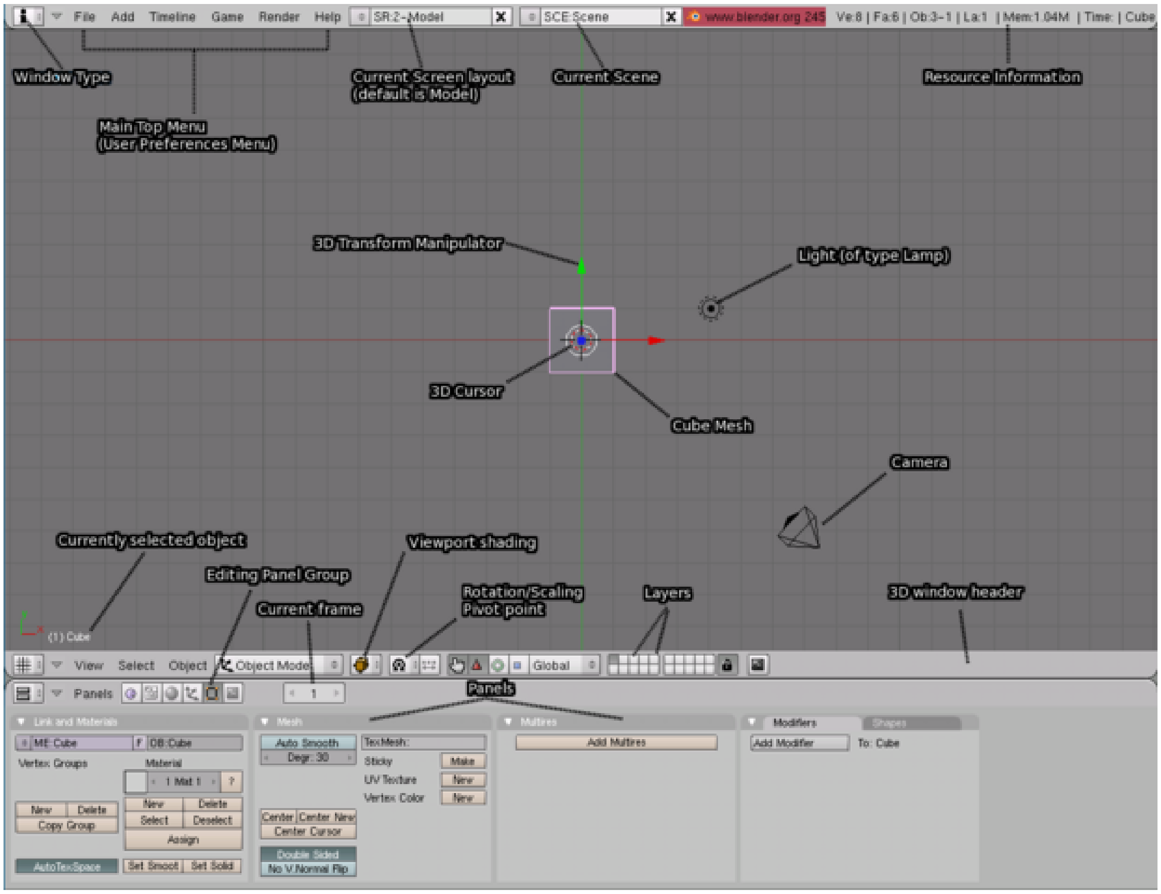

Figure 4-1: The default Blender scene.

By default a Blender scene is separated into three windows:

- The main menu at the top is the header part of the User Preferences window.
- A large 3D window (3D Viewport window).
- The Buttons Window (at the bottom).

The screen with the viewport window and the buttons window in Blender looks as in Figure 4-2 [35]:

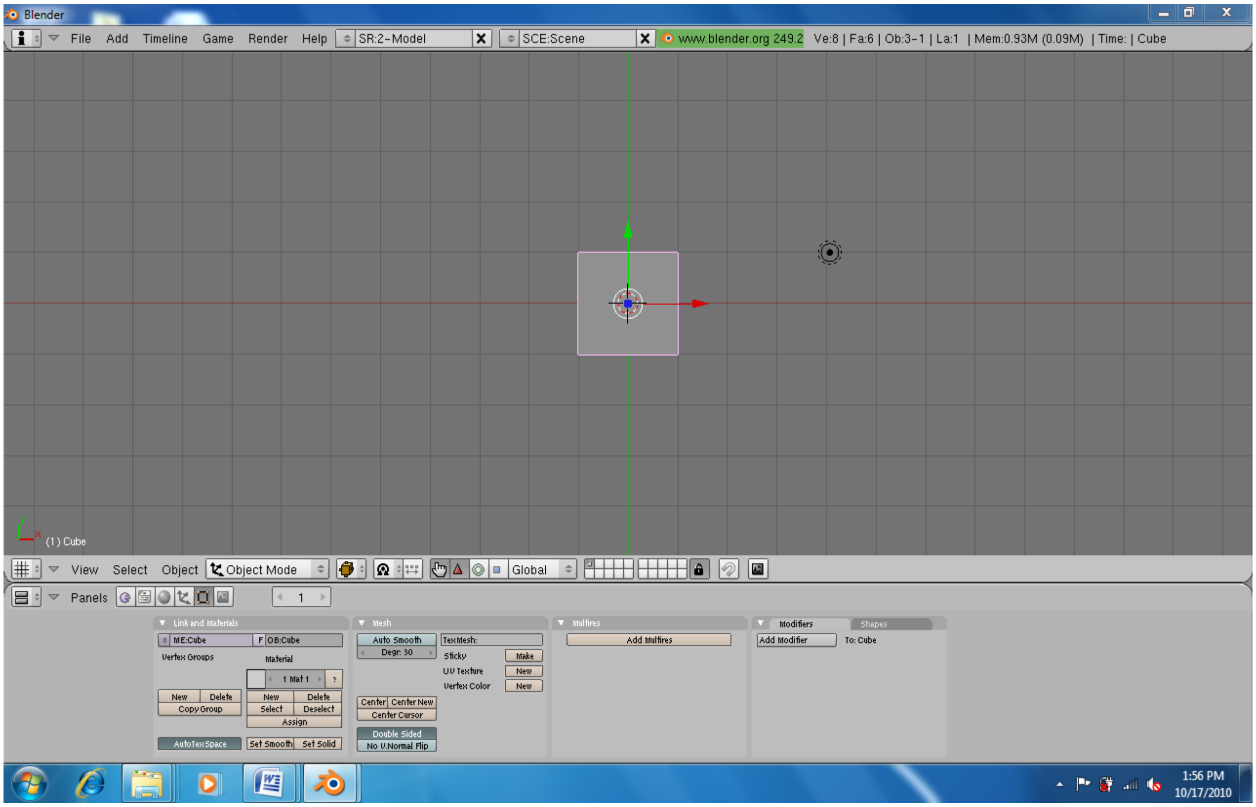

Figure 4-2: Windows of Blender scene. The Main Menu (Top), 3D window (Middle) and Buttons window (Bottom).

The fundamental elements of the Blender window system are explained as follows:

Current Scene: Current scene is the New scene on which the user is working. Multiple scenes allow the user to break up his/her work into organized patterns.

Resource Information: It gives the user information about application and system resources. It tells the user how much memory is being consumed based on the number of vertices, faces and objects in the selected scene.

Cube Mesh: By default, a new installation of Blender will always start with a Cube Mesh sitting in the center of Global 3D space. After a while, the user will most likely want to change the default settings. This is done by configuring Blender as he/she would want it on startup and then saving it as the default.

Light: By default, a new installation of Blender will always start with a light source positioned somewhere close to the center of Global 3D space.

Camera: By default, a new installation of Blender will always start with a camera positioned somewhere close to the center of Global 3D space and facing it.

Currently Selected Object: This field shows the name of the currently selected object.

3D Cursor: It can have multiple functions. For example, it represents where new objects appear when they are first created. It can also represent where the base of a rotation will take place. The 3D cursor is shown in Figure 4-3 [35].

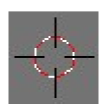

Figure 4-3: The 3D cursor.

3D Window Header: This is the header for the 3D window. All windows in Blender have a header. The header may in some cases be footer at the bottom of a window.

- Viewport shading**:** Blender renders the 3D window using OpenGL. The user can select the type of interactive shading that takes place by clicking this button and selecting from a variety of shading styles. He/she can select from boxes all the way to complex textured shading. It is recommended that the user has a powerful graphics card if he/she is going to use the textured style.

- Rotation/Scaling Pivot point: This option, allows the user to select where rotation/scaling will occur. For example, rotation could occur about the object's local origin or about the 3D Cursor's position, amongst many others.

Layers: Blender layers are provided to help organize objects into functional groups. For example, one layer may contain a water object and another layer may contain trees, or one layer may contain cameras and lights. These buttons then control the visibility of each layer's objects, making it easier to work on a subset of the objects in a scene **[35]**.

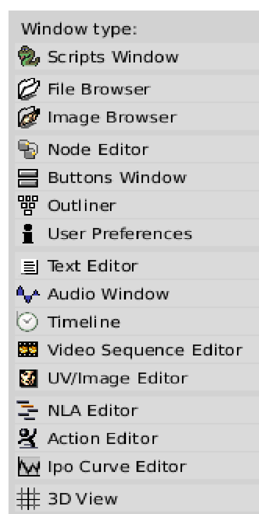

Figure 4-4: Types of windows in blender.

The buttons window is one of the types of windows that blender offers. It is a very important window, as the user performs most operations for creating an object from the buttons window. It has different types of buttons as shown in Figure 4-4 [36]:

- Logic Buttons: The set of logic buttons is used for game engine for developing games.
- Scripts Buttons: The script buttons are used to extend the capabilities of blender. Script Buttons allow the user to connect different events to objects.
- Shading Buttons: The set of buttons control the colors and texture of objects.
- Object Buttons: The set of buttons are related to the active object. It is different from object view of 3D window. TAB key changes object mode to edit mode while when you press F7 blender opens up the object button set at the button window.
- Edit Buttons: This set of buttons is used to edit objects in edit mode.
- Scene Buttons*:* Scene buttons are used for rendering frames or movies.

A user can customize Blender's window system to suit his/her needs and wishes. The user can create a new window by splitting an existing one in half. The blender interface can be split into four windows simultaneously. The four windows can have four different views out of the six views available in blender. The different views are:

1. Left view
2. Right view
3. Top view
4. Front view
5. Back view
6. Camera view

The new window will start as a clone of the window that is split, but it can then be set to a different window type, or to display the scene from a different point of view as shown in Figure 4-5.

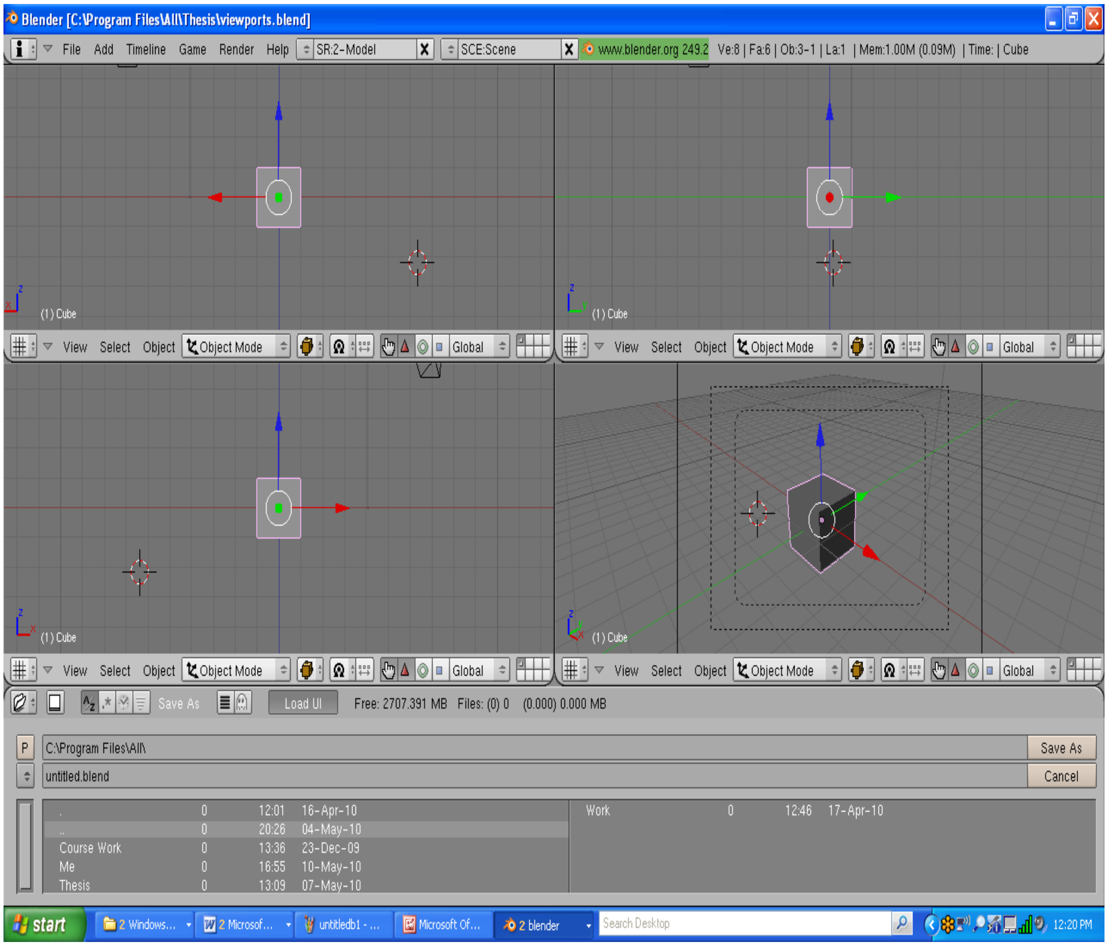

Figure 4-5: Different views of viewport window. The screen in Blender has been divided into the viewport window and the buttons window.

4.1.3 The Blender Toolbox

The Blender toolbox contains 6 main contexts, arranged on two lines, each of which opens menus and submenus. Three of these contexts open the same three menus present in the 3D Viewport header, of the other three, ‘Add’ allows adding new Objects to the scene while ‘Edit’ and ‘Transform’ shows all possible operations on selected Object(s) [36].

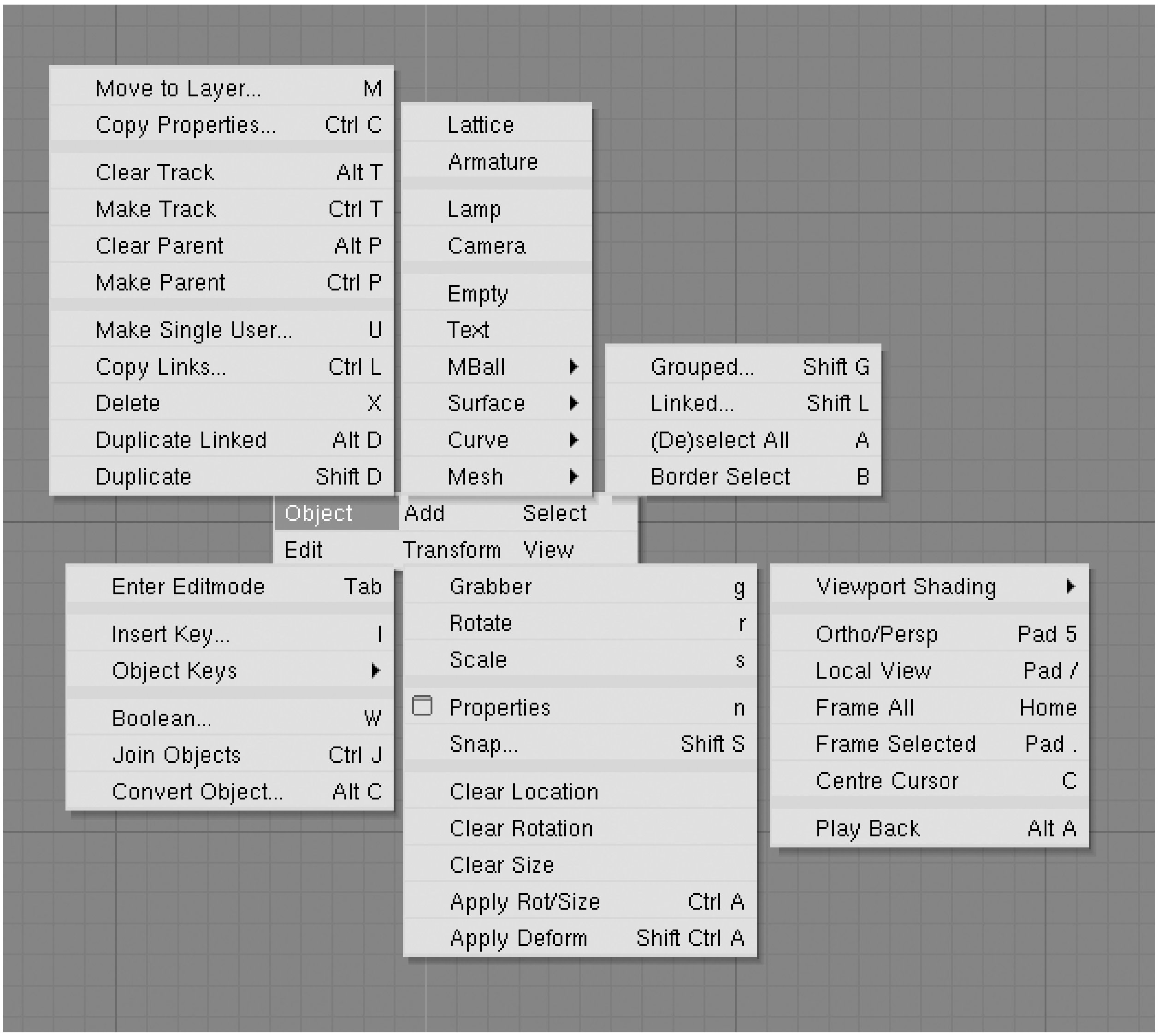

Figure 4-6: The Blender Toolbox.

4.1.4 Menus

Blender contains many menus, each of which is accessible from either the window headers or directly at the mouse's location using Hotkeys. Some menus are context sensitive in that they are only available under certain situations. For example, the Booleans menu is only available in Object Mode.

Figure 4-7: Menu Selection Drop Down in Blender

4.1.5 Panels

Panels generally appear in the buttons widow. Each button on the buttons header groups panels together into what is called a context. And those contexts are grouped further into sub-contexts. The panels are not fixed in position relative to the window. They can be moved around the active window [36]. Figure 4-8 shows the panels in button window.

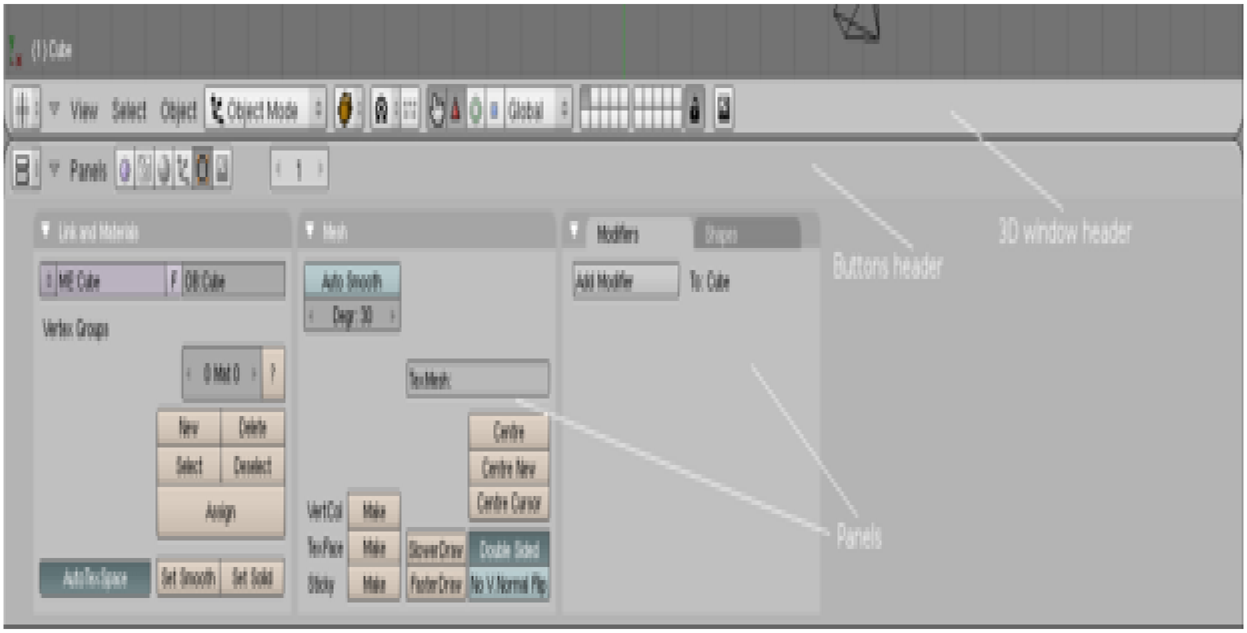

Figure 4-8: Panels in buttons window.

Particularly complex panels are organized in tabs. Tabs can be separated from a panel to form independent panels. In a similar way, separate panels can be turned into a single panel with tabs by dropping one panel's header into another.

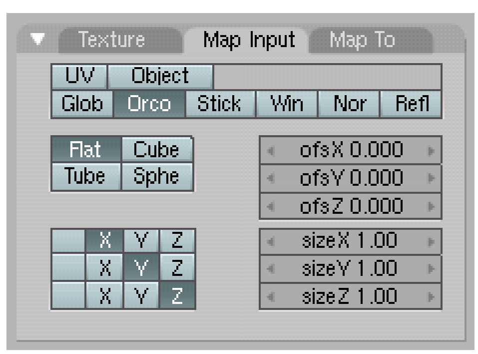

Fig 4-9: Panel with tabs example

4.1.6 Screens and Scenes

Blender's flexibility with windows lets the user create customized working environments for different tasks, such as modeling, animating, and scripting. It is often useful to quickly switch between different environments within the same file. This is made possible by creating several screens. All changes to windows are saved within one screen, so if the user changes the windows in one screen, other screens won't be affected. But the scene the user is working on stays the same in all screens. Three different default screens are provided with blender.

It is also possible to have several scenes within the same Blender file. The scenes may use one another's objects or be completely separate from one another. When a user creates a new scene, he/she can choose between different options to control its contents. [36].

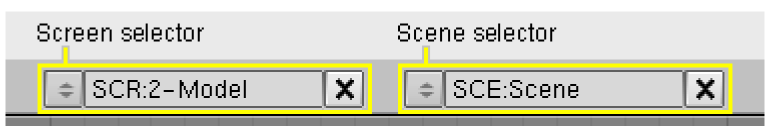

Figure 4-10: Screen and Scene selector in blender.

4.1.7 The Layer System

3D scenes often become exponentially more confusing with growing complexity. To get this under control, objects can be grouped into "layers," so that only the layers users select are displayed at any one time. [36].

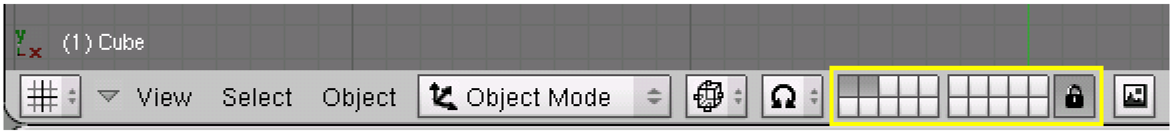

Figure 4-11: 3D Viewport's Layer Buttons

4.2 Creating a 2D Model Using Blender

There are many software's available but are not open source. So I have chosen blender which is open-source software downloadable from the internet. It is a very powerful tool in creating virtual models. Its main advantages over more powerful systems are ease of use, flexibility and relatively low hardware demands. The ability for the users to write their own scripts and plug-ins for Blender makes the software even more versatile.

For creating an object in blender, the first step is to model that object. Modeling an object in skeletal form in blender can be done through rigging.

Rigging is a special tool in blender which is used to form bone structures and skeleton structures. Through blender creating an object using rigging mainly depends on placing points at different places and joining them together with the help of the mouse cursor. Different parts like bones can be added through the already present tools and options given in blender.

A model of the spine can be constructed through rigging in the following way:

- Each bone has a three dimensional transformation which includes its position, scale and orientation, and an optional parent bone.

- The bones therefore form a hierarchy. The full transform of a child node is the product of its parent transform and its own transform. So moving an upper-bone will move the lower one too.

- As the spine is modeled, the bones change their transformation over time.

As the first step in creating the model, I have selected a JPEG image of the human spine. The image of the human spine that I have selected is as shown in Figure 4-12.

Figure 4-12: Image of the spine.

In the next step, I have imported the image into blender through the import option which is available in the file menu.

The third step is segmenting the model using Bezier curve. Segmentation is the creation of a model from the image through Bezier curves. For this, I have used the add menu to select the Bezier Curve option. Figure 4-13 illustrates the tracing of the spine model using Bezier curves and Figure 4-14 shows the traced structure of the spine.

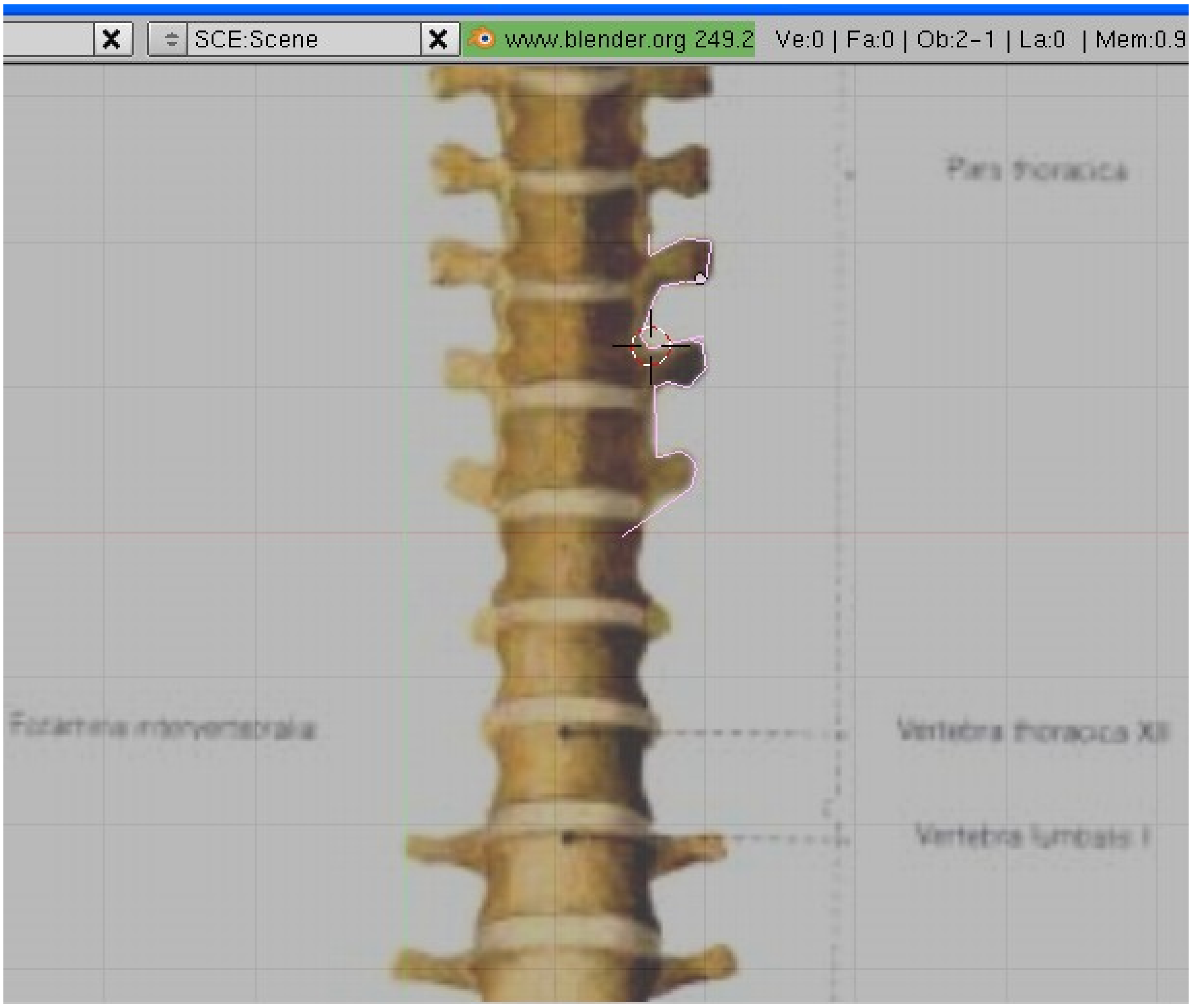

Figure 4-13: Tracing the spine design with the help of Bezier curves.

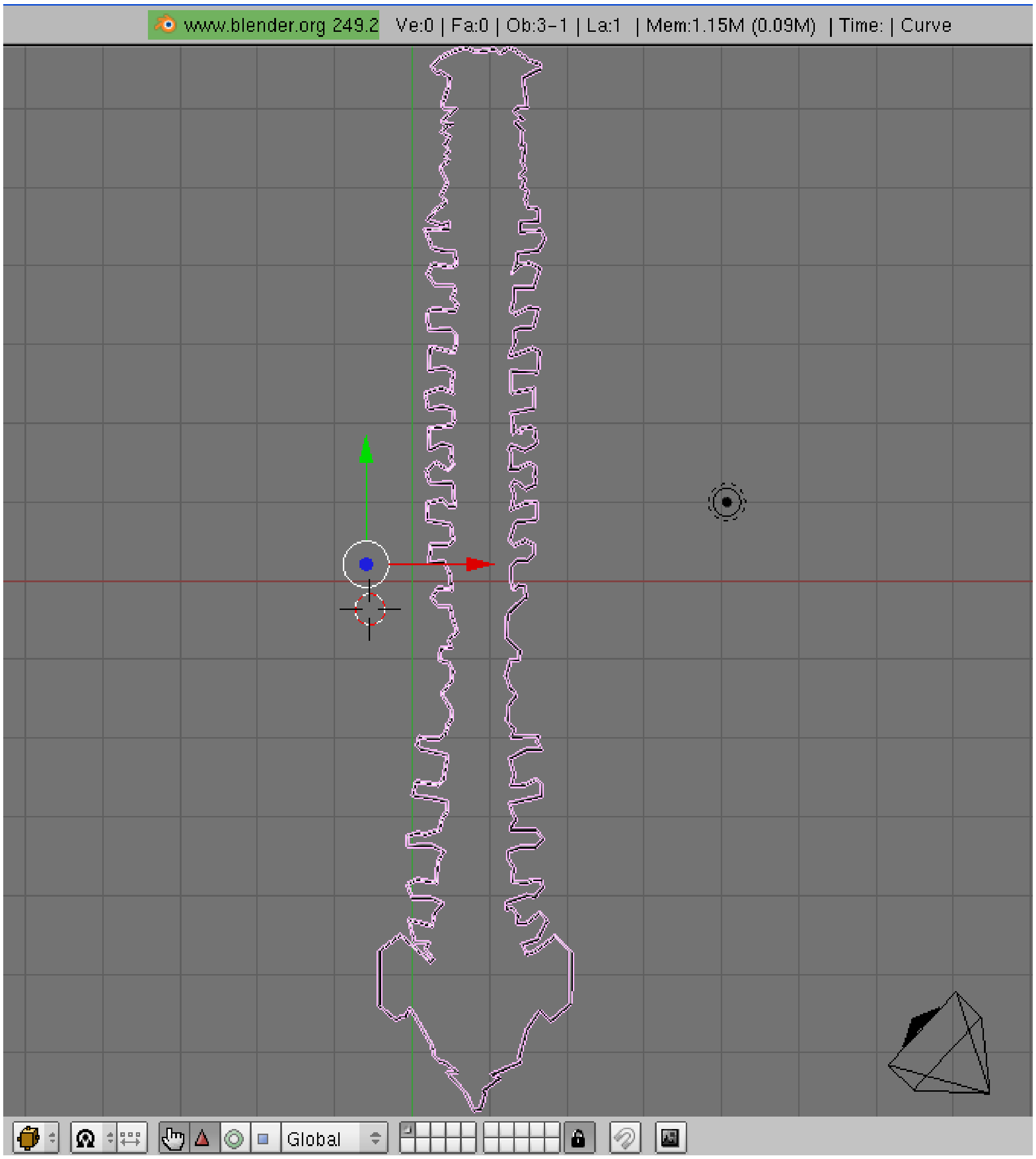

Figure 4-14: The traced design of the spine with the help of Bezier curves.

In step four, I have selected the particular image that I have segmented using the Bezier curves and have added bones to the image through which I can get the image as a 2D model. Figure 4-15 illustrates the structure of an armature (Bones) and Figure 4-16 illustrates the complete 2D bone structure of the spine.

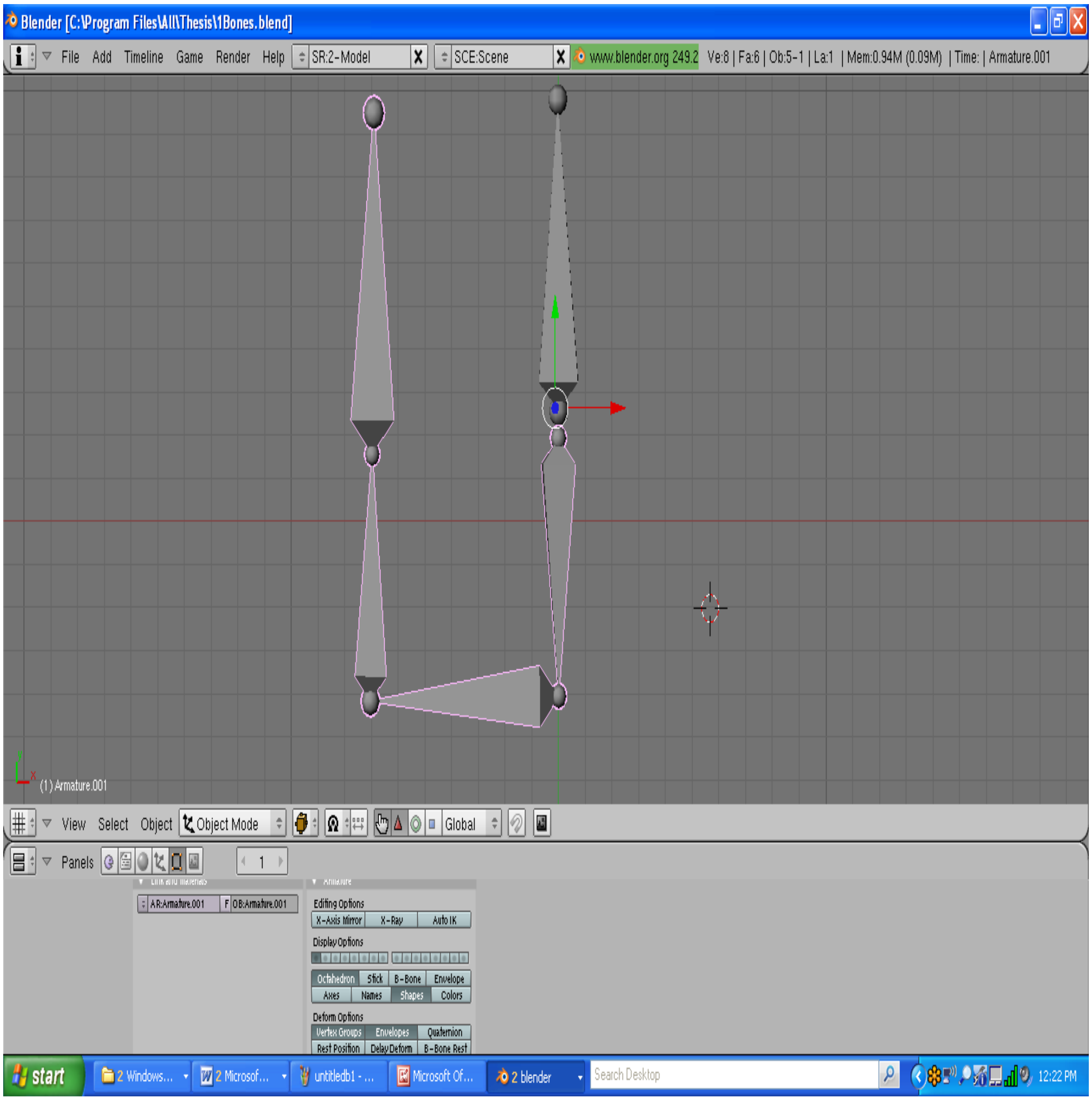

Figure 4-15: The bones that makeup the 2D model.

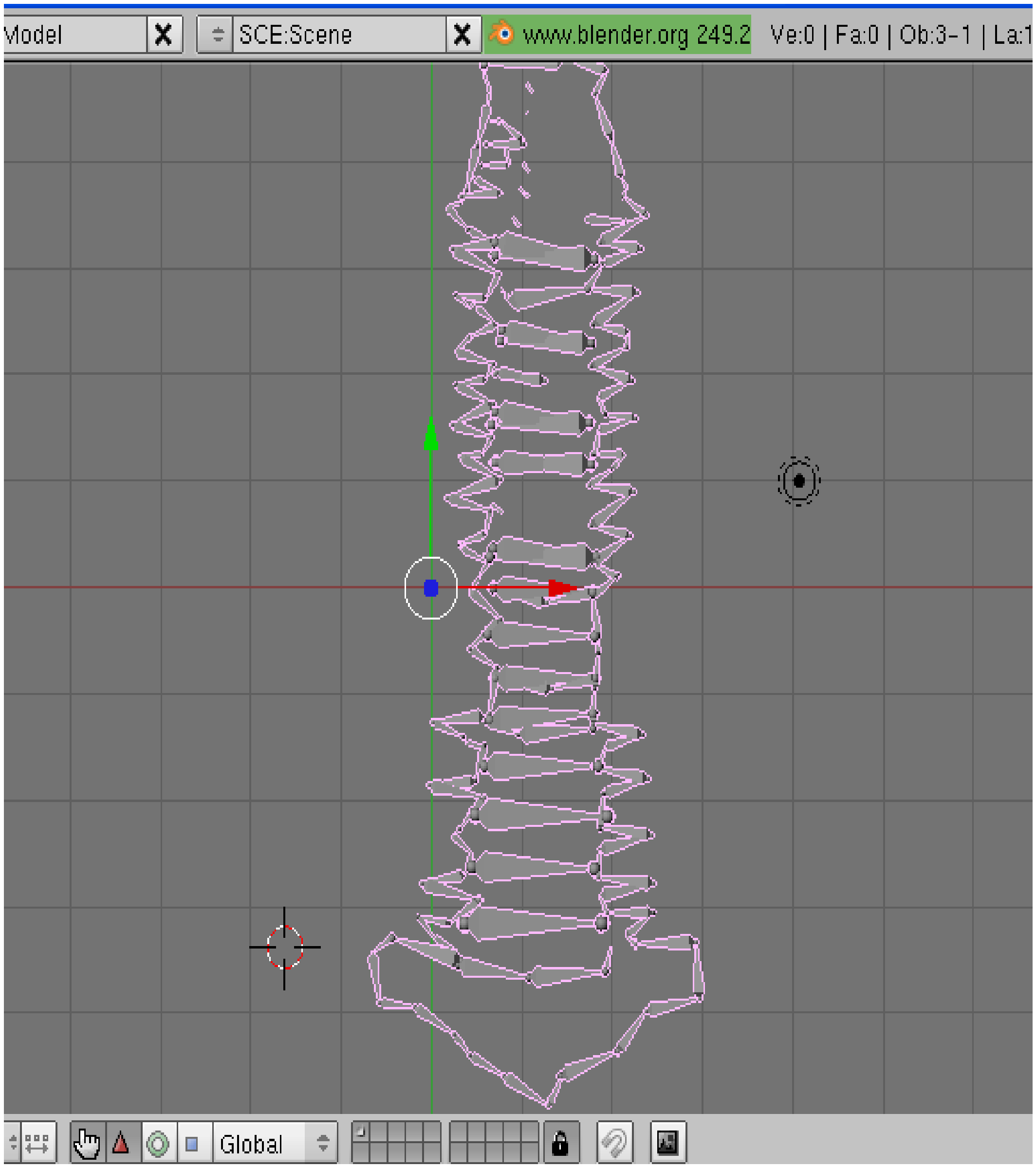

Figure 4-16: The 2D model of the spine.

Chapter 5

Modeling with Maya

Using blender, I have created a 2D model of the human spine. But to construct a 3D model, a more complex software would be needed which would be less time taking than blender and which would have more effective results. In this chapter, I will describe the virtual human spine model I have created using Autodesk Maya.

5.1 Autodesk Maya

Autodesk Maya is a software application used for 3D animation, 3D Modeling, simulation, visual effects and rendering. It is the 3D animation software that provides a number of tools for creating complex characters and animations. Maya's powerful feature set gives you an almost unlimited power to create any kind of animation [37].

5.2 History of Maya

Maya is the culmination of three 3D software lines: Wavefront's The Advanced Visualizer (in California), Thomson Digital Image (TDI) Explore (in France) and Alias' Power Animator (in Canada) [12]. In 1993 Wavefront purchased TDI, and in 1995 Silicon Graphics Incorporated (SGI) purchased both Alias and Wavefront (due to pressure from Microsoft's purchase of SoftImage earlier that year) and combined them into one working company, producing a single package from their collective source code [37]. The core of Maya is written in C++) [37].

5.3 A Brief Description of the Maya Interface

The Maya user interface looks complex to the beginner, but once the user understands its interface, it is quite easy and very user friendly. The Maya interface in Figure 5-1 [38].

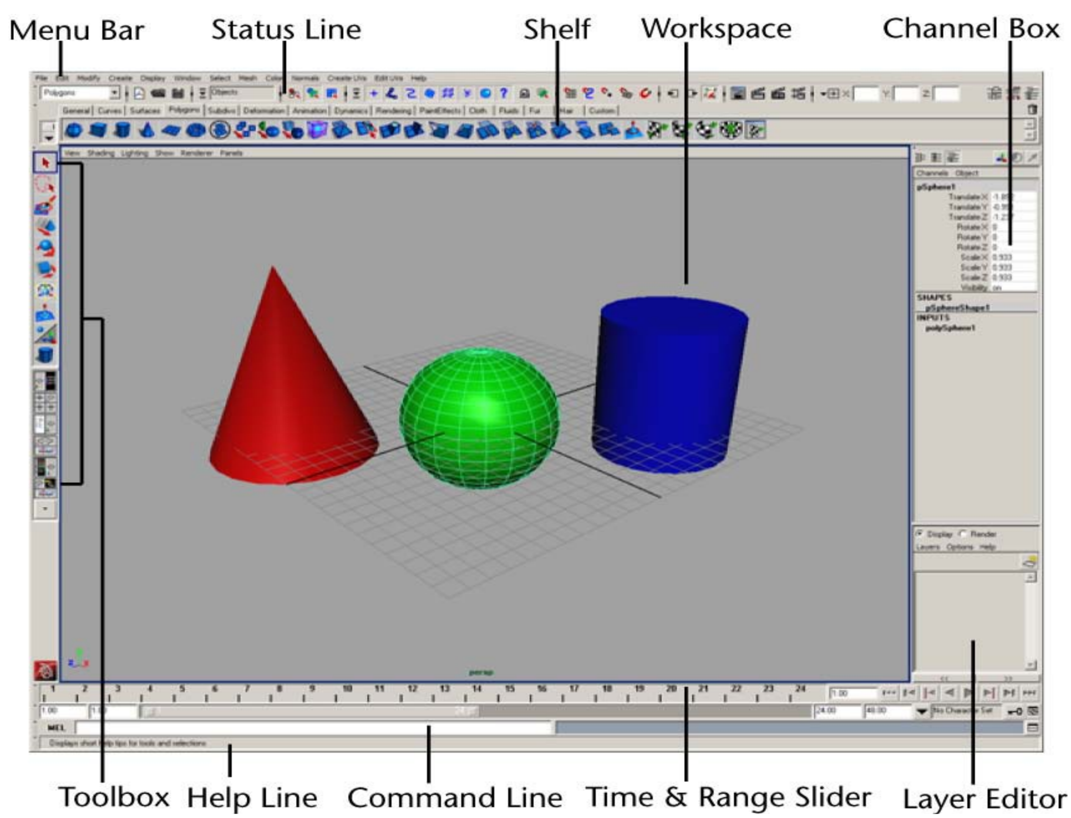

Figure 5-1: The Maya interface

5.3.1 Menu Bar

Each menu set on the menu bar corresponds to a module within Maya: animation, Polygons, Surfaces, Rendering, and Dynamics. Modules are a method for grouping related features and tools. When you select a module from the menu bar, Maya creates a 3D primitive object and places it at the center (origin) of its workspace [38].

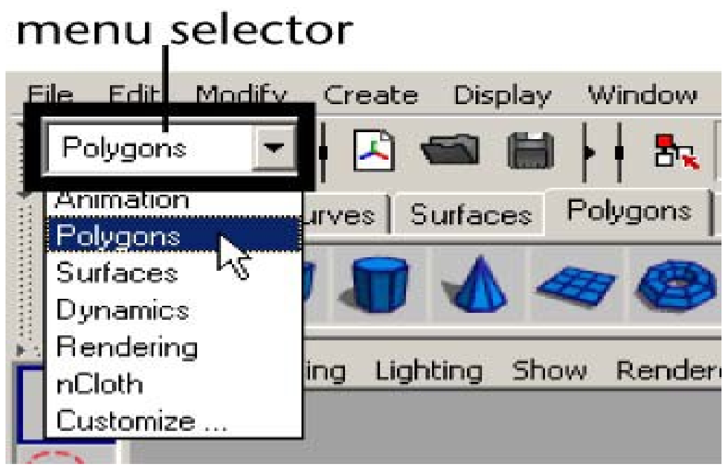

Figure 5-2: Menu Bar

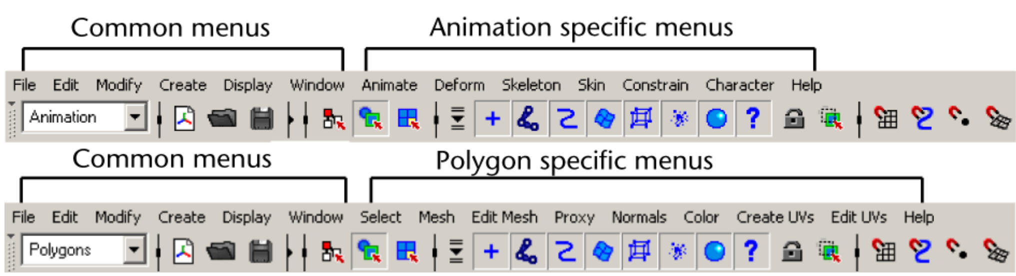

Figure 5-3: Specific Menu Bars.

5.3.2 Status Line

The Status Line, located directly below the Main Menu bar, contains a variety of items, most of which are used while modeling or working with objects within Maya. Many of the Status Line items are represented by a graphical icon [38].

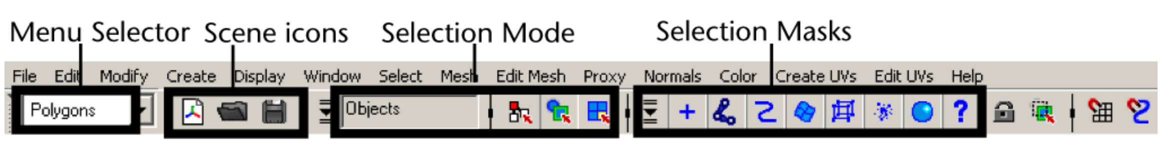

Figure 5-4: Status Line

5.3.3 Shelf

The Maya shelf is useful for storing tools and items that are frequently used or have been customized for the users own use. The user can keep the tools and items he/she uses most frequently in a location that provides handy access [38].

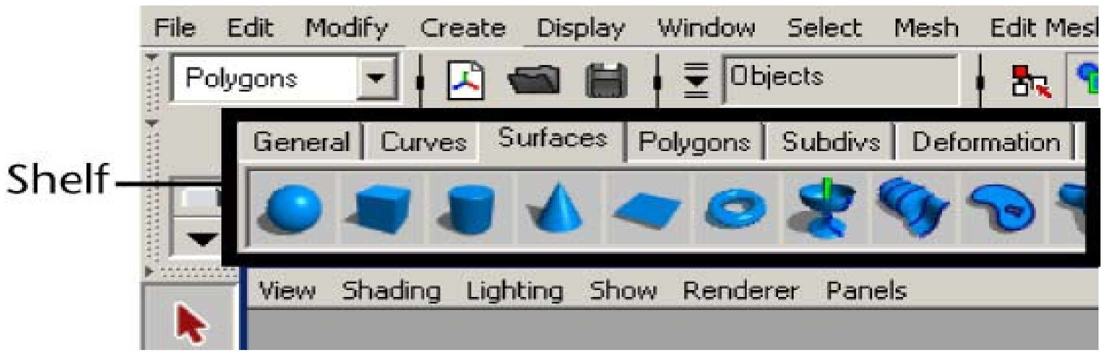

Figure 5-5: Shelf.

5.3.4 Workspace

The Maya workspace is where the user conducts most of the work within Maya. The workspace is the central window where the active objects and most editor panels appear [38].

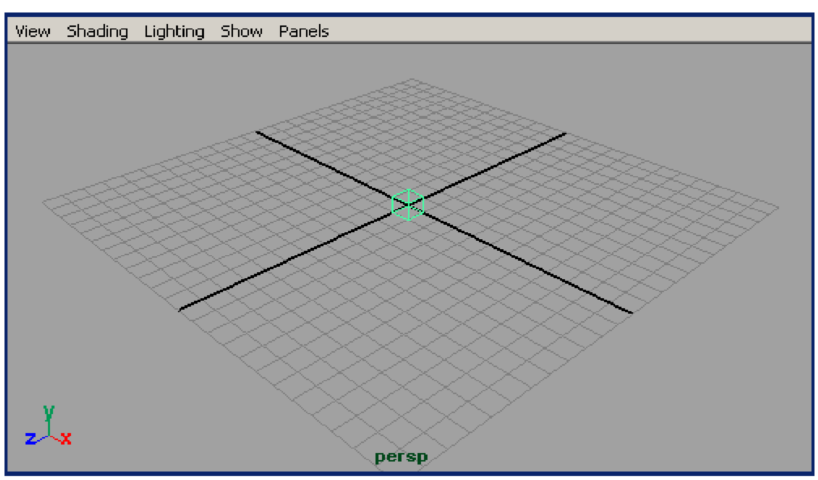

Figure 5-6: The Maya workspace

5.3.5 Channel Box

The channel box, when selected from the main menu, appears on the right hand side of the user interface. It has numerical information relating to the X, Y and Z translation, rotation and scaling for the transforming objects [38].

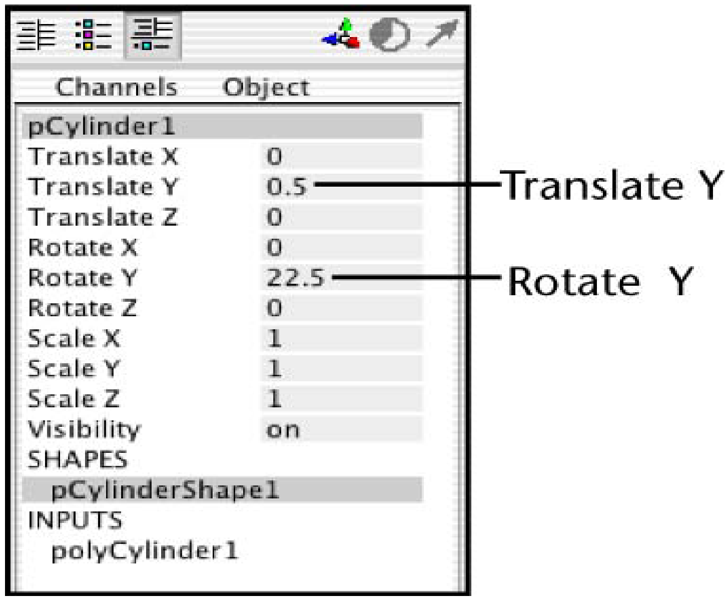

Figure 5-7: The Channel Box

5.3.6 Toolbox

The toolbox is located on the left hand side of the maya user interface. It contains icons that open tools for transforming objects within maya like selection, move, rotate, scale as well as layout shortcuts for changing the views and panel layouts [38].

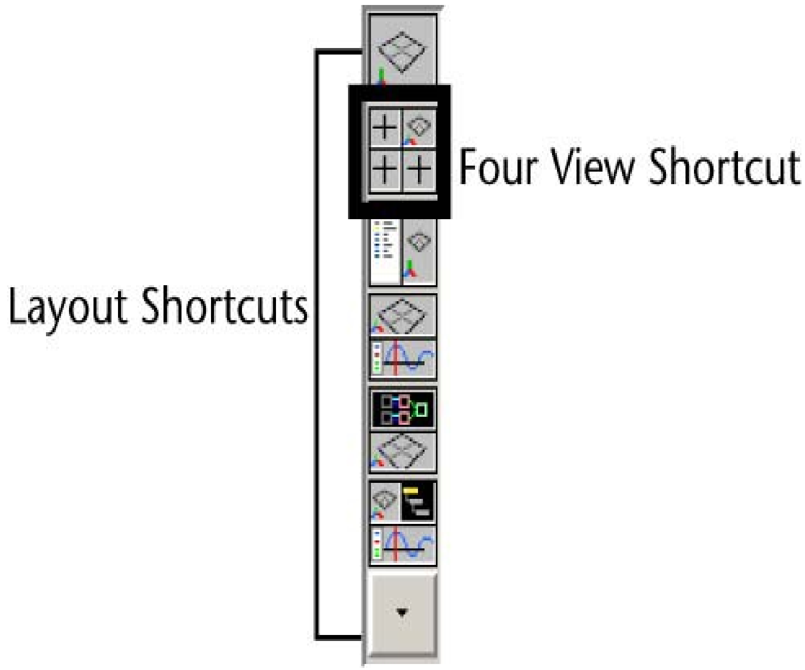

Figure 5-8: Toolbox

5.3.7 Helpline

Maya Helpline provides users with answers to questions about Autodesk Maya software [38].

5.3.8 Command Line

Users can enter commands in the command line. The command line can only accept single line commands. The command line is located near the bottom edge of the Maya interface [38].

Figure 5-9: Command Line for Maya interface.

5.3.9 Time and Range Slider

The time and range slider controls are used to control the playback. The time and range slider controls allow the user to playback or scroll through an animation or move to a specific point in the time of the animation so the user can set key frames [38].

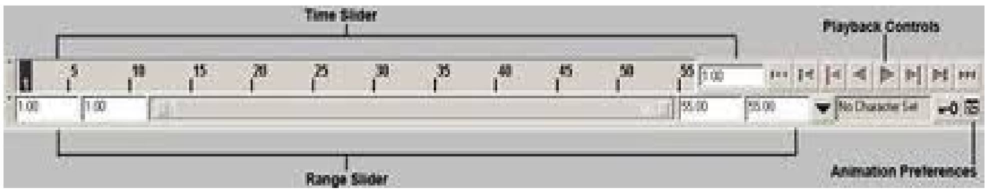

Figure 5-10: Time and Range Slider.

5.3.10 Layer Editor

The layer editor is used to set up layers to the active object. It is present in the channel box [38].

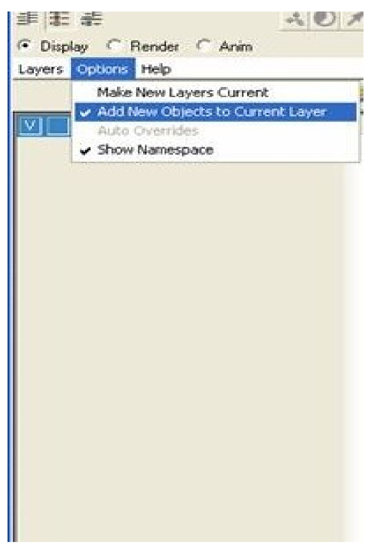

Figure 5-11: Layer Editor.

5.4 Creating a 3D model of the Human Spine in Maya

Creating a 3D model of the human spine involves 3 main steps:

- Creating the Mesh.
- Modeling.
- Rigging.

5.4.1 Creating the Mesh

A user can create many types of 3D objects using Maya and then move, scale, and rotate them to create more complex forms in a scene. As the first part in creating a mesh of the 3d model, I have taken a cube from the polygons option in the shelf menu as the base of my model. From this cube, I have developed the entire model.

Once I have placed the cube at the center of the workspace, I switched to the editing mode and selected the layer editor from the channel box to divide the cube into 5 or 6 divisions and have specified the height, depth and width of each cube. After doing this, the model looks like a pillar of cubes one on top of the other. This sets the height, depth and width of the 3D model.

The second step is to make as many divisions in the model as the number of bones in the human spine. So, I have specified 22 divisions in the channel box representing the 22bones in the spine. Once the division is done, the designing of the model comes next. For this, I have extruded the faces of the model to create a shape. Each division in the model has a face on each side. So I have selected 'Extrude' from the 'Edit Mesh' option to extrude (expand the particular face in a particular direction). Similarly, I have extruded faces in each division according to the reference picture of the spine to give it a shape of the human spine. This just extrudes the main cube into extended cube shapes. To give sharp features to the model is a different job together about which I have explained in the 'Modeling' part.

I have then tapered the model. Tapering is a technique used in blender to shape up the model vertically so that we can narrow the model at the areas where we want it in a much thinner shape and broaden it where we want it in a wider shape. I have also used the 'CV Curve TOOL' to give a curve to the 3D model as the human spine has a certain curve to it and is not straight.

After all these steps, the crude model of the spine is created. I have used the smooth option to smoothen the rugged model. The next step is modeling the spine.

5.4.2 Modeling

Modeling the spine involves adding transparency to it by adding colors to it. Adding to colors where they are necessary creates certain effects by which the 3D model appears to be real. Since the 3D model is still rugged, I have selected a number of faces and extruded them to create a accurate model of the spine. I have then used the 'Insert Edge Loop' tool to create depth in the model. It creates a feel that there is depth in the model. I have selected the rendering option and added colors to the faces to increase the transparency of the model. Then, I have added highlights to parts of the model where I would later on insert bones.

The spine model is now accurate but is not flexible. The next step is rigging where I do the rest of the process to complete the 3D spine model.

5.4.3 Rigging

The first step in rigging is creating flexibility to the spine. I have done this by selecting the 'polygons + mesh + smooth' option to get flexibility and smoothness to the spine.

The next step is adding bones to the model. Inserting bones in the model is called armature insertion. To do this, I have selected the animation option and then selected the skeleton option and added armatures to the bone. After applying all the bones, the bones are now individual bones. But to make a curve out of all the bones, I have used the 'K spline Handle' tool from the 'skeleton' option to get a curve of the bones. Now I have used the 'Edit Curve' option and selected 'Cluster Curve' tool to make the bones as a cluster. Now I have selected both the armatures and the skin and by using the 'Bind Skin' tool, binded them. This process is called cluster creation. Now operations like moving the model, rotation, bending, twisting can de done with the help of mouse controls.

I have also created controllers so that the 3D model can be moved with the help of the controllers. I have created six controllers on total. One for twisting the model to the left side, second for bending the model to the left side, third for bending the model to the right side, fourth for bending the model forward, fifth for bending the model backward, sixth for twisting the model to the right side. I have assigned the controllers with the help of the layer box and have assigned tasks to the controllers.

Figures 5-12 to Figure 5-25 illustrate the screenshots of the 3D human spine model:

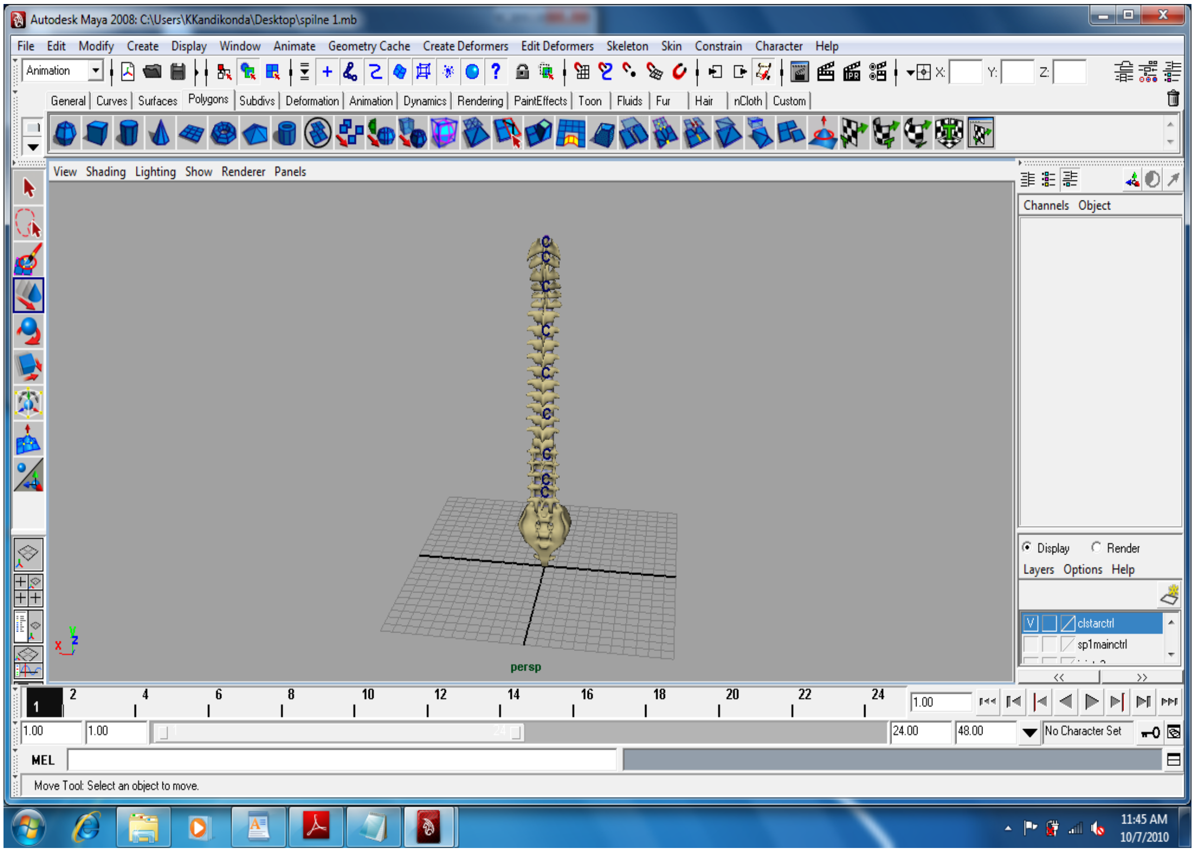

Figure 5-12: The model without the Controllers

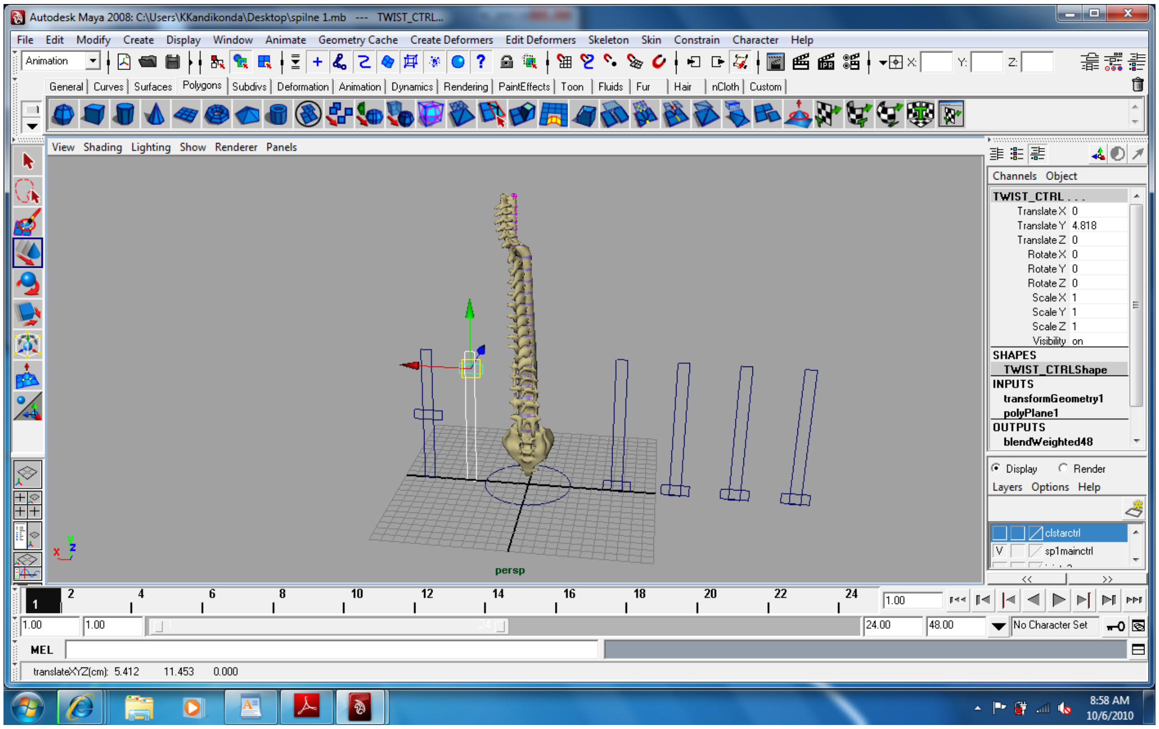

Figure 5-13: Twisting the model to the Right

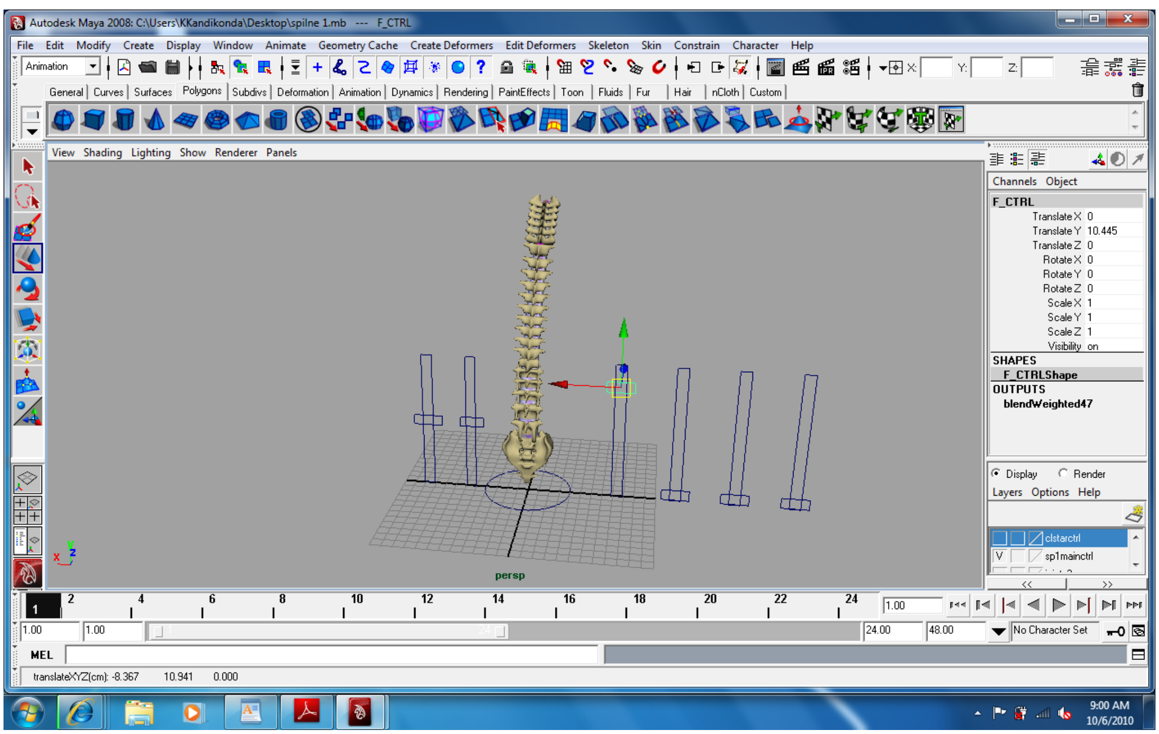

Figure 5-14: Bending the model backward

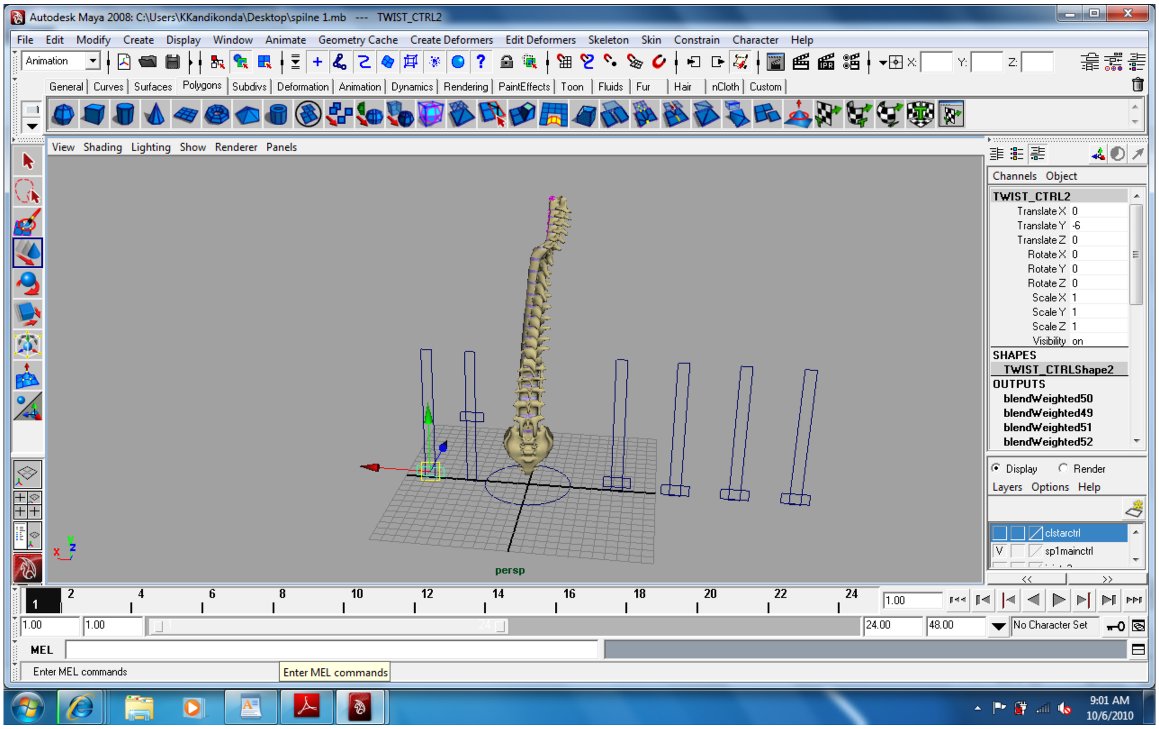

Figure 5-15: Twisting the model to the Left

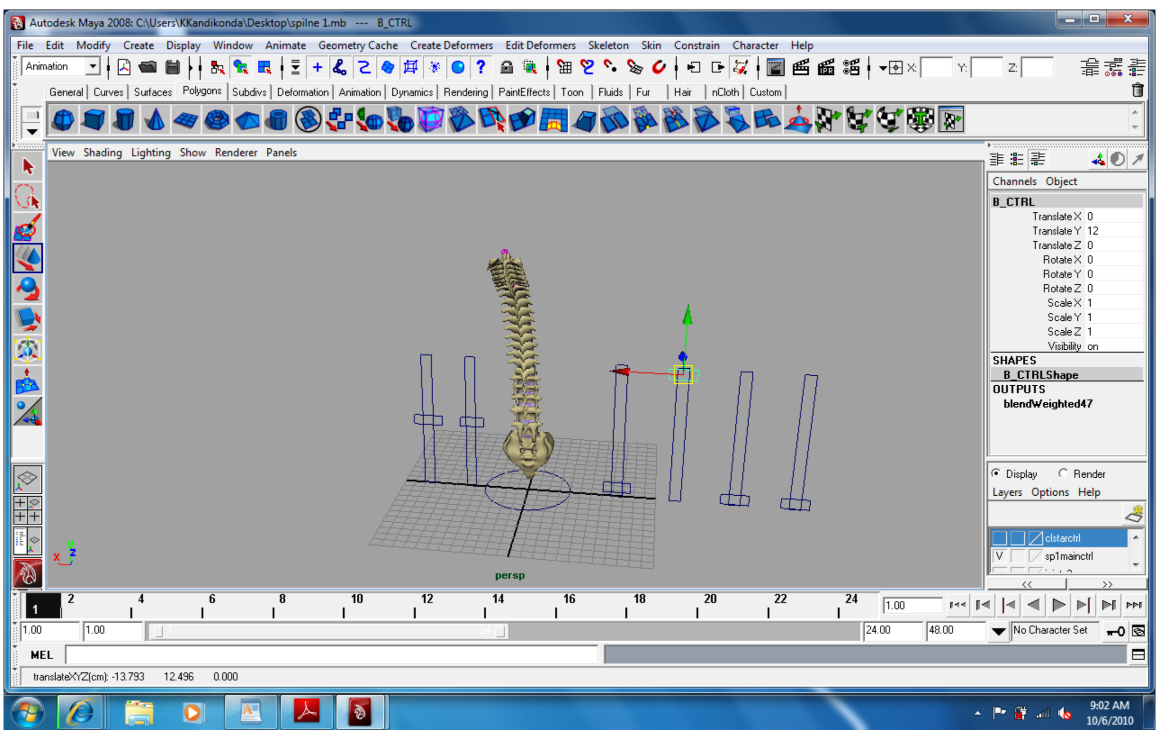

Figure 5-16: Bending the model Forward

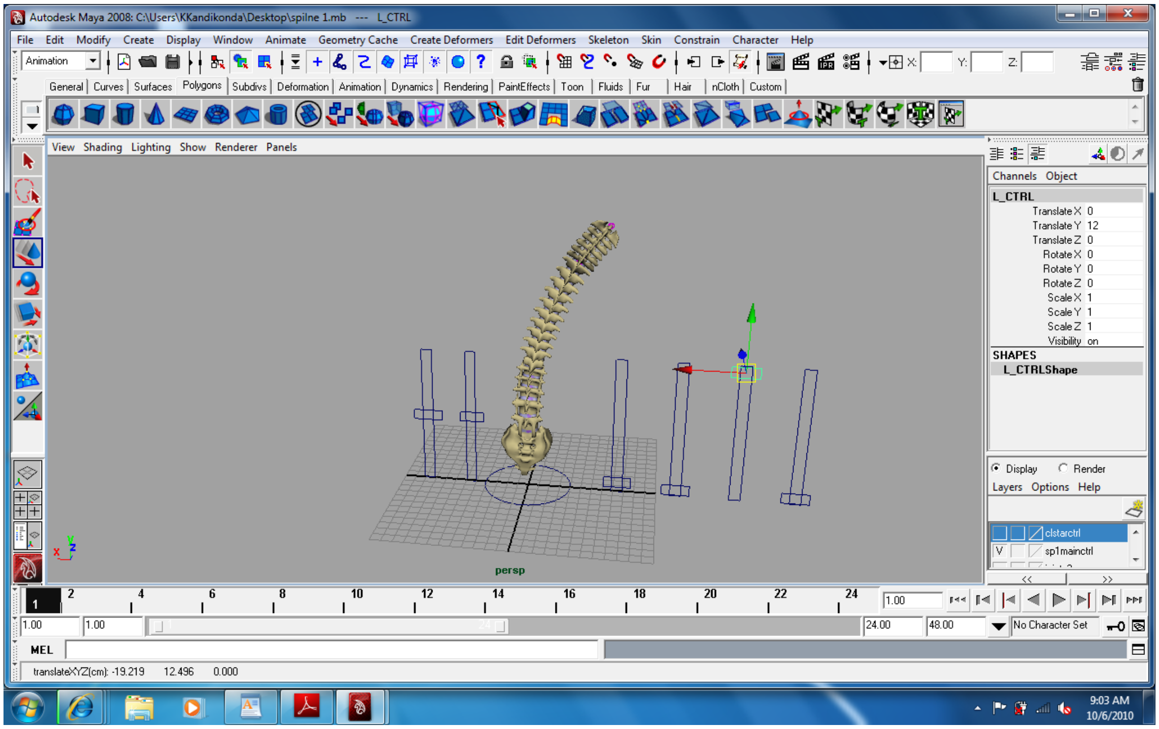

Figure 5-17: Bending the model to the Left Side

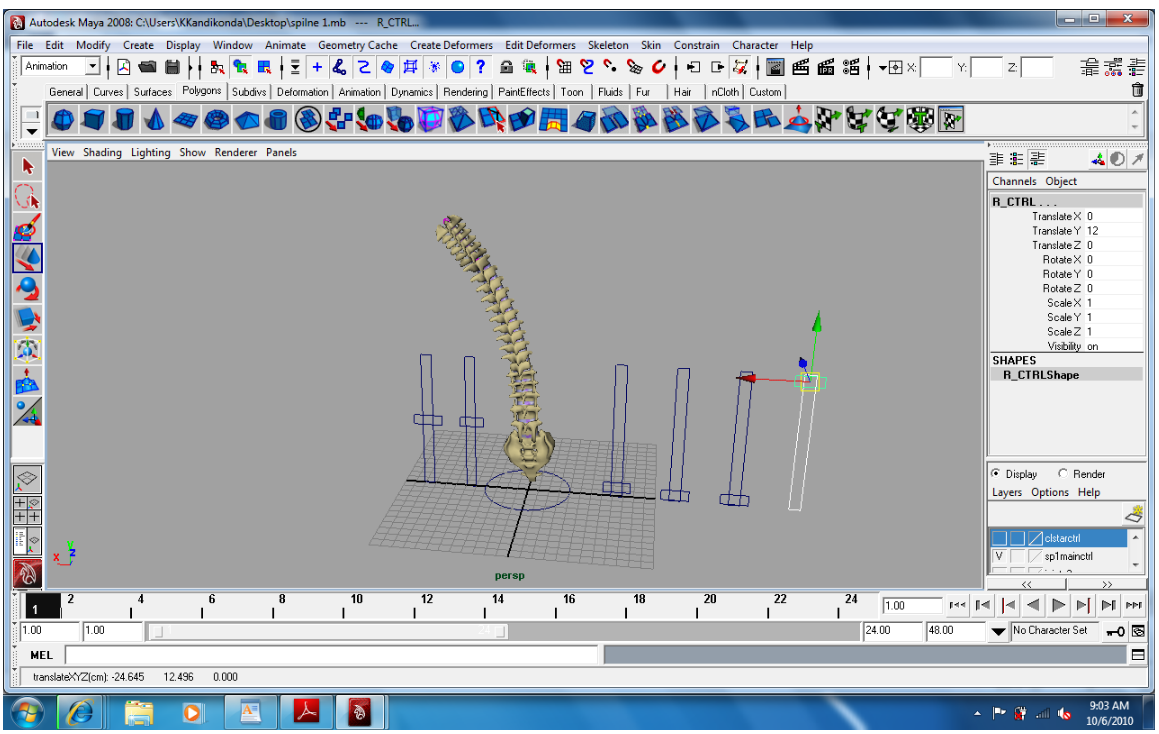

Figure 5-18: Bending the model to the Right Side

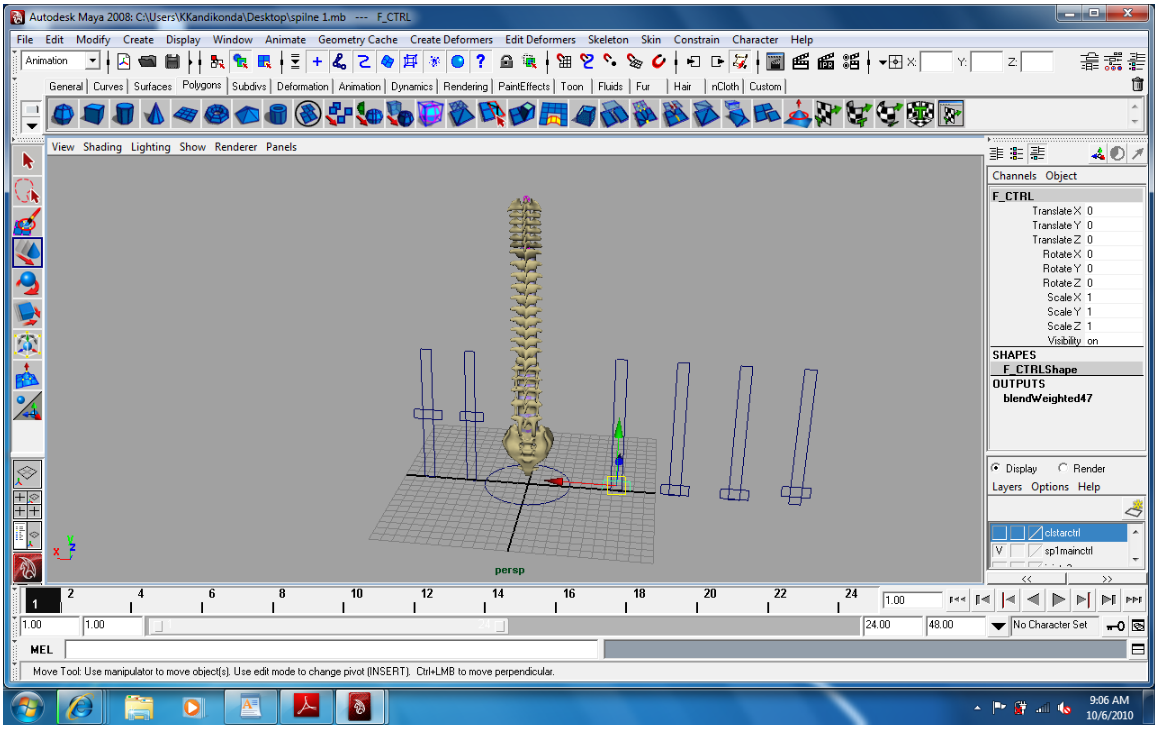

Figure 5-19: The 3D model in a Straight position.

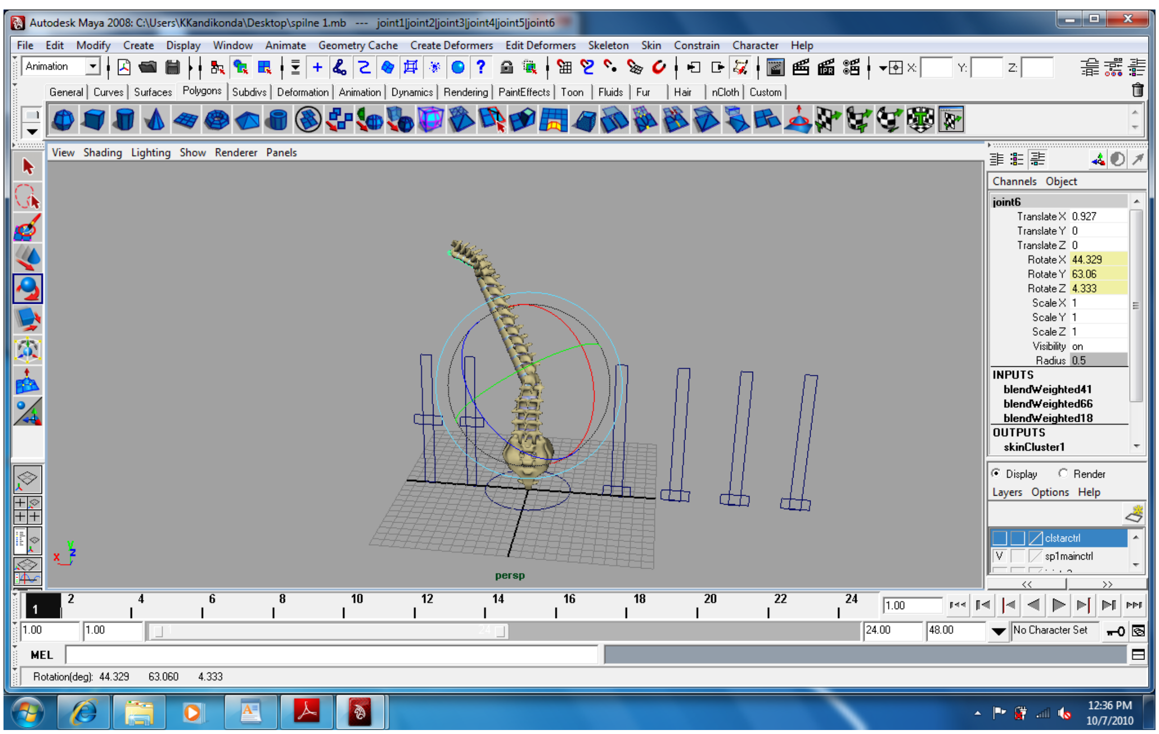

Figure 5-20: Rotating the 3D Model

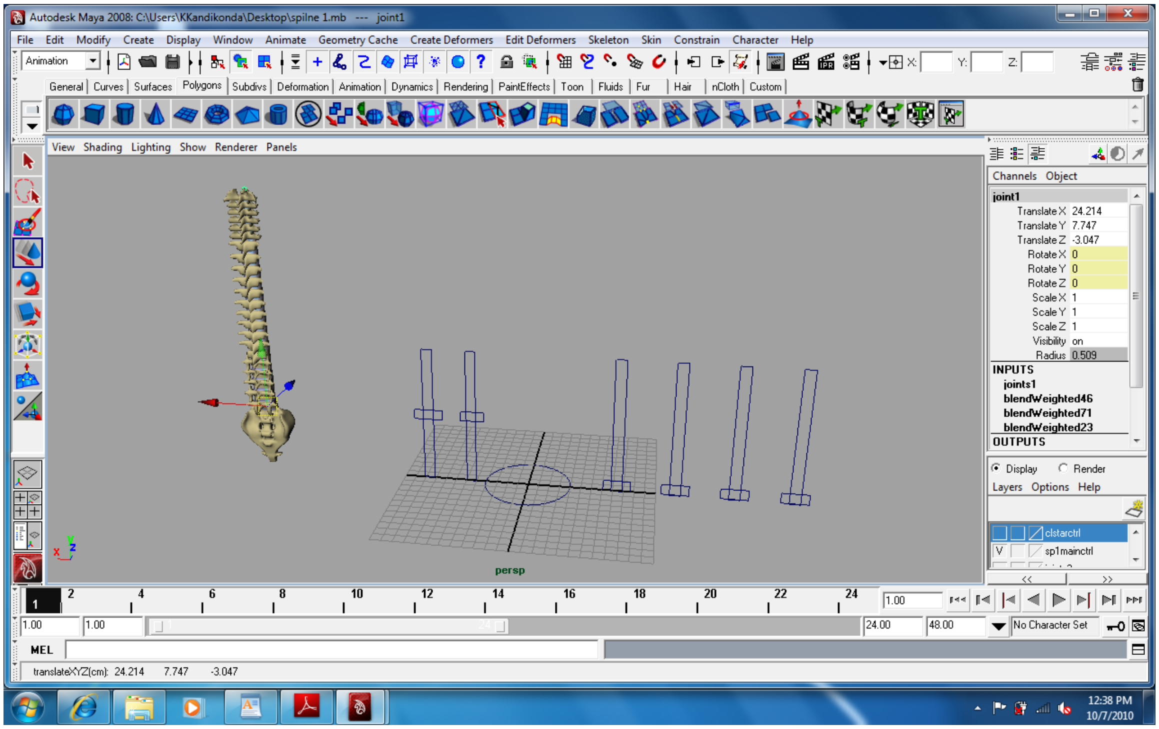

Figure 5-21: Moving the 3D Model

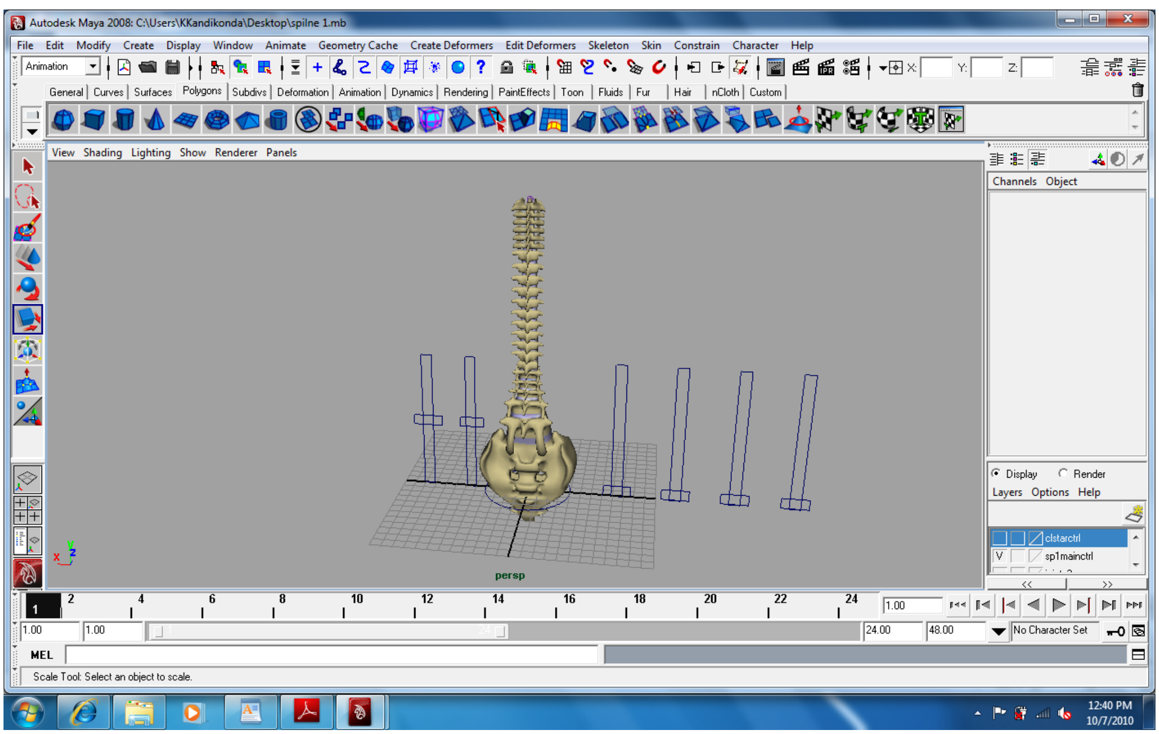

Figure 5-22: Scaling the 3D Model - To increase and decrease the size of the 3D Model.

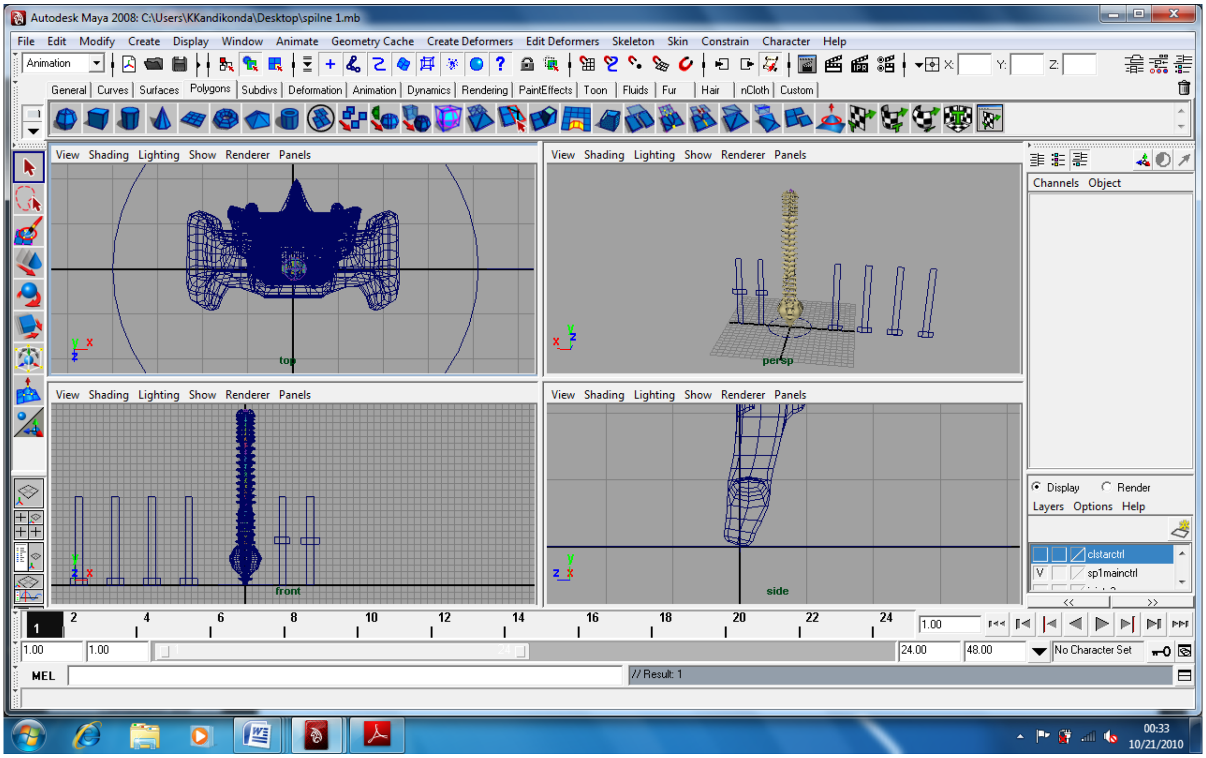

Figure 5-23: The four View Layout of the model. The figure shows the top View, Perspective View, Front View and Side view respectively.

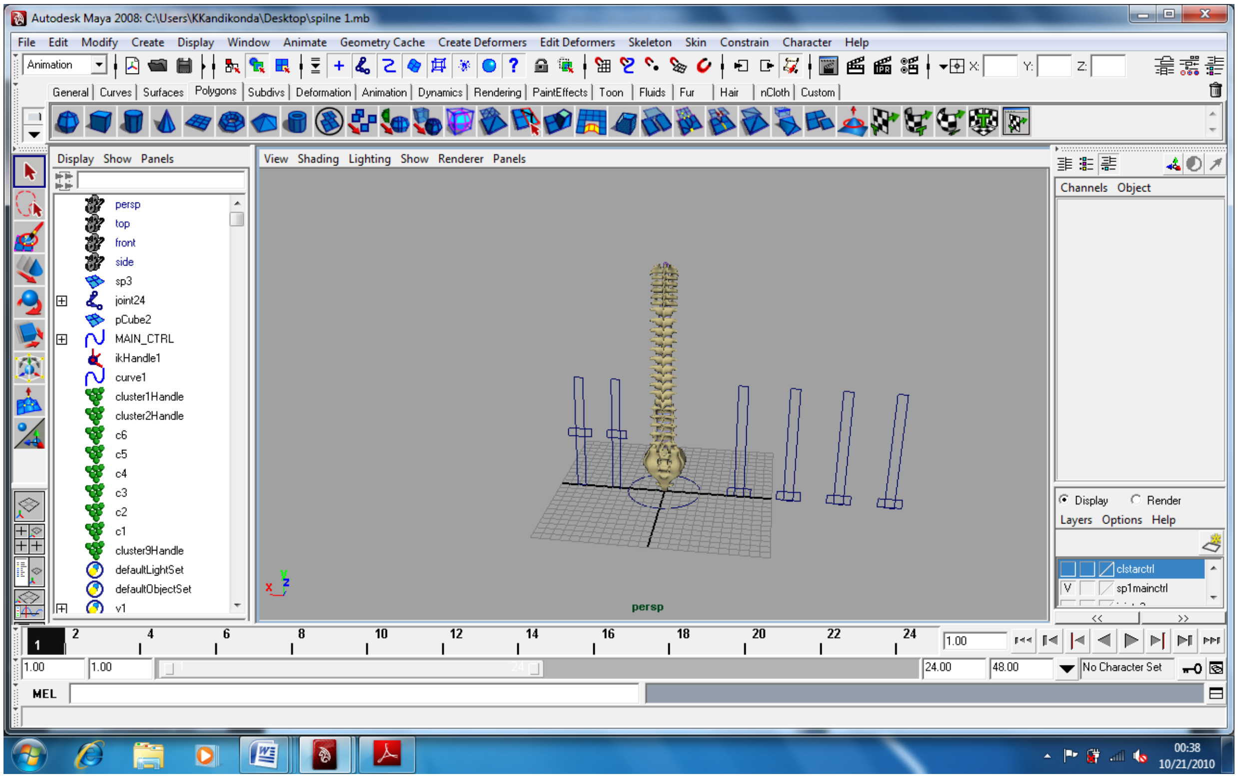

Figure 5-24: The model with the panel and view selection at the side for the ease of the user.

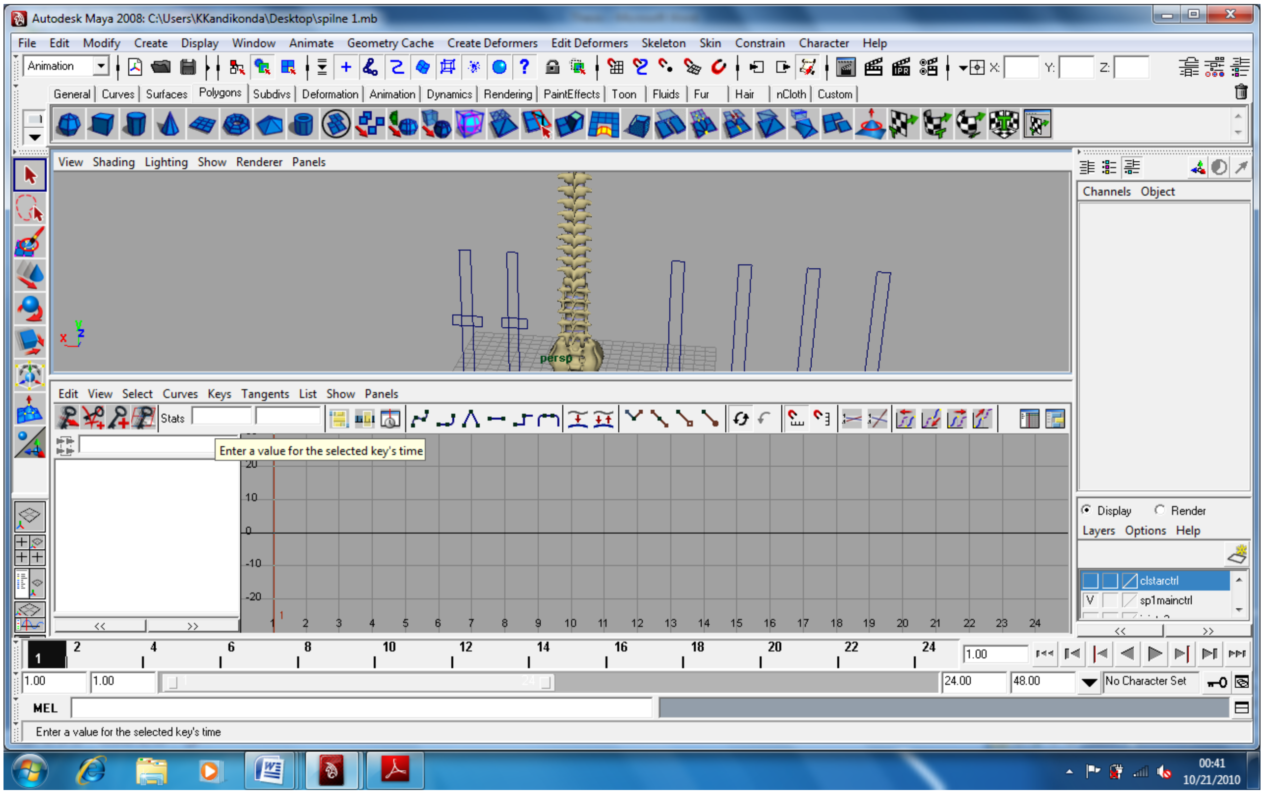

Figure 5-25: The Perspective/Graph view of the model. The graph appears and changes according to how we perform different manipulations on the model.

5.5 Comparing Blender and Maya

The use of Blender in this work is limited to the creation of a 2D model of the human spine. For a 3D model of the human spine, I found Maya to be a more adequate tool when compared to Blender. I found Maya more user friendly compared to Blender. Table 5-1 lists the major advantages and disadvantages according to my experience with them.

Table 5-1: Comparison between Maya and Blender

Maya	Blender
Its intuitive user interface makes Maya an easy to learn imaging software. It is user friendly and I have found it easier to create a 3d model.	The user interface of Blender is complex when compared to that of Maya.
It has default functions which make it easier to experiment with making it less time consuming than Blender. In Blender, I had to fill in every little detail which is otherwise taken care in Maya.	Even though there are default functions in Blender, due to the complex interface, a user may still become confused. The user should first spend time to become familiar with its interface.
It is commercial software and it is quite expensive to purchase.	It is free software which can be downloaded from the internet.

5.6 Advantages and Disadvantages of Virtual Reality and Augmented Reality and Relation between Them

It is a fact that augmented reality and virtual reality are related and that it is quite valid to consider the two concepts together [39]. Table 5-2 lists the advantages and disadvantages of both.

Table 5-2: Comparison between Virtual Reality and Augmented Reality.

Virtual reality	**Augmented Reality**
Virtual reality is a total different world which is created in the computer's virtual environment. Even thought the user can interact with it, he/she is not present in the virtual world.	In augmented reality, the user is present and both the real world and virtual world are combined to get the experience of the 3D world.
Virtual reality involves the creation of a computer-generated world that a person can interact within such a way that he or she believes that the virtual world is real.	Augmented reality, however, is a meeting of virtual reality and real life, as a computer image melds with real-life images to create a composite for the user to interact with. The ultimate goal of augmented reality is the user's inability to distinguish the fabricated from the real.

For virtual reality to be convincing to the user, a program requires the construction of an entire world to painstaking detail, which can be expensive to produce at the risk of seeming false.	Augmented reality faces a similar problem in convincing the user. Computer-generated images must appear photo-realistic in order to seamlessly integrate with the real world images. Augmented Reality needs to occur in real time. This means, the composite image would need to be constantly accurate, and any lag or inaccuracy will disrupt the experience.

Both virtual reality and augmented reality are very useful for teaching as both the technologies are interactive and make it easier for the students to understand human anatomy. Both the technologies take teaching the human anatomy to a new level. Both teachers as well as students are benefitted from these technologies. The teachers can interact with the 3D applications while teaching which makes teaching and learning more interesting. A student can parallel what is being taught on the projector and manipulate the 3D model on his/her computer. A number of modifications can be done to the applications I have created, as per the requirements. By updating the 3D models and by modifying them as per the requirements, computer aided teaching through virtual reality and augmented reality applications can replace old school teaching of the human anatomy.

Chapter 6

Conclusion and Future Work

6.1 Conclusion

I have developed applications in both virtual reality and augmented reality in order to investigate their characteristics and how they can be used in teaching human anatomy. As part of virtual reality, I have created a virtual 3D human spine model using 3D animation software, Maya. In augmented reality, I constructed an augmented reality application using the 3D human spine that I have developed, to illustrate augmented reality characteristics. The advantages and disadvantages of both technologies have been discussed and a comparative study of both technologies has been made.

6.2 Future Work

There is a lot of scope for future work in virtual and augmented reality in the field of teaching. Interacting with a model in multiple ways is going to be the future work related to this thesis. Apart from just showing the students about human anatomy through virtual reality and augmented reality, the students would have an advantage in learning about it, if they would have a chance to interact in different ways with the model.

Multimodality is a technique in which more than one modes of interaction is used to interact with the virtual object created. Many interaction technologies are now available that can be integrated into multi-modal virtual and augmented reality interactive interfaces. Speech and gestures would be included as additional as additional forms of interaction.

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