UNIVERSITI PUTRA MALAYSIA

DESIGN AND DEVELOPMENT OF AN INTERACTIVE DIGITAL SPECTRAL LIBRARY

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DESIGN AND DEVELOPMENT OF AN INTERACTIVE DIGITAL SPECTRAL LIBRARY

By

SITI NOORADZAH BINTI ADAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

February 2012

Specially dedicated

to

My Husband, *Azreul Ahmad*

My Son, Muhammad Ameer Syahmi Azreul

My Parents, *Adam Daim and Noorazizah Othman*

My Brother, *Muhammad Nooradzam*

My Sisters, *Siti Hawa Noor and Siti Noor Hamizah*

My In-Laws

For their

Love, Patience, Understanding and endless Encouragement when it is most needed

Abstract of thesis to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Master of Science

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February 2012

Chairman: **Assoc. Prof. Helmi Zulhaidi Mohd Shafri, PhD**

Institute: **Institute of Advanced Technology**

Spectral library is a database system that stores the spectral data of materials. The materials include vegetations, soils, minerals, rocks, water and manmade. Many spectral libraries were already available online and being referred by end users. However, these libraries of materials were specifically designed for their own use. Therefore, there is a need to develop a practical spectral library towards facilitating spectral remote sensing technological development in Malaysia. This library will be made available in public domain as these data are useful as reference material for future study.

Spectral data from laboratory or field measurements, need to be stored and managed in a specially designed database that act as a unified repository of

spectral signatures as well as additional information (metadata or ancillary data) which describes the relationship to specific physiographic and ecological background conditions of the areas under observation.

The process of designing and developing the library involves selecting documents for inclusion, suitable metadata set, assigning metadata to each document or group of documents, designing the form for the collection in terms of document formats, searchable indexes, browsing facilities, building the necessary indexes and data structures and putting the collection in place for others to use. Furthermore, it will be developed in such a way so that registered users can contribute to the richness of the data in the library.

The developed spectral library is online or web based, so it provides the convenient share of spectral information not only in Malaysia but throughout the world. The spectral library also acts as a center for spectral identification and cataloguing as well as providing useful information for any remote sensing based research in Malaysia**.**

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Master Sains

REKABENTUK DAN PEMBANGUNAN PERPUSTAKAAN DIGITAL INTERAKTIF SPEKTRUM

Oleh

SITI NOORADZAH BINTI ADAM

Februari 2012

Pengerusi: **Prof. Madya Helmi Zulhaidi Mohd Shafri, PhD**

Institut: **Institut Teknologi Maju**

Perpustakaan spektrum ialah sebuah sistem pangkalan data yang menyimpan data spektrum untuk bahan-bahan. Bahan-bahan tersebut termasuklah tumbuh-tumbuhan, tanah-tanih, mineral, batu-batan, air dan buatan manusia. Banyak perpustakaan spektrum yang telah sedia ada digunakan atas talian dan menjadi rujukan oleh pengguna akhir. Tetapi, perpustakaan bahan-bahan ini direkabentuk khas untuk kegunaan mereka sendiri. Oleh itu, terdapat keperluan untuk membangunkan sebuah perpustakaan spektrum yang praktikal ke arah memudahkan pembangunan teknologi spektrum penderiaan jauh di Malaysia. Perpustakaan ini akan disediakan dalam domain awam kerana data ini berguna sebagai bahan rujukan untuk kajian masa depan.

Data spektrum daripada pengukuran makmal atau lapangan, perlu disimpan dan diuruskan di dalam sistem pangkalan data yang direka khas yang bertindak sebagai repositori bersatu bagi pengenalan spektrum serta maklumat tambahan (metadata atau data sampingan) yang menggambarkan hubungan kepada syarat-syarat latar belakang khusus fisiografi dan ekologi kawasan-kawasan di bawah pemerhatian.

Proses merekabentuk dan membangunkan perpustakaan melibatkan pemilihan dokumen untuk dimasukkan, set metadata yang sesuai, memberikan metadata untuk setiap dokumen atau kumpulan dokumen, merekabentuk borang bagi pengumpulan format dokumen, indeks pencarian, kemudahan pelayaran, membina indeks yang diperlukan dan struktur data dan meletakkan koleksi tersebut ditempatnya untuk kegunaan pengguna. Selain itu, ia akan dibangunkan dalam cara yang berkesan supaya pengguna yang berdaftar boleh menyumbang kepada kekayaan data di perpustakaan tersebut.

Perpustakaan spektrum yang dibangunkan adalah dalam talian atau berasaskan web, jadi ia memudahkan perkongsian maklumat spektrum bukan sahaja di Malaysia tetapi di seluruh dunia. Perpustakaan spektrum juga bertindak sebagai pusat untuk mengenal pasti spektrum dan pengkatalogan serta menyediakan maklumat yang berguna untuk apa-apa penyelidikan penderiaan jauh yang berpangkalan di Malaysia.

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Thank you all and May Allah blesses all of you with good health and great life.

I certify that a Thesis Examination Committee has met on 27 February 2012 to conduct the final examination of Siti Nooradzah binti Adam on her thesis entitled "Design and Development of an Interactive Digital Spectral Library" in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work expect for quotations and citations which have been duly acknowledged. I also declare that is has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

SITI NOORADZAH BINTI ADAM

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CHAPTER 1

PREAMBLE

1.1 Introduction

The most significant recent breakthrough in remote sensing has been the development of hyperspectral sensors and software to analyze the resulting image data (Shippert, 2003). Multispectral remote sensing is defined as the collection of reflected, emitted or backscattered energy from an object or area of interest in multiple bands (regions) of the electromagnetic spectrum. Multispectral remote sensors produces images with a few relatively broad wavelengths bands whilst hyperspectral remote sensors collect image data simultaneously in dozens or hundreds of narrow, adjacent spectral bands (Smith, 2008). Most multispectral and hyperspectral remote sensing systems collect data in a digital format.

In more detailed description, the “hyper” in hyperspectral means “over” as in “too many” and refers to the large number of measured wavelength bands. Hyperspectral images are spectrally over determined, which means that they provide ample spectral information to identify and distinguish spectrally unique materials. Hyperspectral imagery provides the potential for more accurate and detailed information extraction than possible with any other type of remotely sensed data (Shippert, 2003). Other than that, Jensen (2000) defined hyperspectral imaging as the simultaneous acquisition of images in many relatively narrow, contiguous and/or non-contiguous spectral bands throughout the ultraviolet, visible and infrared portions of the spectrum. While Kruse (1994) states that hyperspectral imaging sample at close intervals (bands on the order of tens of nanometers wide) and have a sufficient number of spectral bands to allow construction of spectra that closely resemble those measured on laboratory instruments.

Figure 1.1 shows the schematic illustration of the imaging spectrometry concept that is shown with a spectrum measured for each spatial element in an image. Measurements are made at many narrow contiguous wavelength bands, resulting in a complete spectrum for each pixel (Green et al., 1998). Besides that, hyperspectral images are sometimes referred to as "image cubes" because they have a large spectral dimension as well as the two spatial dimensions as shown in Figure 1.2. This figure shows an AVIRIS hyperspectral image of the Leadville mining district in Colorado with the spectral dimension shown as the top and right faces of the cube. The front of the cube is a true color composite, with areas containing secondary minerals from acid mine drainage highlighted in red, orange and yellow. This cube was processed using ENVI (Shippert, 2004).

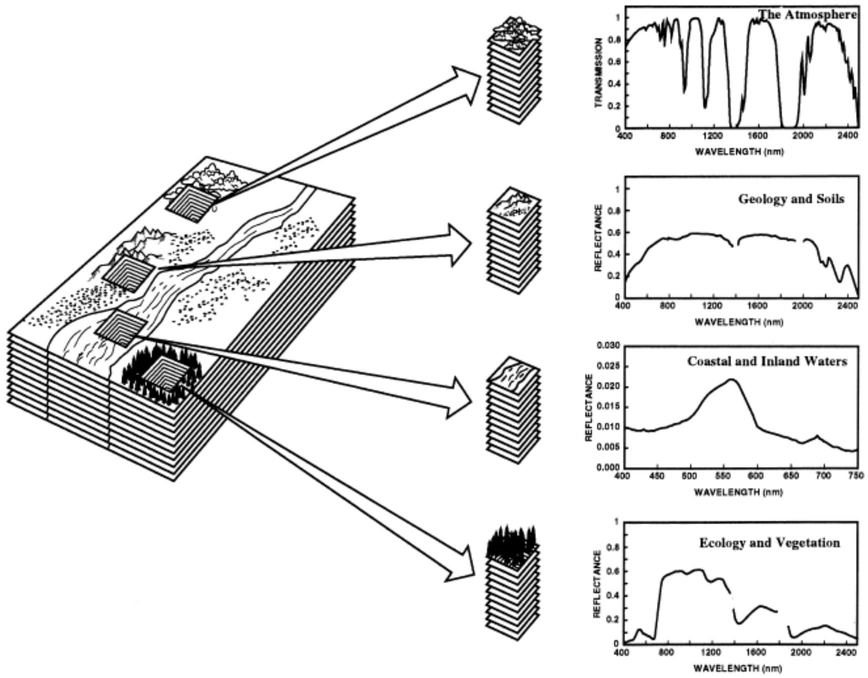

Figure 1.1: The concept of imaging spectroscopy

Figure 1.2: AVIRIS hyperspectral image of the Leadville mining district in Colorado

This emerging technology uses sensor fusion techniques to detect and identify an object through multi-dimensional aspects involving spatial, spectral, radiometric and temporal data from the combined capabilities of imagery, spectrometry and radiometry instruments (Gomez, 2001).

Although most hyperspectral sensors measure hundreds of bands, it is not the *number* of measured wavelength bands that qualifies a sensor as hyperspectral but rather the *narrowness* and *contiguous nature of the measurements.* A hyperspectral sensor is one that oversamples the phenomena of interest. Because of this, the number and spacing of bands required to qualify a sensor as hyperspectral somewhat depends on the spectral characteristics of the materials under study (Shippert, 2004).

Furthermore, even though hyperspectral images contain a wealth of data, but interpreting them requires an understanding of exactly what properties of ground materials to be measured, and how they relate to the measurements actually made by the hyperspectral sensor.

1.2 Applications of Hyperspectral Imaging

Projects utilizing hyperspectral imagery usually have one of the following objectives:

I. *Target detection.* Investigators are generally trying to locate known target materials. This can sometimes involve distinguishing targets from very similar backgrounds, or locating examples of targets that are smaller than the normal pixel size.

II. *Material identification.* Investigators do not know which materials are present in the scene. Under this scenario, the analysis is designed to use hyperspectral imagery for identifying the unknown materials. This analysis may also be accompanied by material mapping in which the identified materials are geographically located throughout the image. Material mapping is also performed with hyperspectral imagery when the materials present in the scene are known beforehand.

III. *Material mapping and mapping details of surface properties.* Material mapping is use to represent an area, a symbolic depiction highlighting relationships between elements of that space such as objects, regions, and themes and hyperspectral imagery has also been used to study details of surface properties that are undetectable using other types of imagery (Shippert, 2004).

Other than that, hyperspectral imagery also being applied to the following:

- *Transportation analysis:* obtaining crucial transportation information in and around major national highways and centers of freight transportation activity (Gomez, 2001) and asphalt road conditions (Herold, 2005).

- *Precision agriculture.* Detecting crop stress, early detection of crop infestation (Gomez, 2001), vegetation species (Clark et al, 1995), study plant canopy chemistry (Aber and Martin, 1995), spectral of featured crop (Chen et al., 2005), crop stress detection (Shibendu et al., 2010), bamboo mapping (Kamaruzaman, 2007), agricultural business (Kamaruzaman et al, 2008) and disease infection in oil palm plantation (Shafri et al., 2009**)**

- *Military applications.* Detecting military vehicles under partial vegetation canopy (Pabich, 2002)

- *Geology.* Mineral mapping (Clark et al., 1995, Roger et al., 2006), detection of soil properties including moisture, organic content and salinity (Ben-Dor, 2002), lithologic recognition and mapping (Salvi et al., 2001) and mapping acidic mine waste (Swayze, 2000)

- *Ocean.* Coastal characterization (Shaw and Burke, 2003) and detecting onshore oil seeps (Ellis et. al., 2001)

Hence, hyperspectral technology is an excellent complement to the large investment in conventional image processing by adding quantitave physical information to each pixel in a scene thereby adding an entirely new dimension for object location, classification and identification (Gomez, 2001).

These signatures often provide enough information to identify and quantify the material(s) existing within the pixels. A user could, for instance, employ a hyperspectral image to locate and quantify different types of building materials or minerals that might be present within an area of interest or even within a single pixel (Shippert, 2002).

1.3 Hyperspectral sensors

Hyperspectral images are produced by an instrument called *imaging spectrometers*. Two related technologies that were involved in the development of the instrument were *spectroscopy* and *remote imaging* of Earth and planetary surfaces (Smith, 2008).

Spectroscopy is the study of light that is emitted by or reflected from materials and its variation in energy with wavelength. As applied to the field of optical remote sensing, spectroscopy deals with spectrum of sunlight that is diffusely scattered by materials at the Earth's surface.

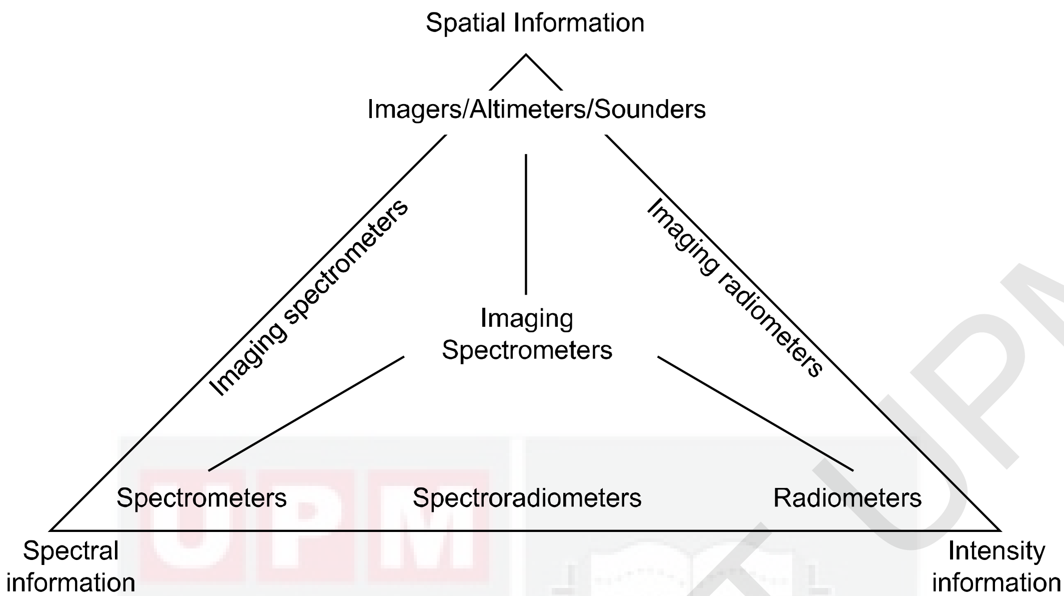

Figure 1.3: Relationship among radiometric, spectrometric and imaging techniques

Figure 1.3 illustrates the different type of information sought after and the type of sensor to acquire the information. For instance, spectral information is acquired with a spectrometer. Two-dimensional surface spatial information is acquired with an imager such as camera. An imaging spectrometer also acquires data for each pixel in the image spectral information (Elachi, 2006). Most hyperspectral sensors detect reflected energy between 0.3 to 2.5 micron wavelengths in the electromagnetic spectrum (Jackson, 2000).

1.4 Spectral Library

Spectral library, as being described by Preissler (1998) was; besides the spectral signatures of natural materials components, additional elements describing the relationship to specific physiographic and ecological background conditions of the areas under observation.

Bainbridge (2003) describes that in developing a digital library, the process that involves are selecting documents for inclusion, coming up with a suitable metadata set, assigning metadata to each document or group of documents, designing the form for the collection in terms of document formats, searchable indexes, and browsing facilities, building the necessary indexes and data structures, and putting the collection in place for others to use.

The time and effort that is spent in collecting spectral data, combined with characteristically large number of files, makes it clear that spectral data should be well organized. Otherwise, valuable data can be lost or loses its value because of missing metadata (Hueni and Tuohy, 2006).

The spectral library is a database that consists of literally thousands of individual spectral curves, obtained by spectrometers applied to discrete materials (as pure as possible) and classes in laboratory and field settings. Metadata/ancillary data need to be gathered as well to describe the characteristics of the spectra.

1.5 Problem Statement

Although the development of spectral library is hot at home and abroad since 90's, it has defects and cannot meet the demands of theory research and application of remote sensing nowadays (Chen et al, 2005). Gomez (2001) explains that as result of abundant of data that were collected using hyperspectral sensors, the users have to spend considerable time gathering spectral data and identifying knowledgeable points of contacts as they try to answer such question as: has the type of work being done before? If so, what specifically was done and how does it relate to the application of interest to us? Who did the work, for what application, in what timeframe? How did the user evaluate the spectral sensor's performance? Without a single reference source to help answer all these questions, the user will not only be less efficient, but will risk the possibility of not exploiting key and relevant experience in the field.

Moreover, the data to be referred existed in assortment of media including laboratory books, floppy disks, zip disks, CDs and internal hard disks. So, to perform what would seem to be relatively simple tasks, such as extracting all signatures of vegetation, could actually take several days due to searching through all the storage medias as well as have to reformatting the formats. In order to further complete and make practical of the library, the data need to have additional information (metadata or ancillary data) which describes the relationship to specific physiographic and ecological background conditions of the areas under observation. Thus, in order to combine all the information in a manageable format, it is essential that a well-populated spectral library exists and be accessible in a user-friendly way by the user of this technology.

At the present time, especially in Malaysia, there is no single Internet place for spectral sensing users to rely on to gather comprehensive data of spectral signatures of materials that are available for their field of study. Currently the user can only retrieve the end data or result from available stand-alone spectral libraries without having the opportunity to contribute towards the richness of spectral data in the library in real-time. With the development of UPM Spectral Library (UPMSpecLib), it is a hope that this will be the place for Malaysian spectral sensing users turn to when they demand for various spectral sensing data to carry out their research.

The gap that can be filled in this research is to develop a spectral library that represents Malaysian materials with its own classification of materials and their environment parameters. It can be accessible online (web based) to provide the convenient sharing of data with collaborative research peers, storing and distributing the hyperspectral signatures as well as their metadata. It also provides interactiveness in terms of searching methods, spectral signature analyses and data management.

1.6 Aim and Objective of Study

The aim of this study is to design and develop an interactive spectral library of materials for hyperspectral data utilisation. The objectives of this study are as follows:

- To design a database for storing and distributing hyperspectral signatures and their metadata

- To determine and develop the most practical and user friendly web-based spectral library to facilitate the sharing of stored data of materials that is known as UPM Spectral Library (UPMSpecLib)

- To evaluate the performance of the developed system

1.7 Scope and Limitation of the Study

This study only concentrates on the design, development and data handling of the spectral library. Test data from ASTER Spectral Library is used to test the spectral graphing (spectral signature) of the materials as the matter of fact that it can show the comparison for the quality and accuracy of the graph.

Furthermore, this research does not deals with how the measurement of the spectral signature was collected or obtained but it is more focused on providing a repository for collection of spectral data.

1.8 Organization of Chapters

This study comprises of five phases shown in Figure 1.4 and the chapters are organized as follows. Chapter 2 critically reviews the relevant literature of this study. In this chapter, existing international and local spectral libraries that have been developed are reviewed and analysed in terms of their purposes and covered spectral signature and research area. From this chapter, the gaps that need to be filled for this study are identified.

Management of the library that comprises of design structure, relationship model, materials classification, metadata, test data, software and applications that is being used and user management concept are discussed in Chapter 3. The final Graphical User Interface (GUI) of the library, query features, graphing techniques and interactivity are discussed in Chapter 4. Finally, the last chapter summarizes the findings of this study by highlighting the relationship between the objectives and studies achievements, limitations of the study and suggestions for future studies.

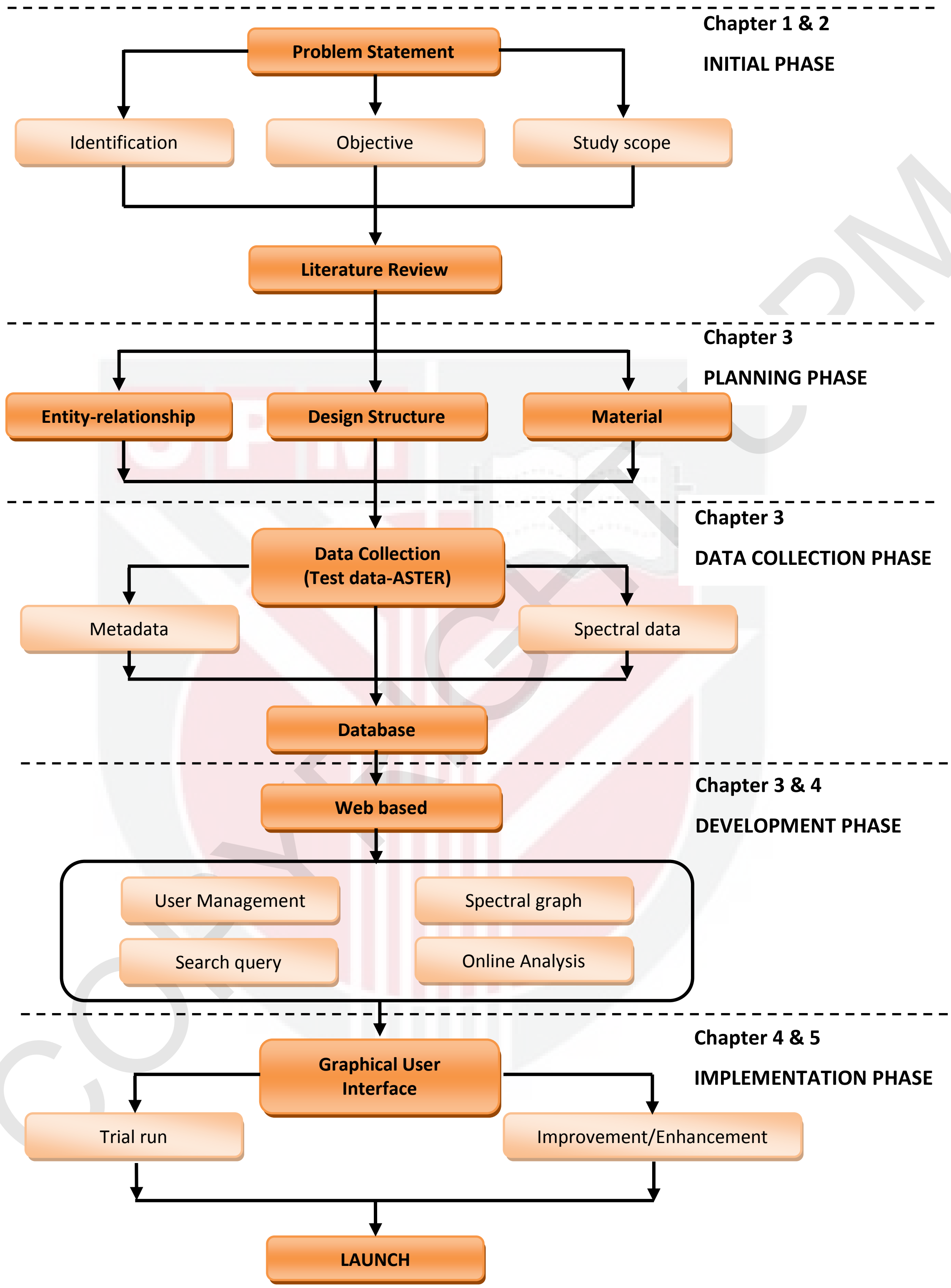

Figure 1.4: Summary of the study

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