VIRTUAL REALITY - MULTIMEDIA SYSTEM FOR ANATOMY EDUCATION

by

JITKAMOL THANASAK

Submitted in Partial Fulfillment of
The Requirements for the Degree of
Master of Science
In Information Technology
Assumption University

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ABSTRACT

Virtual Reality-Multimedia System (VR-MM) is a system that combines Virtual Reality (VR) and Multimedia (MM) resource. The purpose of this thesis is to experiment and develop a prototype application, VR-MM, for anatomy education. This system is implemented on high performance stand-alone PC, which users can interact to the system via mouse and keyboard with magnificent visualization on regular CRT monitor. Initial lessons concerning first the anatomy of the cardiac system of a dog. This application combines 3D anatomic models (base on Polygon-based 3D models of a dog) with supporting 2D media (eg. Lesson text, histological images, radiographs etc.) to establish a comprehensive learning environment for anatomy.

This thesis describes VR-MM concept, 3D model construction, design and development strategy for VR-MM application, and engineering using an object-oriented program. At the core of VR-MM is the ability to identify, access, view and manipulate heterogenous contents and the capacity to query a database to retrieve specified resource.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER1: INTRODUCTION

1.1 What is virtual reality?

Virtual reality (VR) is a synthetic, three-dimensional, interactive environment typically generated by computer. People immerse themselves in a VR environment with sensory interfaces that allow them to see, feel, hear, and interact in the synthetic environment.

If you look it up, the dictionary defines **Virtual** as "***existing or resulting in essence or effect though not in actual fact, form or name***" and Reality as ***"the quality or state of being actual or true.***" However, Virtual Reality is being defined in very specific ways as a combination of sophisticated, high-speed computer power with images, sound and other effects, VR has been defined alternately as:-

- **A computer-synthesized, three-dimensional environment in which a plurality of human participants, appropriately interfaced, may engage and manipulate simulated physical elements in the environment and, in some forms, may engage and interact with representations of other humans, past, present or fictional, or with invented creatures.**
- **Or, An interactive computer system so fast and intuitive that the computer disappears from the mind of the user, leaving the computer-generated environment as the reality.**
- **Or, simply, A cartoon world you can get into.**

Immersion and interactivity are the two criteria on which VR simulations are based. Immersion refers to the ability of participants to believe they are "present" in the virtual world and can navigate through and function within the simulation as if it were physical reality. Interactivity pertains to the participant's ability to manipulate objects encountered within a virtual world.

Then virtual reality is based on the interface between mind and machine, our senses and how they work are central to VR.

Our brains allow us to perceive the exterior, physical world. A VR system processes and displays a simulated world, presenting it to the senses through VR output devices. A VR output device changes electronic signals into physical phenomena. A VR input device measures and records physical phenomena electronically, creating digital signals that the computer understands. Ultimately, VR input and output devices seek to provide sense data that the brain can interpret.

Our senses are the data channels between the outside world and the brain. All the senses rely on specialized receptors that translate into nerve impulses physical phenomena such as sound waves, light, or heat. These nerve impulses move along the pathways of the nervous system to specific areas of the brain. The visual cortex is an example of one area of the brain that is actually a complex signal processor. It transforms nerve impulses into information the brain can interpret.

To provide appropriate output, VR systems need to receive input from the participant. Input devices for VR systems rang from traditional computer keyboards and mice to more unusual navigation and interaction devices developed specifically for virtual reality, such as position trackers.

1.1.1 The various forms of VR

There are a variety of different formats and systems calling themselves VR. Level of immersion or visual display configuration can be used to classify the forms of VR. These four configurations are:

- Non-immersive configuration : regular color CRT monitor
- Partial-immersive configuration : Stereographic CRT with shutterglasses
- Immersive configuration : head mounted display

1.1.2 Virtual reality-based animation

Virtual reality-based animation is interactive 3D animation that is used to simulate a 3D environment, which the user can explore. Virtual reality can be designed to operate in three modes [1].

- Passive
- Exploratory
- Interactive

A passive virtual reality session is not interactive. An automated tour through the 3D environment is provided while the user simply observes. Architectural walkthroughs and fly-past are example of passive virtual reality.

An exploratory virtual reality session allows the user to roam through the 3D environment. The user interacts with the virtual reality engine, but can not interact with any entities residing inside the virtual space. A simulated museum exhibit is an example of exploratory virtual reality.

An interactive virtual reality session allows the user to interact with entitles within the virtual environment. The user can push, pull, grab, throw, and influence entities residing in virtual space.

1.1.3 System Environment

- Hardware and Software

Virtual reality systems, like other types of computer systems, rely on hardware and software to build simulations. Personal computers, workstations, or supercomputers are examples of the type of hardware to produce simulations. Input and output devices also fall under the category of VR hardware. VR word-building programs allow participants to manipulate their environment within a simulation. World-building consists of modeling and rendering objects, assigning behaviors to those objects, incorporating interactivity, and programming. Object-oriented programming (OOP) has had a very favorable impact on the development of VR applications. This type of programming breaks segments of code into self-contained objects that are reusable and can be easily ported between different types of computers. Object-oriented programming languages, such as C++, are practical tools for creating virtual worlds, because they allow the programmer to write code in a modular fashion. This feature allows for greater flexibility than standard programming techniques.

- Computer Power

It is the core of any virtual reality system, because it processes and generates virtual worlds. It can consist of a single computer or a group of computers. In either case, a reality engine follows software instructions in order to assemble, process, and display all the data involved in creating a virtual world. This data includes all information sent to or coming from the participant, along with any data already stored in the VR system.

The computer in a VR system handles three types of tasks: data input, data output, and virtual world management and generation. Keyboards, mice, forceballs, gloves, and so on are typical data input devices that are used in VR systems. These devices often rely on a preprocessor to translate raw data into a format the computer can accept. A preprocessor's main function is transferring data from the main processor to a second processor, which allows VR software to run faster.

Generating and processing graphics and audio output for VR systems involves considerable processing time. This is especially true of rendering. Add-in computer boards, separate processors, or even separate computer may be required to handle rendering. Audio processing uses an internal or external sound-generating device to create and play different sounds within the virtual environment.

So, the reality engine must be powerful enough to process and generate virtual worlds. This type of processing must be done in "real time" in order to those movements.

- <u>Input Devices</u>

VR system requires input data from the participant that allow him or her to navigate and interact with a virtual world. An input device facilitates a participant's interaction with a three-dimensional simulation that a VR system generates. The input devices can be classified in to two types.

- Six degree of freedom (6DOF) : The 6DOF performance specification refers to the ability of an input device to control the position and orientation of a virtual object. Position is measure along X, Y, and Z axes, which correspond to degrees, or dimensions of width, height, and depth. Input devices, ranging from mice to wired gloves and other specific input mediums for VR system.

- Two degree of freedom (2DOF) : Standard computer mice, trackballs, and joysticks are examples of two degrees of freedom (2DOF) input devices. Each of these devices measures movement along the X and Y axes only. While regular trackballs and mice can be used with a VR system, specialized input devices that can measure more than two degrees of freedom provide a more natural interface.

An input device allows the participant to change his or her position, viewpoint, and field of view within a VR simulation. Viewpoint is determined by the coordinates of axes that correspond to the participant's position. Orientation and the direction in which the participant is looking at any given point also influence the viewpoint. The viewpoint can move up or down, from left to right, or it can be tilted from side to side. This mobility is similar to the shifts of your visual viewpoint in the real world. The field of view refers to the width, height, and range of human vision.

- <u>Software</u>

VR software packages are usually called world-building programs. World-building involves designing the landscape and objects a participant encounters in a virtual world. A VR programmer must take into account behavioral characteristics of the objects that exist in that world. The programmer must then incorporate this information into the actual virtual world, or application.

Graphics programs or computer-aid design (CAD) programs are used to model objects that appear in virtual worlds. Modeling involves creating a wireframe, or sketch in which all sides and components of an object are outlined, even those parts that will be hidden when the object is filled in. Rendering, adds textures, color, and shadows, and otherwise fills out the appearance of an object.

VR toolkits are used to combine 3-D objects and virtual worlds and assign their characteristics. For example, a VR toolkit handles the functionality behind opening a door, turning on a fan, or playing a musical instrument within a virtual world, Many VR world-building toolkits include libraries of preexisting program code. These toolkits are based on a modular approach toward programming that lends itself well to the development of VR applications. *C++ is the language of choice for most VR programmers.*

1.2 Virtual Reality and Multimedia system

Multimedia (MM) has many different meaning to many different people. Multimedia (MM) is a computer system allowing for integrated access to range of data through the means of simulating human senses using digital technology. Multimedia covers the integration of **images, video and graphics** (both still and animated); including raster and vector data, maps, photographs, **text**; in a variety of forms including alphanumeric databases and **sound.** Under computer control, it allows interaction with real world digital data in the form mentioned above (including spatial digital data) with 'hyper-card' tools, visualization software, audio and video players [25].

Virtual Reality (VR) is a computer systems which able to combine a mixture of real world experiences and computer generated material to allow for simulated real world representation. VR addresses the construction of artificial worlds, with clear spatial dimensions. Under computer control, it allows access to the artificial worlds with internet viewers, VR navigators and dedicated stand-alone hardware stations.

Among the important concepts in MM and VR are database construction and integration, and user navigation and interaction.

Multimedia requires perception and interaction with use of visual and auditory participation, i.e. the production of vision and sound, Virtual Reality additionally requires tactile and vestibular participation. So, a **Virtual Reality system may be considered to be an expansion of a multimedia system into a multi-sensory system** which may require special software and hardware [25]. However, Virtual Reality is being defined in very specific ways as a combination of sophisticated, high-speed computer power with image, sound and other effects. So, it would be more challenge to explore the educational application of Virtual Reality (VR) and the potential synergism arising from combining VR with multimedia (MM) resource that we call **Virtual Reality – Multimedia System (VR-MM)**.

1.3 Virtual Reality–Multimedia System for Anatomy Education

Anatomy, in general, is the process of learning to identify and memorize the body structures, locations, supply source and also understand their functions and development of relationships between or among structures. The study is usually both in gloss and histological structure. The traditional training materials are text books, dissectors, atlases and currently available multimedia are anatomical models, videotapes and some traditional computer programs (CAI). Increase in the number of students make anatomical models a higher demand. A number of dogs are prepared for dissection and demonstration. This problematic style of teaching and learning areas included visualizing potential spaces, studying relatively inaccessible areas, tracing layers and linings, establishing external landmarks for deep structures and correlating gross anatomy with various diagnostic imaging modalities such as radiation images. The goal of medical and veterinary learning process is how to integrate their knowledge base of anatomy to other related subject including histology, physiology, pathology and any other in clinical medicine. Another problem of using dogs as the anatomical models is that dogs have to be quarantine and ensure that they are out off risk during the process of study.

So this Virtual Reality-Multimedia system is focused on anatomy education, and is designed to help the students develop the internalized spatial representation of dog anatomy necessary for clinical practice. The VR aspect of these lessons is an essential methodology designed to encourage exploration, discovery, and active learning by:

- Free the student from the necessity to dissect linearly through tissue layers or to follow rigid protocols
- Permitting structures to be taken apart repeatedly
- Allowing users to examine from multiple point of views
- Allowing users to investigate structures in a way that is not possible in the real world
- Manifesting a wide range of anatomical variation
- Enabling students to establish and reinforce strong cognitive links to associated histology, physiology, and other related subjects.

Why does anatomy education use dogs?

For medical education, dogs are used as laboratory animals for teaching anatomy, physiology and surgery. Because it is easy to approach, not very complicate, small size and the completed structure of a dog can apply or compare to other species especially human. In addition, there are many paper and text books support them. So, dogs are widely used for medical students, veterinary students and others in some fields of science.

1.4 Objective

1. To explore the educational application of Virtual Reality (VR) and the potential synergism arising from combining VR with multimedia resource.
2. To study a 3D Model Construction.
3. To develop program, used to combine 3D objects with Virtual World, with object oriented methodology extended with database driven resource.
4. Develop a prototype application for Anatomy Education, which combines Virtual Reality and Multimedia resource.
5. This Virtual Reality-Multimedia System for Anatomy Training for Veterinary would provide users with the capability to identify structure, substructure and potential space; display appropriate multimedia resource--2D MM components—effectively in conjunction with the 3D objects and manipulate the display to facilitate visualization.

1.5 Scope of work

The work of this thesis is consisted of

1.5.1) Apply any concept for VR-MM development

The work in this phase, including reviewing the previous work and gathering information, defining requirements, specifications, and other system's components. Then apply those conceptual reviews to design the new system.

1.5.2) Design interface, database and system

The first version of VR-MM lesson interface is identified to provide the students (users) an active learning. The data in various forms are collected. The database is designed to make the relationship between and among these various types. And the system's inputs, outputs and processes are also designed in this phase.

1.5.3) Develop the prototype application of VR-MM Learning Environment, focusing on cardiac system of dog

A) 3D Model Construction

3D Models used in this Virtual Reality – Multimedia (VR-MM) application are polygon-based which 3D wireframe models of dog anatomy are derived from Wireframe 3-D Geometry Model Directories of Purdue University providing computer graphics. If any additional objects are needed, graphical programs or computer and design programs may be used. Finally, rendering, adding textures, color and shadows, and otherwise fill out the appearance of an object.

B) Software Development

To create a comprehensive learning program by hybridizing educational resource, the software component of VR-MM environment are engineered using an object-oriented methodology. Merging multiple types of external information resources within the VR world. Methodology must be devised for storage, retrieval, and display of multimedia within this complex integration. This includes:

- Creation of an extensible database-driven resource manager which articulates relationships between and among diverse forms of instructional material. All data, multimedia data including spatial data, text, imaginary, sounds etc and virtual reality data including the construction of virtual worlds are stored in local resources. The relational database management is used to relate among different forms of data components, both 3D models and 2D multimedia materials.
- Exploration of appropriated programming language and tools or their combination is performed to links within the VR application, which not only enables database query for local resource identification, but is also responsible for display functions, function link between the 3D VR and 2D MM components of the system, and manage all interaction. These tool sets are based on an object-oriented methodology

At the end of this experiment, the first prototype application of virtual reality-multimedia system for anatomy education, focusing on cardiac system of dog, is constructed using the **simplest display**, regular color CRT monitor and **common input devices**, mouse and keyboard which can be operated on **high performance stand-alone**

PC. An application would provide with the capability to display appropriate multimedia resource effectively in conjunction with the 3D objects and manipulate the display to facilitate visualization. For example, user can choose to : 1) make the anatomic models appear transparent or even invisible; 2) separate (and later regroup) individual components in a group of models; or 3) request that structures be reoriented to anatomical position; and can search or query for the related resource in database.

1.5.4) Discussion, defining the problems and trend of using this prototype to the future education and future development of Virtual Reality – Multimedia system (VR-MM).

1.6 Benefits

1.6.1 For IT Personals

- This prototype would be one aspect of using appropriate multimedia resources effectively in conjunction with 3D animation.
- can be a prototype for apply to develop other systems which alternate programming languages or application tools
- enabling other designers or developers to develop VR systems for education and training instead of developing traditional CAI

1.6.2 For Students (Users)

- providing interactive tools for active learning
- enabling students learning anatomy to establish and reinforce strong cognitive link to other associated subjects.
- integrating traditional training materials by Virtual Reality and Multimedia System which is compatible, portable and cost effective.

CHAPTER 2: LITERATURE SURVEY

2.1 Related Work

There are many works, which related to the study of VR-MM for Anatomy Education. The evolution of the applications for anatomy training and the related are in the following.

In 1991, Department of Biological Structure, University of Washington has developed a multimedia program for teaching anatomy. The program, called **"the Anatomy Browser"**, displays cross-sectional and topographical images, with outlines around structures and regions of interest [6]. The user may point to these structures and retrieve text descriptions, view symbolic relationships between structures, or view spatial relationships by accessing 3-D graphics animations from videodiscs produced specifically for this program. This program was implemented in a client-server architecture, with the user interface residing on a Macintosh, while images, data, and a growing symbolic knowledge base of anatomy are stored on a fileserver.

In 1995 the Learning Resource Center (LRC) of the University of California, San Diego (UCSD) School of Medicine, began to investigate the educational application of advanced technologies, particularly Virtual Reality (VR) based simulation [11]. Supported by a grant from the Defense Advanced Research Projects Agency (DARPA), the LRC began development of virtual world which would provide a compelling learning environment and paradigm for navigating through the world of medical information. The LRC's design also incorporated extant multimedia (MM) learning resources and reference materials derived from traditional books, atlases, image banks, databases, animations, and video. Then they have begun to actively explore the educational applications of virtual Reality (VR) and the synergism arising from combining VR with these multimedia (MM) curricular resources. This strategy is called Virtual Reality – Multimedia Synthesis (VR-MMS) [12]. The goal of this project is to create comprehensive learning programs by hybridizing diverse educational resources and incorporating the communications technologies increasingly central to medical education and practice. The first prototype for VR-MMs lessons are focused on anatomy education [13]. Initial lessons concern first the anatomy of the hepatobiliary system and this prototype curricular application was created to support the study of human anatomy by preclinical medical student.

IBM Almaden Research Center, USA has been develop **"A 3D medical image database management system"** [2]. They have described the design and implementation of QBISM (Query By Interactive, Spatial Multimedia), a prototype for querying and visualizing 3D spatial data. Their medical image application is focused on the brain mapping requirements for multi-modality relationships across multiple subjects. It incorporates data describing both structure and function. It includes data structures that describe anatomy, physiology, coordinates using rendered imagery and statistical output. The system is built on top of the Starburst DBMS extended to handle spatial data types, specially, scalar fields and arbitrary regions or space within such fields.

Development of Biological Structure, University of Washington has been developed information systems in anatomy that can deliver relevant knowledge directly to the clinician, researcher or educator. This project is **"The digital anatomist**

information system and its use in the generation and delivery of Web-based anatomy atlases" [4]. A software framework is described for developing such a system within a distributed architecture that includes spatial and symbolic anatomy information resources, Web and custom servers, and authoring and end-user client programs. The authoring tools have been used to create 3-D atlases of the brain, knee and thorax that are used both locally and throughout the world.

School of Mechanical, Manufacturing and Medical Engineering, Queensland University of Technology, has been developed interactive documents for use with the World Wide Web for viewing multi-dimensional radiographic and visual images of human anatomy, derived from the Visible Human Project. This project was called **"Design of a Web interface for anatomy images"** [3]. These interfaces were implemented using HyperText Markup Language (HTML) forms, C programming language and Perl scripting language. Images were pre-processed using ANALYZE and stored on a Web server in CompuServe GIF format.

Kim N develop **"Web based 3-D medical image visualization on the PC"** [16]. This development of world-wide-web based medical consultation system for radiology imaging is addressed to provide platform independence and greater accessibility. The system supports sharing of 3-dimensional objects. They use VRML (Virtual Reality Modeling Language), which is the defacto standard in 3-D modeling on the Web. 3-D objects are reconstructed from CT or MRI volume data using a VRML format, which can be viewed and manipulated easily in Web-browsers with a VRML plug-in. A Marching cubes method is used in the transformation of scanned volume data sets to polygonal surfaces of VRML. A decimation algorithm is adopted to reduce the number of meshes in the resulting VRML file.

There were virtual reality programs developed at Department of Neurobiology, UCLA School of Medicine. First project was **"a stereoscopic 3-D interactive multimedia computer program for cranial osteology"** [26] which was the creation of an image database and program for studying the human skull. Stereoscopic image pairs of a museum-quality skull were digitized from multiple views. For each view, the stereo pairs were interlaced into a single, field-sequential stereoscopic picture using an image processing program. The resulting interlaced image files are organized in an interactive multimedia program. In addition, another program was creation of an image database and program for administering a practical examination in human gross anatomy called **"the virtual anatomy practical: a stereoscopic 3D interactive multimedia computer examination program"** [27]. Stereoscopic image pairs of prepared laboratory dissections were digitized from multiple views of the thorax, abdomen, pelvic region, and upper and lower extremities. For each view, the stereo pairs were interlaced into a single, field-sequential stereoscopic picture using an image processing program. The resulting color-corrected, interlaced image files were organized in a database stored on a large-capacity hard disk. Selected views were provided with structural identification pointers and letters (A and B). For each view, appropriate two-part examination questions were spoken by a human narrator, digitally recorded, and saved as universal audio format files on the archival hard disk. Images and digital narration were organized in an interactive multimedia program created with a high-level multimedia authoring system.

School of the Biomedical Sciences, University of ST Andrews has studied to construct 3D model using histological section. Two articles are 1)**"the study of early human embryos using interactive 3-dimensional computer reconstructions"** [24] and **"Computer-aided interactive three-dimensional reconstruction of the embryonic human heart"** [28]. They use tracings of serial histological sections from 4 human embryos at different Carnegie stages to create 3-dimensional (3D) computer models of the developing heart. The models were constructed using commercially available software developed for graphic design and the production of computer generated virtual reality environments. They are available as interactive objects, which can be downloaded via the World Wide Web.

There was a project developing for surgeons' training and practice performing on the temporal bone, **"Building a virtual reality temporal bone dissection simulator"** [17]. The temporal bone is one of seven bones that comprise the human skull, and has an intimate relationship with many vital structures. Anatomically, its three-dimensional relationships make it one of the most challenging areas for surgeons to understand and master.

Using virtual reality to teach radiographic positioning can overcomes many of the limitations of traditional teaching methods and offers several unique advantages. **"Using virtual reality to teach radiographic positioning"** [30] is the one describing a virtual reality prototype that could be used to teach radiographic positioning of the elbow joint. By using virtual reality, students are able to see the movement of bones as the arm is manipulated.

In addition, there are other related works, which have been developed. For example: **"The fetal imaging workstation demonstration project":** Interactive multimedia can supplement traditional prenatal ultrasound training by providing complex three-dimensional anatomy for physicians to better understand their two–dimensional ultrasound [19]. **"Nail-Tutor":** an image-based personal computer program that teaches the anatomy, patterns of pathology, and disorders of the nails [9]. **"A.D.A.M. (Animated Dissection of Anatomy for Medicine) comprehensive":** a computerized human anatomy program [23]. **"ATLAS-plus" [Advanced Tools for Learning Anatomical Structure]:** a multimedia program used to assist in the teaching of anatomy at the University of Michigan Medical School. It contains three courses: Histology, Embryology, and Gross Anatomy that be accessible in the ATLAS-plus environment [5].

2.2 The Existing System and Limitations

The Purdue School of Veterinary Medicine has been launching a project called **"Computer Graphics Alternatives to the Use of Animals in Education"**. One of the interests at Purdue has been the development of a **"Virtual dog"** for teaching anatomy and physiology. It has been developing image processing and 3D Modeling resources to allow the creation of dog anatomy. To develop the virtual dog, the wireframe 3-D geometry models of the dog anatomy are extracted with their MESS software (MESS is the model extraction surface software created at Purdue University. This software was created to facilitate the rapid extraction of geometric anatomy models from volumetric medical scan data, such as serial MRI and CT scan). These extracted models are available in several formats including spline versions for IGES, NURBS versions for Alias, OBJ for Wavefront, DXF for SoftImage and 3D Studio, and DES for other CAD systems. The geometry model of the dog was also rendered and transferred to the animation. These animations have been developed both for Quicktime movies and MPEG movies. The production of this project is a CD ROM containing canine MRI and CT data, 3-D Wire frame Models of dog anatomy, and software for model extraction and image processing. Some preparations have been providing on ftp server that can be downloaded via internet.

The Limitations of existing system

- Actually the extracted 3D model has some distortion in the data because the MRI scans that they used to create the model were only 256x256 pixels, not enough to really extract smaller structure, muscles, blood vessels, bones, and the others with any accuracy. For example, the small intestine are shown as its' outlines, not in its' details of the individual loops and turns.
- The animation of dog was developed using 90 frames animation, which refers to the animation displayed in sequence of frames. Although an interactive that provides a means for the user to influence the animation can be implemented using this frame base animation, it can provide just a limitation of functionality.
- Although the students can explore and investigate these anatomical structures and their location, they requires some specific display applications, for example 3D Studio to display DXF format, and CAD systems to display DES format.
- Generally, like other systems, developer can convert the existing formats or reconstruct from CT or MRI volume to a VRML format (Virtual Reality Modeling Language), which is the standard in 3-D modeling on the Web. Although VRML can

be viewed and manipulated easily in Web-browsers with a VRML plug-in, users still simply observe, walkthrough, rotate and fly past. In addition, they require more interactive such as grab, move and influence the activity inside.

- The existing system does not fit to the educational need. Students need more comprehensive learning environment.

To expand the capacity of this existing system, this thesis will emphasize on developing a prototype, which provide more powerful application for anatomy education by merging these anatomical structures (3-D Wire frame Models of dog anatomy derived from Wireframe 3-D Geometry Model Directories of Purdue University providing computer graphics) with the various forms of supporting resources such as text, graphic images and other animations to establish a comprehensive learning of anatomy. The database management is also concerned for the correlation of these components.

CHAPTER 3: THE PROPOSED SYSTEM

3.1 System Requirements and Specifications

To specify the needs of users , this process included observations of the student in the gloss anatomy laboratory, analyses of traditional anatomy teaching materials (text books, dissectors, atlases etc.) and evaluations of currently available multimedia (anatomical models, videotapes, CAI, etc.) and specified the problem of learning process of the students in anatomy training. The general requirements for anatomy curriculum can be classified into three broad categories [13]:

- Factual Knowledge – the identification and memorization of three dimensional (3D) structures, location and supply sources.
- Spatial Knowledge – the development of an internalized conceptual understanding which includes functional and developmental relationships between and among structures
- Anatomical reasoning – the application of this knowledge in clinically meaningful ways.

These problematic teaching and learning areas including identified the structures especially, studying in the relatively inaccessible areas; establishing external landmarks for deep structures; establishing the cognitive link by correlating gross anatomy with various associated subjects as well as histology, physiology and any other in clinical medicine.

3.1.1 User requirements

After performing the need assessment, the educational requirements of this VR-MM lesson have been specified.

- The system can fill three categories of general requirements of anatomy curriculum.
- The system can solve the learning problem by enabling students to establish and reinforce strong cognitive link anatomy to associated subjects, integrated learning.
- The system which provides comprehensive learning environment and use multidisciplinary approach.
- Real-time interaction
- User friendly and no complicated for learning

3.1.2 System Specifications

After user requirements were defined, the first prototype called "Virtual Reality multimedia system for Anatomy Education" was developed to fill these requirements. These are some specification of this system.

Software

- The program would provide an intuitive virtual environment (VE) where users are able to manipulate 3-D anatomy model while accessing supporting resource elements (explanatory diagram and text, image, animation etc.).

- This application combines 3-D anatomic models (base on dog's model) with support 2D media (e.g. explanatory text, image, animation etc.) and displays appropriate these multimedia resources effectively in conjunction with the 3D world.
- The system would provide the student with capability to identify structures, substructures and their location.
- Users are freed to explore in multiple ways and also freely select and move the object in real time.
- Provide the users to investigate structures in way that impossible in the real world.
- The size or scale of an object can be changed.
- Provide the mode of opaque and transparency that allows users to see its internal structure.
- Ability to identify access, view, and manipulate disparate types of lesson resource while using the same interface.
- Provide an interactive table of contents for flexible non-sequential access to the lesson
- No complicated interpretations result when performing multiple tasks
- Anatomical model can be freely manipulated and learning by providing some options that 1) make the anatomic models appear transparent or even invisible; 2) separate and later regroup individual components in a group of models; or 3) request that structure be reoriented to anatomical position.

Hardware

- Input device : users interact with lesson materials and narvigate the 3D world using a mouse and keyboard
- Output :
  - Visual display – regular color CRT monitor
  - Audio device – require sound card supported
- Computer : powerful PC with high performance processor

3.2 Interface design

3.2.1 Design The Virtual Environment

The first version of the interface was developed to meet user requirement. Designing for the expansion, the first interface will begin with the 3D polygonal model of a dog locating the nucleus of this virtual environment as shown in figure 3-1. This model can be free manipulated and learning by providing some options that 1) make the anatomic models appear transparent or even invisible; 2) separate and later regroup individual components in a group of models; or 3) request that structure be reoriented to anatomical position.

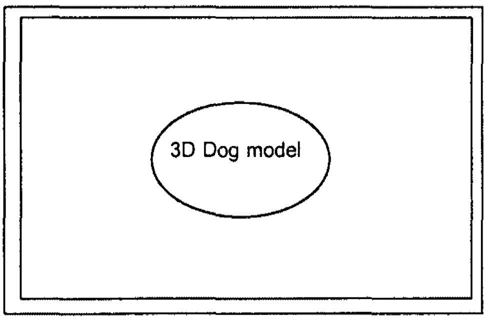

Figure 3-1: Interface Design (first interface)

As student navigates through the model and specified its' sub-structure, the application loads the 3D anatomy model defined for the current exercise. The additional resource elements are also loaded at this time. After being placed in the 3D world, elements can be selected and move at the student's discretion according to their needs at any given time.

Because this first prototype focuses on cardiac system of dog, by selecting dog's heart, the second interface will be presented with the 3D polygonal model of a heart locating the nucleus of the virtual environment and four associated window are appeared with their resource, as shown in figure 3-2. For this prototype, these four windows are the subjects that related to a model including anatomy, physiology, histology and radiology.

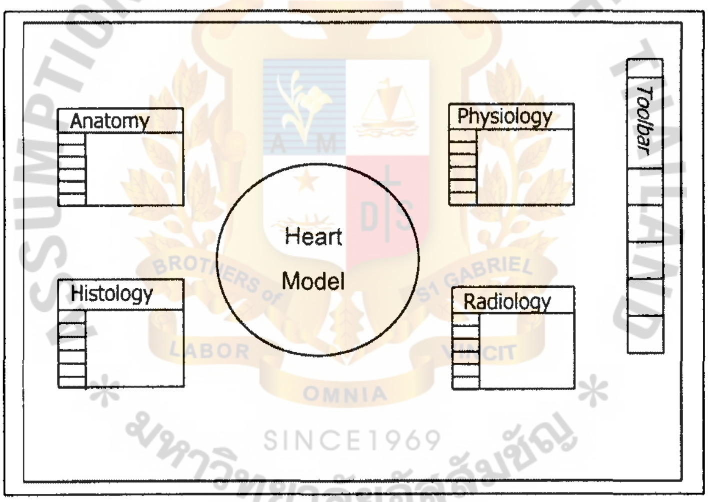

Figure 3-2: Interface Design (second interface)

Each sub-window is defined as an object, which free the user to manipulate. Any lesson resource loaded in it must be related to the anatomical model. Users can explore an anatomical model by using mouse and keyboard. In addition, the system provides the Lesson Environment Manager, "**Toolbar**", that users can specify what elements visible or invisible.

3.2.2 Interface of Anatomy lesson

This interface provides the user with capability to identify structures, substructures and their location by following with the instruction, as shown in figure 3-3.

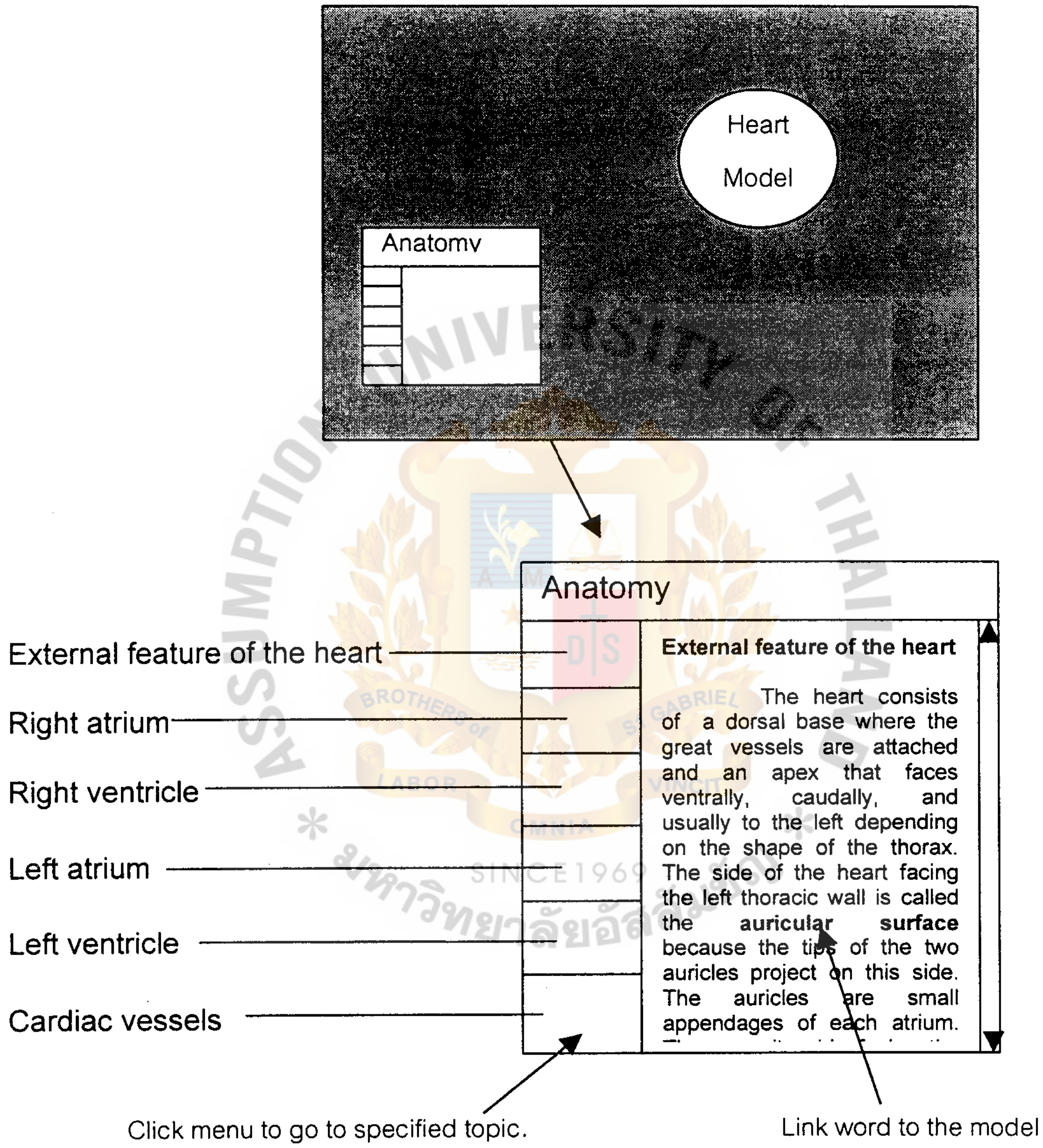

Figure 3-3: Interface of Anatomy lesson

3.2.3 Interface of Histology lesson

Histology is the learning about the microscopic finding of tissues. In case of this prototype after selecting a heart, the lesson resource of histology of a heart will be retrieved and presented in this sub-window. The interface of histology lesson should provide the users with a table of content that allows users to go to the specific page, microscopic images and their explanatory text. Figure 3-4 explains the interface of histology lesson in more details.

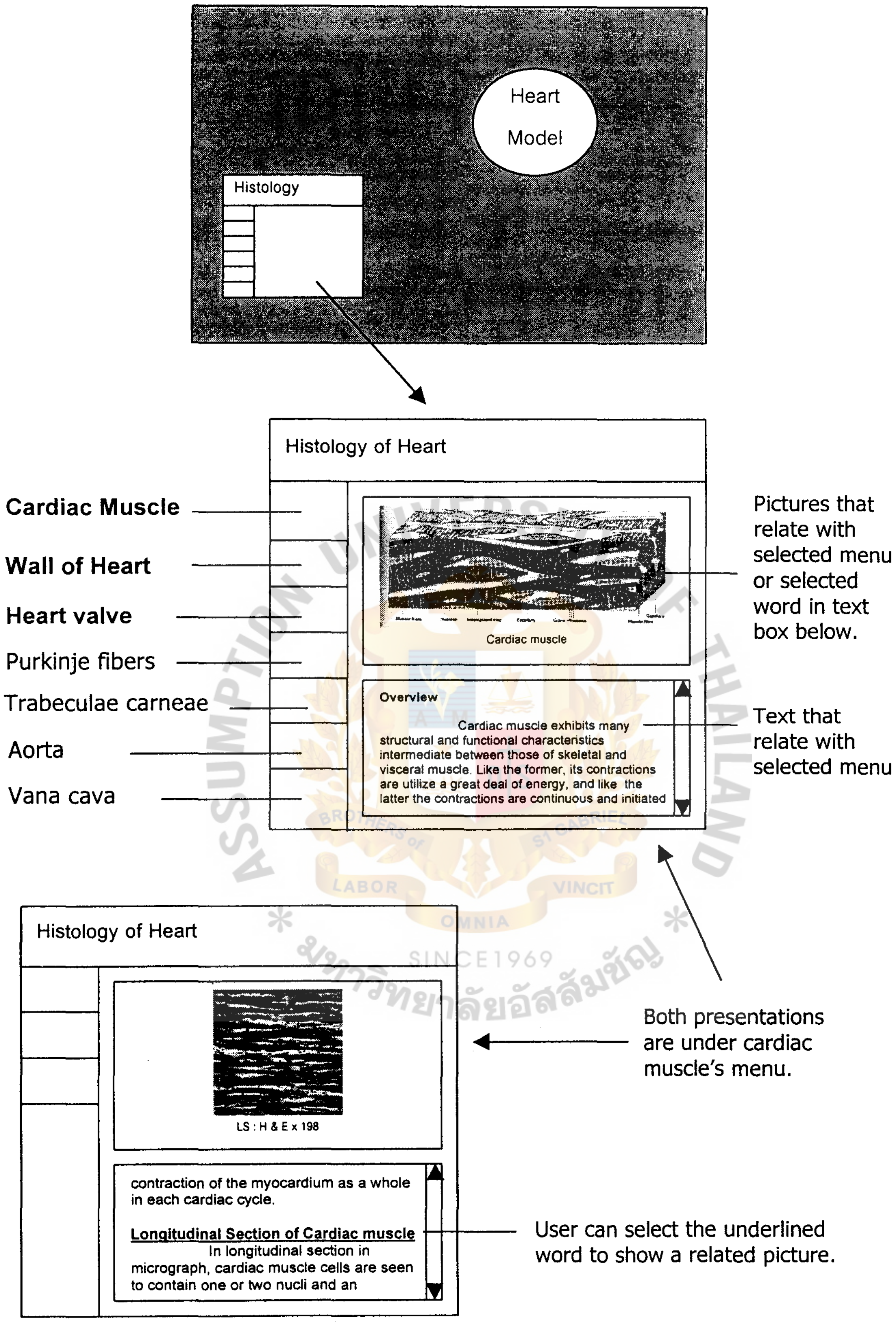

Figure 3-4: Interface of Histology lesson

3.2.4 Interface of Physiology lesson

Physiology is the learning about the function of the system. In case of this prototype after selecting a heart, the lesson resource of physiology related to cardiac system will be presented in this sub-window. The interface of physiology lesson should provide the users with a table of content that allows users to go to the specific page. Various types of supported resources are combined into this instruction including text, image, sound, animation, video files. See figure 3-5.

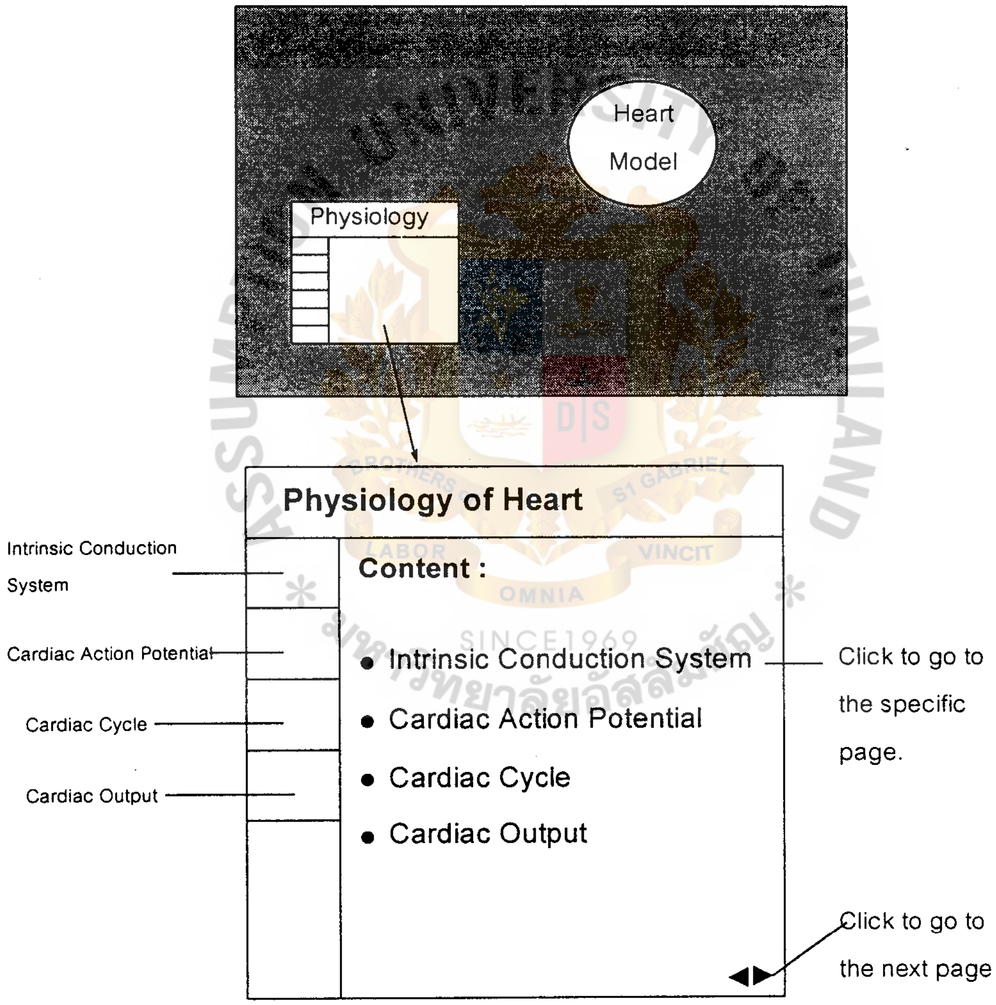

Figure 3-5: Interface of Physiology lesson

User can access more data by following the program's instruction. User can take advantage of the table of content or menu to navigate and see more details in this lesson. For an example, The picture below demonstrates more contents in each topic, intrinsic conduction system and cardiac action potential.

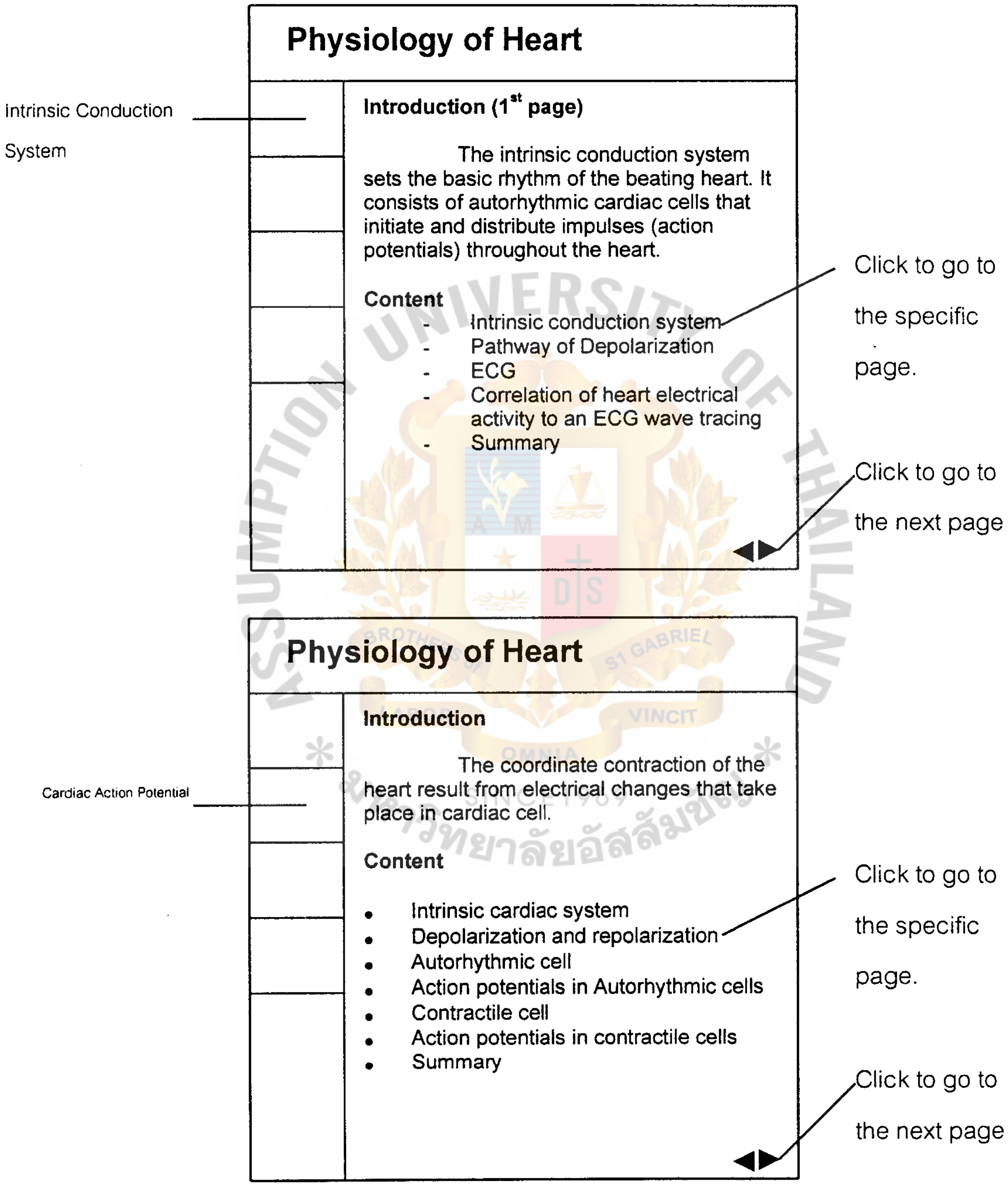

Figure 3-6: Interface of Physiology lesson demonstrated in more details

3.2.5 Interface of Radiology lesson

The interface of radiology lesson should provide the users with a table of content that allows users to go to the specific page, Radiographic images and their guild line image, as shown in figure 3-7.

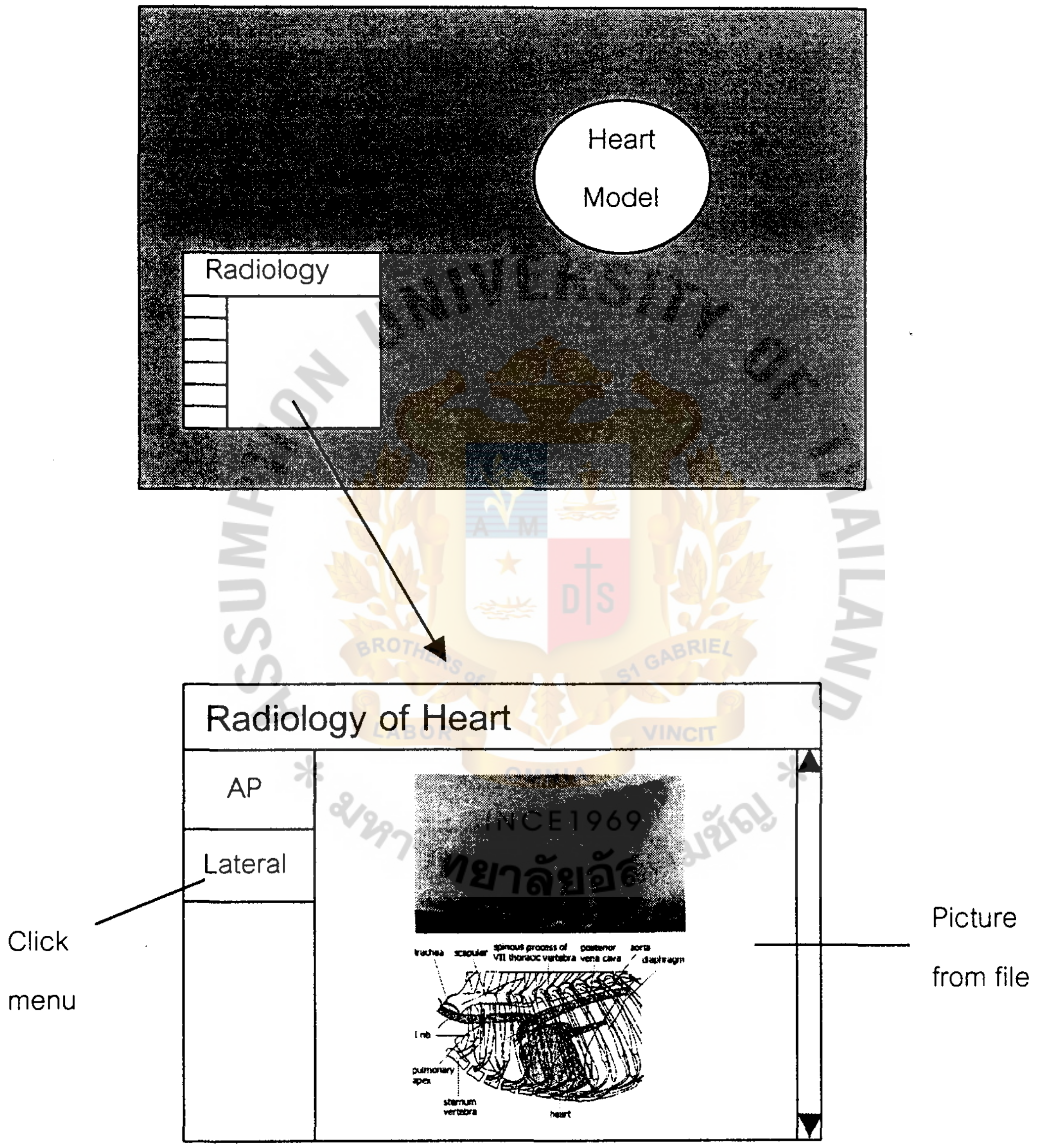

Figure 3-7: Interface of Radiology lesson

3.3 System Design

3.3.1 System Overview

The components of the system are input, process and output. To design the whole system, each component would be concerned.

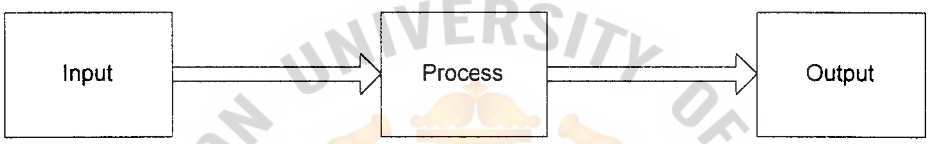

Figure 3-8: System Overview

3.3.2 Input Design

The system's input is classified into two types, interface input and data input. In this system the interface receives command from its' input devices, mouse and keyboard. Users can use single key or combine key to send command from keyboard or performing click, double click and drag to send command from mouse. Graphic and text are two types of data. These Graphics compose of non-animation (still image) and animation (Video and VRML). 3D animation or VRML in this system is developed by LightWave program. Figure 3-9 shows the hierarchy of input design.

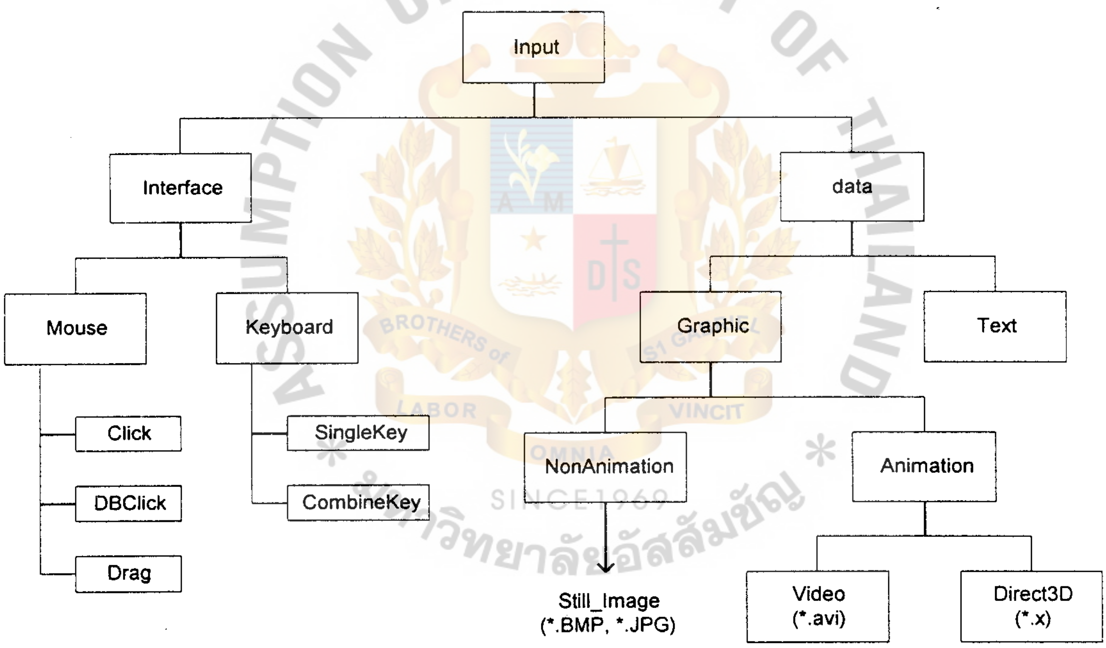

Figure 3-9: Input Design

3.3.3 Output design

The output of this system is designed for both interface and system. There are two types of the presentation, interactive and non-interactive, performing both text and graphic. Focusing on system output, they can be classified into four types, Presentation system, Retrieval system, Animation system and Report system. The output of the presentation system are text and graphic while the output from the process of retrieval system are text, graphic and text-graphic object database. The output of the animation system and report system are respectively animation and text. Figure 3-10 shows the hierarchy of output design.

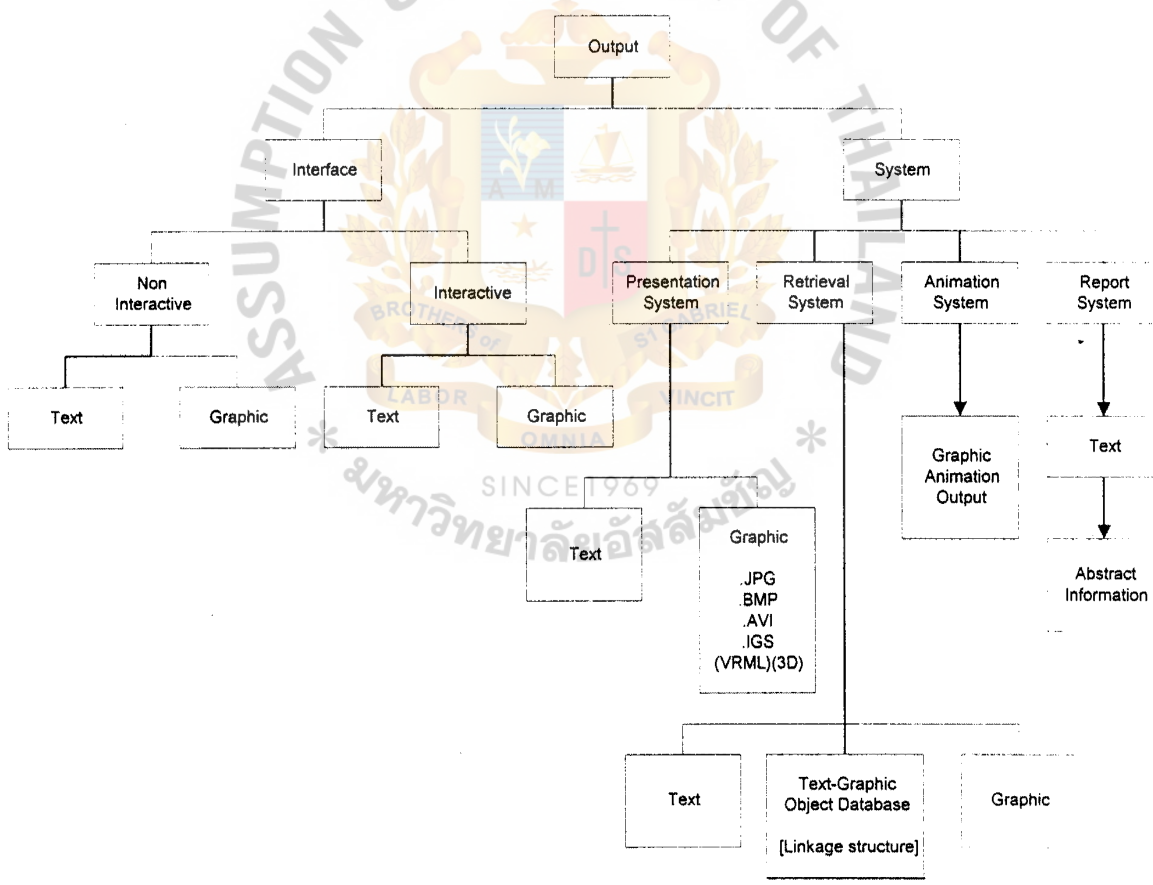

Figure 3-10: Output Design

3.3.4 Process Design

There are four majorities of the process of this system including Presentation process, Retrieval process, Animation process and Report process. Defining each process as a module, each module contains sub-module. Presentation process has two sub-modules, text presentation process and graphic presentation process. Three sub-modules; text retrieval process, graphic retrieval process and linkage process; for retrieval process, and two sub-modules, screen output process and printable output process, for report processing. This hierarchical model is presented below.

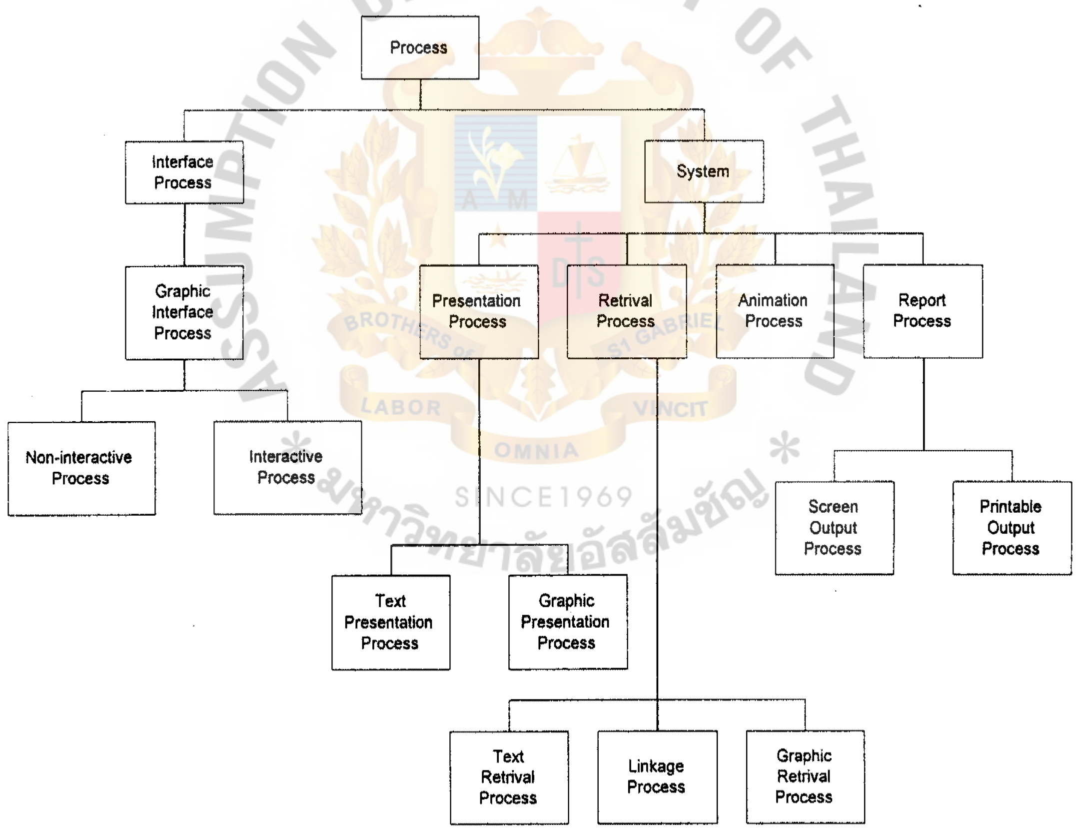

Figure 3-11: Process Design

3.3.5 Step of the system

After identification of the system's input, process and output; the System Flow, Context Diagram and Data Flow Diagrams (DFDs) of the system are developed to describe the flow of the system and data.

3.3.5.1 Context Diagram

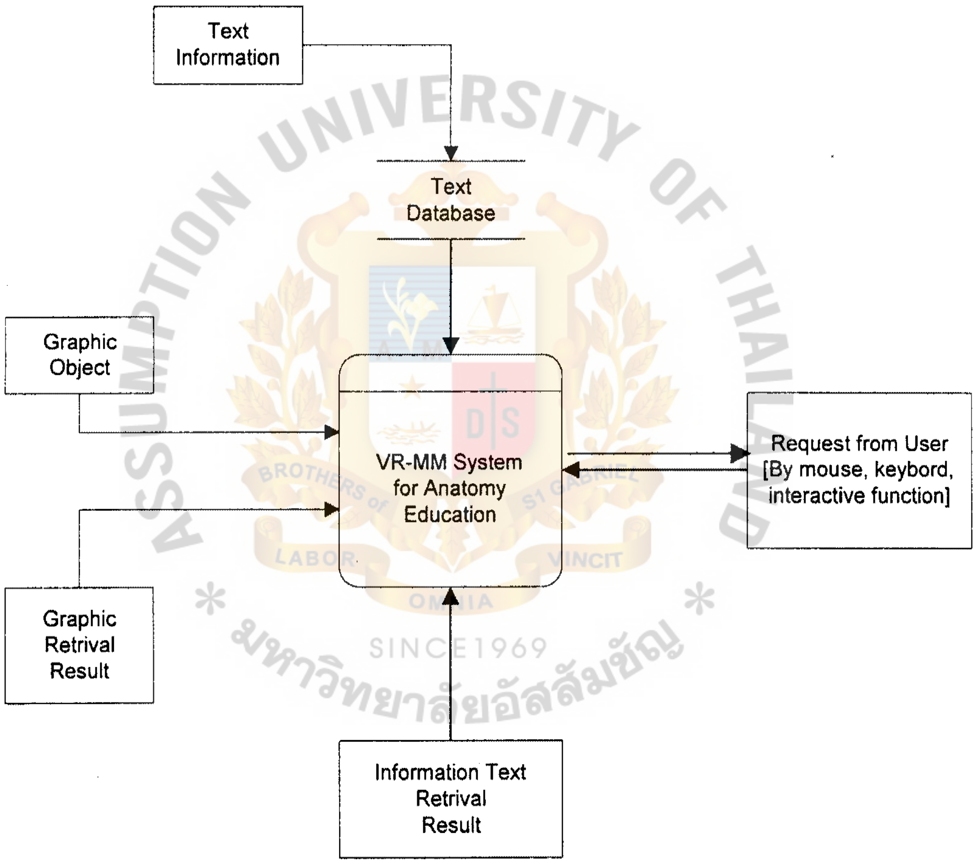

Figure 3-12: Context Diagram

3.3.5.2 System Flow

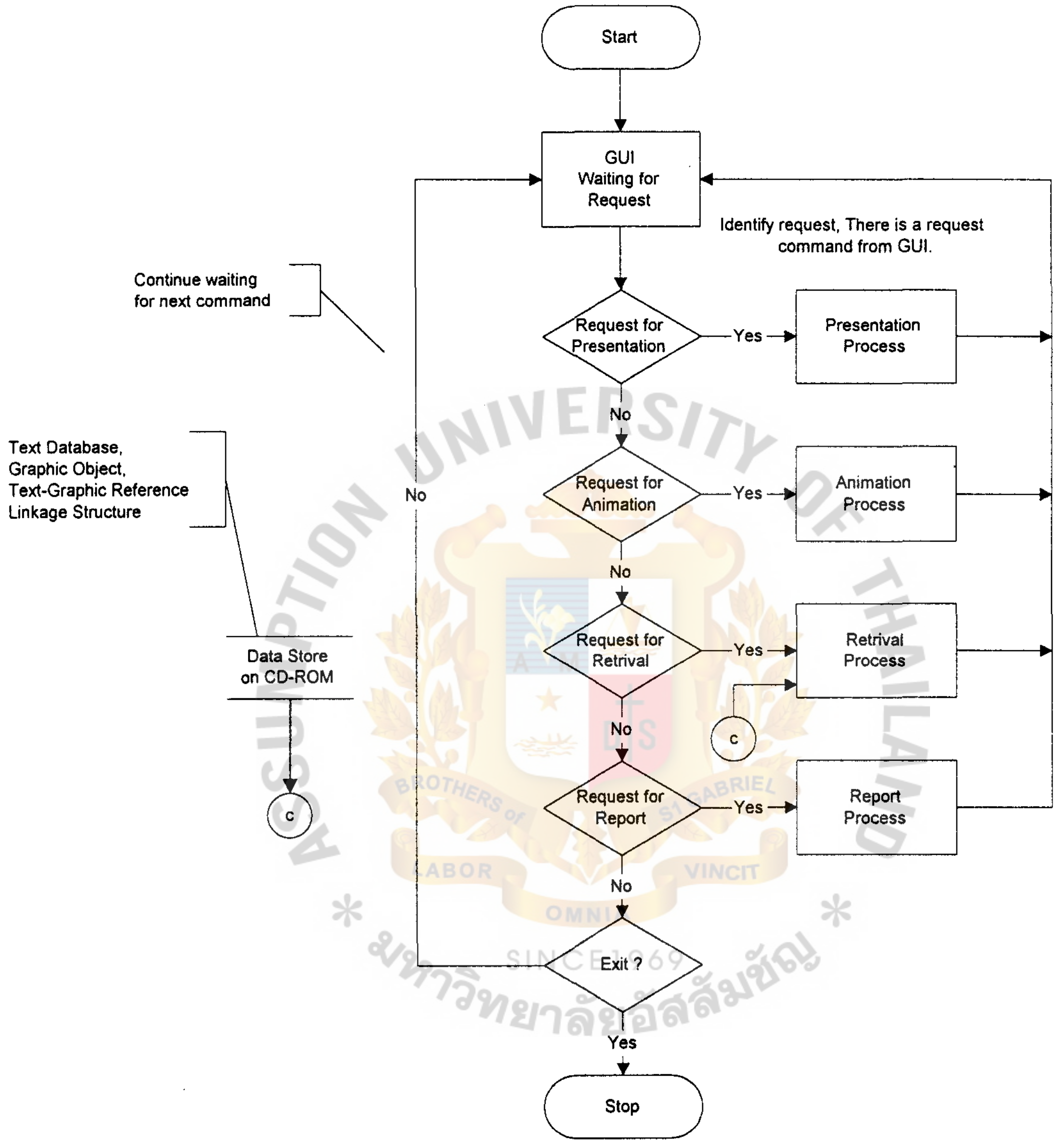

Figure 3-13: System Flow

3.3.5.3 Data Flow Diagram (DFD 1st level)

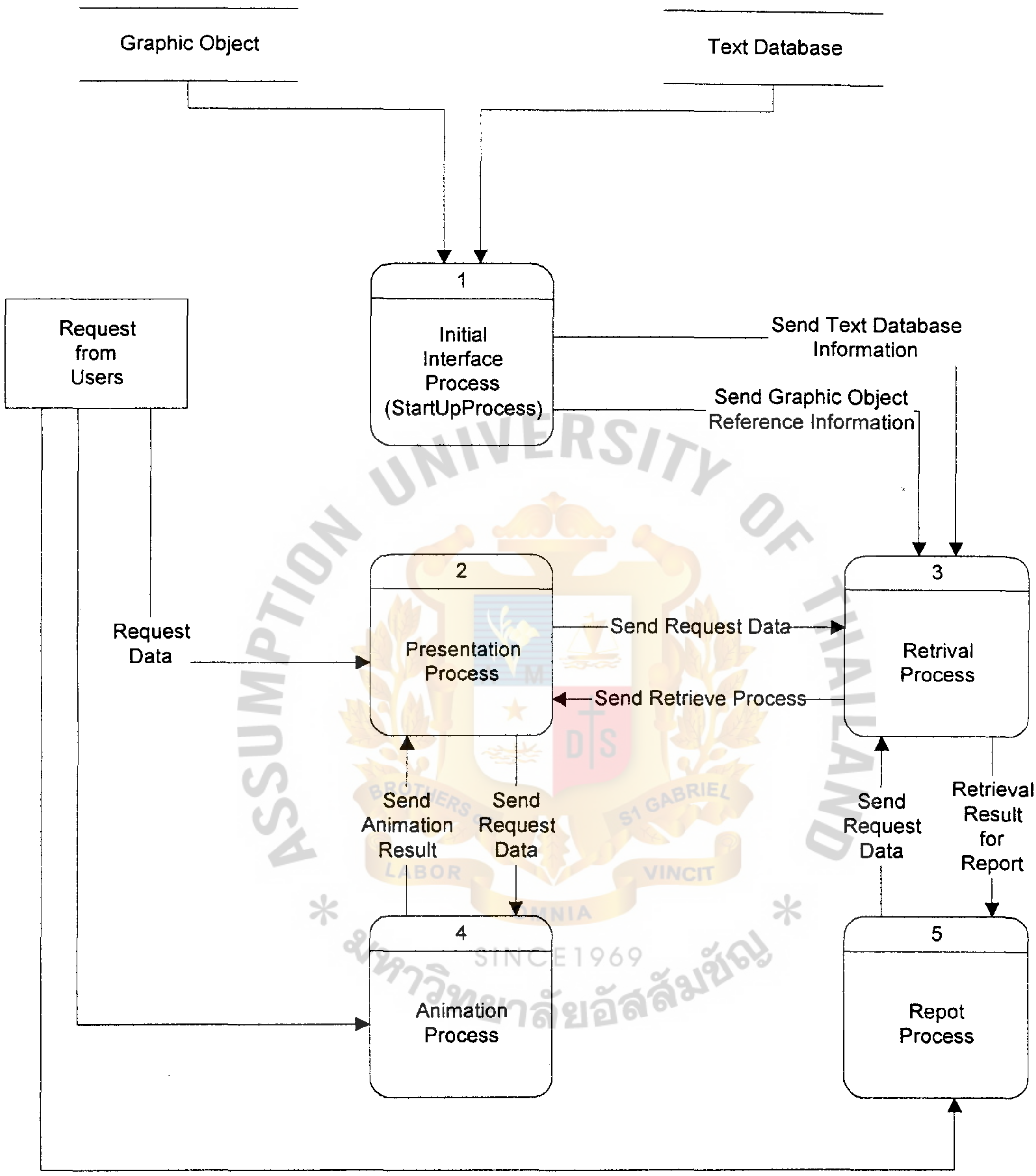

Figure 3-14: Data Flow Diagram (DFD 1st level)

3.3.5.4 Subsystem flow: Presentation Process (2nd level)

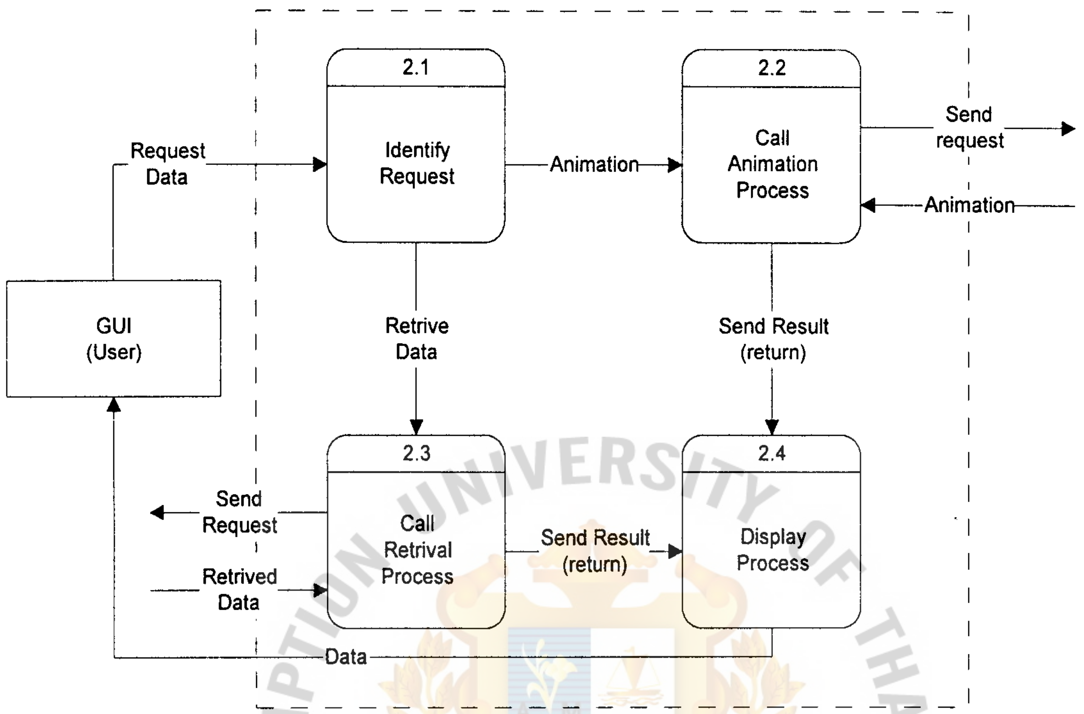

Figure 3-15: Subsystem flow: Presentation Process (2nd level)

3.3.5.5 Subsystem flow: Display process (3rd level)

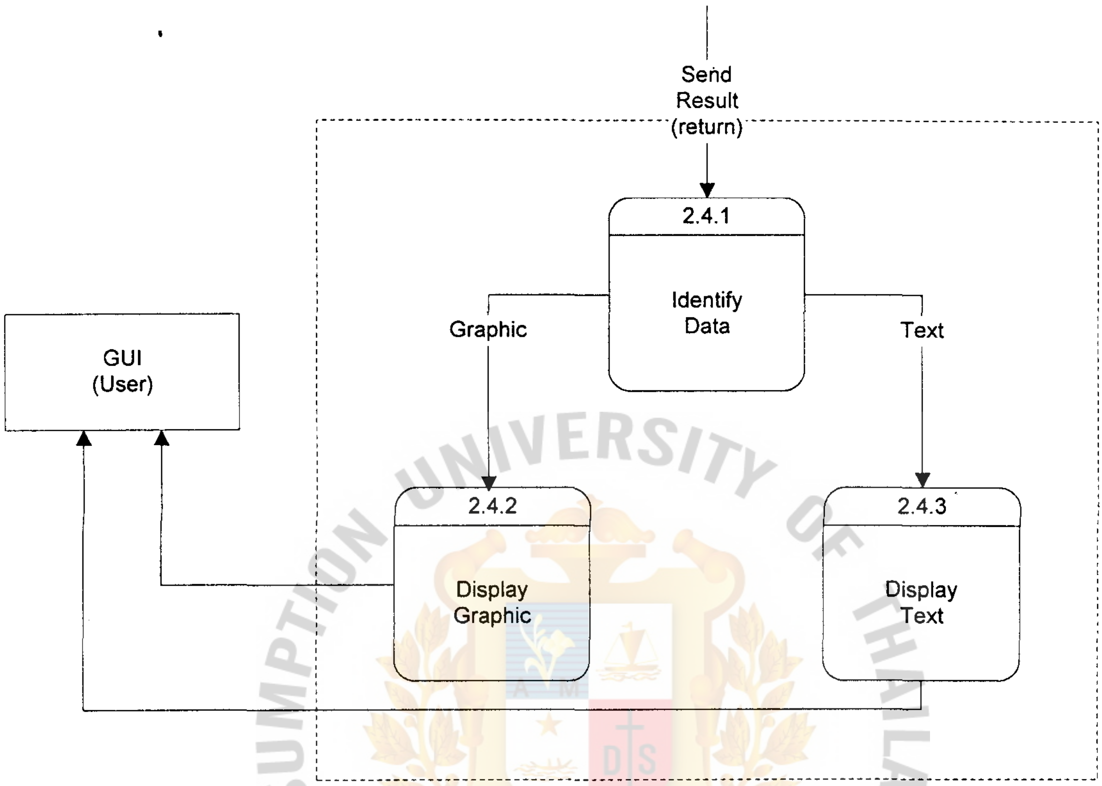

Figure 3-16: Subsystem flow: Display Process (3rd level)

3.3.5.6 Subsystem flow: Animation Process (2^{nd} level)

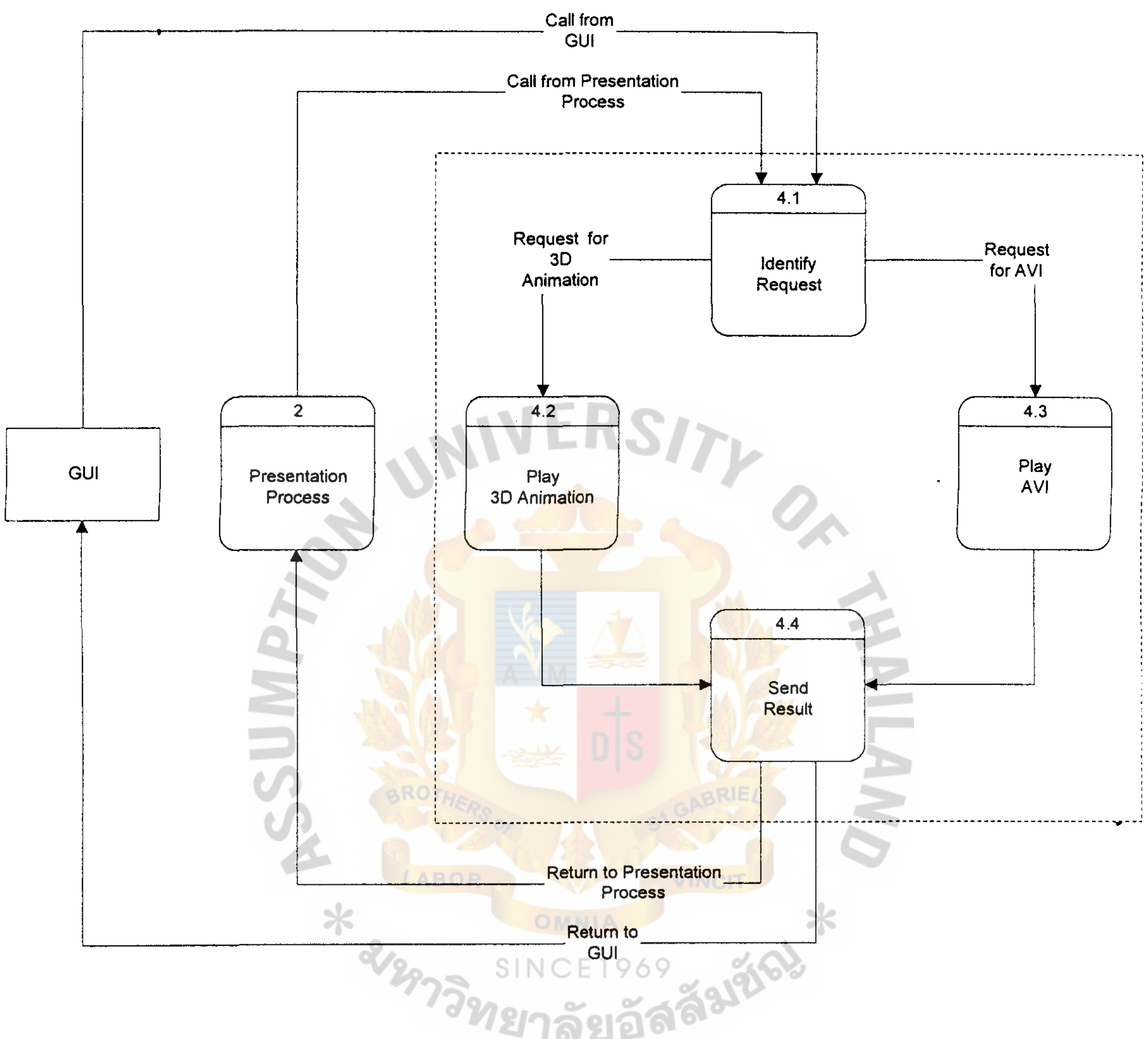

Figure 3-17: Subsystem flow: Animation Process (2^{nd} level)

3.3.5.7 Subsystem flow: Retrieval Process (2nd level)

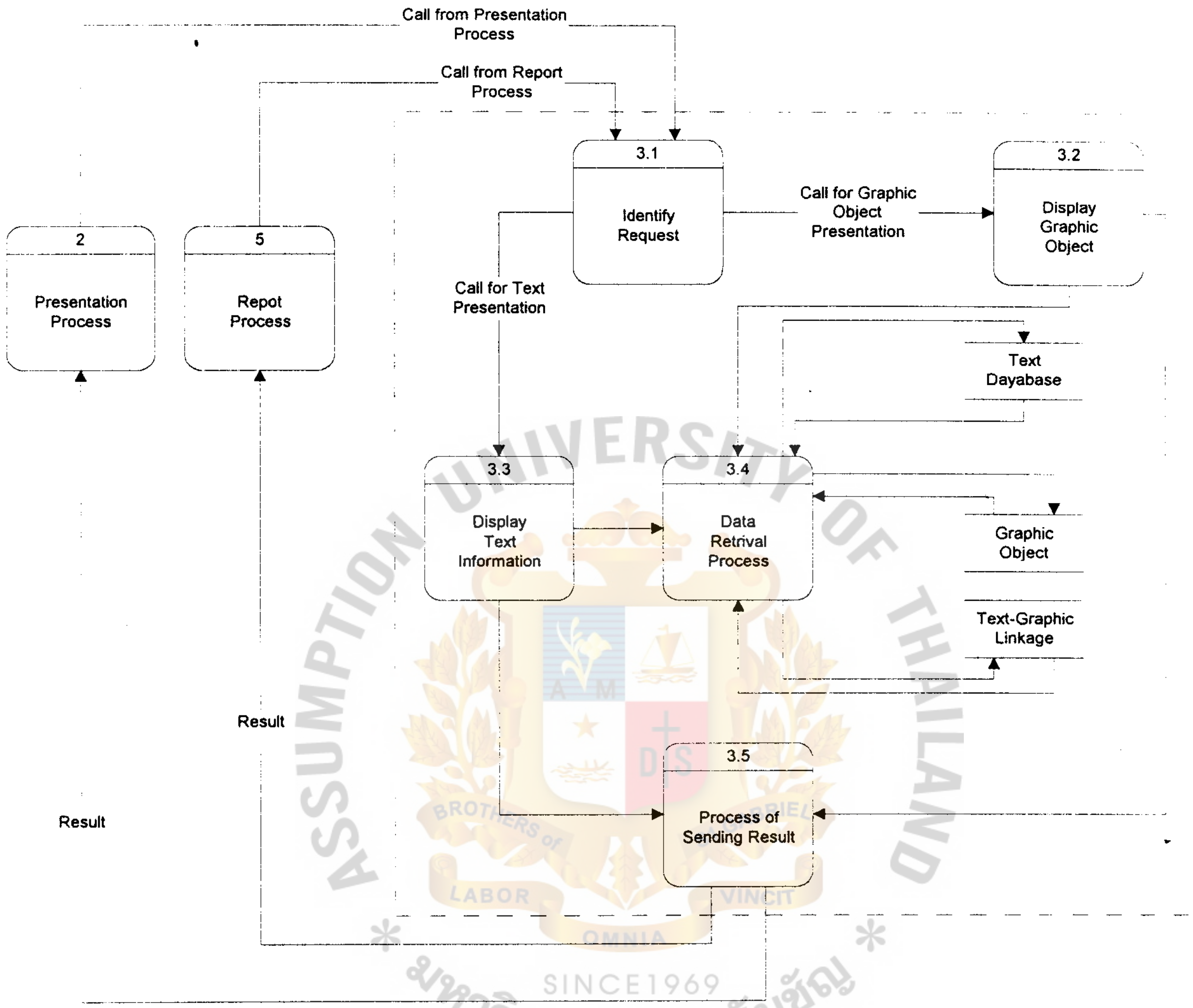

Figure 3-18: Subsystem flow: Retrieval Process (2nd level)

3.3.5.8 Subsystem flow: Report Process (2nd level)

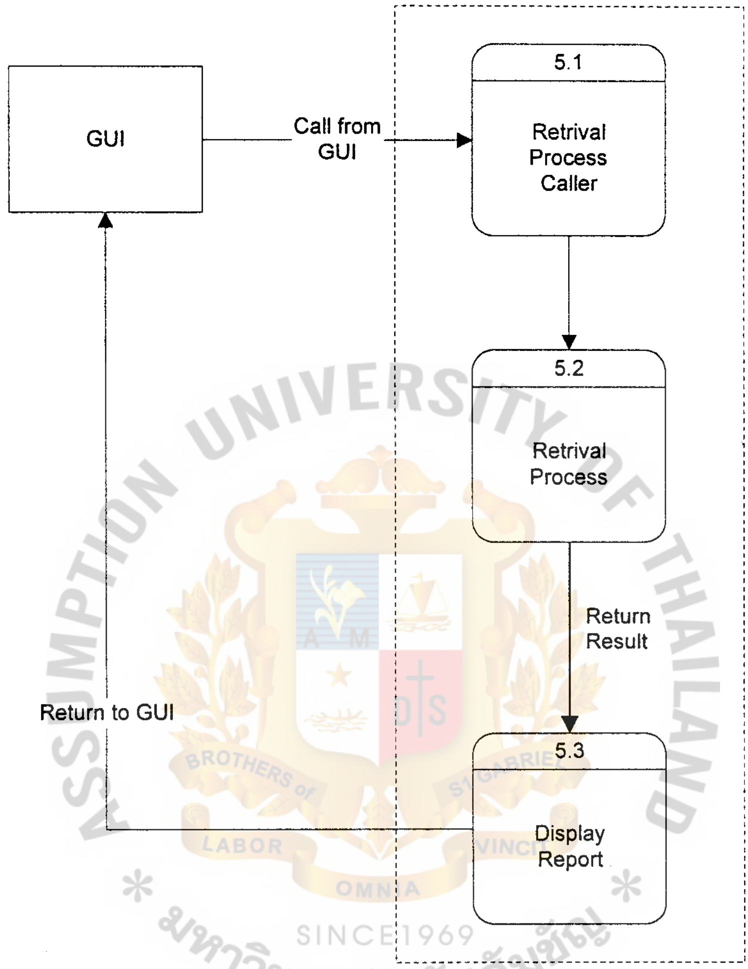

Figure 3-19: Subsystem flow: Report Process (2nd level)

3.4 Database Design

The database of this prototype is composed of various forms of instructional content. Relationships between and among diverse forms of these elements, both 3D models and 2D multimedia materials, are very important.

To consider the problem of data management in the different type of environment, which must be stored in the local external storage, A direct access file is used to access the data at given position directly. So, in the external storage or external file, it would be advantageous to organize an index to the data file rather than to organize the data file itself. Although you do not organize the data file, you must organize the index file so that you can search and update it rapidly. In generally, the advantage of index is; 1) data file can be organize in any way, 2) index record will be small, and 3) you can maintain several index simultaneously.

There are some benefits from using index in this prototype.

- The data files can be left in an external storage in a disorganized state and maintain index file to it.
- It would be an appropriated management of various forms of data, which difficult to place it in a data record. It allows the data to be stored independently in file and specify the index to it.
- To locate a particular record of the table of data, it will search the index, which will tell you where to find the desired record. This is a better solution to decrease searching time.

- Because this prototype does not need to maintain the data file in any particular order, there is more flexible to add and eliminate these independent files for further development.
- The small size of index file (only two fields contained in index record) requires small size of internal memory and allows quicker access.

By utilizing the index to manage the external resources of this prototype, VR-MM, this index file contains an index record that consists of two fields:

1) A key field, named "Object_index", which contains the object's identification, and
2) A reference field, named "Index", which contains the same value (index number) as the search key of its corresponding record in the data file.

In the following, the figure 3-20 will indicate the database design of this prototype. On the left is the index file, each record of which contains a key, "Object_index". Each key is associated with reference field giving the address of the corresponding data record. On the right is the table of data containing information about the correction of recordings. Only two fields are shown, index and content. In a content field, there is a file name, which is stored independently in external drive, CD-ROM.

Table of Index

Object_Index	Index
[object ID]	[index]

Table of Data

Index	Content
[index]	[Text file (*.txt) or RTF file (*.rtf)]

Figure 3-20: Database Design

Consideration of data management, the data in this system can be classified into three groups: text, graphic and object. The following, figure 3-21, is the rearrangement of database design.

Table of Index

Object_Index	Index
[object ID]	[index]

Table of Data

Index	Content
[index]	[Text file (*.txt) or RTF file (*.rtf)]

Table of Graphic

Index	Graphic
[index]	[Non animation file, (*.jpg, *.BMP, VRML)]

Table of Object

Index	Graphic
[index]	[Animation file, (*.AVI, *.mov]

Figure 3-21: Database Design (rearrangement)

CHAPTER4: SYSTEM IMPLEMENTATION

4.1 Overview of System Implementation

First of all is to plan the way for implementation, the first step is to study the old feature of the old works in the past. Then start using those conceptual reviews to implement this new system. So, this one includes some features or some techniques of the old feature and uses other techniques difference from those old theme.

In the conceptual design of this system, 3D Graphics Model represent visualization dog's heart functioning. What is presented is the model of the dog containing the abdominal viscera inside (the organs in abdominal cavity). The 3-D dog's model, constituting the nucleus of this application would be shown at first as a solid dog's model, which can be viewed and be rotated in both free rotation and forced by the direction rotation. After clicking mouse, what the audience will meet is the transparency model of the previous solid model. The advantage of transparency mode is to show the organ 3-D model focusing on the abdominal viscera containing inside the structure of a dog. These organs also include a heart 3-D model mostly concerned in this first prototype. This only one model, a 3-D model of heart, will be extended its' function in supported resources; Anatomy, Histology, Physiology, and radiology item. The user-interface, which will be used, is described in the detail of "User Interface design". And other details will be described as be shown them in the sub part of "Designing the System".

4.2 Steps of Schedules

The steps of schedules are as follows.

a) Gathering Users Requirement

b) Analyze Users Requirement

c) Gathering old theme about Model Designing and Implementation

d) Design the concept(its' capability, resources usage environment, interface, utility)

e) Design the Input

f) Design the Output (Giving the detail by using story board)

g) Design the process

h) Design the sub – process

i) Programming the code

j) Testing and Debugging the code

k) Prepare the complete product

4.3 Resources Utilization

The resources utilization of this prototype are as follows.

a) CD-ROM Drive Package

b) Visual C++

c) CD-R blank

d) 3D graphics creation software

e) 3D Artist

f) AVI files input

g) Content information input for implementation

h) CD-R writer Drive Package

4.4 Software Development

4.4.1 3D Models Construction

3D Models used in this Virtual Reality – Multimedia (VR-MM) application are polygon-based which 3D wireframe models of dog anatomy are derived from Wireframe 3-D Geometry Model Directories of Purdue University providing computer graphics. The graphic data inputs are generated by using a graphic program, such as 3D Studio MAX, to convert the existing file format, IGES graphic file format, to the DXF file format. This strategy can decrease the time and reduce the cost for supporting equipment such as a Digitizer. The deep details and sub-structure of a heart model, concerning in this prototype, are generated. Finally, rendering, adding textures, color and surface fill out the appearance of the models.

4.4.2 Software Engineering

The software components of the VR-MM learning environment are engineered using an object-oriented program (Visual C++). This strategy maximizes code reuses and facilitates the adaptation of appropriate off-the-shelf technologies. The process of coding is responsible for three elements.

1) **Display functions**, which are not only for displaying and manipulating multimedia, but also provide the function link between 3D models and 2D components. The specific multimedia resources are linked to the specific structure on the 3D models. The flowchart in figure 4-1 and 4-2 explains steps of the function in this VR-MM system.

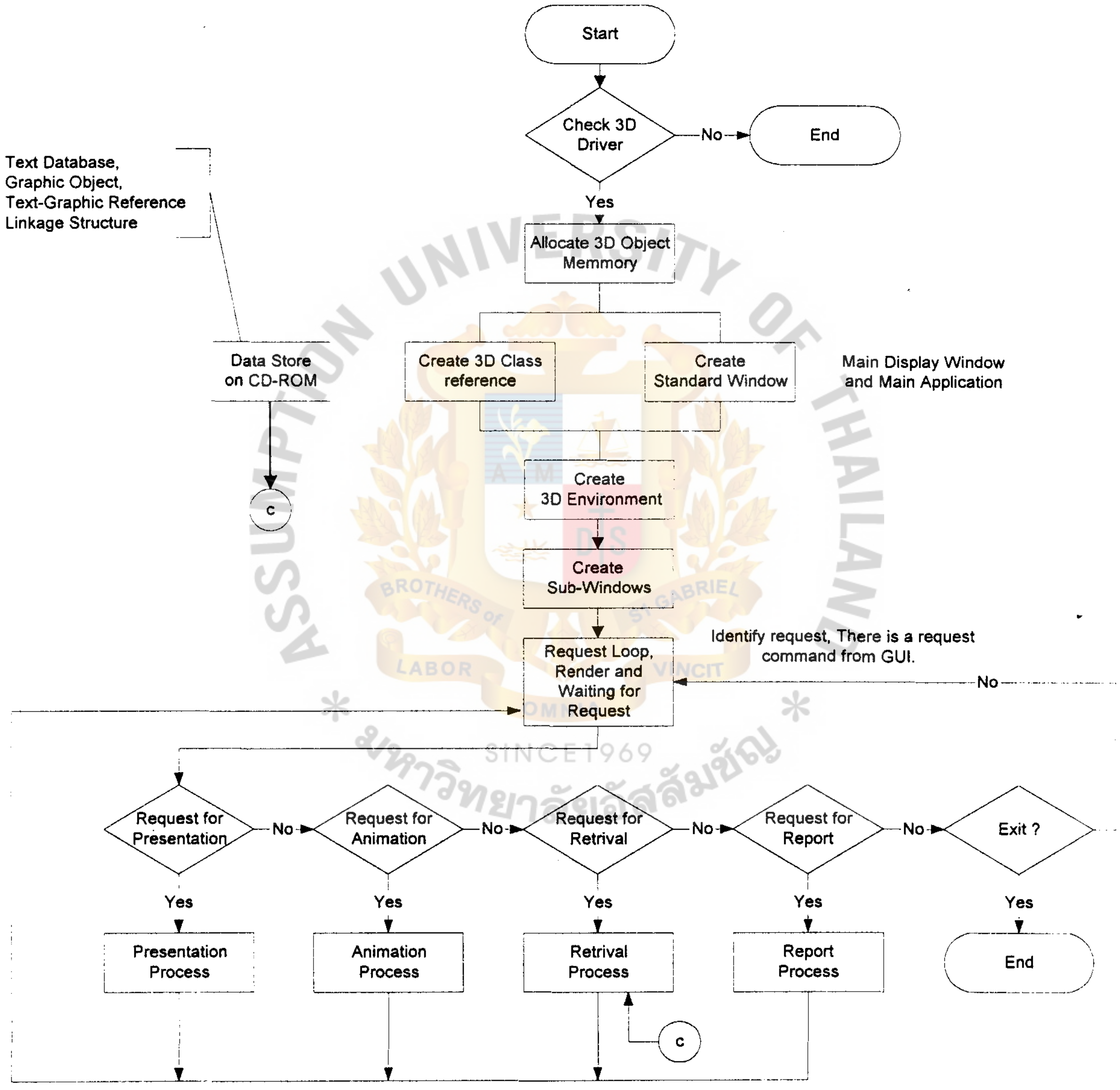

Figure 4-1: System Flowchart

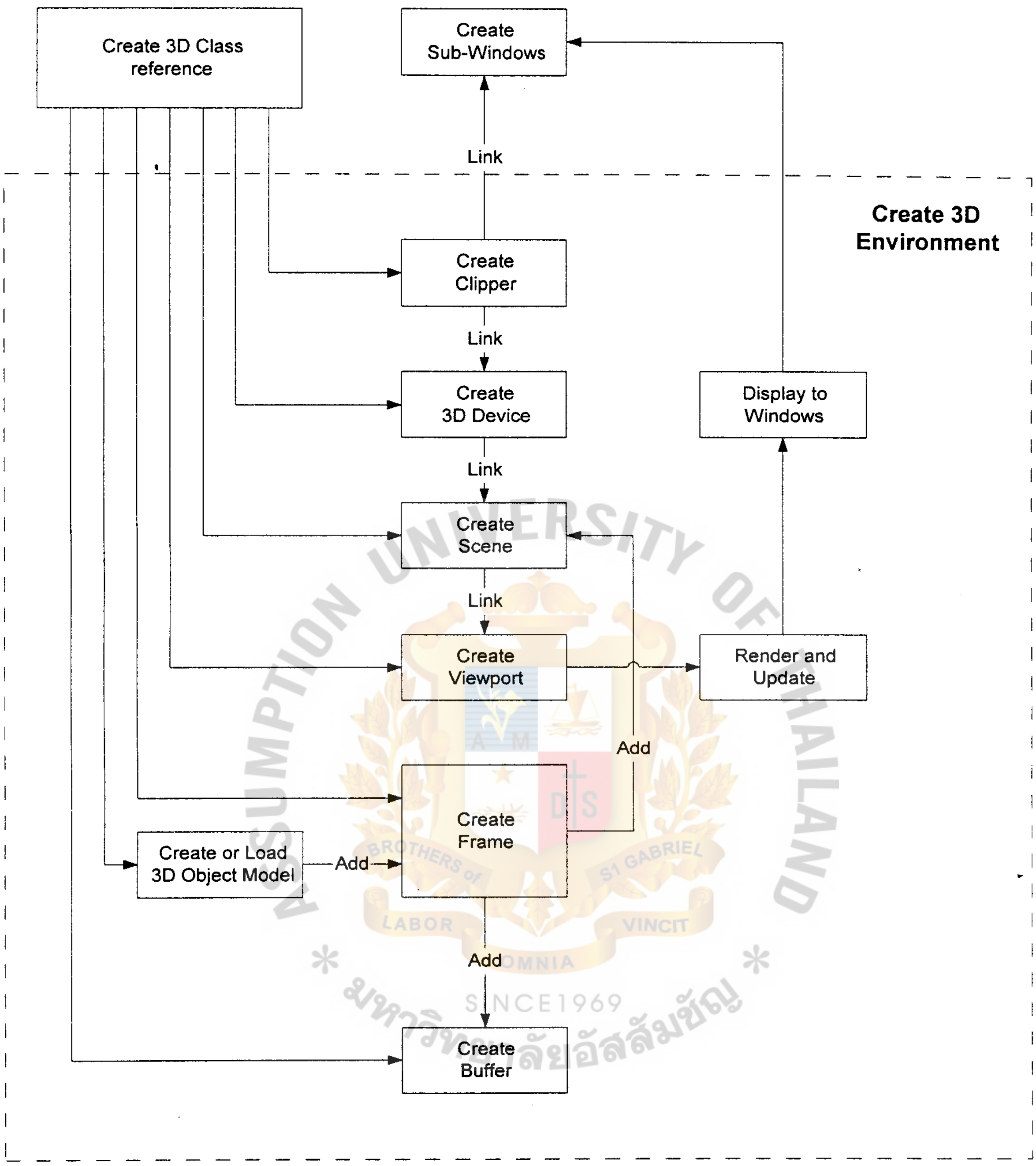

Figure 4-2: Sub-System Flowchart: Create 3D Environment

The listing detailed of the re-usable modules, see appendix A.

2) **Interactions** between user and the virtual world, for example grab, move and rotate.

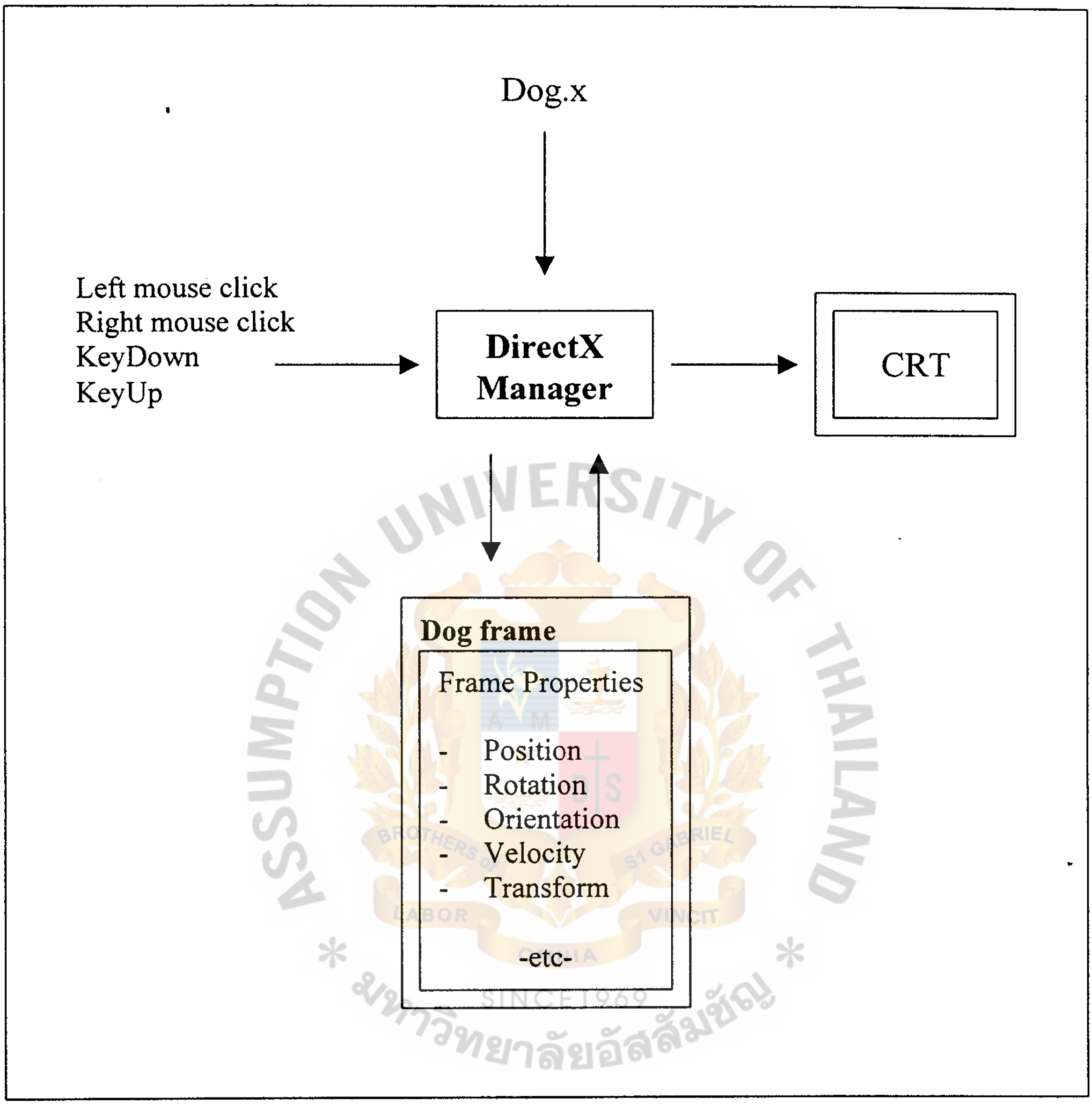

Figure 4-3: Interaction between user and the system

For the detail of DirectX functions used in VR-MM system, see appendix B.

3) **Data manager**, which articulates relationships between and among diverse forms of instructional content, both 3D models and other 2D multimedia materials. These resources are independent files stored locally in CD ROM, which program organizes an index to make the relationships. The figure below describes this relationship.

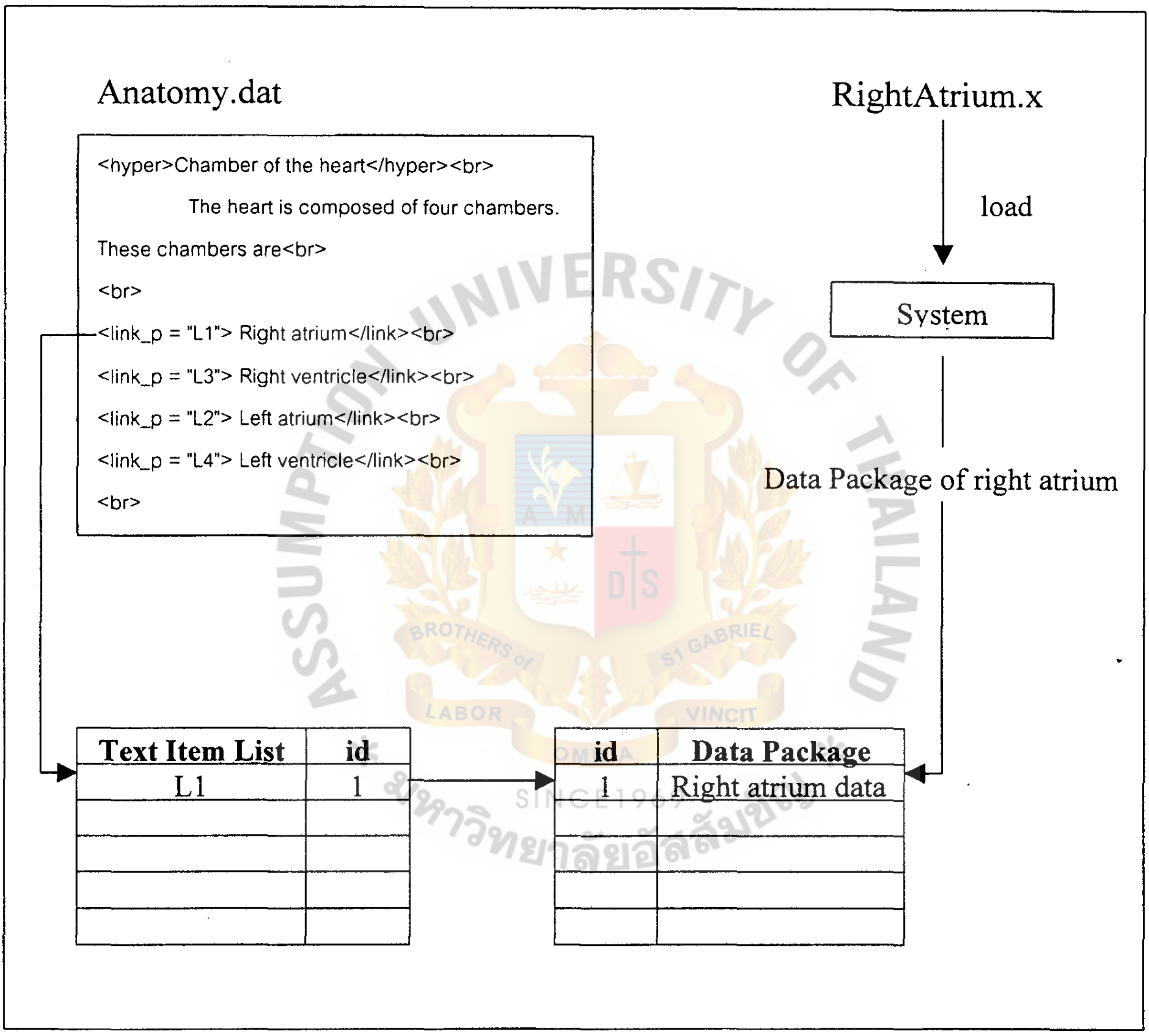

Figure 4-4: The diagram indicates the relationship between text and 3D object

CHAPTER 5: CONCLUSION AND FUTURE WORK

5.1 Conclusion

After the thesis completion, the first prototype application of VR-MM for anatomy education focusing on cardiac system of a dog can be placed as a paradigm of combining the VR with multimedia resources.

The result suggested that VR could be used to develop a unifying interface for accessing supporting multimedia resources and vice versa. This is important because no single technology can provide a complete curriculum for student. So these multimedia resources can be made available within VR to add depth and clearity to the learning process as well as support and enrich the virtual environment.

In the development of this application prototype, there are some **technical issues** enhancing this VR environment.

- The 3D animation in this prototype is developed base on **procedural animation**, which is object-oriented animation. During animation playbacks, the software prepares the next frame by calculating the next position for each entity in the scene. So, the programmer is able to correlate it's data to other resources directly. This strategy will provide users an interactive program with magnificent visualization.
- The software components of this VR-MM learning environment are engineered using an **object-oriented methodology**. This strategy maximizes code reuses and facilitates the adaptation of appropriate off-the-shelf

technologies. An object-oriented approach also allows encapsulation of other components for easier integration.

- This system is developed by Visual C++. It is different from other commercial multimedia products, which require an application, such as Quicktime, to run the program.
- This prototype also applies **DirectX** technology which provides developer with opportunities for creativity and innovation by allowing developer to focus on building unique features for application without having to worry about which display adapter, sound card, or 3-D accelerator chip is installed in PC. And because DirectX was designed to support future innovations in software and hardware, developer can be confident that will continue to get the best possible performance from this application as technology advances.
- Critical element of this VR-MM system is a data management. Relationships between and among diverse forms of instructional content, both 3D models and 2D multimedia materials are effectively organized by **index**.
- The presentation of this system is applied from the information gathered from the best feature of the previous work presentation.

To **compare with the current web-based technology**, some differences are as follows.

1. VR-MM provides 2D windows, which support more information for virtual 3D objects.

2. VR-MM provides users more specific application for anatomy education instead of conventional web-based VR.
3. Unlike 3D object in web-based VR, each 3D object model contains its' data and links to other supporting resources.
4. Each 2D window and 3D object in VR environment can be manipulated independently, so it will free the users for learning processes.
5. This VR-MM can be run under industry standard window system without requirement of any specific display application such as web browser.
6. The 2D text and graphic windows that support resources for VR-MM environment are developed in mode of windows fixed to the CRT display. This mode allows windows to move with during an exploration of VR environment. To compare with other systems which windows fixed to the information surround or fixed to locations and objects in the 3D world, all of them are develop in graphic mode, so they are not appropriate to display and modify text resources. While performing text in the windows fixed to CRT display, it will provide user with the better display and provide developer easier to modify later in text mode.
7. Most virtual reality-base animations on the web are exploratory mode that allows user to interact with the VR engine, but cannot interact with any entities inside the virtual space. While this VR-MM system was developed in interactive mode that allows user to influence the entities inside the virtual space.
8. VR-MM is appropriate to explore the high quality 3D objects. It provides the better 3D presentation such as faster loading and rendering because the system uses the memory of hardware directly while the web based technology depend on evolution of

browser and plug-in limited by capability of Windows. So VR-MM is more suitable for Anatomy education which requires the high quality 3D models.

9. There is another differentiation between VR in web-based technology such as VRML, and VR-MM. The VRML is the Virtual reality modeling language, which is the standard in 3D modeling suitable performing on the web, so it will be better viewed and manipulated by supportive web-browser with VRML plug-in. This VR-MM is a virtual reality–multimedia system developing under standard windows configuration and using DirectX performance, so it will be better run and manipulated on any PC with windows operation containing DirectX.

The **achievements** of this experiment are as following.

- The Algorithm and technique of coding and using DirectX driver provide this VR-MM system the better solution of loading and displaying high quality and complicated 3D objects in interactive mode and properly display their related resources in 2D windows without the requirement of high performance processor or any specific hardware. The minimum requirements of this VR-MM system are as follows.
  - Window95 or above
  - DirectX 5.0 or above
  - RAM 16 MB (require 10 MB)
  - Disk Space 112 MB
  - CPU Speed 200 MHz with MMX

- With these minimum requirements, VRMM can provide the capability to load, render and display high quality models smoothly up to 3 MB of model's size (tested with the 3D model size 3,157KB, 13,563 polygons of total surfaces and 25,486 total points). While comparing with another web-base VRML, the maximum model's size is only 1 MB.

These are indications that VR-MM is appropriate in allowing users to explore the high quality 3D objects. It provides the better 3D presentation such as faster loading and rendering while providing 2D supporting windows for interactive. So VR-MM could be more appropriate system for Anatomy education which requires the high quality and very complicated 3D models.

5.2 Future Work

As work continues, this VR-MM environment would be expanded in scope and sophistication. This expansion includes enhancement to the visualization and user interface, expansion of 3D models and multimedia lesson contents, and refinement to display and command option for interaction. If this prototype is developed in advance, it would be an evolution of interactive tool for active learning, which can replace the conventional procedure and provide more flexibility.

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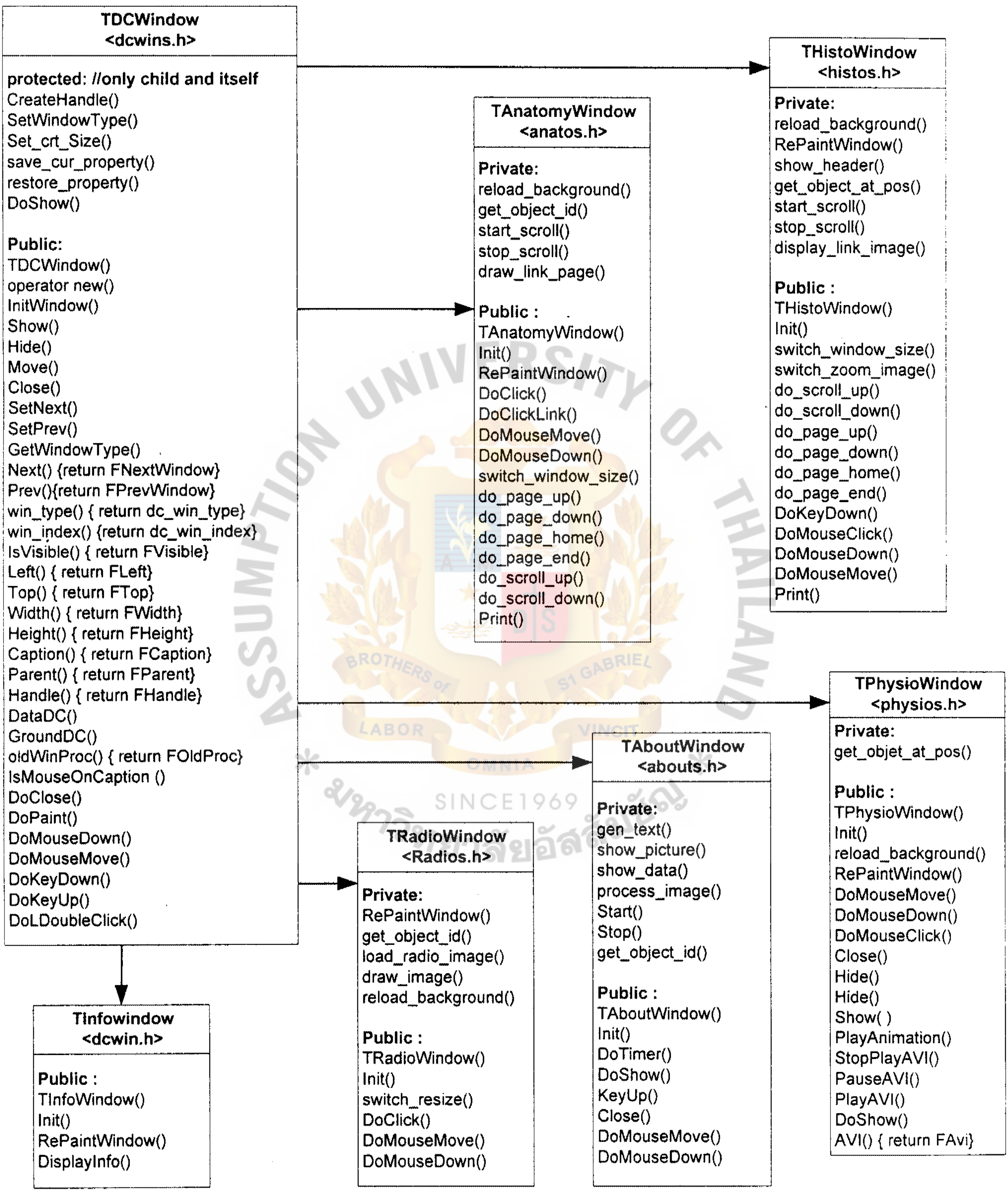
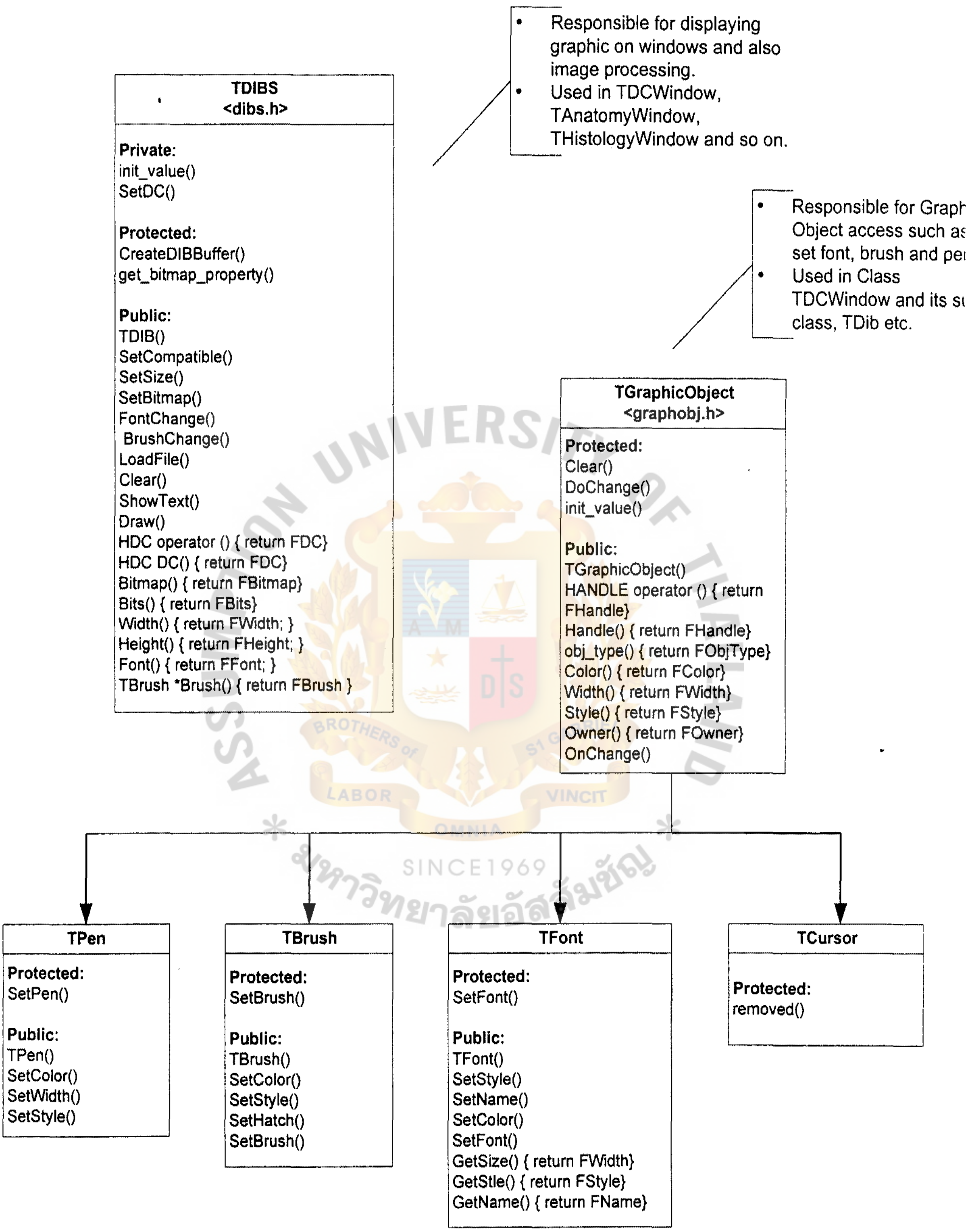
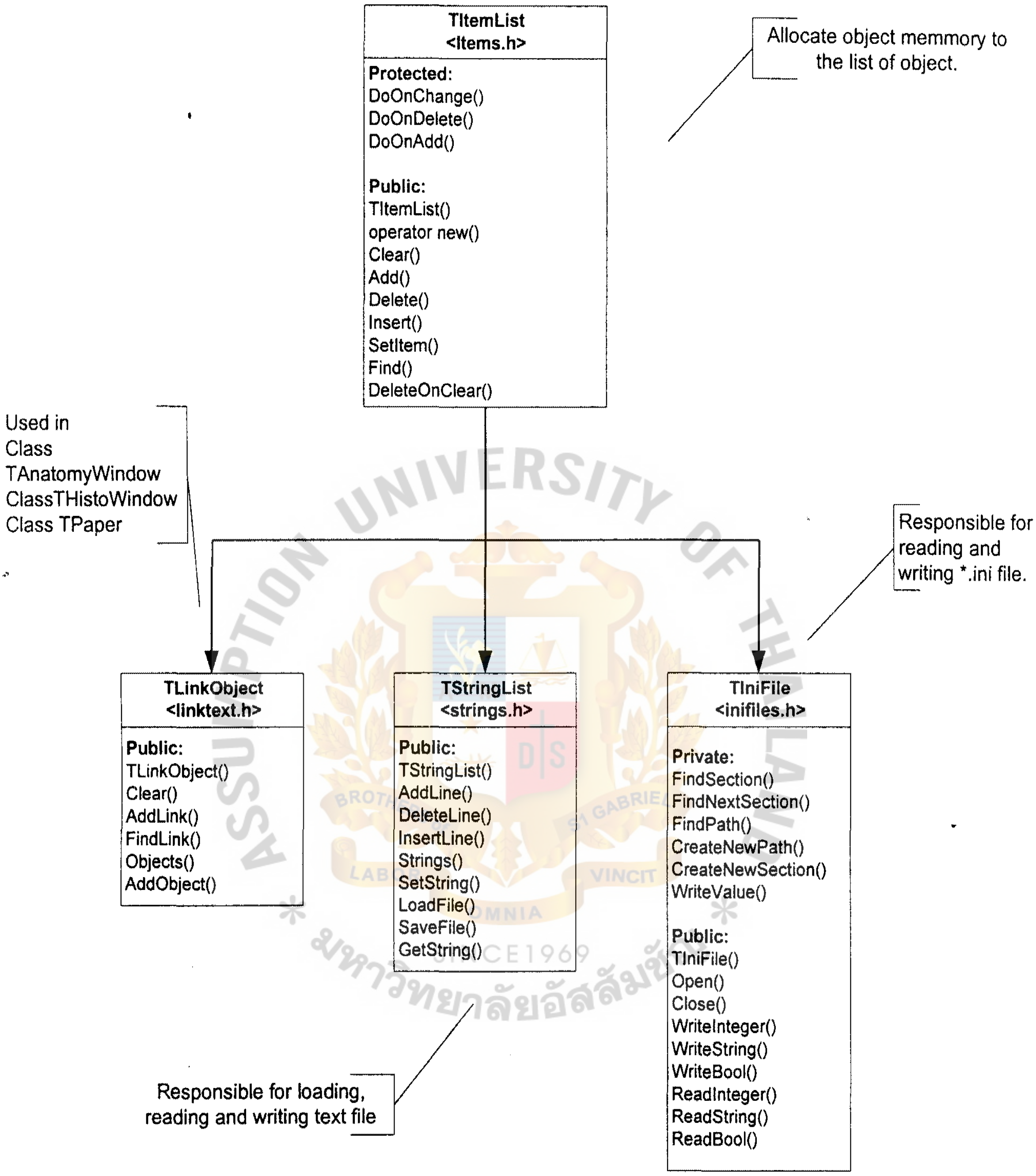
APPENDIX A: Re-Usable Modules

I. Class of Windows presentation



II. Class of Graphic Object




TItemList
<Items.h>
Protected:
DoOnChange()
DoOnDelete()
DoOnAdd()
Public:
TItemList()
operator new()
Clear()
Add()
Delete()
Insert()
SetItem()
Find()
DeleteOnClear()
Allocate object memmory to the list of object.
Used in
Class
TAnatomyWindow
ClassTHistoWindow
Class TPaper
Responsible for reading and writing *.ini file.
TLinkObject
<linktext.h>
Public:
TLinkObject()
Clear()
AddLink()
FindLink()
Objects()
AddObject()
TStringList
<strings.h>
Public:
TStringList()
AddLine()
DeleteLine()
InsertLine()
Strings()
SetString()
LoadFile()
SaveFile()
GetString()
TIniFile
<inifiles.h>
Private:
FindSection()
FindNextSection()
FindPath()
CreateNewPath()
CreateNewSection()
WriteValue()
Public:
TIniFile()
Open()
Close()
WriteInteger()
WriteString()
WriteBool()
ReadInteger()
ReadString()
ReadBool()
Responsible for loading, reading and writing text file

III. Class of General Utilities

TPaperWindow <papers.h>	
Private: gen_text() paint_text() print_page_no() print_doc() **Public:** TPaperWindow() Init() Objects() { return FLink->Objects(i)} ObjectCount() { return FLink->Count()} do_scroll_up() do_scroll_down() do_page_up() do_page_down() do_page_home() do_page_end() SetPageLine() find_object_at_pos() Print()	Responsible for Link-Text Structure (HTML) For Example, used in TAnatomyWindow and THistoWindo

TPrinter <printers.h>	
Private: GetPrinters() SetToDefaultPrinter() SetPrinter() SetPrinterCapabilities() **Public:** TPrinter() SetTitle() ShowText() Begin() End() NewPage() GetPrinterIndex() GetNumCopies() SetNumCopies() TPrinterOrientation GetOrientation() SetOrientation() GetPageHeight() GetPageWidth() HDC DC() { return FDC} PageNumber() { return FPageNumber}	Responsible for printing data via printer.

auto_init_effect <effects.cpp>
retain memory for fadein and Fade-out (internal used only)

APPENDIX B:
DirectX Function used in VR-MM system

I. DirectDraw Reference Function

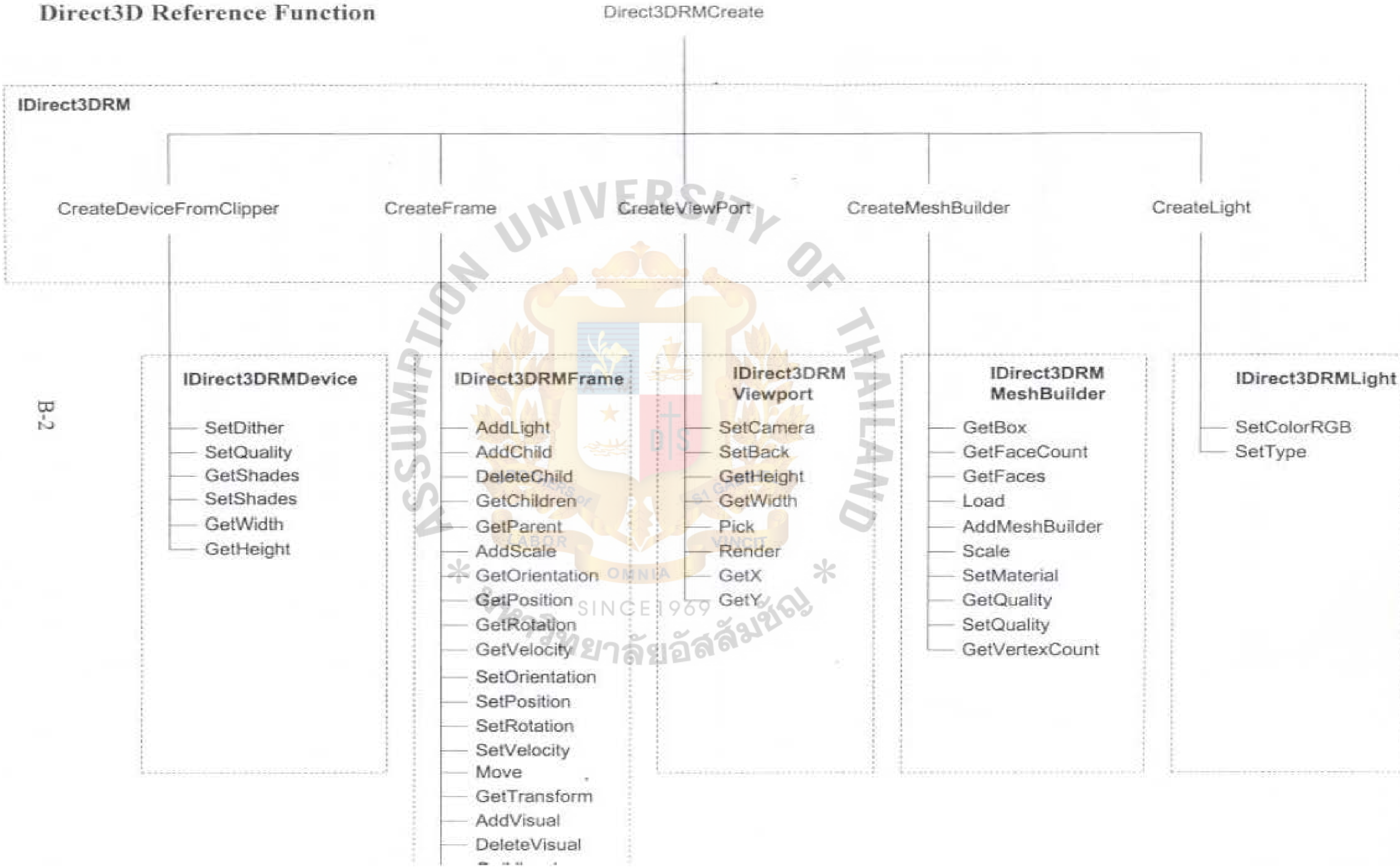
- **DirectDrawCreate**

  The DirectDrawCreate function creates an instance of a DirectDraw object.

- **DirectdrawCreateClipper**

  The DirectDrawCreateClipper function creates an instance of a DirectDrawClipper object not associated with a DirectDraw object.

Direct3D Reference Function



DirectDrawCreate

The DirectDrawCreate function creates an instance of a DirectDraw object.

HRESULT DirectDrawCreate(GUID FAR *lpGUID, LPDIRECTDRAW FAR *lplpDD,

IUnknown FAR *pUnkOuter);

- If the function succeeds, the return value is DD_OK.

lpGUID

Address of the globally unique identifier (GUID) that represents the driver to be created. This can be NULL to indicate the active display driver, or you can pass one of the following flags to restrict the active display driver's behavior for debugging purposes:

- DDCREATE_EMULATIONONLY

  The DirectDraw object will use emulation for all features; it will not take advantage of any hardware supported features.

- DDCREATE_HARDWAREONLY

  The DirectDraw object will never emulate features not supported by the hardware. Attempts to call methods that require unsupported features will fail, returning DDERR_UNSUPPORTED.

lplpDD

Address of a pointer that will be initialized with a valid DirectDraw pointer if the call succeeds.

pUnkOuter

Allows for future compatibility with COM aggregation features. Presently, however, DirectDrawCreate returns an error if this parameter is anything but NULL.

DirectDrawCreateClipper

The DirectDrawCreateClipper function creates an instance of a DirectDrawClipper object not associated with a DirectDraw object.

HRESULT DirectDrawCreateClipper(DWORD dwFlags, LPDIRECTDRAWCLIPPER FAR *lplpDDClipper, IUnknown FAR *pUnkOuter);

- If the function succeeds, the return value is DD_OK.

DwFlags

This parameter is currently not used and must be set to 0.

LplpDDClipper

Address of a pointer that will be filled with the address of the new DirectDrawClipper object.

pUnkOuter

Allows for future compatibility with COM aggregation features. Presently, however, DirectDrawCreateClipper returns an error if this parameter is anything but NULL.

Direct3DRMCreate

Create an instance of a Direct 3DRM object.

HRESULT Direct3DRMCreate (LPDIRECT3DRM FAR * lplpD3DRM) ;

- Returns D3DRM_OK if successful, or an error otherwise.

lplpD3DRM

Address of a pointer that will be initiated with a valid Direct3DRM pointer if the call succeeds.

IDirect3DRM::CreateDeviceFromCliper

Creates a Direct3DRM Windows device by using aspecified DirectDrawClipper object.

HRESULT CreateDeviceFromClipper (LPDIRECTDRWCLIPPER lpDDClipper,

LPGUID lpGUID, int width, int height,

LPDiIRECT3DRMDEVICE * lplpD3DRMDevice) ;

- Returns D3DRM_OK if successful, or an error otherwise.

lpDDClipper

Address of a DirectDrawClipper object.

lpGUID

Address of a globally unique identifier (GUID). This parameter can be NULL.

width and height

Width and height of the device to be created.

LplpD3DRMDevice

Address that will be filled with a pointer to an *Idirect3DDRMDevice* interface if the call succeeds.

If the *lpGUID* parameter is NULL, the system searches for a device with a default set of device capabilities. This is the recommended way to create a Retained Mode device because it always works, even if the user installs new hardware.

The system describes the default settings by using the following flags from the D3DPRIMCAPS structure in internal device-enumeration calls:

D3DPCMPCAPS_LESSEQUAL

D3DPMISCCAPS_CULLCCW

D3DPRASTERCAPS_FOGVERTEX

D3DPSHADECAPS_ALPHAFLATSTIPPLED

D3DPTADDRESSCAPS_WRAP

D3DPTBLENDCAPS_COPY | D3DPTBLENDCAPS_MODULATE

D3DPTEXTURECAPS_PERSPECTIVE |

D3DPTEXTURECAPS_TRANSPARENCY

D3DPTFILTERCAPS_NEAREST

If a hardware device is not found, the monochromatic (ramp) software driver is loaded. An application should enumerate devices instead of specifying NULL for *lpGUID* if it has special needs that are not met by this list of default settings.

IDirect3DRM::CreateViewport

Creates a viewport on a device with device coordinates *(dwXPos, dwYPos)* to *(dwXPos + dwWidth, dwYPos + dwHeight).*

HRESULT CreateViewport (LPDIRECT3DRMDEVICE lpDev,

LPDIRECT3DRMFRAME lpCamera, DWORD dwXPos,

DWORD dwYPos, DWORD dwWidth, DWORD dwHeight,

LPDIRECT3DRMVIEWPORT* lplpD3DRMViewport) ;

- Returns D3DRN_OK if successful, or an error otherwise.

lpDev

Device on which the viewport is to be created.

lpCamera

Frame that describes the position and direction of the view.

dwXPos, dwYPos, dwWidth, and dwHeight

Position and size of the viewport, in device coordinates.

lplpD3DRMViewport

Address that will be filled with a pointer to an *IDirect3DDRMViewport* interface if the call succeeds.

The viewport displays objects in the scene that contains the camera, with the view direction and up vector taken from the camera.

IDirect3DRM::CreateLightRGB

Creates a new light source with the given type and color.

HRESULT CreateLightRGB (D3DRMLIGHTTYPE ltLightType, D3DVALUE vRed, D3DVALUE vGreen, D3DVALUE vBlue, LPDIRECT3DRMLIGHT* lplpD3DRMLight) ;

- Returns D3DRM_OK if successful, or an error otherwise.

LtLightType

One of the light types given in the D3DRMLIGHTTYPE enumerate type.

VRed, vGreen, and vBlue

Color of the light.

LplpD3DRMLLight

Address that will be filled with a pointer to an *IDirect3DRMLight* interface if the call succeeds.

IDirect3DRM::CreateFrame

Creates a new child frame of the given parent frame.

HRESULT CreateFrame (LPDIRECT3DRMFRAMEnlpD3DRMFrame,

LPDIRECT3DRMFRAME* lplpD3DRMFrame) ;

- Return D3DRM_OK if successful, or an error otherwise.

lpD3DRMFrame

Address of a frame that is to be the parent of the new frame.

lplpD3DRMFrame

Address that will be filled with a pointer to an *IDirect3DRMFrame* interface if the call succeeds

The child frame inherits the motion attributes of its parent. For example, if the parent is moving with a given velocity, the child frame will also move with that velocity. Furthermore, if the parent is set rotating, the child frame will rotate about the origin of the parent. Frames that have no parent are call scenes. To create a scene, specify NULL as the parent. An application can create a frame with no parent and then associate it with a parent frame later by using the **IDirect3DRMFrame::AddChild** method.

IDirect3DRM::CreateMeshBuilder

Creates a new mesh builder object.

HRESULT CreateMeshBuilder (LPDIRECT3DRMMESHBUILDER*
    LplpD3DRMMeshBuilder);

- Returns 3DRM_OK if successful, or an error otherwise.

lplpD3DRMMeshBuilder

Address that will be filled with a pointer to an *IDirect3DmeshBuilder* interface if the call succeeds.