Practical Implications and Challenges of Multispectral Image Analysis

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***Abstract*— Multispectral Image Analysis (MIA) is an exciting area of research and famous due to its utilization in geo monitoring, such as environmental change detection and region classification. Currently, many other areas are also emerging and are utilizing the multispectral imagery for improving the existing business processes and ensuring the reliability in the existing business methods. However, the process of generating and analyzing multispectral data needs more sophisticated techniques and methods. Also, the multispectral data possesses some temporal and structural inconsistencies, which make the existing multispectral analysis a more challenging task. Therefore, this study surveys the practical implication and possible issues in multispectral image analysis. For that reason, this study aims to investigate the two simple research questions and follow a structured analysis approach to achieve the research objectives. The rest of the paper is structured as; Section II briefly explains the systematic methodology adopted for this survey. Section III is relevant to research finding in response to the RQ1 and RQ2. Finally, Section IV presents the conclusion of this study. In future work, we will sharpen this study towards Skin Disease Analysis using Multispectral Imagery.**

Keywords—Multispectral Image Analysis; Multi-modal; Big Data Analysis

I. INTRODUCTION

Multispectral Images are essential to several socio-economical and environmental applications, including urban and regional planning, natural resources conservation and management, etc. [1-3]. In the last decades, multispectral imagery has manifested as an exigent requirement for analyzing the many critical applications, such as Health, Military, Geology Atmosphere, and Agriculture [4-6]. A multispectral image is one that captures image data at specific frequencies across the electromagnetic spectrum. These images divide the electromagnetic spectrum into many spectral bands. Remote Sensing using Satellites [7], Unnamed Ariel Vehicle (UAV) [8], and Advanced Driver Assistance Systems (ADAS) [9] are few fundamental sources to obtain the multispectral imagery and perform classification and prediction tasks to analyze the behavior of objects or scenes [10]. The distinct types of multispectral images have different processing needs and thus also come with new challenges to algorithms that analyze the data [10], such as; Optimization of computational model complexity, accuracy, and robustness. Multispectral imageries possess the high temporal frequencies, offer a unique opportunity to analyze the object of seen more precisely through the images processing and machine learning techniques, such as image interpretation and classification. Initially, the machine learning techniques were employed the pixel value of image for analysis purposes, such as supervised (maximum likelihood, artificial neural network, decision tree, support vector machine) and unsupervised ((K-means clustering and ISODATA)) techniques, or the hybrid solutions [11]. Pixel-based image analysis has also upfront several critical issues such as missing pixel problem, which has been resolved through the fuzzy and spectral mixture classification techniques [12]. However, after the Very High Resolution (VHR) Imagery, the pixel-based analysis became a more challenging condition. Later, the Deep Learning approaches have employed using a more sophisticated and detail level of pixel analysis. The current deep learning approaches have proven their role to analyze the large and high dense multispectral imagery in a better way. However, the modern

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era of digitization brought further new challenges, which traditional Deep Learning models are not capable of handling.

II. Methodology

To achieve the objective of this study, we have followed a systematic protocol inspired by the SLR guidelines. However, this study does not fulfill the complete SLR guidelines but focuses on SLR based data accusation and quality assessment criteria. This study follows six different stages, as shown in Fig.1. The explanation of the stages is defined below;

1. RQ’s and RO’s formation.
2. Data scooping
3. Study Selection
4. Quality Assessment
5. Data Analysis
6. Data Synthesis

Fig. 1. SLR inspired six (06) steps of the review protocol

To clarify the empirical pieces of evidence on RQ’s and RO’s, this study raises two potential research question and their respective research objectives, as shown in TABLE I.

TABLE I. Study Research Questions and Research Objectives

No.	Research Question	Research Objective
1	What are the practical implications of Multispectral Image Analysis?	To provide a comprehensive overview of applications of Multispectral Image Analysis.
2	What are the critical issues associated with Multispectral Image Analysis?	To determine the potential issues and challenges associated with Multispectral Image Analysis.

The search strategy phase determines the proper search term, optimal literature sources, and adequate literature process to search from electronic databases systematically. The search strategy comprises search terms, literature resources, and search processes. To find out the related literature, initially, few search terms are derived from the research questions, such as Multispectral Classification, Multimodal classification, and Multispectral applications. We also search the literature resources under considering the search terms synonyms, such as remote sensing classification, hyperspectral classification, UAV images classification, and others. More specifically, AND and OR operators use for making the search queries. Most of the research paper was acquired from well-reputed high-quality journal papers from the electronic databases, including IEEE Xplore, Science Direct, Web of Science, Google Scholar, and ACM digital library. More than 300 literature studies have randomly collected from the above electronic databases, based on their titles and abstracts. Later, to ensure the quality assessment, we have selected papers according to the quality assessment results weight, as shown in TABLE II.

Furthermore, we exploited the relevant literature which addressing the designed research questions. However, there is some other paper, which directly not participate in the problem area but essential for defining the research methodology and supporting our argument because these papers were not relevant to the subject matter. Later, we performed data synthesis. The goal of data synthesis is to aggregate evidence from the selected studies for answering the research questions.

TABLE II. Quality Assessment Criteria (QAC) to select relevant research articles.

No.	Quality Assessment Criteria (QAC)
1	Does the research paper clearly define the aim, objectives, methodology?
2	Does the research paper adequately refer to the reputed literature to prove its assumptions or hypothesis (if any)?
3	Do experimental results convey the claimed contribution by the article?
4	Does the research paper use the appropriate experimental environment?
5	Do the selected data-sets illustrate the Concept Drift issue?
6	Does the research paper contribute to academia, industry, or society?
7	Does the research paper conclude the study?

A. Inclusion Criteria

The title or abstract must clearly express that the research papers are pertinent to the study domain. The research paper is explicitly related to the Concept Drift issue in the Machine Learning domain. The research paper addresses the research questions of this study or provides any empirical evidence for the support of the investigated query. The research paper must belong to a conference paper, journal paper, book chapter, or thesis report.

B. Exclusion criteria

The selected studies should not be in any other language except the English language. The selected studies should not relate to an editorial, white papers, introduction to proceedings, poster presentation, or symposium reports. Any study, which does contain personal bias of the author should not consider for the part of the evidence. The studies are not relevant to Multispectral Image Analysis.

III. Results and Discussion

RQ1: What are the practical implications of Multispectral Image Analysis?

Multispectral imageries can sample from tens of spectral bands or channels (unlike color RGB) within the electromagnetic spectrum. This massive information is exceeding the capabilities of the current several critical applications. The practical implications of multispectral image analysis contain a broad spectrum. More specifically, several critical applications consider multispectral applications more appropriate then mono or color imagery. The various layers of multispectral imagery not only contain essential to visualize the object, but also analyze the chemical composition of the object. Some of the critical applications are Healthcare, Aerospace, and Military. In healthcare, multispectral imageries support healthcare to diagnose diseases [13].

Moreover, the high pixel resolution in multispectral imagery combined with nanotechnology to diagnose health issues at the level of individual cells, which are essential to find out the cancer cell regions [14]. Multispectral imagery (remote sensing) significantly contribute to improvise and understand environmental concern. Multispectral Imagery has its significance to understanding the Earth's well-being [15], and disaster management [16]. Besides, the advanced imaging technology (using orbiting satellites) helps to develop a proactive strategy for natural disasters [16]. Observations of weather pattern is an essential task to be analyzed for several benefits. Multispectral Image analysis has a pivotal role in weather pattern analysis and prediction [17].

TABLE III. The Role of Multispectral Image Analysis in the Agriculture Sector

Category	Applications	Advantages	Ref.
Agricultures	Crop production forecasting	To forecast the expected crop production	[18]
	Assessment of crop damage and crop progress	To determine the exact damaged and the progress of the healthy crop in the farm	[19][20]
	Horticulture, Cropping Systems Analysis	To analyze the crop planting system, identify the flower growth pattern and prediction	[21]
	Crop Identification	To determine the mysterious and complex characteristics of crops. The data from the crop is collected to study the crop culture and its significance.	[22]
	Crop acreage estimation	To estimate the farmland. The traditional procedure is manual, time-consuming and contains many limitations	[23]
	Crop condition assessment and stress detection	To assist the health condition of each crop. To determine the quality of the crop.	[24]
	Identification of planting and harvesting dates	To analyze the weather patterns and the soil types to predict the planting and harvesting seasons of each crop.	[25]

Furthermore, the multispectral imagery improved the agriculture sector and utilizing the different cutting-edge technologies, such as machine learning and big data analysis, for the progression of the agriculture sector. Plant disease detection, fruit maturity, and crops production analysis are some notable applications of multispectral imageries. Multispectral Imageries also contribute to deal with conventional and unconventional threats. Specifically, it has wide applications relevant to security, law enforcement, and military.

A large number of health studies involving multispectral health image analysis were relevant to parasitic disease and referred to the pathogen [26]. Also, there is a massive contribution to the diagnoses of the severity and symptoms of malaria [27], and most of the studies conducted on the multispectral point of view. For example, remote sensing imagery (a type of multispectral image) has become a potent instrument for primary infection diseases, such as Dengue fever and Ebola fever [28]. Furthermore, multispectral imagery has extensively recorded for determining the tropical disease [29], with the consideration of a variety of environmental factors. Besides, the multispectral image analysis also has proven as the desirable solution for another disease, for example, circulatory mortality, asthma exacerbations [30], preterm birth [31], ischemic heart disease [32] and diabetes [33]. TABLE IV represents the few critical applications of healthcare using multispectral analysis.

TABLE IV. Critical Applications in Healthcare using Multispectral Image Analysis

Category	Applications	Advantages	Ref.
Healthcare	Disease detection	To diagnose the severity of diseases	[34]
	Disease region segmentation	To locate the correct location of the disease	[35]
	Medical Instruments	To improvise medical instruments	[36]

Summary

Through the comprehensive literature analysis, we can safely conclude that multispectral image analysis has a pivotal role in the development of healthcare. Some critical epidemic diseases such as cancer and Ebola virus have been reduced or well treated using the multispectral imageries. Besides, multispectral imagery is also critical to observe global and environmental health and sustainability. Agriculture developments also consider multispectral imagery as critical elements. Despite the utilization of these broad categories, multispectral also contributed to safety, security, false detection, and object detection applications.

RQ 2: What are the critical issues associated with Multispectral Image Analysis?

Due to the unique characteristics of multispectral imageries, several critical applications have benefited. However, these characteristics also impose practical implementation issues due to its variation of temporal features. The temporal feature of multispectral imagery makes significant changes to its spatial, spectral, temporal, and data sources (single data source or multi-data source). Despite the advantageous characteristics of multispectral data, several challenges also addressed in the literature. TABLE V. Shows some new challenges for multispectral image analysis.

TABLE V. STUDY RESEARCH QUESTIONS AND RESEARCH OBJECTIVES

Category	MSI features	Issues	Ref.
Characteristics of Multispectral Imagery	Spatial	High Spatial resolution, such as LiDAR and RADAR. Super resolution (SR)	[37-39]
	Temporal	Change detection under the spatial-temporal pattern (when detection outline changes concerning the time). To detect the change for multi-temporal remotes sensing images.	[40]
	Spectral	Selection of Spectral bands for distinguished applications (the individual spectral band has different kinds and levels of details). Such as land-use mapping, land-cover mapping, forest inventory, and urban-area monitoring	[41]
	Multi-Data sources	The integration of the data from the various heterogeneous data sources provides a powerful approach for generating more detail characteristics	[42] [43][44]

Summary

In summary, the multispectral image contains massive information related to the object or scene. Multispectral image contains high dense spatial values (pixel values), a large number of spectral bands, temporal invariability during data observation, and ever-growing data using heterogeneous data sources. The traditional machine learning approaches do not efficiently handle these sophisticated features and have limitations to get fully benefited from this massive information incentive resource. Hence, there is a need to develop a more robust, adaptive, dynamic mechanism to overcome these deficiencies.

IV. CONCLUSION

In this paper, we have presented some significant practical implications and possible critical issues for multispectral image analysis. The obtained finding can be summarized as follow;

Nowadays, the utilization of multispectral image analysis is not limited to geo monitoring or earth observations, and multispectral image analysis is also contributing to a wide range of applications, such as military, health, agriculture, and others. Moreover, due to the increasing spatiotemporal dimensions of multispectral images and data acquisition from heterogeneous data sources, current analysis approaches have exposed weaknesses and necessitating further research in the field multispectral image analysis. Furthermore, data preparation is a critical task for analysis, and its process is not generic for each application. Especially, massive attention and field guidance is required to preprocess the data (for analysis) for critical applications. For example, the generation of health-related multispectral data for classification or prediction. In future work, this study will be followed by several experiments to detect the type of skin disease using multispectral skin data.

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