Software Requirement Specification Document For Oil Wells Detection Using Satellite Imagery

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Table 1: Document version history

Version	Date	Reason for Change
1.0	20-Dec-2020	SRS First version's specifications are defined.
2.0	27-Dec-2020	Dr. version of SRS

GitHub: https://github.com/monikaMagdy/oil-well-detection-by-HSI

Abstract

The oil industry is considered the heart of the economy of the world and the most expensive energy source. Egypt signifies a great place in Oil production, which affects the economy of Egypt in a great way. Our project is mainly focusing on the detection of Oil fields using satellite imagery precisely using hyperspectral images. The principle feature we are focusing on getting from our images is Hydrocarbon emissions using hyperspectral images that are mainly used nowadays by all geologists teams that are searching on oil and gas reservoirs. After getting hyperspectral images from satellite our system will image process these images using some filters and classifiers. The system will first do some preprocessing filters on the trained data by using Principle Component Analysis (PCA). The second stage in our system is using three main Classifiers which are Support Vector Machine (SVM), Convolution Neural Network CNN, and Three Band Ratio in order to detect hydro-carbon emissions. We aim in our project to present a new way to increase Egyptian oil production by detecting new oil fields through a faster, more efficient, and less expensive way.

1 Introduction

1.1 Purpose of this document

The purpose of this Software Requirement Specification Document is to study and examine all the different ideas and concepts that build our system in a way that demonstrates it's requirements, concerning our potential market and customers. The system's main purpose to automatically detect with higher accuracy and predict of Oil fields using remote sensing data precisely using hyperspectral images which is higher accuracy [1]. The main component that we are looking for in our hyperspectral images is hydrocarbon emotions that it was proven by most geologists that under this seepage there is oil[2] [3]. The System targets the petroleum Firms and especially the geologist team that works on detecting new oil fields. The Project will consist of Web research in which the geologists can easily login or sign-up on the system and start inserting the images of the area that could contain oil wells in it and receive the result accurately.

1.2 Scope of this document

This document, will be explaining more how this software is used to obtain a better understanding of the whole system and define other functional and non-functional requirements that we may develop along the way as the project progresses.

1.3 System Overview

The proposed system consists of some linked stages: The first stage is data input. The Satellite hyperspectral camera starts to capture the earth's ground with a wide spectrum of light. The second stage is the feature extractions. Those images are taken as a 3D array for each R-G-B to find new features by selecting existing features to reduce the feature space without loss of information by using Principal Component Analysis(PCA) to reduce the excess of dimensions of the HIS [4].

Then the machine learning stage. The system has some algorithms used to choose the highest accuracy. First; The Support Vector Machine(SVM) is a machine learning algorithm based on statistical supervised learning theory used to analyze and classify[5]. Second, the three-band ratio to enhance the spectral differences between bands and to reduce the effects of the atmosphere on camera. Then the Convolutional Neural Network is used to analyzing visual imagery. Finally, the accuracy report will decide to classify the ground truth classes for the current data-set.

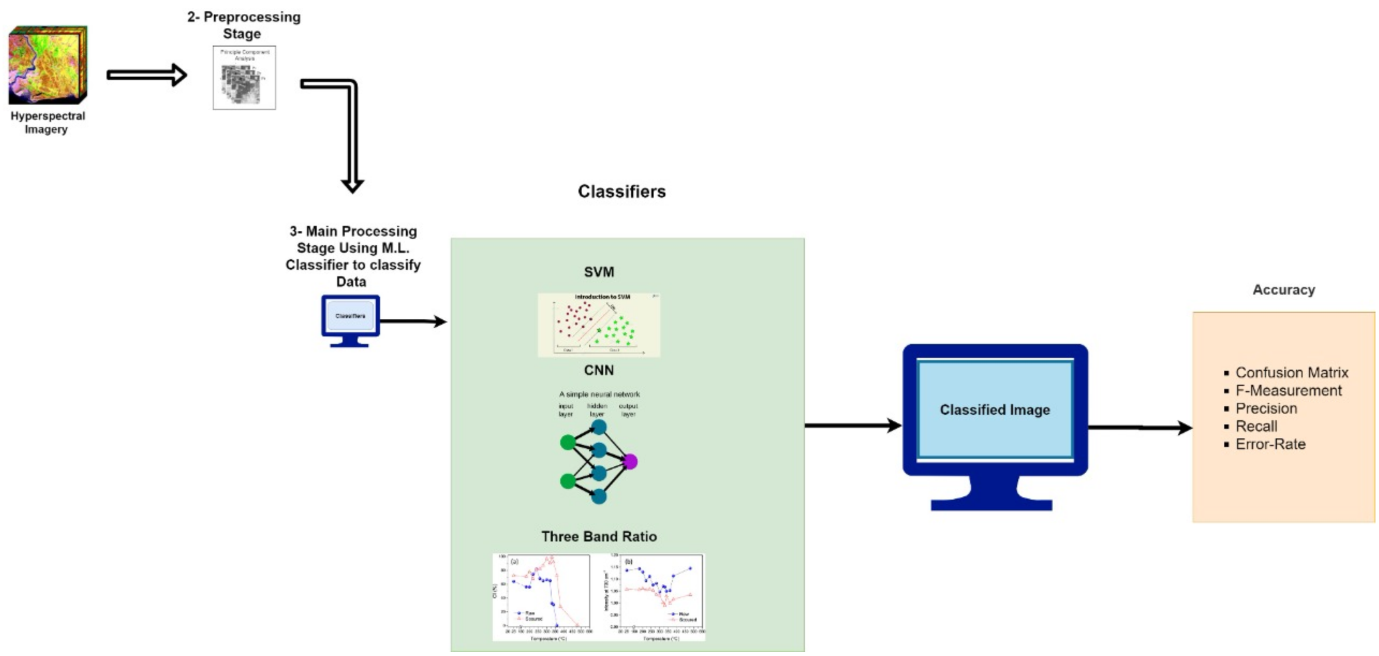

Figure 1: Project Overview

In figure 2, we present the flowchart of our system to explain more our main system functionalities. Firstly, we start by uploading the Bip image on ARCgis to modify the image by assigning the RGB bands of the image. Then we improve the contrast of the image by changing the histogram equal- ization[6]. At the end of using ARCgis we extract the Bip image into TIF image to be loaded easier in Matlab. Secondly, we update TIF image in Matlab and we start preparing the image for processing by reshaping RGB array from 3D to 2D. After that we reduce the dimensions of the image by applying PCA[7], then we obtain the output of Principal component features (can be more than one principal component) [8]. At the end of the process, we split data of the output features of principal components into training and testing models[8]. We will select RBF kernel which is a specific kernel type used especially for oil spills[9], after that we train SVM model then we do SVM prediction on the testing model based on the trained model. We take the actual class and predicted class for applying the accuracy.

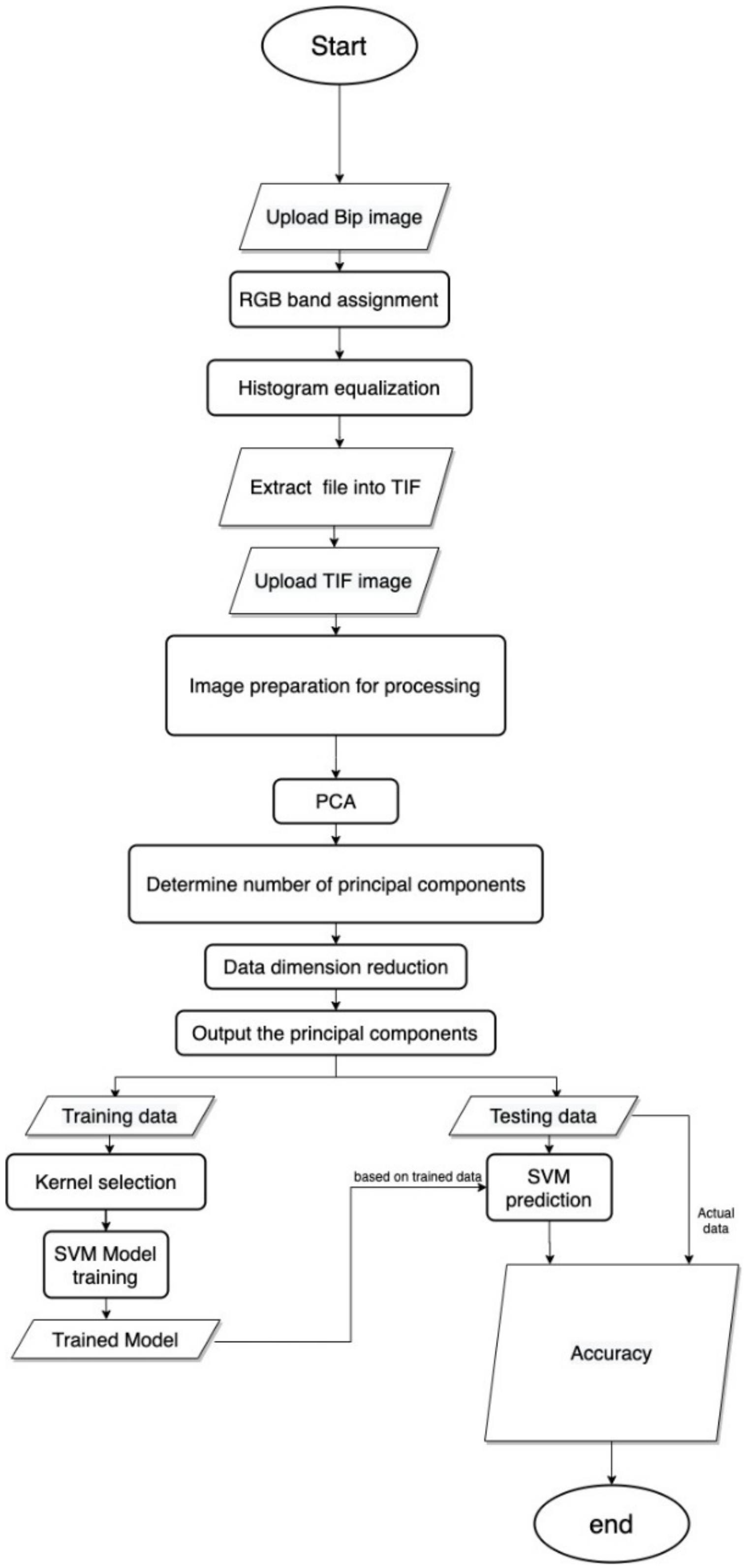

Figure 2: Project Flow Chart

1.4 System Scope

The proposed system aims to automatically detect new oil wells by using different algorithms and classifiers by satellite imagery. The main purpose is increasing the accuracy of the Classifiers to experiment with various techniques by ensembling different frame works. Ensemble classifiers have been developed to integrate several classifiers as supervised or unsupervised learning techniques to enhance the accuracy and consistency of a single classifier[10]. The system will be working by locating certain locations in the hyperspectral images those images will be classified according to hydrocarbon emissions that are emitted from the oil reservoirs then Inform the results detected from our system to competent authorities.

1.5 Business Context

Crude oil became the most demanded mineral in the global industry as it supports more than 40% of the global energy needs[11]. Egypt owns second place in Africa in oil production, with oil production of 682,904 barrels per day, also Egypt had reached the twenty-fifth place in the world in oil reserve with 4,400,000,000 barrels. Egypt possesses an essential role in the exportation operation we export 25% of our production. Although, We still have a daily conflict with an average of 194,096 barrels per day [12]. Although Egypt needs to increase the production of oil as every day the energy industry increases its demand. The challenging part of Oil extraction is the oil Wells detection process as the responsibility falls on the geology team to locate the suitable conditions to extract the oil and to find the right source of rock, which has under it the oil reservoir and the hydrocarbon [13]. Schlumberger one of the petroleum pioneer company's try to make it easier for geologists by providing automated Software systems to help in oil detection which made us more interested in such a project. The main idea from our project is trying to increase the petroleum production of Egypt with less expanse, which will affect in a great way the Egyptian economy and will help us move in a parallel way with the daily demand.

2 Similar Systems

2.1 Academic

- Detecting the hydrocarbon emission didn't gain the full interest of Turkey as they are trying to locate the hydrocarbon-induced anomalies that are vastly recognized in Remote sensing literature, indicating the existent absorption features of Hydrocarbon bearing minerals in the electromagnetic spectrum. Remote sensing from a satellite has still owned the solution for the problem, here our area of concern is Turkey especially offshore. Results are obtained by correcting the multispectral images that are prepared to be the input of the used algorithms. The article uses the same concept but for the same goal and the same concept to apply the techniques [14].

- The hydrocarbon emission is a common phenome in offshore oil detection, a team of scientists concluded that the hyperspectral images are an efficient fast solution to detect the location of the well, adding the privilege of helping more the environment by detecting any leak of oil or gas to a water surface. The hyperspectral data is obtained using remote sensing techniques of Liaodong Bay, China as an ROI. The results are satisfying mention that they manage to detect the radiation of hydrocarbon compound material and specify the waveband to be the most suitable image band multi-factor environment. As discussed they did use the same techniques to a related goal, they have a different area of interest as here they tried with China and our area of interest is The Gulf Of Mexico[15].

- As a forum of pollution oil spills is considered, which the accident of oil released into the environment (a surface of the water), due to the oil spills many plants and animals were killed, a lot of money is spent to clean up the oil and to reach different technologies or methods to clean up the oil as well. The researchers had reached a solution to use the hyperspectral images from satellites, which its classifications are being used in several fields beside the oil while considering the limitations of the hyperspectral images distortion due to the spherical shape of the planet which may lead to inaccuracies in the properties. The dataset used is "The Gulf Mexico". Experimental results on the real hyperspectral images had proven that the SVM, MD, BE have a close performance rate even better than the parallelepiped approach, after reaching the results a confusion matrix has used the accuracy of the classification compared to ground-truth information. The discussed article owns the same concern of the region, the subject of detection and the method, as well they have the preferred area which is the Gulf of Mexico. They mentioned accuracies of their work which is really really it reached 95% [5].

- Detecting the hydrocarbon emission is one of the ways to identify an oil well in the area which is considered a general practice to screen essential basins. The process of detecting hydrocarbon is very expensive it can reach up to 100 Million USD. Researchers had realized a new technique the seismic which is preferred due to its higher depth analysis which presents a wide option of geological formation, and an estimated volume of the reservoir, all is accomplished with the help of the satellite remote sensing. Our dataset is collected from the coast of Lagos State, southwest Nigeria. The article is using a different dataset and a different ROI as they are concerning our interest in The Gulf Of Mexico, the work here is focused on detecting the heat signature of the hydrocarbon, which is one of our main targets[16].

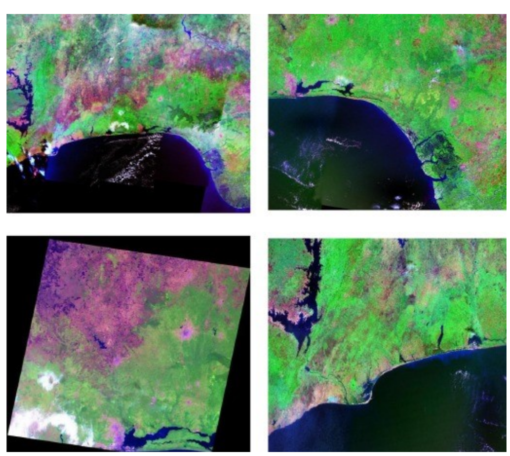

Figure 3: Surface geology of the region

2.2 Business Applications

N/A

3 System Description

3.1 User Problem Statement

The system goal is to improve oil production in Egypt by identifying more oil wells in a shorter period of time so that the national economy grow in a faster way with high accuracy to help the geologists teams in their researches.

3.2 User Objectives

Using Machine learning and image processing techniques throughout our automated System, technicians will be able to see the classified images if it detects the presence of hydrocarbon emissions in the specified image or not. If the Hydrocarbon emission is detected with high accuracy it means that it predicts the occurrence of oil wells.

3.3 User Characteristics

- Technician or Geologist :
    1. Must have basic knowledge of dealing with a Computer platform (PC/Laptop)
    2. Must be able to understand the basic features of the output images.

3.4 System Context

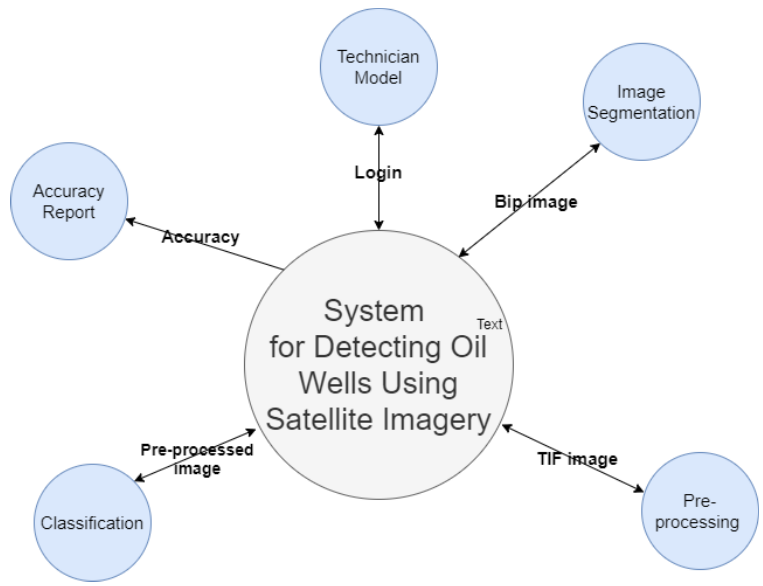

Figure 4: System Context Diagram

4 Functional Requirements

4.1 System Functions

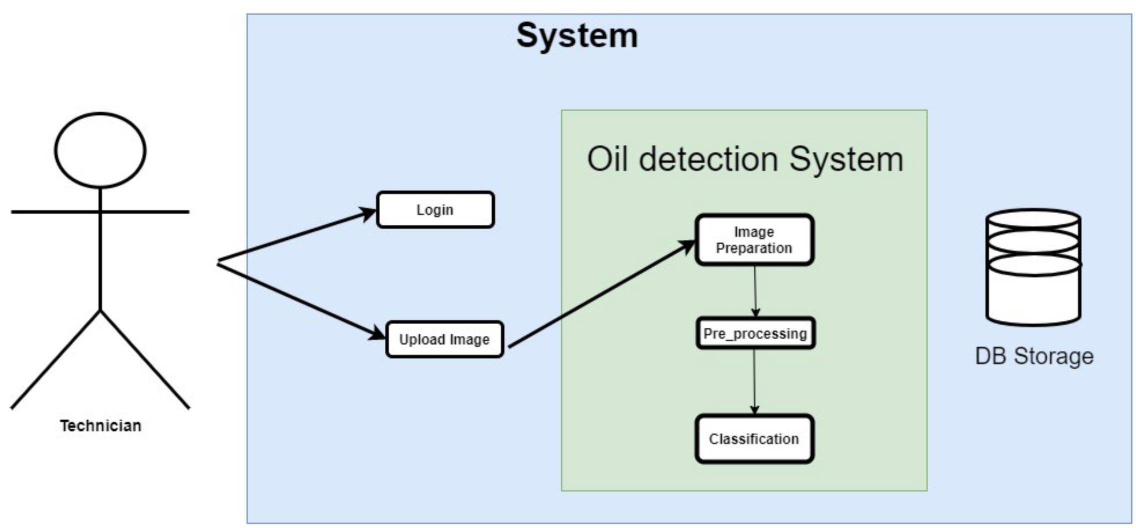

Figure 5: Use Case Diagram

4.2 Detailed Functional Specification

The next functionality describes the steps the user uses in the system.

Table 2: Login Function Description

Name	Login
Code	FR01
Priority	high
Critical	This function is essential to start the System.
Description	The technician/geologist must login into the system to start using it's main functions, using their usernames and passwords.
Input	Username, Password.
Output	Boolean (true for success, false otherwise).
Pre-condition	No access to system's functions and Data.
Post-condition	Login Successful, Proceed to Post-login page and access to the system Functions and Data.
Dependency	None
Risk	The user can't access the system if he can't login

Table 3: Upload image Function Description

Name	Upload image as Bip
Code	FR02
Priority	Extremely
Critical	This function is essential for image segmentation.
Description	The User/Technician can upload a hyper-spectral Bip image of the detecting place, before proceeding to prepossessing and classification stage.
Input	Binary file.
Output	Upload the Bip image.
Pre-condition	No image available for image segmentation.
Post-condition	The image is uploaded to the system and can be used in the next stage, which is the prepossessing and Classification stage.
Dependency	None
Risk	That the type of image could be different then the one required.

Table 4: Histogram Equalization Function Description

Name	Histogram Equalization
Code	FR03
Priority	Extremely
Critical	This function is essential for image Segmentation.
Description	This function is used to improve the contrast of image by changing the histogram's intensity distribution.
Input	Uploaded Bip image.
Output	Enhanced Histogram Equalization image.
Pre-condition	Uploaded as hyper-spectral image with no enhancements .
Post-condition	The Image is enhanced into more detailed image .
Dependency	FR02
Risk	That image can't be seen clearly so it could affect the next stage.

Table 5: Changing RGB bands combination Function Description

Name	Changing RGB bands combination
Code	FR04
Priority	Extremely
Critical	This function is essential for band assignment.
Description	This function is used to improve the RGB bands of image .
Input	Uploaded Bip image.
Output	Enhanced RGB image.
Pre-condition	Uploaded as hyper-spectral Bip image with bad band selection or with not appropriate contrast stretch.
Post-condition	The Image is enhanced into Colored image that can be seen clearly.
Dependency	FR03
Risk	That image can't be seen clearly so it could affect the next stage.

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Table 6: TIF Function Description

Name	Extract file to TIF
Code	FR05
Priority	Extremely
Critical	This function is essential for processing the image.
Description	This function is used to change the enhanced Bip image into TIF to be used in the next stage, which is the prepossessing and Classification stage .
Input	Enhanced Bip image.
Output	TIF file.
Pre-condition	Uploaded as enhanced Histogram Equalization and RGB bands assignment image.
Post-condition	The image is changed into TIF file to be used in the next stage, which is the prepossessing and Classification stage.
Dependency	FR04
Risk	The preprocessing and classification will be hard to adjust.

Table 7: Dimensionality Reduction

Name	Dimensionality Reduction
Code	FR06
Priority	Extremely
Critical	This function is essential for Data to be preprocessed for classification.
Description	This function is applied to reduce the redundant data from file.
Input	loaded TIF file.
Output	PCA data.
Pre-condition	The data with no preprocessing .
Post-condition	The image is ready for classification steps.
Dependency	FR05.
Risk	It will affect the classification stage as it will take longer processing time.

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Table 8: Classification Function Description

Name	Classification
Code	FR07
Priority	Extremely
Critical	This function is essential for accuracy prediction.
Description	This function is used to train data and integrate the similar features to classify new inputs of images to predict it's accuracy.
Input	PCA Data.
Output	SVM Model.
Pre-condition	Trained and tested data without calculating the accuracy.
Post-condition	Trained and tested classes compared with each other then the data is classified.
Dependency	FR06,
Risk	The system will not obtain accuracy that we seek for.

Table 9: Prediction Report Function Description

Name	Generate Report
Code	FR08
Priority	Extremely
Critical	This function is essential for Accuracy results.
Description	This function Returns the accuracy of tested classes.
Input	Classifier result.
Output	Accuracy Percentages.
Pre-condition	The data is classified and different types of accuracy is predicted.
Post-condition	The system obtained it goal which is detection of oil place.
Dependency	FR07,
Risk	The system will not be aware of the percentage of accuracy.

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5 Interface Requirements

5.1 User Interfaces

The system user interface is designed to be simple enough and allow minimal interaction.

5.1.1 GUI

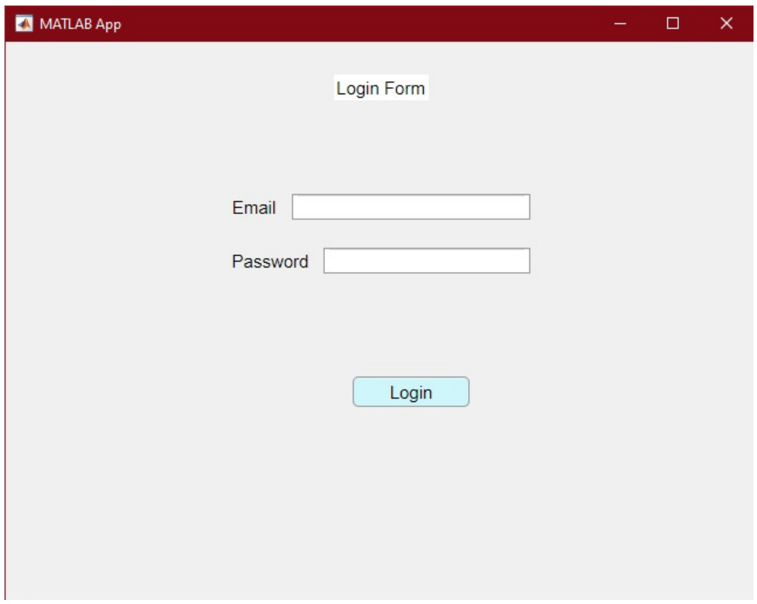

Figure 6: System Login UI

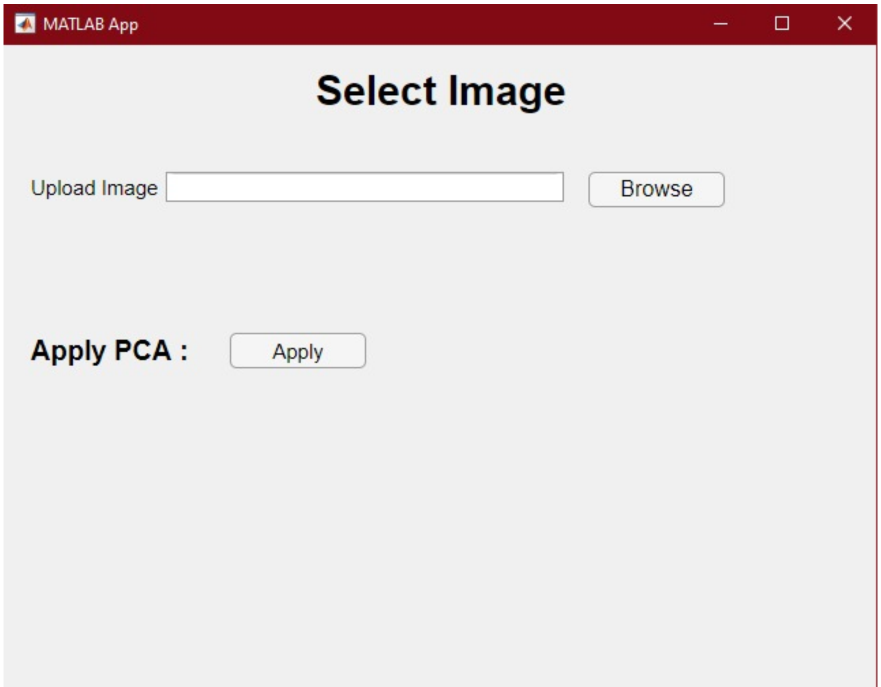

Figure 7: Main System UI

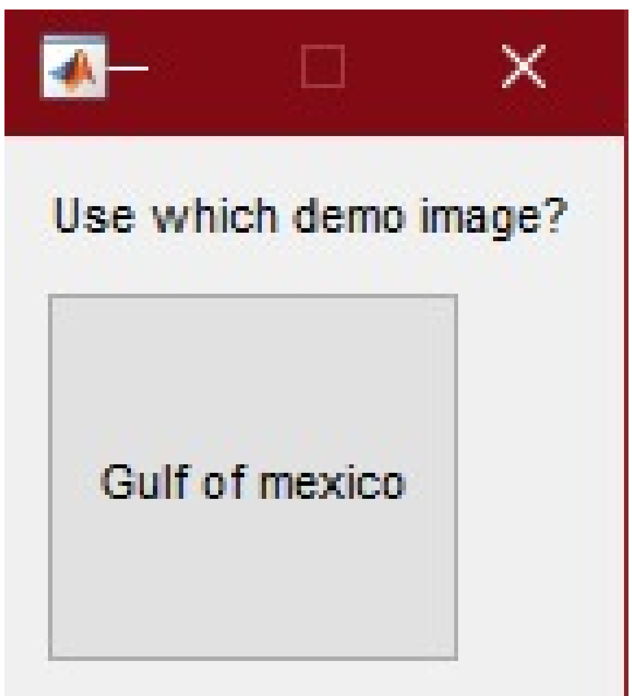

Figure 8: Upload image

5.1.2 Desktop Application

- ARCgis is installed to maintain the Data.
- Matlab is installed to build the system on it[17].

5.2 Hardware Interfaces

N/A.

5.3 Communications Interfaces

Local network interfaces

5.4 API

- ARGis is used for image processing techniques done on the image.
- Matlab toolbox is used to implement PCA and the SVM classifier.

6 Design Constraints

6.1 Standards Compliance

We are following the Standard structure of hyper-spectral images with its required bands we use in the system [18] [19].

6.2 Hardware Limitations

The system requires a multi-processor CPU core not less than i5 with RAM that is at least 8 GB preferably higher with concurrent usage and hard disk space with at least 10 GB.

6.3 Other Constraints as appropriate

N/A

7 Non-functional Requirements

7.1 Security

- The Technician and User Data and Diagnosis must be protected and preserved since they are sensitive and privileged information, and the system should not be accessed by anyone other than the assigned Technician.

- The Dataset should be secured as it may have secret data that couldn't except by authorized people
- The accuracy report must be secured as it display sensitive information

7.2 Reliability

The System must be very accurate since the result provided by the system determines whether the detected place contains oil or not. So it is very important and pivotal that geologists can rely on and trust the system in their detection research, and be assured that the output result is precise. To achieve this requirement, the system will be trained and tested on a very big Dataset, which will increase the accuracy of the system's classification result.

7.3 Maintainability

The System can be modified and upgrade if there is a problem with it. The system also can re-training itself by a new set of hyperspectral Images chosen by the Technician, after the Relevance Feedback process is completed.

8 Data Design

8.1 Data Description

As our area of interest is "Gulf Of Mexico", we obtained the data using an AVIRIS camera which collects the data using flights drawn on the map, so from the nearest flight record, a 2 GB dataset was collected for the mentioned location in binary[20].The dataset contains two important files which are the header file that contains information about the image and the second file is the Bip file of the image. To prepare our data to import to our platform we used ARCgis to convert our data from binary format into 4 files the most important one is TIFF (Tag Image File Format), which has four types one of them is RGB which we need while dealing with our hyperspectral multispectral images. TIFF files own the privilege of the option of owning a supplementary file called TFW which contain 6 rows of data [21].

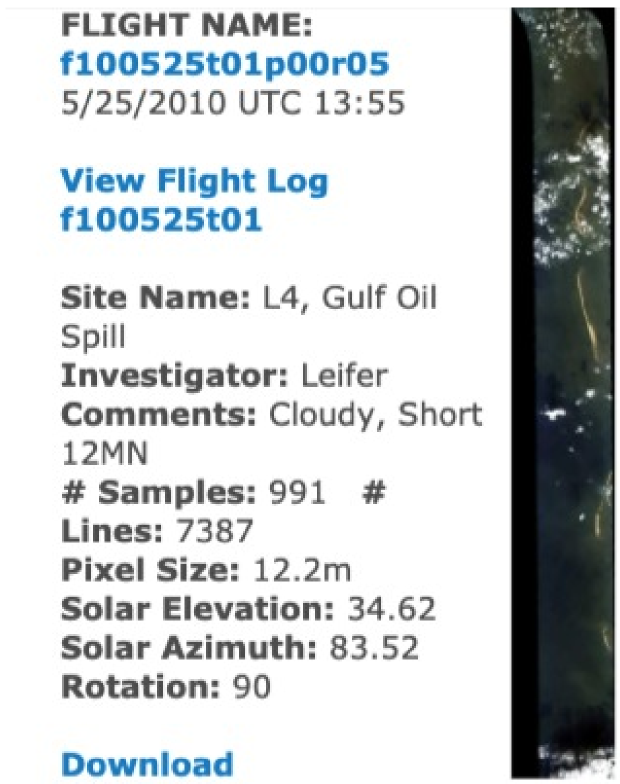

Figure 9: Installed Dataset

8.2 Database design description

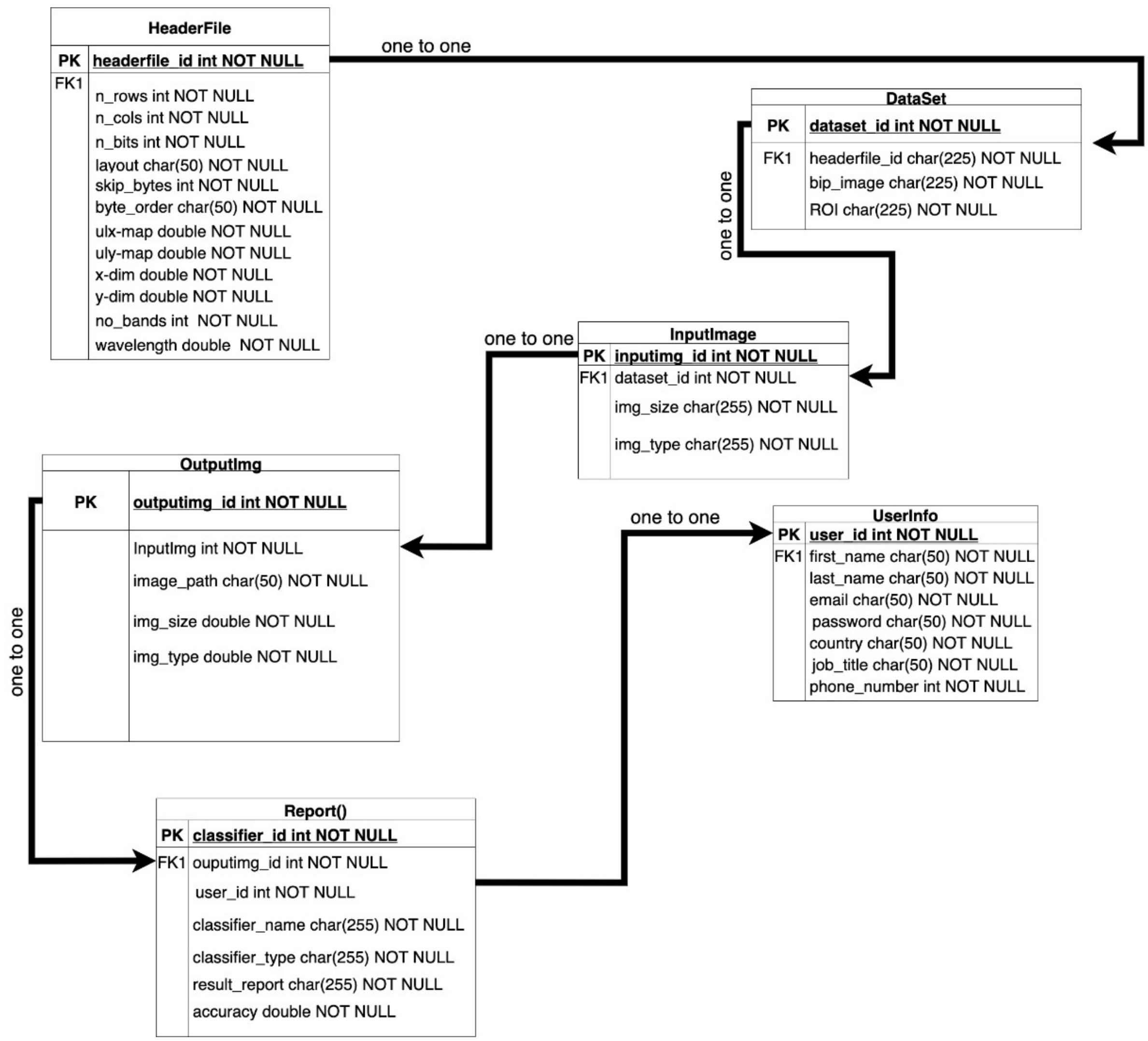

Figure 10: Database Schema Diagram

9 Preliminary Object-Oriented Domain Analysis

Figure 11: Class Diagram

9.1 Inheritance Relationships

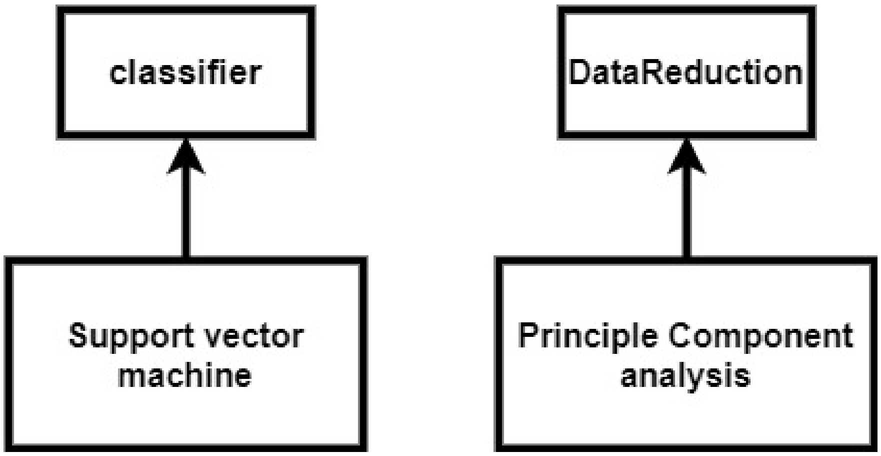

Figure 12: Inheritance Relations

9.2 Class descriptions

Table 10: Class Name - PetroleumEngineer

Abstract or Concrete:	Abstract.
List of Superclasses	None
List of Subclasses	None
Purpose	Class for user.
Collaborations	Dependence on InputImage and Classifier classes
Attributes	CompanyName : String, CompanyID : String
Operations	SearchLocation(String Location):String , UploadImage(Image img);String, viewClassificationResult():Void, SearchUsers(ID):String .
Constraints	None.

Table 11: Class Name - InputImage

Abstract or Concrete:	Concrete.
List of Superclasses	None.
List of Subclasses	None.
Purpose	Class represents the image file.
Collaborations	Aggregates Classifier classes
Attributes	ID : int, Name : String, type: String, Size: int, BandNumber: int
Operations	getBandNumber(int BandNumber) : int , writePixel();String, ReadPixel(): String.
Constraints	The system can't be accessed without the presence of petroleum engineer.

Table 12: Class Name - PCA

Abstract or Concrete:	Abstract.
List of Superclasses	None.
List of Subclasses	DataReduction.
Purpose	Class represents the preprocessing of the image .
Collaborations	None
Attributes	CovarianceMatrix:String, TempMatrix:String, Img$_{s}ize : int, ImageBands : int.$
Operations	BandMatrix(Image):void , Normalize(Image):void, Display(Band): void.
Constraints	can't be accessed without the input image.

Table 13: Class Name - Classifier

Abstract or Concrete:	Concrete.
List of Superclasses	SVM Classifier.
List of Subclasses	None.
Purpose	Class represents the classification of image .
Collaborations	Aggregates InputImage class
Attributes	ID : int, Name : String, type: String, Size: int, BandNumber: int
Operations	None.
Constraints	The class can't be accessed without the PCA.

.

Table 14: Class Name - DataReduction

Abstract or Concrete:	Concret.
List of Superclasses	PCA.
List of Subclasses	None.
Purpose	Class reduces the size of image .
Collaborations	None.
Attributes	pixel array:int.
Operations	reducepix(px):int.
Constraints	None.

Table 15: Class Name - SVM classifier

Abstract or Concrete:	Abstract.
List of Superclasses	None.
List of Subclasses	Classifier.
Purpose	Class detect features of image .
Collaborations	Aggregate Accuracy and output image classes.
Attributes	actualData: String, predictData: String, kernel: String, C:double, Deg:double.
Operations	confusionMatrix(actual,predict):void, grad-asc-poly(actual,c,Deg):void , holdOut (actualData,predictData):void.
Constraints	None.

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Table 16: Class Name - Accuracy

Abstract or Concrete:	Abstract.
List of Superclasses	None.
List of Subclasses	None.
Purpose	Class the accuracy of image .
Collaborations	None.
Attributes	Accuracy:double, type:String.
Operations	confusionMatrix():void, addReport(response):void, getErrRate():void, getAccuracy(percentage):void .
Constraints	The Accuracy can't be obtained without Classifier.

Table 17: Class Name - Output Image

Abstract or Concrete:	Abstract.
List of Superclasses	None.
List of Subclasses	None.
Purpose	Class that give us the final result image .
Collaborations	None.
Attributes	ID: int, Name:String , type:String , size:int.
Operations	getBandNumber(int number):int , ReadPixel():String.
Constraints	Can't work without SVMClassifier.

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10 Operational Scenarios

We have two case operation scenarios, first one if the user already has a TIF file, the user will upload the image on Matlab (Main System), then the user will apply PCA on the input file, after that the user applies the classifier SVM that has an output accuracy report.

Second case scenario, the user has a dataset of Bip image, the user must convert the dataset into TIF file to upload it onto Matlab (Main System) to apply principal component analysis on the input data file and then use the classifier to obtain the highest classification and output report of accuracy.

11 Project Plan

Table 18: Oil Detection time plan

Id	Task	Start Date	Number of Days	Team Member
1	Collect Dataset	11/15/2020	25	Madonna,Omar
2	Testing on different tools	12/1/2020	15	Monica Magdy, Madonna
3	Writting SRS	12/10/2020	20	Monica Hany, Omar
4	Uploading Dataset on ARGis	12/16/2020	5	Monica Magdy, Madonna
5	Uploading Dataset on Matlab	12/21/2020	2	Monica Magdy, Omar
6	Pre-processing	12/23/2021	2	Monica Magdy, Madonna
7	Experiments	12/25/2021	-	Monica M., Madonna,Omar,Monica H.

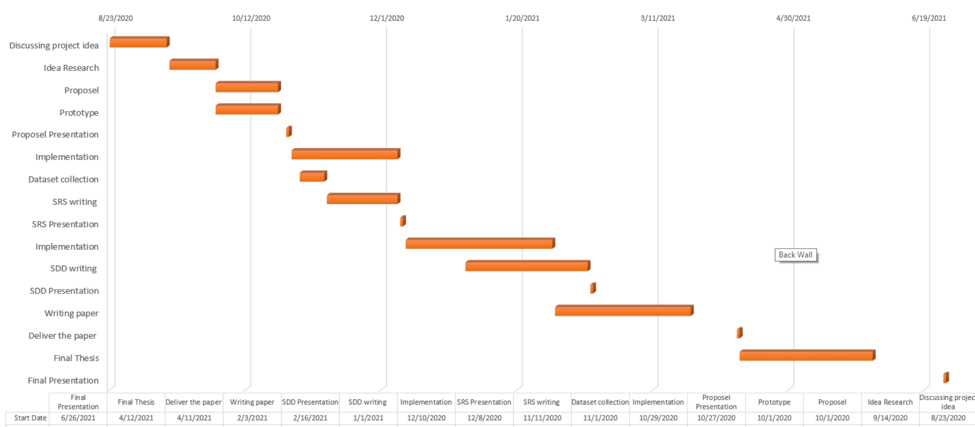

Figure 13: Time plan

12 Appendices

12.1 Definitions, Acronyms, Abbreviations

- PCA: Principle Component Analyzes.
- SVM: Support Vector Machine.
- Bip: Binary Image File.
- TIF or TIFF: Tagged Image File.
- RGB : Red, Green, Blue.

12.2 Supportive Documents

N/A

13 References

References

[1] Sahar A El Rahman, Wateen A Aliady, and Nada I Alrashed. “Supervised classification approaches to analyze hyperspectral dataset”. In: *International Journal of Image, Graphics and Signal Processing (IJIGSP)* 7.5 (2015), pp. 42–48.

[2] Richard s. Kruas. “Chapter 75 - Oil Exploration and Drilling”. In: *Encyclopaedia of occupational and health and safety*. Vol. 4. 5. International labour office. 1998.

[3] S. Salati. “Characterization and remote detection of onshore hydrocarbon seep - induced alteration”. English. ITC Dissertation; 245. PhD thesis. University of Twente, Mar. 2014. ISBN: 978-90-365-3629-5. DOI: `10.3990/1.9789036536295`.

[4] *Dimensionality Reduction in Hyperspectral Images using Python | by Syam Kakarla | Towards Data Science*. `https://towardsdatascience.com/dimensionality-reduction-in-hyperspectral-images-using-python-611b40b6accc`.

[5] Sahar A El-Rahman and Ali Hussein Saleh Zolait. “Hyperspectral image analysis for oil spill detection: a comparative study”. In: *International Journal of Computing Science and Mathematics* 9.2 (2018), pp. 103–121.

[6] *Histogram Equalization. Image Contrast Enhancement | by Shreenidhi Sudhakar | Towards Data Science*. `https://towardsdatascience.com/histogram-equalization-5d1013626e64`.

[7] Ke Li, Yi Liu, Quanxin Wang, et al. “A Spacecraft Electrical Characteristics Multi-Label Classification Method Based on Off-Line FCM Clustering and On-Line WPSVM”. In: *PloS one* 10 (Nov. 2015), e0140395. DOI: `10.1371/journal.pone.0140395`.

[8] Tsun-Kuo Lin. “PCA/SVM-based method for pattern detection in a multisensor system”. In: *Mathematical Problems in Engineering* 2018 (2018).

[9] H. Zhou and C. Peng. "Oil Spills Identification in SAR Image Using mRMR and SVM Model". In: *2018 5th International Conference on Information Science and Control Engineering (ICISCE)*. Los Alamitos, CA, USA: IEEE Computer Society, July 2018, pp. 355–359. DOI: 10.1109/ICISCE.2018.00081. URL: https://doi.ieeecomputersociety.org/10.1109/ICISCE.2018.00081.

[10] Shasha Mao, Licheng Jiao, Lin Xiong, et al. "Weighted classifier ensemble based on quadratic form". In: *Pattern Recognition* 48.5 (2015), pp. 1688–1706. ISSN: 0031-3203. DOI: https://doi.org/10.1016/j.patcog.2014.10.017. URL: http://www.sciencedirect.com/science/article/pii/S0031320314004348.

[11] Maizar Rahman. "Oil and gas: the engine of the world economy". In: *Presentation as OPEC Secretary General at the Tenth International Financial and Economic Forum, Vienna, Austria*. 2004, pp. 10–11.

[12] *Egypt Oil Reserves, Production and Consumption Statistics - Worldometer*. https://www.worldometers.info/oil/egypt-oil/#:~:text=Oil\%20Production\%20in\%20Egypt&text=Egypt\%20produces\%20682\%2C904.14\%20barrels\%20per,reserves\%20(as\%20of\%202016).

[13] Colin D Prosser. "Geoconservation, quarrying and mining: opportunities and challenges illustrated through working in partnership with the mineral extraction industry in England". In: *Geoheritage* 10.2 (2018), pp. 259–270.

[14] Hilal Soydan, Alper Koz, and H Şebnem Düzgün. "Identification of hydrocarbon microseepage induced alterations with spectral target detection and unmixing algorithms". In: *International Journal of Applied Earth Observation and Geoinformation* 74 (2019), pp. 209–221.

[15] Jianwei Xiao, Qingjiu Tian, Yingcheng Lu, et al. "Extraction of hydrocarbon content information by using hyperspectral image at Liaodong Bay, China". In: *2010 18th International Conference on Geoinformatics*. IEEE. 2010, pp. 1–5.

[16] ME Emetere. "Modified satellite remote sensing technique for hydrocarbon deposit detection". In: *Journal of Petroleum Science and Engineering* 181 (2019), p. 106228.

[17] *MATLAB version 9.3.0.713579 (R2017b)*. The Mathworks, Inc. Natick, Massachusetts, 2017.

[18] F. Vasefi, N. MacKinnon, and D.L. Farkas. "Chapter 16 - Hyperspectral and Multispectral Imaging in Dermatology". In: *Imaging in Dermatology*. Ed. by Michael R. Hamblin, Pinar Avci, and Gaurav K. Gupta. Boston: Academic Press, 2016, pp. 187–201. ISBN: 978-0-12-802838-4. DOI: https://doi.org/10.1016/B978-0-12-802838-4.00016-9. URL: http://www.sciencedirect.com/science/article/pii/B9780128028384000169.

[19] Paul Geladi, Jim Burger, and Torbjörn Lestander. "Hyperspectral imaging: calibration problems and solutions". In: *Chemometrics and Intelligent Laboratory Systems* 72.2 (2004). Advances in Chromatography and Electrophoresis - Conferentia Chemometrica 2003, Budapest, pp. 209–217. ISSN: 0169-7439. DOI: https://doi.org/10.1016/j.chemolab.2004.01.023. URL: http://www.sciencedirect.com/science/article/pii/S0169743904000371.

[20] Nasa. *JPL | AVIRIS Data Portal*. https://aviris.jpl.nasa.gov/dataportal/.

[21] File info. *TIFF File Extension - What is a .tiff file and how do I open it?* https://fileinfo.com/extension/tiff.