MASTER'S THESIS

Long-term Preservation of Three Dimensional Digital Drawings and Maps

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Provided

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ABSTRACT

The three dimensional data is increasingly making its ways in data warehouses of various organizations. Many organizations are confronted with massive volumes of 3D data of digital diagrams and maps. The active management and best possible use of their 3D collection require the development of viable preservation system.

This research has provided fundamental insight into the special characteristics and preservation requirements of three dimensional data. This thesis concluded that the current repository systems do not support the indexing, analysis, storage and retrieval of three dimensional digital data. It is suggested to manage the challenges of developing open file formats, data-sharing devices, tools of automatic content-based indexing and metadata extractors in order to integrate the three dimensional data with existing digital repository systems. The different repository systems have also been evaluated in this report so that highly productive applications can be produced for the long-term preservation of three dimensional digital drawings and maps.

Keywords: Digital Preservation, Management of 3D data, Preservation of 3D drawings and maps.

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INTRODUCTION

This chapter describes the motivation and background of my research. It also highlights the importance of this research topic and concept of long-term preservation of three dimensional digital drawings and maps.

1.1 BACKGROUND

The idea of this thesis was proposed by "Center for Long-term Digital Preservation (LDP)", Sweden. The LDP center is a competence center for research and technical development of methods and technologies for long-term digital preservation and access (LTU 2011). In recent years, the significant increase is observed in the development and use of three dimensional digital diagrams and maps in various organizations. The three dimensional data is created by spending lot of resources, time and efforts. The long-term value of this kind of data is inevitable. Therefore, LDP center proposed to investigate "the state of the art in long-term preservation of three dimensional (3D) drawings and maps". I found this area of research very important and interesting.

1.2 PROBLEM DESCRIPTION

Three dimensional (3D) digital technologies are expected to lead a paradigm shift due to its substantial benefits and emerging use (Lu, Rose & Vitkavage 2007). The education, engineering, medical, cultural heritage, archeology, entertainment and corporate sectors are using 3D digital technologies for their everyday business, and research activities.

In recent years, the giant leap in 3D technologies has also increased the trends of presenting the complex graphic structures in the form of 3D diagrams and maps. The three dimensional (3D) digital diagrams and maps are transforming the world by providing true virtual reality. There is rapid growth of 3D diagrams and maps in the inventories of engineering, medical science, bioinformatics, archeology, manufacturing and business organizations. The 3D diagrams have become important tool of analyzing the complex engineering models. The mining and geoscientists are using 3D diagrams to examine the subsurface structures and calculate volumes. The 3D mapping technology is also increasingly used for analysis of terrain data, sustainable development, natural resource exploration, human anatomy analysis, crime mapping, military missions and urban planning. The Google Maps and GPS technologies have introduced new navigation approaches by providing high quality 3D map services. The medical professionals are using 3D maps for analysis and visualization of human anatomy. The military personnel use these 3D maps to perform realistic missions and flight path analysis during potential threats (ArcGIS 2011).

The continuous growth of three dimensional (3D) digital diagrams and maps has also emerged new challenges for its long-term preservation. The long-term preservation of complex structure of three dimensional data is non-trivial problem. The three dimensional digital data is currently managed in ad-hoc fashion and there is significant risk of data loss. In last few years, a great deal of work has been done internationally to develop digital repository systems for management of two dimensional (2D) digital data. However, there is lack of research efforts for development of digital repository system of 3D data. It is worth noting to investigate the compatibility of 3D data with the framework of existing digital repositories. The value of three dimensional digital data of diagrams and maps is also inevitable because it is produced by using great efforts and money. Therefore, there is a great need to ensure the long-term preservation of three dimensional (3D) digital drawings and maps.

1.3 OBJECTIVES

The objective of this research is to investigate the significance, characteristics and features of three dimensional (3D) digital data. It will describe the important challenges for design and development of three dimensional digital repositories. This study will also explore the important applications required to ensure the preservation of three dimensional (3D) digital drawings and maps over a long time period.

1.4 RESEARCH QUESTIONS

1. What are the important features, attributes and characteristics of three dimensional (3D) digital data?
2. What are the main challenges for long-term preservation of three dimensional (3D) digital data?
3. How longevity of three dimensional (3D) digital drawings and maps can be ensured?

1.5 DELIMITATION

This thesis has addressed the several aspects of three dimensional (3D) digital data. The 3D data is being created in different forms such as motion pictures, computer games, artwork, drawings, maps and cultural heritage. However, each form of three dimensional data has its own characteristics, formats and preservation requirements. Therefore, the focus of this research has been limited to investigate the long-term preservation solutions of three dimensional (3D) digital drawings and maps.

1.6 SIGNIFICANCE OF RESEARCH

This research will enhance our knowledge in the field of "digital preservation of three dimensional data". It will help librarians, archivists and data-managers to develop a viable infrastructure for long-term preservation of three dimensional digital diagrams and maps.

1.7 THESIS STRUCTURE

This report is organized into eight chapters as described in figure 1. The first chapter introduces the background, problem description, objectives, research questions, delimitation and significance of this study. Chapter two, three and four comprised of detail review of relevant literature. These chapters describe the significant characteristics of 3D data, digital preservation and management of three dimensional data. The chapter five contains the methodology used to carry out this research. The chapter six presents the brief summary of interviews. The chapter seven contains a thorough analysis of this research. The chapter eight provides the conclusion and recommendations for further research.

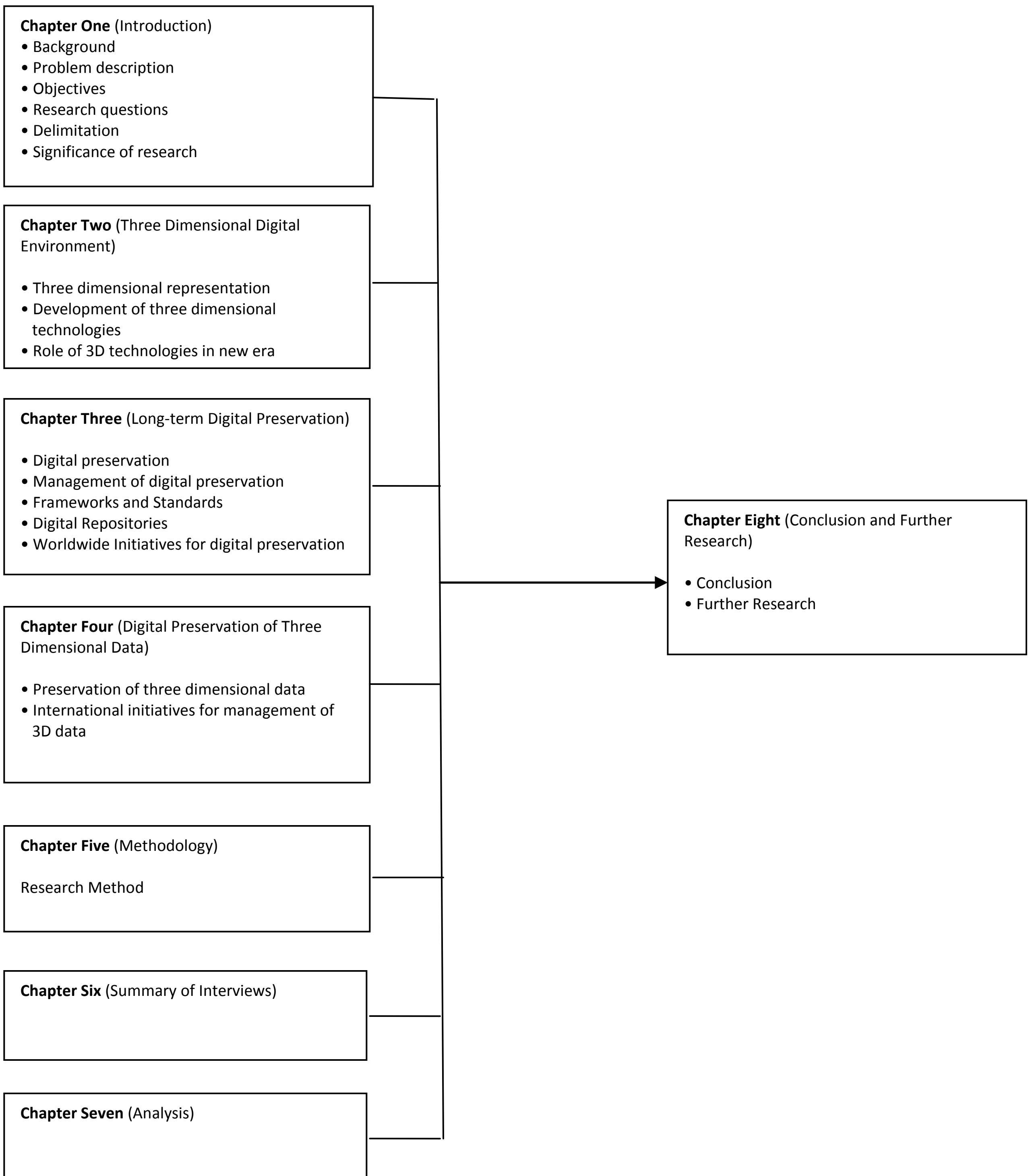

Figure 1: Thesis Structure

THREE DIMENSIONAL DIGITAL ENVIRONMENT

This chapter deals with the important characteristics and features of three dimensional data. It also describes the historical development of three dimensional digital technologies and its emerging use in our lives.

2.1 THREE DIMENSIONAL REPRESENTATION

The three dimensional data is digital surrogate of real objects that can be manipulated and viewed from all angles, and sufficiently precise to allow detailed measurements and analyses (DANA-WH 2011). It is a complex mixture of colors, textural, and virtual lighting. The 3D representation is visual illusion that employs complex synchronization of two separate images in such a way that the brain, interprets both images as one, thus create an illusion of depth (3D-HDTV 2011) .The 3D visualization has following characteristics:

• Easy navigation of information space allowing better user interaction with virtual objects
• Improved perception and understanding of data through the existence of visual metaphors
• The capability to display more data at one time

(Jian, Yugo & Fan 2009)

The 3D shapes are digital representations of either physical existing objects or virtual objects that can be processed by computer applications. The 3D representation provides foundation for computer graphics, computer-aided geometric design, visualization and robotics. The three dimensional geometrical structure is representation of semantic values, operations and data structures. It provides complete description of an object by sketching raw data, surfaces, solids and high level structures (Biasotti et al. 2007).

According to Bustos, the three dimensional data has canonical representation and better understanding is required for analyzing its hierarchy. The shape representations of 3D data are different in its expressiveness and semantics. The taxonomy of 3D representations is needed for better understanding of relationships between the existing representations (Bustos et al. 2007). The taxonomy of 3D representation is described in figure 2.

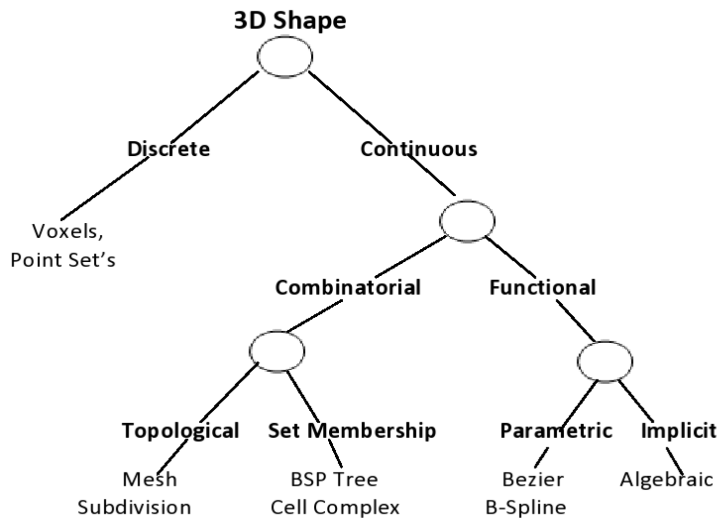

Figure 2 : Taxonomy of 3D Representation

(Biasotti ,2007)

The three dimensional animation is a dynamic representation of moving objects created by using inverse kinematics, motion capture, key-frame animation, procedural animation and artificial intelligence. The 3D animations are complex structure of storyboard, modeling, materials, rigging, animation, lighting effects and post-production (Mitra 2007). Mitra described the animation pipiline in 2007 by the following diagram (Figure 3).

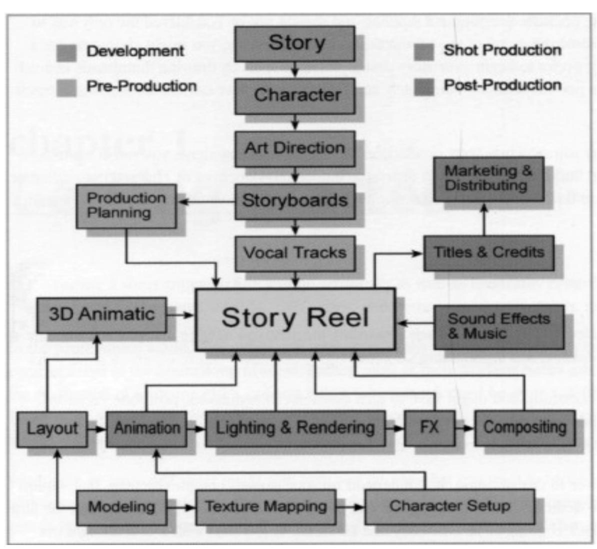

Figure 3 : Inspired 3D Short Film production pipeline

(Mitra, 2007)

There are number of serious problems exist in 3D data representation, encoding, content mark-up and data history management due to its nature and complexities involved in its acquisition, production and (Bustos et al. 2007).

2.2 DEVELOPMENT OF THREE DIMENSIONAL TECHNOLOGIES

The 3D technology is visual representation system which creates or reproduces objects in three dimensions. It is an exclusive domain of high-end machines and software. The work-stations needed considerable processing power and memory to create and render three dimensional data (Neal 2011). The 3D technology was introduced in 19th Century with the invention of stereoscope (3D-HDTV 2011). The increasing popularity of computer animation in all forms of broadcast, entertainment, and educational media is making virtual navigation in 3D space a major and indispensable application in computer graphics (Chen, Sun & Ho 2006).

2.2.1 THREE DIMENSIONAL MOVIES

The three dimension technology was initially used for producing 3D motion pictures. In 1890, the William Friese-Greene filed a patent for the 3D process. In his patent, using the instrumentation of stereoscopy, a viewer was made to see two separate films at right angles to each other, as single 3D film. In 1915 first 3D movie “The Power of Love” was produced by using anaglyph technology. The anaglyph technology used 3D glasses with two different color lenses that would direct an image to each eye. Latter, Edwin H. introduced polarization method for projecting stereoscopic presentations. In 1970, Allan Silliphant and Chris Condon developed new 3D technology “Stereovision” to produced perfect synchronization. In mid 1980s, IMAX technology contributed much for development of 3D cinema (Enciso 2011). Currently, the film makers are using computer generated imagery (CGI) to produce high definition (HD) images and in-depth illusion. In 2009, the release of “Avatar” has changed the old-fashioned cinematography by using advanced stereoscopy filming methods to create real time visualization. In 2011, TV manufacturers pushed the 3D technology at our homes by releasing 3D-TV. These 3D televisions can provide 3D images without using any glasses.

2.2.2 THREE DIMENSIONAL DIGITAL DRAWINGS

The drawing is pictorial representation of shapes by means of lines, colors and shading ARTLEX 2011). It is used to visualize or describe objects. The terms charts, diagrams and graphs are also commonly used for drawings. The drawings are always considered important source of expression in human history.

In the past, the drawings were created on paper but computer graphics tools have made great improvement in this field. Now, the three dimensional digital drawings have changed the traditional way of understanding, analyzing and viewing the complex graphic designs. The 3D drawings gave new insight in geometrical representation of objects by manipulation from all angles. Theses drawings are often used for technical purposes in architecture, engineering and project management. Now, the 3D presentation of architectural ideas became indispensable for building construction projects. The architects are using 3D drawings for providing detailed information and analysis of construction plan. Different software like CAD and 3DMAX are being used for producing 3D models to get realistic view of buildings from all directions. The 3D drawings are also very useful for engineering and manufacturing industries. These drawings provide real visualization and exact dimension of engineering models by giving isometric, oblique and perspective views to each object. These 3D drawings are equally important for manufacturing, tool designing, product development and reverse engineering applications. The 3D-drawings has also major role in big business projects. The 3D models are used for representation of business plans, strategies and achievements.

2.2.3 THREE DIMENSIONAL DIGITAL MAPS

The maps are visual representation of physical objects or areas. The map can be seen as mirror of reality because it shows group of features of an object in terms of its relative size and position. The maps provide great opportunity to gain insights into the nature of objects or places (Stephen 2011).

The 3D technological tools have enhanced the functionality of maps. These maps are intuitive and easier to use. They provide perspective of objects from all directions. The 3D maps enable to zoom and rotate the objects to get new insight. The 3D geographical maps are produced by using advanced techniques of photogrammetric and laser scanning. The three dimension technology has reshaped the map-making techniques by integrating the geometric, semantic and symbolic contents (Adami & Guerra 2006). The three dimensional digital cartography is very useful for navigation of places in real-time. It provides truthful description of geometrical and qualitative data of territory. These 3D maps are also used as framework of ground-shaking estimation, resource exploration, water flow modeling, landslide modeling, refined earthquake and fault location. Three dimensional digital maps facilitate the visual simulation of environmental issues in spatial support systems, virtual reality applications, real-time GIS, and interactive cartography (Dollner & Hinrichs 2000). The Google maps and Google earth have changed our way of viewing the world by providing 3D mapping with high resolution and more global viewing features. The 3D maps have also turned GPS devices into 3D viewers. The 3D maps have important applications in molecular biology and bioinformatics. These are equally important for doctors, medical students and researchers to understand the complex structure of human body. These maps are providing 3D visualization and analysis of genetic, protein and molecular structures. The 3D maps are valuable resources for diagnosis and surgical treatments. The 3D maps of brain genetic activity help researchers to pinpoint the brain disorder. Recently, the techniques have been developed to enable CT, MRI and ultrasound scanning software to produced 3D images for the physicians (Udupa & Herman 2000). The doctors and medical students are using 3D maps for number of potential uses whereas they have also significance for the patients to understand their conditions and treatments. There is variety of open source tools available in medical science for generating 3D maps and images such as 3D Silcer and Seg3D. The 3D maps have also importance for military science. Today, large numbers of

3D maps are also available online covering a broad range of topics, time periods and perspectives (Stephen 2011).The variety of tools are available to create 3D maps such as Map Maker Pro, AutoCAD Map 3D, Foreg-FX, Geographical Information System (GIS), World Construction Set (WCS), Visual Nature Studio, 3D Virtual Human Anatomy Studio, Jmol and PyMol.

2.3 ROLE OF 3D TECHNOLOGIES IN NEW ERA

The 3D technology is embracing the new era by its growing use and benefits. The tools of producing 3D shapes are no longer expensive. Now, the techniques of 3D scanning, photogrammetric and procedural/parametric shape design are used for creating massive amount of 3D data (Bustos 2007).

The three dimensional technology is widely used in science, education, engineering, medical science, archeology, entertainment and corporate sectors for real-time representation of complex graphic structure. The 3D visualization has potential to make science education more accessible by detailed and in-depth description of difficult diagrams and experiments. The 3D technology makes it feasible to go beyond the flat viewing of scientific experiments from multiple angels (Dere, Sahasrabudhe & Iyer 2010). The positive learning effects on 3D animations have seen in many areas like microbiology, physics and mathematics (Mark 1996). The 2D animations have limitation regarding the visualization possibilities of showing the depth of the objects apart from the length and breadth. The 3D technology has the ability to describe the internal organs of human body, walk through of a solar system and cross section of mechanical engine (Dere, Sahasrabudhe & Iyer 2010). The Global Positioning System has also made our lives more easy and comfortable by providing 3D mapping of our landscape. The corporate sector is using 3D technologies for presentation of their business plans, achievements and strategies. The industries are producing 3D models to analyze the exact structure, size and dimension of engineering objects. The 3D scanning technology has useful applications in archaeology, paleontology, engineering and cultural heritage. Now, we have high quality 3D digital scanners to record complex designs. These scanners are used for analysis and preservation of engineering models and cultural assets. The entertainment industry uses these scanners to create 3D models for videos and computer games.

The rapid growth in digital technologies is renovating our lives but also emerged significant challenges to produce appropriate tools for enhancing the access, manipulation and graphic processing of three dimensional digital data.

LONG-TERM DIGITAL PRESERVATION

In this chapter the concept of digital preservation will be discussed. It will also describe the challenges and strategies of digital preservation as well as approaches used to maintain the longevity of digital data.

3.1 DIGITAL PRESERVATION

"Digital preservation combines policies, strategies and actions to ensure access to reformatted and born digital content regardless of the challenges of media failure and technological change. The goal of digital preservation is the accurate rendering of authenticated content over time" (ALA 2007).

The digital technology is increasingly used in all fields of our lives. It has revolutionized our information services by providing easy ways of creating and distributing quality information. Today, we are creating large amount of digital data in the forms of documents, books, images, recordings, 3D graphics, software, games, data-bases and web-sites. The growth in digital technologies and expanding volume of digital data has also put very serious challenges on its longevity. On the other hand, the digital data is also very fragile and there is significant risk of data loss. The special care is required to keep the usability and authenticity of digital contents. There is great fear that our current digital data may not accessible or obsolete in near future. In such circumstance, the digital preservation provides ways to manage the risks of data lose and ensure long-term and meaningful access of our digital assets. The goal of digital preservation is to maintain the access, display and use of digital material in the face of rapidly changing technological and organizational infrastructures (National Endowment for the humanities 2011).

3.1.1 PRESERVATION CHALLENGES

The longevity, authenticity, trustworthiness and access of digital data are on stack due to the following serious challenges:

Media Deterioration

The media on which digital contents are stored are more vulnerable to deterioration than other media such as paper. The traditional physical information sources such as books, maps, photos and artifacts can easily survive for years, decades or even centuries but digital media deteriorate more rapidly. The old storage devices such as magnetic tapes are rarely used now , CD-ROMs and DVD's may also disappear in the near future due to its sensitivity and short life. The experts predict that current media types will begin to decay in one to ten years, depending on the quality of the discs and its storage quality (National Endowment for the humanities 2011).

Technological Obsolescence

The rapid technological development is a great threat for the management of digital data. The latest technologies are replacing the old technologies. Every two-to-three years sees the introduction of a new generation of hardware or software, with backward compatibility most often guaranteed for only a limited time thereafter (National Endowment for the humanities 2011). The current hardware and software technologies may obsolete in few years. Therefore, the records created with these tools are at great risk of loss and may no longer accessible. For-example, the old workstations and hardware devices are not supporting the advance and complex computer graphics. Therefore, there is great risk of accessing and understanding our current data in the near future.

Maintaining the Authenticity and Integrity

The authenticity and integrity of digital objects are also at stake. The digital records can easily manipulated without leaving any traces (Richte, Kuntze & Rudolp 2011). It is easy to verify the authenticity and maintain integrity of analogue or physical media, whereas it is hard to safeguard trust that digital object is original, complete and unaltered.

Maintaining Understandability

The future understandability of digital information is very important for conveying the meaning associated with the values in digital data. The data is useless without clear meaning, readability and understandability (Giaretta 2007). The maintenance of future understandability of digital data is also a serious challenge.

3.1.2 OBJECTIVES OF DIGITAL PRESERVATION

The objective of digital preservation is to ensure that current and future users will be able to discover, retrieve, render, interpret and use digital information in the constantly changing technological environment (Innocenti 2008). The digital preservation translates the uncertainties into manageable risks by using following ways:

- Developing an infrastructure for packaging digital data with its associated metadata to maintain its understandability and longevity.
- Providing security controls to prevent unauthorized access and usage in-order to avoid data manipulation.
- Managing risks associated with formats and media which we used for storage of our digital materials.

3.2 MANAGEMENT OF DIGITAL PRESERVATION

The implementation of comprehensive digital preservation infrastructure can manage the risks of losing data and short life of digital technologies. The main stakeholders for management of digital preservation system are human, information technologies and organization (Runardotter 2009). The organizational infrastructure, financial sustainability, technological suitability, system security and procedural accountability are core components for management of digital preservation. The technological infrastructure has great importance in management of digital preservation system. It consists of software and hardware equipments along-with required skills and secure environment to establish digital preservation program. This infrastructure should have also the ability to anticipate and responds wisely to the rapid change in technologies.

3.2.1 PRESERVATION PLANNING

The planning is a key activity in digital preservation. The preservation planning determines the development and implementation of strategies in the essence of digital preservation. Finding the right action is very important to enable future access to digital contents. Therefore, the preservation plan should develop to monitor the technological changes and needs of designated communities.

The PLATO can used as decision support tool to implement a solid preservation planning process and integrates services for content characterization, preservation action and automatic object comparison in a service-oriented architecture to provide maximum support for preservation planning endeavors (PLATO 2011).

3.2.2 PRESERVATION STRATEGIES

The different strategies can be used to deal with the challenges of digital preservation. Some well-known strategies are discussed below:

Migration

The Migration is the transferring of data to newer system environments to keep the resource fully accessible and functional. It includes set of organized tasks designed to achieve the periodic transfer of digital materials from one software/ hardware configuration to another or from one generation of computer technology to a subsequent generation (Garreta et al. 1996). The migration may be undertaken in variety of ways. It can be done by immigrating or transferring data from one platform to another platform. The migration may also include the conversion of data into suitable format and refreshing digital information without changing it. However, the refreshing or copying can overcome the problem of media instability but it is not enough to keep abreast of technological obsolescence. It is important to provide metadata information about successive migrations in order to determine the changes occurred with digital object (PADI 2011).

Emulation

Emulation is the reproduction of functionality of an obsolete system. It is an alternative to migration. In emulation original bit stream of data remain intact. This approach is used to write an emulator that will run on a future hardware platform and ensure the future access of the document. By preserving the original document along with the software necessary to reproduce it, a digital document can be presented in the future with its original "look and feel" and functionality (Hedstrom 2011).

Universal Virtual Computer (UVC)

In 2000, Lorie gave the concept of Universal Virtual Computer (UVC) to ensure the future compatibility of any software with all platforms (Lori 2000). The Universal Virtual Computer uses the elements of both migration and emulation to reconstitute the digital objects in their original form.

The figure 4 described that UVC is based on four components i.e.
UVC program (format decoder), Logical data schema (LDS) with format description, universal virtual computer and logical data viewer (UVC interface)   (PADI 2011).

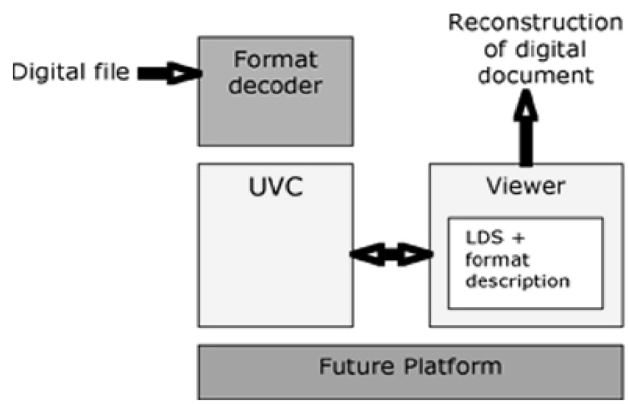

Figure 4: Components of UVC

(Wikipedia, 2011)

Lorie suggests the archiving of original program so that Universal Virtual Computer (UVC) program can write to emulates every instruction of the current hardware machine. In this way, a future UVC interpreter will be able to interpret the original machine’s instructions (Doyle, Viktor & Paquet 2007).

Encapsulation

It is a technique of grouping together digital object and other supporting information to overcome the problem of technological obsolescence. The supporting information may include persistent identifier, metadata and software specifications. The encapsulation can be archived by using physical and logical structures to provide a relationship between all information components (Hedstrom 2011).

3.3 FRAMEWORKS AND STANDARDS

The challenges of preserving and providing sustainable access to digitally born information are not insurmountable. Tools and standards for best practices in digital preservation have been developed. Today, the digital repositories and web harvesters are available for management and preservation of two dimensional (2D) digital materials (Rodes & Neacsu 2008). Some important frameworks and standards are described below:

Open Archival Information System (OAIS)

The Open archival Information System is a reference model for an archival system dedicated for preservation and access of digital data over a long time period. It is developed by Consultative Committee for Space Data System (CCSDS) in January 2002. A number of digital preservation systems and repositories have adopted the OAIS model as conceptual framework (CCSDS 2002).

Data Dictionary for preservation of metadata (PREMIS)

PREMIS is a comprehensive, practice resource for implementing preservation metadata in digital archiving system. The working group of PREMIS has also published a set of XML schema to support the implementation of data dictionary in digital archiving systems. The PREMIS Data Dictionary has awarded the 2005 Digital Preservation Award, given under the auspices of the British Conservation Awards, as well as the 2006 Society of American Archivists Preservation Publication Award (Library of congress 2008).

Metadata Encoding and Transmission Standard (METS)

The METS schema is a standard for encoding descriptive, administrative, and structural metadata of textual and image-based works. The METS provide XML documents format for encoding metadata necessary for both management of digital objects within a repository and exchange of such objects between repositories. The METS can use in the role of submission information (SIP), archival information (AIP) or Dissemination Information Package (DIP) within the Open Archival Information System (OAIS) reference model (METS 2011).

Trustworthy Repositories Audit & Certification (TRAC)

The TRAC provide criteria to evaluate the abilities of reliable storing, migrating, and access of digital collection over time. It provides guidelines for evaluation of planning, objectives, services, organizational administration and technological infrastructure (OCLC 2011).

Digital Repository Audit Method Based on Risk Assessment (DRAMBORA)

The DRAMBORA toolkit provides means to assess the capabilities identify the weaknesses and recognize the strengths of digital repositories. The digital repositories are still in their infancy and DRAMBORA is designed to ensure the development of trustworthy and reliable digital repositories (Innocenti 2008).

3.4 DIGITAL REPOSITORIES

The digital repositories lie at the heart of current generation of digital preservation approaches. The digital repositories form an intersection of interest for different communities' i.e. digital libraries, archives, e-learning, publishing, record management, commercial data exploitation etc. The motivation for creating digital repositories in these communities may differ but the main objective is to secure digital assets for a long time period. Many open source repository systems have been developed to manage the longevity of large variety of digital data. The scope of open source systems is wider than the repositories of proprietary nature. Therefore, few open source repositories are described below:

Fedora

Fedora (Flexible Extensible Digital Object Repository Architecture) is developed by University of Virginia Library and Cornell University. Its new version 2.2 is released in February 2007. The Fedora is developed for storing, managing, accessing and preserving digital content in the form of digital objects. Fedora has very good scalability and can store millions of objects. The Fedora Repository is extremely flexible and can be used to support any type of digital content. The Fedora is being used by numbers of institutions worldwide for digital collections, e-research, digital libraries, archives, digital preservation, institutional repositories, open access publishing, document management and digital asset management (Fedora 2011).

D-Space

D-Space is an open source repository system developed by MIT Libraries (Massachusetts Institute of Technology) and Hewlett-Packard. Its new version is released in November 2011 The D-Space can Stores various types of materials such as text, images, data, audio files, etc. It also supports long-term digital preservation (D-space 2011).

Archivematica

Archivematica is a comprehensive digital preservation system. Archivematica uses a micro-services design pattern to provide an integrated suite of free and open-source tools that allow users to process digital objects from ingest to access in compliance with the ISO-OAIS functional model. Archivematica uses METS, PREMIS, Dublin Core and other best practice metadata standards. The archivists need limited technical and financial capacity to implement the tools and methodology of archivematica (Archivematica 2011).

E-Print

EPrints provides platform to set up repositories of research literature, scientific data, student thesis, project reports, multimedia artifacts, teaching materials, scholarly collections, digitized records, exhibitions and performances. E-Print repository software manage and control a portfolio of local, enterprise and cloud storage services and digital preservation activities (Eprints 2011).

DAITSS

DAITSS (Dark Archive in the Sunshine State) is a digital preservation repository application developed by the Florida Center for Library Automation. In addition to repository functions of ingest, data management and dissemination, DAITSS supports the preservation functions of format normalization, mass format migration, and migration on request. DAITSS is a “dark archive” intended to be used as a back-end to other systems, such as digital library applications or institutional repository software. It has no public interface and allows no public access, but it can be used in conjunction with an access system. DAITSS supports use by multiple customers, whether these are different organizations or different units within an organization. It allows much flexibility in terms of archived material and preservation techniques (Floreda center for library automation 2007).

Islandora

Islandora is an open source framework developed by the University of Prince Edward Island's Robertson Library. Islandora uniquely combines the Drupal and Fedora open software applications to create a robust digital asset management system that can be fitted to meet the short and long term collaborative requirements of digital data stewardship (Islandora 2011). Many institutions are using Islandora framwork to develop their own repository systems.

3.5 WORLDWIDE INITIATIVES FOR DIGITAL PRESERVATION

The worldwide efforts are going on to cop the challenges of digital preservation. The National Library of the Netherlands (KB) has developed e-Depot digital archive in early 2003 based on the IBM product DIAS (Digital Information and Archiving System). The e-Depot provides a long-term solution for both born-digital material and digitized objects. The KB is also using permanent access tool the Universal Virtual Computer (UVC). It is developed in collaboration with IBM as part of a new Preservation Subsystem for the e-Depot (Wijngaarden & Oltmans 2001). The Joint Information Systems Committee (JISC) of UK is funding many archive projects for digitization of numerous resources. The Alliance for Permanent Access has been launched in November 2007. The alliance consists of European research institutes, research funders, national libraries, and international publishers, including the European Science Foundation, CERN, and the Max Planck Society. The alliance plans to establish a "European infrastructure to secure permanent access to the digital records of science (Rovner 2008). The European Commission has also launched i2010 digital library initiative to provide online access to all European cultural and scientific heritages. The aim of this program is to build on the potential of information and communication technologies to improve the access to information for all. The issue of digital preservation is a major theme throughout the i2010 initiative. The European commission recommendations in August 2006 asked the members states to address the digital preservation in a structured way both by action plans and legislation (Forster 2007). The European Union has also funded initiative called ENSURE. It is a joint research project of thirteen European partners to develop the technologies to go beyond current state-of-the-art technologies in long term digital preservation (ENSURE 2011). The Library of Congress has launched National Digital Stewardship Alliance (NDSA) in July 2010 to develop improved preservation standards and practices. It will also provide national leadership for digital preservation education and training(Library of congress 2011). The Digital Preservation Coalition (DPC) in UK and Center for long-term digital preservation and access (LDP) in Sweden are also actively involved in research for developing methods and tools for long-term digital preservation and access.

DIGITAL PRESERVATION OF THREE DIMENSIONAL DATA

This chapter will describe the importance of preserving the three dimensional digital data. It will also highlight the international initiatives taken for management of various kinds of three dimensional digital data.

4.1 PRESERVATION OF THREE DIMENSIONAL DATA

An increasing amount of three dimensional information is making its ways onto the web and corporate databases (Ortiz Jr. 2004). The high financial cost is involved for development of 3D materials, therefore, the user's needs ways to store, index and search this information. The typical approaches used for the preservation of two dimensional data are not fully applicable for management of heterogeneous structure of three dimensional data. The web-searching applications, such as Google, are not providing the viable searching of three dimensional data.

Bustos argued that the next major technological revolution will be triggered by massive 3D data sets that we will be generated in the near future. Therefore, the support of digital repository is crucial for long-term preservation and best possible use of three dimensional data (Bustos et al. 2007). However, the effective use and long-term preservation of three dimensional data is facing many potential obstacles.

4.1.1 Metadata Extraction

Metadata is structured information that describes, explains, locates or otherwise makes it easier to retrieve, use or manage an information resource (National information standards Organization 2007). The metadata extraction is essential component of any preservation environment. However, metadata framework to support semantic information associated with 3D object is currently lacking (Doyel, Vicktor & Paquet 2009). The OAIS reference model defines the broad type metadata information required to preserve and access digital data over a long period of time whereas; OAIS provides no guidance for implementation of metadata framework. The existing metadata approaches are more suitable for non-geometrical or textural data. The long-term preservation of 3D data has completely different metadata requirements. The 3D models require more semantic information than 2D data for future use, editing, recreation and searching. The preservation of 3D data not only involves the storage of geometrical structure of 3D objects but also require semantic information to audit and improve the current models for-example:

- The calibration information of 3D data, color and texture for re-creation of these models.
- The information about software used for creating 3D model. The future post-processing of a model may involve fixing holes in models or colors discrepancies to remove the flaws in current short-lived 3D technologies.
- The list of tools and equipments used in original modeling process i.e. scanner, digital camera.
- The information about creator, date of creation and authenticity measures taken during the process.
- The important features and properties of 3D digital objects including its format, resolution, version, color, orientation, compression, mesh representation, parametric representation etc.

(Doyel, Viktor & Paquet 2009)

4.1.2 Data Analysis and Indexing of 3D Models

The data analysis and indexing are important characteristics of efficient repository services. The quires of data retrieval are based upon the important attributes and features of data. However, there is no appropriate way for description of heterogeneous structure of 3D models(Bustos 2007). The three dimensional data is not sufficiently analyzed and index within the framework of today's digital repositories. The existing repository systems are providing searching facilities through keywords, titles or classifications whereas the 3D model mainly depends on the engineering context associated with that model. The keyword indexing techniques for three dimensional data results in loss of information (Blumel, Krottmaier & Wessel 2008). It is very difficult to speculate the suitable 3D analysis algorithms. The 3D data analysis and indexing are complicated by the fact that it is not clear on which conceptual level the 3D features should be define i.e. on statistical, syntactical or semantic level. The shape representation of 3D objects based on surface, volume or structural properties is also a problematic issue (Bustos et al. 2007).

4.1.3 Retrieval of 3D Data

In recent years, many systems have been developed for retrieval of two dimensional data whereas these applications are not suitable for 3D retrieval due to peculiar nature of 3D data (Assfalg, Bimbo & Pala 2003). The 3D models are created with relatively more metadata information. The nature of 3D models is very difficult to capture by common retrieval solutions because inverted indexes which are widely used in text-based search engines are not applicable in this area (Pein, Amador, Lu & Renz 2008). Mostly, in text-based searching interfaces the access is provided by entering descriptive keywords. However, these query interfaces are not useful for searching 3D objects because in these objects the user's input is not obvious. It might be textural, arbitrary images, basic shapes or strokes. The appropriate searching algorithms are lacking to enable content based searching of 3D objects. The similarity notions are also missing in existing repository systems for automatic assessment of similarity among 3D models. The most methods attempt to be invariant under similarity transformations i.e. position, scale, rotation or orientation (Min 2004). Hence, the effective search algorithms need to design for efficient execution of similarity quires of 3D objects (Bustos, Keim, Saupe & Schreck 2007).

4.1.4 File Formats and Data Sharing Standards

The long-term preservation of the three-dimensional data is a challenging issue because it consists of various applications dependent and proprietary file formats. Therefore, there is great fear that 3D data will no longer accessible for future users after the obsolation of application software. There are various kind of 3D formats for-example; PDF-E is an open standard file format mostly used for the representation of 3D contents of engineering data, the Virtual Reality Modeling Language (VRML) is file format for interactive 3D graphics, X3D is successor of VRML and standard XML-based file format etc. Unfortunately, the generic and comprehensive file format of all kinds of three dimensional data does not exist to date (Bustos et al. 2007). On the other hand, the import of 3D contents from heterogeneous sources to digital repository is also a challenging task. The data interchange standards exist in CAD domain (like STEP and IGES) are very complex and implementing converter programs for these formats is a challenge on its own (Bustos et al. 2007). The shape representation is the main focus of current 3D research whereas generating powerful, transparent and canonical 3D open file format is still ignored.

4.2 INTERNATIONAL INITIATIVES FOR MANAGEMENT OF 3D DATA

In last few years, many international efforts have been made for preservation and retrieval of three dimensional data. Some important initiatives are highlighted below:

4.2.1 PROBADO

The Architectural 3D Architectural model repository is set up at Germany National Library of Science and Technology (TIB) Hannover as part of PROBADO German digital library initiative. The PROBADO project started in February 2006 for tentative duration of 5 years. The main goal of project is to integrate general (in particular non-textual) multimedia documents into the workflow of existing digital libraries. The PROBADO repository provides searching by using textual (metadata-based) and non-textual (3D- sketching) retrieval mechanisms (Blumel, Krottmaier & Wessel 2008).

The PROBADO has developed automatic content-based strategies initially for 3D architectural data and music documents. It provides searching in the metadata of all connected PROBADO repositories. The PROBADO provides visual-interactive and domain specific user interface. The citation features is also included by supporting repository hosts DOI and URN. The web framework is designed by integrating both standard and content-based accessing approaches.
The PROBADO web application supports repository-local or global search based on textual metadata, which is compatible with standard HTML/JavaScript. Content-based access is possible via rich web application modules which relies on plug-in technology such as Microsoft Silverlight. The specific added-value services can be implemented in PROBADO through the integrated core layer. It has already added several added-value services including user profiling and recommendation, provision of document annotations, and result-set visualization (DFG 2011).

The PROBADO system contains three layers i.e. repository layer, core system layer and fronted or presentation layer. The PROBADO system architecture is described in figure 5:

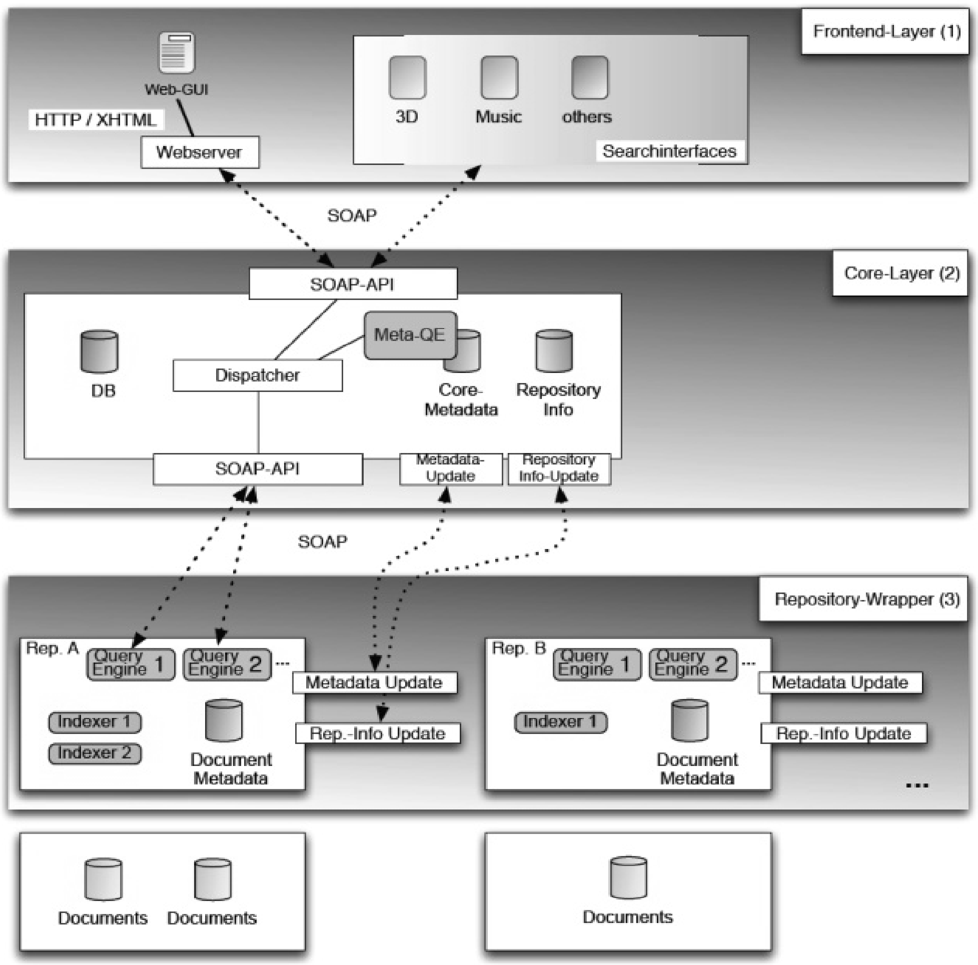

Figure 5: Overall system architecture of the PROBADO framework

(Blumel, 2008)

The repository layer include rich metadata model by implementing document type specific indexing and accessing techniques. The core layer keeps track of all document repositories registered in the system. It maintains an integrated index of all documents. The PROBADO presentation layer offers rich user access methods, including graphical query specification, and document visualization.

PROBADO defines a system protocol based on Web-service technology. It allows dispatching content-based and metadata-based user queries to local repositories, which manage the primary documents. Synchronization methods allow the repositories to inform the core system about availability and updates of hosted contents (DFG 2011). The architecture is not tied to a specific technology or programming language. Currently many parts of the system are implemented using Java-technology (Blumel, Krottmaier & Wessel 2008). The figure 6 described the various components of 3D repository.

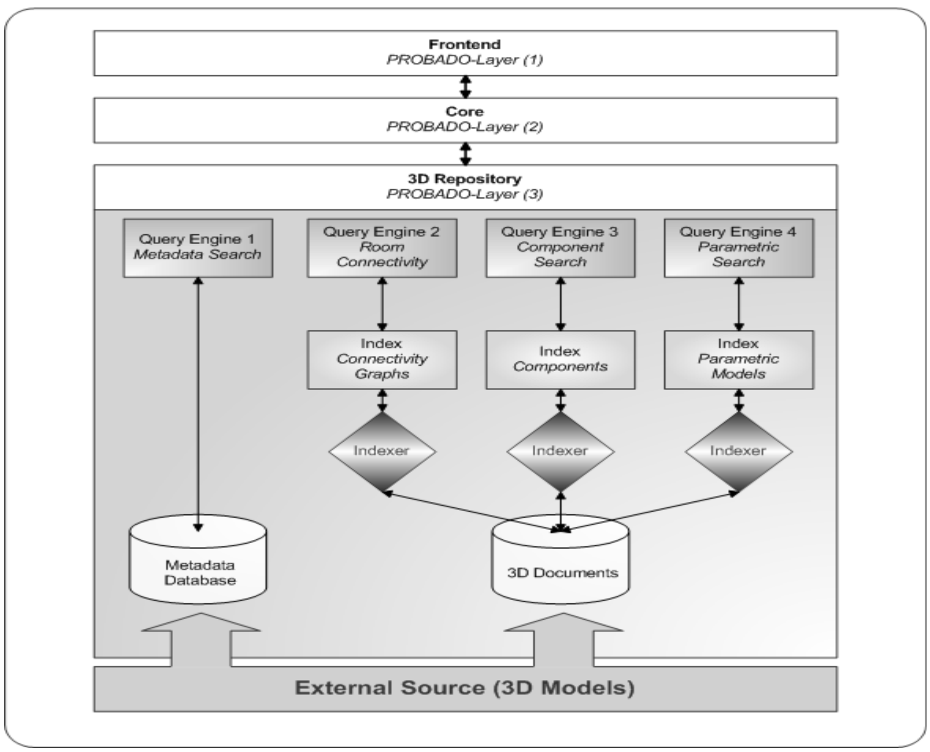

Figure 6: Components of the PROBADO 3D repository

(Blumel, 2008)

4.2.2 SCULPTEUR

The SCULPTEUR project was initiated in 2002 for semantic and content-based exploitation of cultural heritage archives of special scientific and cultural interest. This project was joint venture of different European organizations of Italy, France and United Kingdom. The objective of this project includes the creation of distributed multimedia digital library for sorting, searching and retrieving of more diverse multimedia types, with significant support of 3D objects.

The SCULPTEUR augmented the 3D representation of objects by using innovative techniques such as multi-stereo and silhouette techniques. The re-created stored in an object relational database together with multimedia objects which enrich the information associated to the cultural objects. In this project, the retrieval algorithms have developed for efficient retrieval of 3D objects by content and concept based quires. The Prototype software "Concept Browser" has also been developed to provide access through common ontology (CIDOC CRM). The automatic classification approach has been used in this project. All these innovative technologies have been integrated into an existing image digital library system to create a robust, scalable, distributed, multimedia digital library infrastructure (Sculpteur 2011).

4.2.3 DANA-WH

DANA-WH is a distributed database network, comprised of multiple constituent data sets controlled by separate Relational Database Management Systems (RDBMSs) running on independent computer systems. It is designed for preservation of textual, metric, and visual information of human cultural and biological heritage. The system displays two-dimensional (2D) images of artifacts and fossils, as well as accurate, three-dimensional (3D) models (DANA-WH 2011).

4.2.4 AIM@SHAPE

This three years project was initiated in 2004. The AIMATSHAPE is abbreviation of Advanced and Innovative Models And Tools for the development of Semantic-based systems for Handling, Acquiring, and Processing knowledge Embedded in multidimensional digital objects. The Mission of AIM@SHAPE is to foster the development of new methodologies for modeling and processing the knowledge related to two, three or higher dimensional digital shapes. This knowledge is concerned with geometry, structure, attributes, semantics and interaction with real time.

The Digital Shape Workbench (DSW) was developed during AIM@SHAPE network of excellence. It is common infrastructure for integrating, combining, adapting, enhancing existing and new software tools and shape databases. The DSW acts as an e-Science framework in terms of an operational, large-scale, distributed and web based software system.

The DSW involves the construction of the Shape Repository, the Tool Repository and the Ontology and Metadata Repository, together with an advanced Search Framework. The Search Framework involves both a semantic and a geometric approach for retrieval of multidimensional shapes (AIM@SHAPE 2011). The architecture of search framework of Digital Shape Workbench (DSW) is described in figure 7.

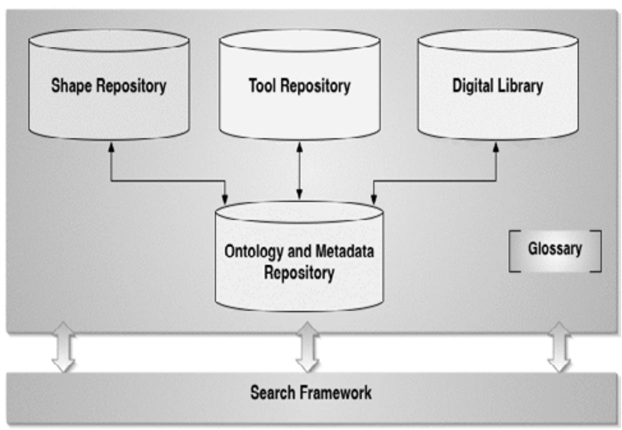

Figure 7: Search Framework of DSW

(AIM@SHAPE, 2011)

4.2.5 VICTORY

This project started in 2007. Its main purpose is to develop a distributed digital repository of heterogeneous visual objects, videos and images by introducing novel search, retrieval and visualization. The VICTORY project provides new insight into the nature of next generation audiovisual content search engines. VICTORY is developing novel architectures for access and delivery of 3D and associated multimedia contents over an interoperable environment, which comprises standard and mobile P2P networks (Daras et al. 2008).

METHODOLOGY

The methodology used to unfold the field of digital preservation of 3D drawings and maps is explained in this chapter.

5.1 RESEARCH METHOD

The qualitative approach is used to explore the field of digital preservation of three dimensional digital drawings and maps. This approach is useful to clarify a phenomenon's characteristics, properties, or features, and explore its implications and meanings (Widerberg, 2002). Thus, qualitative research can provide understandings of digital preservation practices for three dimensional drawings and maps. It can also reflect the current situation by evaluating the experience and interpretations of the people involved in preservation of 3D data.

The characteristics of qualitative research contain methods and approaches that are appropriate for exploring subject matters from a qualitative viewpoint (Widerberg, 2002). Harway argue that empirical materials are merely partial perspectives (Haraway, 1988). According to Runardotter, the researchers can never gain full access to another person (Runardotter, 2009). Hence, introspection approach can use to reach on appropriate conclusion.

The interpretative approach is used to analyze this thesis. It was involved several iterations to get broad understanding of trends and practices. My analysis is based upon theoretical framework, interviews and thorough discussion with colleague at LDP center. The discourse analysis method has been adopted for analysis of empirical material. Discourses embrace structured convictions, rationalities, logics, and forms of knowledge to which people in a society relate when they make decisions, argue, or prioritize (Marry, 2009). I explored the characteristics of 3D data and current situation of 3D preservation by detailed discourse analysis. A thorough analysis of problem description, its implications and underlying assumptions has also been made.

5.1.1 LITERATURE REVIEW

The first phase of this research was involved with extensive literature review to get insight into the scholarly work and related research. It enabled to understand the existing methods, tools and strategies used for the preservation of various kinds of three dimensional data. The literature review also helped to identify the main challenges and appropriate solutions for management of 3D data. It enabled to formulate the practical guidelines for long-term preservation of three dimensional digital diagrams and maps.

The theoretical framework of this research was based upon high level discussion on significance of three dimensional data, three dimensional retrieval, digital libraries and digital preservation for broadening the prospective of this study. The digital repositories are also included to illustrate the theoretical benefits and shortcomings of different approaches. In the start, it was bit confusing to grab so many fields but it became very clear and goal oriented by time.

5.1.2 INTERVIEWS

The second phase of thesis was consisted of evaluation of semi-structured telephonic interviews and e-mail contacts with different stakeholders such as national libraries, national archives, 3D data warehouses and research organizations.

Kuzel and Morse stated that the qualitative samples tends to be purposive, rather than random (Kuzel, 1992; Morse, 1989). Therefore, my sampling technique reflects the purpose of this research. The national libraries and archives are considered as hub of various kinds of digital data. This research gathered information about the preservation activities and the prospective of key members of these institutions, regarding the preservation of three dimensional digital data. The data warehouses of online search engines and corporate sector were included to get information about their 3D repository systems. Similarly, the research organizations involved in 3D preservation were contacted to know about their developments, obstacles and findings.

My research is a part of LDP center project; therefore, the semi structured questionnaire was designed with their consultation to appropriately address the research objectives. The respondents were asked about the functions, architecture and characteristics of their digital repositories. The questions were also included about strengths and weaknesses of their repository systems in order to compare the characteristics of different preservation applications of 3D data. The data from the interviews were analyzed mainly from the theoretical framework and similarity between the respondents answers.

SUMMARY OF INTERVIEWS

The interviews were the main source of investigating "the state of the art in the long-term preservation of three dimensional data of drawings and maps". The findings of interviews show that most of the institutions are not actively engaged in preservation of three dimensional digital drawings and maps. However, they have serious concerns for efficient retrieval and preservation of their three dimensional digital collections. The respondents were agreed with the limitations of their existing systems. Some respondents feel that it is important to preserve the application software along-with the three dimensional data for its long-term access.

It is found that most of the national libraries and national archives do not confront with massive volume of 3D drawings and maps. The development of mechanism for preservation of 3D data is also not on their priorities. However, the importance of 3D preservation has been accepted by all respondents. The corporate sector is also lacking a prescribed mechanism for management of their 3D resources. The respondents of corporate sectors have keen interest to develop infrastructure for storage, preservation and retrieval of their valuable 3D assets. They were interested for development of retrieval mechanism with multiple quires option, so that they can efficiently access and re-use their 3D models.

The questionnaire has also been sent to the managers of data-warehouses of some well-known online search engines through an e-mail. The response from this sector was not satisfactory because they were not ready to share complete information about their systems. However, it is found that 3D search engines are using proprietary software with very limited scope. The respondents from research organizations such as PROBADO, SCULPTEUR, DANA-WH and AIM@SHAPE gave emphases on the importance of developing tools for 3D retrieval, data analysis, metadata-extraction and standard formats. They also describe the significance of their research contributions and practical achievements in this regards. All the respondents accepted that they are having problems for preservation and efficient retrieval of 3D data. The reason of this deficiency is both lack of resources and awareness.

ANALYSIS

This chapter deals with thorough analysis of theoretical framework and information received from different stakeholders.

The growth of three dimensional digital diagrams and maps is increasing in data warehouses of various organizations. The 3D data is created by spending many resources and its long-term preservation is highly desirable (see 4.1). The preservation can retain the access, authenticity and usability of 3D data over time (see 3.1). The respondents argued that preservation of 3D data can low the costs of developing 3D models by maximizing the reuse of existing models. It will also improve the processing and production of 3D objects.

The three dimensional data has special characteristics and many complexities involved in its structure, acquisition and production. It composed of complex geometrical structure associated with topological, metadata and material properties (see 2.1). Therefore, the preservation requirements of three dimensional data are different from two dimensional data (see chapter 4.1). The respondents were also having that three dimensional data cannot be index, search, retrieve and analyze in sufficient way within the framework of existing digital repositories.

The current repository systems are suitable for management of 2D data and not fully applicable to secure the longevity of 3D data of digital diagrams and maps. The lacks of efforts are noticed to integrate 3D data with the existing repository systems. The tools for content-based searching and automatic data analysis of 3D contents are still missing. These tools are important to describe the heterogeneous structure and efficient retrieval of 3D data(see chapter 4). The metadata framework is an integral part for any repository system for managing the knowledge associated with data over a long time period. It enables the easy exploitation, manipulation, retrieval and access of data. The standard framework and ubiquitous tools are not available for automatic extraction of geometrical characteristics and intuitive semantics of three dimensional data (see 4.1). The 3D retrieval is also very serious issue because common text-based search-quires cannot capture the geometrical structure of 3D models. The 3D data is mostly application dependant or proprietary nature (see 4.1). Such formats have limited viewers and make it difficult to repurpose 3D data for downstream use. Although, open standard formats such as PDF-E exists for 3D engineering data but generic and comprehensive open formats of all kinds of 3D data do not exist. Therefore, there is great risk of losing access of 3D diagrams and maps after the obsolescence of application software. Hence, the software associated with 3D data also needs to be preserved for its long-term access and interpretation. The sharing of three dimensional data is also a challenging task because it contains large size and proprietary formats (see chapter 4). The PDM and IGES standards are used for exchange of 3D CAD models but it does not provide open approach for exchange of all kind of 3D data in collaborative way. Therefore, there is great need to create new tools for 3D data sharing.

Both the literature review and interviews pointed-out that 3D preservation is quite new field and satisfactory efforts have not been made in this regards. Most of the organizations dealing with 3D diagrams and maps are managing their collection by informal ways. The online search engines have also developed proprietary nature of software to manage their 3D digital collections, which do not fulfill the long-term preservation requirements. Therefore, it is important to develop a complete preservation solution to ensure the efficient retrieval and longevity of three dimensional data.

The 3D repository of PROBADO is significant development for the management of architectural data and music documents. It has rightly addressed the challenges of 3D retrieval by using approaches of both metadata and content-based searching. It enables a user to perform text-based quires and 3D sketching as well. The PROBADO approach can adopt to develop a repository system for the long-term preservation of 3D diagrams and maps. The automatic indexing, innovative user interface, web-framework and centralized metadata are very useful features of PROBADO 3D repository (see 4.2.1). The use of Dublin core metadata and Java-technology are also good for long-term perspectives. Whereas, the distributed database network approach used in DANA-WH is also significant to manage data housed at different places or institutions (see 4.2.3).

CONCLUSION AND FURTHER RESEARCH

My findings are presented in this chapter. I merely scratched the area of developing three dimensional digital repositories whereas many interesting directions still lie ahead.

8.1 CONCLUSION

The conclusion contains the answers of the following research questions.

What are the important features, attributes and characteristics of three dimensional (3D) digital data?

What are the main challenges for long-term preservation of three dimensional (3D) digital data?

How longevity of three dimensional (3D) digital drawings and maps can be ensured?

The research for long-term preservation of three dimensional data is in its infancy. The three dimensional data has complex geometric structure and special characteristics. Therefore, its preservation requirements are different from two dimensional data. The current repository systems are not appropriate for long-term preservation of three dimensional data. The research challenges of 3D retrieval, content-based searching, metadata-extraction, open standards format and development of data-sharing tools need to be address in-order to integrate three dimensional data with existing repository systems. The PROBADO framework is good initiative for development of three dimensional digital repositories. The PROBADO repository has rightly addressed the issues of content-based searching, metadata-extraction and 3D retrieval but its scope is limited to architectural 3D-models and music documents. The PROBADO approach can also be adopted for development of comprehensive digital repository system for long-term preservation of digital diagrams and maps.

8.2 FURTHER RESEARCH

The field of 3D preservation is significantly important for securing our digital assets. This research has scratched the fundamental issues and many related areas are lie ahead to reach the viable solution of 3D preservation. The further research should perform to develop tools for automatic data analysis, metadata extraction, open standard 3D format and data sharing standards, so that highly productive application can produce for management of all kinds of three dimensional data.

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