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This paper addresses the need for a comprehensive database of dental radiographs that serves as an image repository for the dental students and faculty. The main purpose of this project is to lay the foundation for the development of a dental digital-image library by mapping and describing the steps necessary for the development of such a library. This paper describes the various stages of the project, from gathering functional information, acquiring appropriate radiographic images, designing of the project plan and the development of a dynamic Web based front end for accessing the radiographs. The digital library of images could be used by the students as a quick reference tool and by the faculty as an instructional tool at the School of Dentistry, UNC at Chapel Hill.

Headings:

Digital Library- dental radiographs

Database-Digital radiographs

Digital Repository-Jaw lesions
DIGITAL LIBRARY OF DENTAL RADIOGRAPHS

by
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A Master’s paper submitted to the faculty
of the School of Information and Library Science
of the University of North Carolina at Chapel Hill
in partial fulfillment of the requirements
for the degree of Master of Science in
Information Science.

Chapel Hill, North Carolina
November 2007

Approved by

_______________________________________
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With my deepest gratitude to

Professor Ron Strauss
Distinguished Professor and Chair
Department of Dental Ecology,
School of Dentistry,
UNC, Chapel Hill

A teacher of great prowess and a magnificent person
ACKNOWLEDGEMENTS

I would like to express gratitude for my advisor and teacher Dr Brad Hemminger, for his unwavering support and skilful guidance throughout this project. A special thanks to Prof. Joanne Marshall for her constant help and encouragement.

I wish to express my sincere gratefulness to Dr Jim George, Director of ‘Office of Computing and Information Services’ (OCIS) at the School of Dentistry, UNC for his undaunted support and assistance throughout this project. A special thanks to Tim Murphy of OCIS for providing me with most valuable guidance that helped me throughout in the development of this project.

Finally I wish to thank my family and friends for their never failing support, understanding and love.
LIST OF TABLES

Table 1……………………………………………………………………………………………………….28
Table 2………………………………………………………………………………………………………..30
Table 3………………………………………………………………………………………………………..33
Table 4………………………………………………………………………………………………………..38
Table 5………………………………………………………………………………………………………..39
Table 6………………………………………………………………………………………………………..43
LIST OF FIGURES

Figure 1 .................................................................................................................. 17
Figure 2 .................................................................................................................. 25
Figure 3 .................................................................................................................. 28
Figure 4 .................................................................................................................. 29
Figure 5 .................................................................................................................. 32
Figure 6 .................................................................................................................. 36
Figure 7 .................................................................................................................. 37
Figure 8 .................................................................................................................. 37
Figure 9 .................................................................................................................. 40
Figure 10 ............................................................................................................... 41
Figure 11 ............................................................................................................... 45
Figure 12 ............................................................................................................... 46
Figure 13 ............................................................................................................... 46
# TABLE OF CONTENTS

1. INTRODUCTION ....................................................................................................... 2
2. STATEMENT OF PROBLEM ................................................................................... 6
4. BACKGROUND ......................................................................................................... 8
5. METHODOLOGY ....................................................................................................... 11
   5.1 Introduction ............................................................................................................. 11
   5.2.1 Location of images ............................................................................................... 12
   5.2.2 Basic concepts of digital imaging ........................................................................ 12
   5.2.3 Concept of gray–scale continuous tone image .................................................... 13
   5.2.4 Quantization process ............................................................................................ 13
   5.2.5 Image resolution ................................................................................................... 13
   5.2.5.1 Spatial Resolution ............................................................................................. 14
   5.3 Criteria for selection of Images ............................................................................... 14
   5.4 Classification of Images .......................................................................................... 16
   5.5. Technology Overview ............................................................................................ 22
5.6 Database Design ...................................................................................................... 25
   5.6.1 Stakeholders ......................................................................................................... 25
   5.6.2 User roles ............................................................................................................. 26
   5.6.3 User Requirements ............................................................................................... 26
   5.6.4 Use case Scenarios ............................................................................................... 27
   5.6.4.1 Introduction ....................................................................................................... 27
   5.6.4.2 Use case: Student interaction ............................................................................ 28
   5.6.4.3 Searching the database ...................................................................................... 29
   5.6.4.4 Search by Browsing .......................................................................................... 32
   5.7 Design development................................................................................................ 34
   5.8 Terminology ............................................................................................................ 38
5.9 Web interface design ............................................................................................... 41
   5.9.1 Creating a web space ........................................................................................... 41
   5.9.2 Web interface Design Decision ........................................................................... 42
   5.10 Integration of web Interface with database ........................................................... 47
6. CONCLUSION ......................................................................................................... 47
7. FUTURE PLANS ...................................................................................................... 50
8. LESSONS LEARNED.................................................................................................. 51
BIBLIOGRAPHY ............................................................................................................. 53
1. INTRODUCTION

A Radiology department provides radiographic and imaging services to all the other departments in the hospital by acquiring radiographs, interpreting and reporting the diagnosis of radiographs to the attending clinicians and the students undergoing medical or dental training. Like medical radiology in dentistry dental imaging forms an integral part of the diagnosis and treatment planning and follow up evaluation and care.

The advent of computers has had a huge impact on medicine and dentistry. Technology has continually changed the way in which images are captured delivered and stored. Today, the capture, storage, transmission and display of radiographs is all electronic, making for a filmless workflow.

This paper describes the design and the development of an operational prototype of digital library of digital dental radiographs that would be used by the students and faculty in the School of Dentistry at UNC. This project was initiated during the summer while I was working on a ‘professional field experience’ with the Office of the Computing and information Systems (OCIS) at the School of Dentistry and was identifying the various information challenges faced by the School of Dentistry. While working with the residents of in the department of Oral and Maxillofacial Radiology it came to light that the department faced certain information challenges that needed to be addressed
There were an overwhelming number of radiographs and reports that had accumulated over a period of time and these were stored in numerous folders in the computers of the department. There is no formal database for the storage and organization of these radiographs. With the passage of time and with the advent and adoption of digital radiography there are more and more number of radiographs that get stored and it is hard to access and keep account of these radiographs. The department was looking for some practical solution to address this issue.

School of Dentistry is a teaching institution and radiographs are readily accessed by both undergraduate and graduate students. The end users get an ‘onion like’ feeling while trying to find the radiographs in the teaching file folders. They feel that they have to go through several layers to get to the appropriate images. It is both cumbersome and time consuming to go through several different folders to select an appropriate image. There two types of files one that had patient reports that needed to be organized and another with radiographs of various maxillofacial pathologies lying randomly in the folders named as teaching files. Creating a database and organizing the radiographs in the teaching file folders was something that needed to be addressed more urgently. The idea of a digital radiograph image library was envisioned. This collection of images could be used as a teaching tool for the School of Dentistry.

The development of this project involved several stages, the first one being to conceptualize and appropriately design the project within the given time constraints. The first step in conceptualizing this project was to make a note of the functionality of the system, keeping in mind the main that the main objective was to
create a database that would serve as a data bank of images and that could be used as a tool by the students for learning and by the faculty for teaching.

The initial stage of the development process was to find the details of related work done in the field of Dentistry. Unfortunately there has not been much work done in the area of dentistry. There are teaching tools developed for Oral radiology but those are all limited to the normal anatomical structures seen on a radiograph. There has been limited work done in this area of development of a digital collection of dental radiographs that illustrated pathological lesions found in the oral and maxillofacial region. There are several reference atlases and books with CDs. These are all commercial products that one has to buy from commercial vendors.

There is a wealth of all types of radiographs in the teaching file folders that is not being put to optimum use because it is not well organized and currently not easily accessible. This was another encouraging factor to develop a web based tool that could help the students and the faculty to access these dental radiographs with ease.

This topic was further explored and searched in the medical literature for related work. The search revealed that the digital revolution and increasing trends in medical and dental digital imaging had increasingly shifted towards use of digital and multimedia files in education. To organize and index this information several types of databases have been created that hold all patient related information, such as the electronic health records, images etc. These databases have played an integral role in storage and organization of all types of information needs in a health care organization. The digital format of information has given the clinicians ease of access to all kinds of information from anywhere. A striking point noted was that conventional film based teaching files were
now quickly being replaced by the digital teaching files. Such tools were being used in many institutions, including UNC Chapel Hill Schools of Medicine and Dentistry. There have been several tools built to make use of this technology particularly in medicine. For example, www.images.MD is a very good digital collection of images and is a good resource for all clinicians and students to refer to various types of images but it does not have any dental images in it.

For dentistry and oral and maxillofacial radiology in particular not much work has been done in the area of creating a database of radiographs. Keeping in view the factors listed above developing a database to manage this information need was important. A resource of this kind has not been developed in dental domain. Currently the radiographs are stored in several folders by the name ‘teaching file images’, in the computers of department of Oral and Maxillofacial Radiology. There is a need for them to be organized in a manner that they are easily accessible, searchable and upgraded from time to time.

This project could also serve as one of the many ways of integrating information science skills to dentistry. This was a golden opportunity to explore and address a way to solve one of the information challenges faced by the dental domain.

Designing a database of digital radiographs that would be easy to maintain, inexpensive, and easily accessible for the end users seemed a logical solution.

The next phase in planning this project was to gather information about the functional requirements and design of the database. It was of paramount importance to scope the project and define a project within the given time limit.
The user group and their needs were identified. The design of the tool hinged on the user need. A good product design should address the user requirements and needs. Since there was a time constrain it was decided to produce a smaller ‘operational prototype’ of the bigger final product of a ‘digital library of dental radiographs’. The technology decisions addressed the final product while keeping in mind that work done in developing the prototype can be migrated and used in the development of the final product.

The methodology section of this manuscript discusses in detail the functional specifications, description of the steps taken in acquiring images, development of the database and the web interface. It also discusses the use of ‘cold fusion’ and ‘java script’ to integrate the database to the web interface.

The concluding section of this paper describes and discusses the success and failures of this project. The steps that could have been taken to improve it, the future plans to develop it further and the lessons learned from this project work.

1. STATEMENT OF PROBLEM

Images are a primary tool used across the medical curriculum to communicate information and share content when teaching and practicing medicine and Dentistry. In support of the electronic curriculum the health sciences educators and administrators are becoming more aware of the need for digital libraries. There are a number of articles that address the information needs of medical professionals but there are relatively few articles that have focused on the information needs of the dental professionals.
In a large institution like the School of Dentistry at UNC Chapel Hill, the department of oral and maxillofacial radiology forms the backbone and aids in the diagnosis and treatment planning. There are several types of radiographs taken and interpreted everyday and it is not uncommon to come across interesting cases. The radiographs of such cases are often used for teaching and future reference purposes in the teaching file folders. Currently these radiographs are not easily accessible because of lack of organization and availability on all the computers of the school.

A digital library of dental images would be a benefit to the UNC School of Dentistry for the same reasons it is useful for other branches of medicine where it has been used in other institutions and practice settings. Unfortunately, such a dental digital-image library is currently not in existence at this institution. There is a need of creating a digital library of dental radiographs that could be used by the dental students and faculty for teaching purposes or be used as a quick reference tool.

2. PURPOSE OF THE STUDY

The purpose of this project is to lay a foundation for the development of a dental digital-image library by mapping and describing the steps necessary for the development of such a library. The aim is to create an ‘operational prototype’ of a digital collection of Dental Radiographs for the Department of Oral and Maxillofacial Radiology at the School of Dentistry that could be used as an educational tool for the students. This collection might help instructors and faculty in particular as an instructional tool. The digital library of images could also be used by the students and the faculty as a quick reference tool in a dental operatory by helping them view the pathologies occurring in the
maxillofacial region, and helping them in drawing a diagnosis of an existing condition on a patient.

3. BACKGROUND

Training dental radiologists focuses primarily on an accurate and a speedy interpretation of the dental radiographs of the dental and the surrounding maxillofacial region. The teaching files remain the core element in the education of the dental students. The traditional method of building a radiological teaching file has been tedious and labor intensive. The teaching file used to be bulky, hard to maintain and had a very limited accessibility. The conventional film based system was costly, difficult to maintain, hard to index and information sharing with the peers was always a challenge with radiologists. The other disadvantages of this system were that it is not interactive and did not lead the learning student through a solution.

The birth of personal computers was the dawn of digitalization of information and the PC catalyzed an explosive growth of digital information. The digital form of information gave us more flexibility because of its non linear approach. Since the mid 80’s computers have become increasingly influential in medical and dental instruction (Howerton et al., 2004). Today most of the medical and dental institutions are going digital. The Radiology departments today are going film-less. A potential benefit of all-digital information is that the information can be stored, manipulated, transmitted, filed, and most importantly retrieved in a timely basis using affordable, readily available computer technology.
However many have discovered that the advent of digitalization is a mixed blessing; In particular, the sheer number of digital assets is overwhelming. With the growth of digitalization new challenges have emerged like organizing these digital files in a manner that is easily retrievable to the user. Sooner or later many find themselves worse off than before unable to find or locate a particular image among the countless others on hard drives, CDs etc. (Gomoll A.H., & Thornhill T.S., 2004)

These challenges are faced by both the medical and dental radiologists. Maintaining a collection of radiographic images is cumbersome and expensive. Recent advances in digital and diagnostic images and filmless radiography offer the potential for a better method of maintaining such a collection (Richardson, M.L., & Gillespy, T., 1993) There have been a number of articles and databases designed in the medical domain to create teaching files. In 1993 Richardson and Thurman described an inexpensive way to build a computer based digital imaging teaching files and addressed the issue of high cost involved in the building of such databases. In another article Roach and Thune described creating a digital radiographic teaching file and Database using a PC and common software. They designed a database that could be saved in a standard format using readily available software. Users of this database could save images in a jpg format allowing their easy incorporation into other programs (Tran et al., 2000).

Henderson and Camorlinga in their article stated that in spite of the advances in the digital technology in the radiology departments, the teaching files have not yet seen the application of this new technology. Part of the reason could be due to the poor or incomplete implementation in many of the commercial software packages. The authors
have utilized free software from the internet, and created a teaching file which is web-based, easy to operate, cost effective and secure (Blair, H., et al., 2004)

However there has not been much work done in this area in dentistry. Ludlow and Platin point out those dental educators have been slow to incorporate varied media into their curricula. (Ludlow J.B., & Platin, E., 2000)

Titus Schleyer suggested that one explanation for this may be many institutions are faced with a support service crisis. Implementation of computers, user training, and expansion of user base creates more demand, requiring upgraded hardware, more training and expanded support.” The development of web based or computer based teaching files are costly both in time and effort. However once developed these systems can be modified or updated. (Schleyer T., 1999)

Dental education administrators have been making extensive efforts to the available technology and make optimal use of potential benefits of computer technology for teaching. The results of a study conducted by Fleming 2003 suggest that there is a need to encourage dental educators to develop materials and tools that enhance clinical learning and didactic instruction. In another study Bruce concluded that students preferred the interactive instructional program because of convenience and ease of navigation. Based on the results of the above studies there is a need in dentistry and in oral and maxillofacial radiology in particular to develop teaching files that are easily accessible both by the students and the faculty. (Fleming et al., 2003)

As stated earlier there has been a good amount of work done in the medicine. But its use in dentistry in general and dental radiology in particular has not been explored completely and its practicality is still ambiguous. The teaching formats which were made
with the aim of making learning an easy and enjoyable task, has actually made it difficult for students to appraise and steer freely without having to search for specific subject content. So far some work has been done on annotations of normal anatomical landmarks on radiographs but there is collection of dental radiographs where pathological conditions are annotated in dentistry.

Therefore, to address this specific problem of accessing and interaction with digital information in the department of Oral and Maxillofacial Radiology at the School of Dentistry, UNC at Chapel Hill, this teaching tool is being developed in the form of a digital collection of radiographic images.

This collection might help the students and the instructors for learning and teaching purposes. A searchable interface can save time and make information accessible with ease is constructed.

5. METHODOLOGY

5.1 Introduction

Digital dental radiographs now form the backbone of a patient’s diagnosis and treatment planning. It is also crucial to keep these digital radiographs in easily accessible for reference by the students and faculty. A dental student or a dental faculty member should be able to readily retrieve the images from any location.

The aim of this project is to create a digital collection of radiographs for the Department of Oral Radiology at the School of Dentistry at UNC at Chapel Hill that could be used as an educational tool for the students and as a quick chairside reference tool. One of the most important benefits and applications of providing this information
online is to provide an electronic learning tool for the students to be able to benefit from a good quality resource of radiographs of dental pathologies. The Health Sciences Library at UNC could also have a link to this collection so that the students and faculty are able to access this information from there. Librarians at the Health Sciences Library at UNC can use this database in case there is a query from a student about dental radiograph resources.

5.2 Image selection

5.2.1 Location of images

The first step that initiated this project was collection of digital dental radiographs. The digital radiographs were all housed in the computers in the department of oral and maxillofacial radiology in the School of Dentistry at UNC, Chapel Hill. Since this project related to the development of a library of dental digital radiographs the existing teaching file folders were utilized. There were several folders with hundreds of digital radiographs in each folder.

5.2.2 Basic concepts of digital imaging

Before proceeding further it is important to understand the basic concepts of digital imaging. A natural image is an uninterrupted arrangement of shades and colors. In case of a photograph shades vary from light to dark colors. An image of this type is known as a continuous tone image. This means that the various shades and color blend with no disruptions.
5.2.3 Concept of gray–scale continuous tone image

All images especially radiographs are made up of levels of gray varying from black to white. A digital radiograph is composed of discrete points of gray tone, or brightness rather than continuously varying tones. To make a digital image from a continuous-tone image it must be divided up into individual points of brightness. Each point of brightness must be described by a digital data value. The process of breaking up a continuous tone image determining digital brightness values are referred to as sampling and quantization. The sampling process samples the intensity of each sample ranging from black to white through the tones of grays.

5.2.4 Quantization process

The quantization process determines the digital brightness. A quantized sample is referred to as a pixel or picture element. It represents a discrete picture element of the digital image. The combination of sampling and quantization process is referred to as image digitalization. The quality of a digital image is directly related to the number of pixels and lines, along with the range of brightness values, in the image. These aspects are called as the image resolution.

5.2.5 Image resolution

Image resolution can be defined as the capability of the digital image to resolve the elements of the original scene. For digital image, the resolution characteristics can be broken into two primary parts

- Spatial resolution
- Brightness resolution.
5.2.5.1 Spatial Resolution

The term spatial resolution in a radiograph refers to a two dimensional space to describe how many pixels comprise of a digital image. The more pixels in the image sampled for given spatial physical size, the greater is the ‘spatial resolution’. The number of pixels in a digital image depends on how finely we sample and divide the image into discrete pixels. The measurement of spatial resolution of and image is related to its spatial density and its optical resolution. Optical resolution is a measure of the capability of how the entire physical imaging system can resolve the spatial details of an original scene.

5.2.5.2 Brightness resolution

The concept of brightness resolution addresses how accurately the digital pixel’s brightness can represent the intensity of the original image. Every pixel in a digital image represents the intensity of the original image at the spatial location where it was sampled. When the numeric range of a pixel’s brightness is increased, so is the pixels brightness resolution.

5.3 Criteria for selection of Images

All the radiographs were collected from the computers at the department of Oral and Maxillofacial radiology computers at UNC School of Dentistry at UNC-CH. After taking the permission from the director oral and maxillofacial radiology the radiographs were accessed.

The following steps were carried out in selection of the digital radiographs:

- The first step was to make sure that none of the radiographs selected had any patient information on them.
• Reformatting the images: All the radiographs were selected from the teaching files and the image folders present in the computers and the department of Oral and Maxillofacial radiology. There are hundreds of radiographic images that are randomly stored in the folders. They are not arranged or indexed in any specific order.

• All the images are stored in .pcd extension. The first step was to identify ways to convert the images to a .jpg format. Adobe Photoshop was one of the editors that could help accomplish this. It was also important to explore what PCD stands for. PCD stands for Photo CD and means a high resolution format for images on a CD. It was developed by Kodak. A PCD file contains five different resolution (ranging from low to high) of a slide or film negative. Due to it PCD is often used by many photographers and graphics professionals for high-end printed applications.

PCD files can be accessed in a variety of dimensions and color depths, which is quite handy, and the format is good at encoding and storing authentic color information. The PCD files are typically 4 to 6 MB in size and, therefore, take some time to transfer via the web.

The images were reformatted from a PCD format to jpg format using an adobe Photoshop.

• Image size

The term "image size" is generally used for two things:

• The actual size on the screen or the dimensions in width and height of an image are measured in pixels.
For this project we want the images to be displayed in their maximum resolution and a size that allows the user to view the image clearly.

- Image resolution

As discussed earlier images are made up of dots (called pixels) that combine to create the shapes and colors of an image. Resolution is the number of these dots, or pixels, appearing in the space of one inch. Images for the Web are set at 72 DPI (dots per inch), or 72 pixels per inch. We conformed to these definitions.

- Annotation of the Digital radiographs

For this project the radiographs were annotated using the Adobe Photoshop software. The area where the pathology existed was identified and then annotated using the arrow tool.

5.4 Classification of Images

The images were classified as per the pathology present and hierarchical-top level/sub-level classification was used. This classification is most commonly used in dental radiology and is based on types of pathologies found in the maxillofacial region.

For the purpose of this project one hundred images were selected based on the above classification of pathologies in oral and maxillofacial region.

Radiographs of all the pathologies listed were not available but all the names are included in the image database so that the database can be upgraded periodically as and when the images are available.
Jaw Pathology

Inflammatory lesions
- Acute
- Chronic

Tumors
- Benign
- Malignant

Cysts
- Odontogenic cyst
- Non-Odontogenic cyst

Odontogenic
- Epithelial
- Mixed origin
- Mesenchymal origin
- Neural origin
- Mesodermal origin
- carcinomas
- sarcomas
- Malignancies of the Hematopoietic system

Non-odontogenic
Details of the Classification

- Inflammatory Lesions of the Jaws
  - Acute Lesions
    - Acute Periapical Inflammatory Lesions
    - Acute Pericoronitis
    - Acute Osteomyelitis
      - Acute Phase (acute suppurative osteomyelitis, pyogenic osteomyelitis, subacute suppurative osteomyelitis, proliferative periostitis, periostitis ossificans)
  - Chronic Lesions
    - Osteoradionecrosis
    - Chronic Osteomyelitis (Chronic diffuse sclerosing osteomyelitis, chronic non suppurative osteomyelitis, chronic osteomyelitis with proliferative periostitis, Garre's chronic nonsuppurative sclerosing osteitis)

- Cysts of the Jaws
  - Odontogenic Cysts
    - Radicular Cyst (Periapical cyst, apical periodontal cyst, dental cyst)
    - Dentigerous Cyst (follicular cyst)
- Buccal Bifurcation Cyst (Mandibular infected buccal cyst, Paradaental cyst, inflammatory collateral dental cyst)
- Odontogenic Keratocyst (Primordial cyst)
- Basal Cell Nevus Syndrome (Gorlin-Goltz syndrome, nevoid basal carcinoma syndrome)
- Lateral Periodontal Cyst
- Calcifying Odontogenic Cyst (Calcifying epithelial odontogenic cyst, Gorlin cyst)
- Non-odontogenic Cysts
  - Nasopalatine Duct Cyst (Nasopalatine canal cyst, Incisive canal cyst, nasopalatine cyst, median palatine cyst, median anterior maxillary cyst)
  - Nasolabial Cyst (Nasoalveolar cyst)
  - Dermoid cyst
  - Simple Bone cyst

- Benign Tumors of the Jaws
  - Hyperplasia
    - Torus Palatinus (Palatine torus)
    - Torus Mandibularis (Mandibular torus)
    - Other Exostoses
    - Enostoses
  - Odontogenic Epithelial Tumors
- Ameloblastoma (Adamantinoma, adamantoblastoma, adontomes embryolastiques, epithelial odontoma)
- Calcifying Epithelial Odontogenic Tumor (Pindborg tumor)
- Odontogenic Mixed Tumors
  - Odontoma (compound odontoma, compound composite odontoma, complex odontoma, complex composite odontoma, odontogenic hamartoma, calcified mixed odontoma, cystic odontoma)
  - Ameloblastic Fibroma (soft odontoma, soft mixed odontoma, mixed odontogenic tumor, fibroadamantoblastoma)
- Odontogenic Fibro-Odontoma
- Adenomatoid Odontogenic Tumor (adenoameloblastoma, ameloblastic adenomatoid tumor)
- Odontogenic Mesenchymal Tumors
  - Odontogenic Myxoma
  - Benign Cementoblastoma (cementoblastoma, true cementoma)
  - Central Odontogenic Fibroma (simple odontogenic fibroma, odontogenic fibroma)
- Non odontogenic tumors
  - Benign Tumors of Neural Origin
    - Neurilemoma (schwannoma)
    - Neuroma (traumatic neuroma, amputation neuroma)
    - Neurofibroma (neurinoma)
    - Neurofibromatosis (von Recklinghausen's disease)
o Mesodermal Tumors
  o Osteoma
  o Gardner's Syndrome (Familial multiple polyposis)
  o AV fistula
  o Osteoblastoma (Giant osteoid osteoma)
  o Osteoid Osteoma
  o Desmoplastic Fibroma of Bone (aggressive fibromatosis)

- Malignant Lesion of the Jaws
  o Carcinomas
    o Squamous Cell carcinoma in Soft Tissue (epidermoid carcinoma)
    o Squamous Cell carcinoma in Bone (primary intraosseous carcinoma, intraalveolar carcinoma, primary epithelial tumor of the jaw, central squamous cell carcinoma, odontogenic carcinoma)
    o Squamous Cell carcinoma in a Cyst (epidermoid cell carcinoma, carcinoma ex odontogenic cyst)
    o Central Mucoepidermoid Carcinoma (mucoepidermoid carcinoma)
    o Ameloblastic Carcinoma
  o Metastatic Tumors (secondary malignancy)
  o Sarcomas
    o Osteosarcoma (osteogenic carcinoma)
    o Chondrosarcoma (chondrogenic carcinoma)
    o Ewing's Sarcoma (endothelial myeloma, round cell sarcoma)
    o Fibrosarcoma
• Malignancies of Hematopoietic System
  o Multiple Myeloma(myeloma, plasma cell myeloma, plasmacytoma)
  o Non_Hodgkin's Lymphoma(malignant lymphoma, lymphosarcoma)
  o Burkitt's lymphoma(African Jaw lymphoma)
  o Leukemia(Acute myelogenous leukemia, acute lymphoblastic leukemia, chronic myelogenous leukemia, chronic lymphocytic leukemia)

5.5. Technology Overview

For this project two database solutions were investigated MS Access and MySQL. Each of the system provides an SQL compliant relational database which allows access to multiple users.

MySQL was evaluated, it is an open source SQL compliant client/server database. It can be freely downloaded from www.mysql.com. There are several advantages of this system in the form robustness, high retrieval, speed, accuracy and most importantly its easy integration with other web technologies such as Apache web server and PHP application server. All these products (i.e. MySQL, apache web server and PHP) are freely available through open source, and are very flexible, cost effective and robust. They form a very effective combination and form of web application framework. This is typically referred to as a LAMP (Linux, Apache, MySQL, and PHP) setup.
Other advantages of MySQL are its capability to efficiently handle extremely large databases. It supports a myriad of operating systems, web servers and application servers including IIS server.

MS Access was the other system that I evaluated. MS Access has much to offer in terms of ease of use. The other advantage was that almost all computers in the School of Dentistry have MS Access. It was an advantage to share the database design and the queries with the dental radiology faculty during the development of the database.

MS Access has an easy graphical user interface for performing all tasks involved in creating, populating and querying the database. There are various built-in functions like the wizard that helps and walks through the process of selecting tables, fields and condition to construct appropriate queries. It also provides an advantage of graphically displaying the relationship between the tables in the database. Access can be easily transferred to an SQL database.

MS Access also has certain disadvantages; it suffers in the areas of performance and scalability. MS Access is not a true client/server database system; instead it uses a file-system database model. The model requires the user of the database to access the same physical copy of the database in order to edit or make changes in the database. This is a serious handicap.

For the purpose of this project MS Access was chosen. The reasons were familiarity and training to use MS Access during course work in ‘introduction to database’ course. It was best suited for creating an ‘operational prototype’ of the final envisioned product, because of the various functionalities of this system (like the ease to
discuss the project and clearly design the queries). The data can be migrated from MS Access to SQL server.

Since this prototype was to be housed in the School of Dentistry server further investigations were done to find the type of server hosted by the school. School of Dentistry has an ‘Internet Information Server’ (IIS) which is a powerful web server that provides a highly reliable, manageable and scalable web application infrastructure for all versions of window server 2003.

During the project development process it was also discovered that PHP hypertext preprocessor language would not work in IIS environment. Investigations revealed that a basic knowledge of cold fusion or visual basic was essential to integrate the web interface with the database.

‘Cold Fusion’ is an application server and software development framework used for the development of computer software in general, and dynamic web sites in particular. In this regard, ‘Cold Fusion’ is a similar product to Microsoft ASP.NET, Java Enterprise Edition or PHP. In terms of flexibility it falls between ASP.NET and PHP. By the use of ‘cfm’ tags and special characters one can insert code into the body of html pages to retrieve and display data dynamically. These features made ‘cold fusion’ a clear choice over PHP or Microsoft ASP.net to display data dynamically.
5.6 Database Design

5.6.1 Stakeholders

UNC dental students and faculty would form the core group of users while new students during their orientation can be informed about such an existing resource.

The user group of this database consists of:

- Dental students, including
  - Under graduate students
  - Graduate students especially those who are residents in the disciplines of oral and maxillofacial radiology
  - Dental hygiene students

- Dental faculty
  - Faculty members of oral and maxillofacial radiology
  - Generalists and specialists in general
5.6.2 User roles

The user roles can be divided into three groups:

- **The student group**
  
The student group would use the system for learning, presenting papers and referencing.

- **Faculty**
  
The faculty would access the system primarily to access information for teaching purposes, for example while guiding the student and helping him/her to understand the characteristics of particular jaw pathology. This tool could also be used for clarification of diagnosis.
  
The faculty role may also be in posting a new image on the system with the help of a system administrator.

- **System administrator**
  
The System administrator would be involved with the ongoing up gradation and expansion of the system and add images or information while often working hand–in-hand with the oral radiologist at the School of Dentistry UNC at Chapel Hill.

5.6.3 User Requirements

The system is designed to address the following tasks:

a) Display the non annotated and annotated images of the maxillofacial facial lesions
b) Enumerate the lesion types and subtypes in the hierarchical tree of the commonly accepted maxillofacial pathology classification
c) Ease of search for the information in the database according to name, type, subtype of the image.
d) Storage of new images

5.6.4 Use case Scenarios

5.6.4.1 Introduction

This section describes the main tasks for the system, including the task hierarchy diagrams for each task. To understand in detail the user task a detailed task analysis is used to investigate the purpose of what the end users are trying to accomplish, why are they trying to accomplish it and how are they accomplishing it. The task hierarchy diagram shows a detailed breakdown of a task down to its subtasks, and further into the subtasks. The use cases are included in this section to identify the main tasks.

Ivar, J., in 1992 was the first to introduce the concept of a use cases. Use cases are short stories using a system to meet goals of the patrons and the end users of that system. A complete set of the use cases will specify the different ways to use the system and defines all the various characteristics needs for the system.

Sharp et al., suggests that use cases allow a designer to understand the functionality of a system by describing different tasks or uses. To conceptualize the system functionalities use cases were drafted based on the clinical setting at the School of Dentistry. Since I had interacted with the students I was aware of the level of expertise and subject knowledge they had in the area of oral radiology and oral pathology.
5.6.4.2 Use case: Student interaction

Figure 3- Accessing the Database

Table 1: Use case: Student/Faculty accessing the database

<table>
<thead>
<tr>
<th>USER INTENT</th>
<th>SYSTEM RESPONSIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicks on the saved URL: <a href="http://www.dent.unc.edu/test/dldrg">www.dent.unc.edu/test/dldrg</a></td>
<td>Requests for user name and password</td>
</tr>
<tr>
<td>Supply information in fields</td>
<td>Validate required fields</td>
</tr>
<tr>
<td></td>
<td>(Display Error Message)</td>
</tr>
<tr>
<td></td>
<td>(Resubmit missing or in-use information)</td>
</tr>
<tr>
<td></td>
<td>(Re-validate submission)</td>
</tr>
<tr>
<td></td>
<td>Displays home page</td>
</tr>
</tbody>
</table>

Scenario: Jack a final year DDS student has just come to know of the new online resource of the Digital dental radiographs through the email.

Jack enters the URL: www.dent.unc.edu/test/dldrg

The system prompts him to enter his dentistry domain user name and password.
Jack enters his user name and password and enters login.

Enters the URL: 

The system gives him any error message because he has accidentally filled in wrong information. He fills in the password again and re submits the login information. The system verifies his user name and password and displays the main page of the digital collection of dental radiographs.

5.6.4.3 Searching the database

![Diagram of searching the database process](image_url)
<table>
<thead>
<tr>
<th><a href="http://www.dent.unc.edu/test/dldrg">www.dent.unc.edu/test/dldrg</a></th>
<th>Prompts for entering user name and password</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Intention</td>
<td>Verifies the information</td>
</tr>
<tr>
<td></td>
<td>Displays the homepage of digital library</td>
</tr>
<tr>
<td>Selects the type of lesion in the search box and submit the search (for example: Cysts)</td>
<td>System populates the second search box with the sub type of the lesion. (example: Odontogenic or Non-odontogenic cysts)</td>
</tr>
<tr>
<td>Selects one of the subtype of lesion in the second search box</td>
<td>Populates the third box with the names of the lesions</td>
</tr>
<tr>
<td>Selects the name of the lesion and submits the search</td>
<td>Displays the non-annotated radiograph of the lesion</td>
</tr>
<tr>
<td>(Not sure where to look for the lesion) User clicks on the radiographs</td>
<td>Displays the annotated radiograph (the arrows point to the lesions)</td>
</tr>
</tbody>
</table>

Table 2: Use Case 2: Student/faculty interactions
Scenario: Search the database

Ash is a final year DDS student and she has just returned from her fall break. On the first day of her return she realizes that she has a radiology quiz coming up the next day. With so little time and so much to go through she wants to get to the database so as to quickly review the jaw pathologies.

She enters the Digital library of dental radiographs homepage by clicking on the saved URL: http://www.dent.unc.edu/test/dldrg. The system prompts her to enter the user name and password. She enters her dental user name and password and submits. The system verifies her information and displays the main page.

Ash wants to view the radiographs of ‘Dentigerous cyst’. In the first search box she chooses the option of cysts. The system populates the second box with the type of cysts as ‘Odontogenic cysts’ or ‘Non-odontogenic cysts’. Ash knows that ‘Dentigerous cyst’ is a type of ‘Odontogenic cyst’. So she chooses ‘Odontogenic cyst’. The system populates the third search box and requests to choose the name of the cysts she wants. Ash chooses ‘Dentigerous cyst’ and hits search and the system displays the image of the ‘dentigerous cyst’.

After the image is displayed Ash is not sure the location of the lesion and wants to be sure. To check she clicks on the displayed image and the system displays the annotated image, with the arrows that are pointing to the boundaries of the lesion on the radiograph.
5.6.4.4 Search by Browsing

Figure 5- Search by Browsing
Table 3: Search by browsing

<table>
<thead>
<tr>
<th>User Intention</th>
<th>System responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displays the homepage of digital library</td>
<td></td>
</tr>
<tr>
<td>Clicks on the type of lesion in the browse section</td>
<td>System displays the webpage with hyperlinks to the individual names of the lesions</td>
</tr>
<tr>
<td>Clicks on the hyperlink of the name of the lesion</td>
<td>Displays the non-annotated radiograph of the lesion</td>
</tr>
<tr>
<td>(Not sure where to look for the lesion) User clicks on the radiographs</td>
<td>Displays the annotated radiograph (the arrows point to the lesions)</td>
</tr>
</tbody>
</table>

Scenario: Search by browsing

John Smith has just entered his third year DDS and he is started his oral pathology classes where he is learning different types of jaw pathologies. He is not very familiar with classification, the sub categories of the jaw pathologies. He wants to know what the various types of malignant tumors are. When he gets to the main page of the Digital Library of Dental images he chooses the browse option.
At a glance it is clear to him that there are three sub categories under the malignant tumors namely carcinomas, sarcomas, and the ‘Malignancies of the hematopoietic system’. John is curious to find out the names of the lesions listed under each of the subcategory. He clicks on carcinomas and the system displays him with all the names of the carcinomas in the collection. John clicks on names and views the radiographs of the various carcinomas listed one by one.

5.7 Design development

After a careful evaluation of the technology on hand and the user needs the development of this project was undertaken. Dr Brad Hemminger’s guideline ‘separate content from presentation’ was followed throughout the development of this project.

The first step in development phase of the project was to carefully define the data characteristics that needed to be stored in the database. An ER diagram for the database design was drawn to create the necessary tables for storing the data. To be able to achieve this it was important to classify the radiographic images according to the most commonly used classification for ‘jaw pathologies’. A background in dentistry was helpful in identifying and making a the most appropriate choice of classification. There was some difficulty faced in representing the design of the database. It took several iterations to come up with a simple design that addressed all the aspects of classification.

While drawing the EER (enhanced entity relationship) model the subclass and superclass concept and the concepts of specialization and generalization were kept in mind. In this case the ‘jaw pathology’ was the superclass and the ‘types of jaw
pathology’ as subclasses of ‘jaw pathology’. This relationship is a superclass/subclass relationship. The subclass member in this case is the same as the entity in the superclass but in a distinct specific role. An important concept associated with subclasses is that of type of inheritance. In this case the entity inherits all the relationships in which the superclass participates. The subclass at the same time has its own specific attributes and relationships. Together with all the attributes and relationships it inherits from the superclass it is considered an ‘entity type’ in its own right. (Elmasri, R., & Navathe, S.B., 2006)

For this project it was decided to focus on the most commonly used classification of jaw pathology in radiology. There were certain exclusions made (like other possible classifications based on the type of radiographic features, or signs and symptoms). Designing a database addressing all types of classifications would be the ‘big picture’ and would need much more time, planning and effort.

Once the ER diagram was made the next step was to construct the tables in MS Access and establish the relationship. For this database each name of the lesion had one or more images associated with it.

The image table was assigned a two part primary key the pathology identification (P_ID) and Image identification (I_ID). To test the database the tables were populated with ten entries each and the database was queried. Several queries were designed and the database was searched from different facets ranging from type of pathology, origin of pathology, name of pathology.
Figure 6 - ER Diagram
Jaw Pathology

Inflammatory Lesions

Cysts

Benign Tumors

Malignant Tumors

Images

Figure 8- Schema of the Database
5.8 Terminology

There were two types of terminology issues while designing the database.

a) Terminology used for the names of the lesions for jaw pathologies: The terminology of several jaw pathologies have one or more alias for example an ‘Ameloblastoma’ can also be called as an ‘Adamantinoma’. For the purposes of this project the names of the lesions used when the image was displayed were the most common names used by the dentists at School of Dentistry at Chapel Hill. Various graduates were consulted to get this information. This issue was also addressed in the web interface display where most of the aliases were displayed.

b) The terminology used in the database tables needed some adaptation and had to be kept as simple and clear as possible for the database administrator who would use the database to update the information. The titles used in the database were self explanatory and simple to understand. For example- Inflammatory lesion type, cyst type, tumor type etc.

Table 4: Data dictionary

<table>
<thead>
<tr>
<th>Entity</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaw Pathology</td>
<td>Abnormal lesions occurring in the oral and maxillofacial region. For this project we considered three types of lesions. i.e. Inflammatory lesions, cysts and tumors.</td>
</tr>
<tr>
<td>Inflammatory lesions</td>
<td>An abnormal or a destructive change in the oral and maxillofacial region (relating to the upper and lower jaw and face) such as an infection that leads to inflammation or swelling</td>
</tr>
<tr>
<td>Cysts</td>
<td>An abnormal sac containing gas, fluid, or a semisolid material occurring in the maxillofacial region (relating to the upper and lower jaw and</td>
</tr>
</tbody>
</table>
• Malignant tumors  A cancerous tumor which has the ability to invade surrounding tissue or other parts of the body occurring in the maxillofacial region (relating to the upper and lower jaw and face)

• Benign tumors  A tumor that growing locally in the maxillofacial region and that does not spread to other parts of the body

• Images  An image produced on film by X-rays or a radiograph that are of the teeth and the surrounding structure.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I_ID</td>
<td>Unique identification number of the images table</td>
</tr>
<tr>
<td>P_ID</td>
<td>Unique identification of jaw pathology</td>
</tr>
<tr>
<td>Type</td>
<td>The type of jaw pathology (like Inflammatory lesion, cyst, tumors)</td>
</tr>
<tr>
<td>Name</td>
<td>Unique name of the jaw pathology</td>
</tr>
<tr>
<td>Inflammatory lesion type</td>
<td>An inflammatory lesion could be acute or chronic</td>
</tr>
<tr>
<td>Cyst type</td>
<td>A cyst could be odontogenic or non-odontogenic</td>
</tr>
<tr>
<td>Malignant tumor type</td>
<td>A tumor that could be carcinoma, sarcoma, or hematopoitic system.</td>
</tr>
<tr>
<td>Benign tumor type</td>
<td>A benign tumor could be of odontogenic or non-odontogenic</td>
</tr>
<tr>
<td>Annotated image</td>
<td>A digital image displayed with an annotation used in the form of a superimposed arrow on a digital radiograph showing the lesion without changing the underlying raster image</td>
</tr>
</tbody>
</table>
Non-annotated image | A digital radiograph displayed in its normal format without any annotations.

Figure 9: Screenshot of the tables Populated with data
5.9 Web interface design

A pleasing and a simple web interface that is self explanatory was the aim on mind while designing the web interface. The color coding was kept similar to the colors of the school of dentistry website as the plans are to house the database on school of dentistry web server. The banner was designed using adobe Photoshop and named as ‘Digital Library of Dental Radiographs’.

The url for this digital library is http://www.dent.unc.edu/test/dldrg

5.9.1 Creating a web space

The ‘Office of Computing and Information Systems’ (OCIS) was contacted so that they could allot the web space to house this collection. It was desirable to have a space to
house the image folder, the database, and all the related HTML pages on the School of Dentistry server. It was also of importance to involve the department of OCIS since the future maintenance and expansion of this project would be handled by them.

Web administrator Tim Murphy at the department of OCIS created a folder on the dentistry web server. The folder was created in the test directory on the dental server and was named as ‘dldrg’ (Digital Library of Dental Radiographs) It was restricted to authorized users that are currently Tim and I. It was ensured that this collection was made available to the dentistry domain for the end users to view it once it was ready.

5.9.2 Web interface Design Decision

Basic page layout

Criteria: To create a unique product that addresses to the users’ needs. The content should be logically and clearly presented in an appropriate manner for our target audience.

Evidence: Home pages of three websites of digital library of images were referred and a competitor analysis was conducted. An exhaustive understanding of unique design decisions taken by other websites to address the needs of their domain is helpful in creating a good web interface. The ultimate, aim is to have a web interface that is “more attractive” to users and it should enable them to accomplish various desired tasks. The criteria used in this analysis were based on information from IBM Ease of Use: Design Basics, from http://www-03.ibm.com/easy/page/6.
Table 6: Competitor Analysis

<table>
<thead>
<tr>
<th>Evaluation criteria</th>
<th>images.md/</th>
<th>images.fws.gov/</th>
<th>Openvideo.org</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the homepage clear in purpose?</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Is it useful or relevant to the audience?</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Is the page helpful in accomplishing tasks easily?</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Is the presentation attractive, interesting and engaging?</td>
<td>somewhat</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Is information organized for the needs of the target audience?</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Is the interface busy?</td>
<td>Somewhat</td>
<td>somewhat</td>
<td>No</td>
</tr>
</tbody>
</table>

The literature was also examined for guidelines on web interface in order to determine how best to design the page.

“Homepages are the portal through which most visitors pass. They must seduce visitors while simultaneously balancing many issues, including branding, navigation, content, and the ability to download quickly.” (Van D.A., Landay, J. A., & Hong, J. I., 2003).

Discussion of Evidence: The competitor analysis revealed that the design of the sites was split; two of the sites were somewhat busy for the users. One site was very attractive and relatively simple to follow by the users. Overall, the evidence suggested that “flashy” elements should be avoided. Furthermore, the evidence suggested that users like simplicity in certain respects, but they also desire a design that creates an impression –
i.e. not so simple that the page is easily forgotten. Ultimately, users desire an interface design that is easy to follow and pleasing.

**Decision:** The webpage design is both simple, yet has substantive content and a moderate amount of graphics. The consideration to design the layout of the webpage was to match it with the Dental school website. For this purpose the same color schema and design was used. The web pages were made simple for the user to search and browse. At this point the database provides a smaller version of the bigger picture and suggests a method to solve the problem on hand by creating a database based on the schema described.

The main search interface enables the user to choose the type of lesion and conduct the search according to the hierarchical classification described above. The web interface gives the user the flexibility to search or browse the database.

A basic search box was something all users would like to see and use as they are familiar with search interfaces such as the Google, UNC Health sciences Library etc. Three drop down search boxes were created.

The first box gave the user the option to choose the type of jaw pathology (for example: Cysts of the jaws, benign tumors of the jaw or malignant tumors of the jaws) Once the user chose anyone of the type the second dropdown combo box would get populated, the user could choose the subtype of the lesion and based on the sub-type of the lesion selected the third box would be populated with the appropriate names falling under that sub-type. The user can hit the search button and the system would display the image from the database.
It was ensured that the web page design and layout conformed to the usability.gov guidelines. The basic elements (like an easy navigation, breadcrumbs) of a webpage that make the navigation of the website simpler were incorporated.

Figure 11- Screenshot of the Home page
Figure 12- Screenshot of the Image displayed

Figure 13- Screenshot of the Annotated image
5.10 Integration of web Interface with database

The HTML pages were linked to the database using Cold fusion. Cold fusion takes the information from the drop down menu boxes or when the user clicks on the name of the image. It communicates and processes the request and pulls out the necessary data from the database.

6. CONCLUSION

This project resulted in an operational prototype of a digital library of dental radiographs. This database was developed intending to provide a more flexible and intuitive system to organize and view digital dental radiographs. The proposed system overcomes several limitations of the current method of storage and organization of the digital radiographic images. The proposed system is simple to use, and easy to maintain. Once the database is tested by the users it can easily be scaled up. The data can be migrated to any SQL database system. The web interface is coded in HTML and the ‘Cold Fusion’ is used as the preprocessor language.

The system is flexible and adaptable to future need. This proposed approach allows for an easy storage, classification, viewing, editing and sharing of the radiographs. This collection can be further improved by adding more features to the search criteria. More types of jaw pathologies can be added to this collection by adding tables to the existing schema.

Throughout the process of development of this project the specifications of the project kept on changing and there were constant updates involved especially during the phase of integrating the web interface to the database. Overall this project was a great
learning experience. From the inception stage to the final stages at every step there was a lesson learned.

During the information gathering phase the end users requirements, expectations, were very valuable in conceptualizing the design of the database. Prioritizing the information gathered and evaluating the user needs were most important in designing the functionality of the system.

A project of this magnitude required a lot of skills in developing the prototype, e.g. knowledge of basics of databases, HTML coding, PHP etc. During this course it was learned that knowledge of ‘Cold Fusion’ and ‘JavaScript’ were of great importance. It was important to have investigated this in earlier stages of this project, rather than later as it would have given more time to get a better grip of these scripting languages.

Due to time constrains the prototype could not be formally tested for its usability by the end users. This project does provide the department with a schema that could organize the radiographs and create an image bank for the personal use of the department.

Regardless of the shortcomings of the project management and planning areas, there are several features of the prototype that are highly successful.

The most successful feature incorporated into the design was the schema of the database. It was ensured that the final schema was simple and easy to upgrade by the future users of this database. The content of the database was separated from the presentation. The tables of the database can be upgraded or altered easily. The image folder is kept separate and each time an image is to be added it can be added to the image folder with an appropriate name and a link to that image be in the appropriate database table.
The query building process in MS Access can be easily used to design simple and complicated queries. It enables a novice user to understand better the process involved in query building. An expert can easily view the same query in MySQL. The writing of the ‘Cold Fusion’ code was a steep learning curve but this enabled the successful integration of the web interface to the database.

The most important lesson learned during the course of this project was dealing with ‘feature creep’. As a developer, it is important to be more cautious about acknowledging the ability to modify the system in certain ways merely to cut down on the amount of changes which seem to be continually required. This was especially true for this project because with increased involvement in the development, the wish list to have more features incorporated kept growing and the boundaries of limitation of skills involved to accomplish a task was stepped over to include those features. For the success of building such a tool the understanding of the database design and function is of paramount importance.

The future of this project is not assured, but it is expected that with the help of the collaborative efforts of the department of ‘Oral and Maxillofacial Radiology’ and ‘Office of Computing and Information Systems’ at the School of Dentistry this project will reach its original goal. There is still room for improvement to give complete flexibility to the user for conducting a free text search, or have a floating menu but as mentioned earlier that it is beyond the scope of this project.

Overall the goal of this project has been accomplished by producing an easy to use operational prototype of the final product. This digital library of dental radiographs
can serve as an image data bank for the department of Oral radiology, and an effective resource and a teaching tool for School of Dentistry, UNC at Chapel Hill.

7. FUTURE PLANS

The future plans of this project would include:

- Formal testing of the database by the users based on the feedback from the current users. Certain changes may have to be made after the finished product has been thoroughly tested by conducting a full scale ‘usability testing’. Those results can help and serve as an evidence for refining the final product.
- After this operational prototype is tested the data can be transferred to MySQL database. MySQL is a better and a more robust system, designed for speed and accuracy. A better and more extensive database can be developed and this will not be an issue as the dentistry server hosts and supports MySQL.
- This ‘operational prototype’ provides a basic schema and can be used in expansion of the database by including images of other jaw pathologies that have not been included like ‘systemic diseases in the jaws, systemic diseases of the bones manifested in jaws’ etc.
- This schema could also be used in developing digital collection of maxillofacial CT scans, cone beam CT images and MRIs.
- The same schema could be expanded and one could develop and produce a ‘computer assisted diagnosis’ tool.
It would not be possible for me to see these plans materializing before my graduation; This project would be handed over to the Department of Oral and Maxillofacial Radiology the OCIS. Both the departments can work in collaboration and pursue this project further. The final product would be the bigger picture of this ‘operational prototype’ being presented to them.

8. LESSONS LEARNED

The most important lesson learned during this project development was the changing features of the database. It was an ambitious aim of developing a database with all the functionalities, but as the development process progressed, there were shortcomings that surfaced. Having a more cautious approach for the task undertaken could prevent feature creep. A system with complete functionality was envisioned, but due to the lack of complete knowledge of scripting languages advanced features like free text search or a floating menu was could not be embedded into the system. The prototype has limited functionality. The practical experience gained was that projects of this magnitude take longer and more experience in execution.

Another valuable lesson learned was representation of the hierarchical tree or a classification used in the dental domain with much more comfort and ease. This experience was gained by iterating the database design until the final hierarchical tree was fully represented to conduct a search at any level.

Overall it was also a learning experience on time management. It is vital to appropriate time to each section of the project to deliver a finished product. This project was successful in achieving its goals. It would however be interesting to investigate if
the end users would benefit from this resource, as the outcome of such an investigation
would encourage the development of more of these resources.
BIBLIOGRAPHY


