ADVANCED IMAGING APPLICATIONS FOR INTERDISCIPLINARY ENGINEERING

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FOREWORD

It is with great enthusiasm that I introduce "Advanced Imaging Applications for Interdisciplinary Engineering." In this remarkable volume, the authors explore the ever-evolving landscape of imaging technology, highlighting its profound impact across multiple engineering domains. Once a supplementary tool, imaging has now become a driving force in enhancing visual interpretation and analytical capabilities fundamentally reshaping traditional methodologies and enabling novel breakthroughs. Charting the trajectory from early imaging techniques to today's sophisticated systems, the book offers a thorough account of the field's progression.

The authors skillfully build a strong conceptual foundation, making complex topics approachable for readers from varied disciplinary backgrounds. They systematically unpack the core principles and design strategies that define modern imaging systems. In parallel, the book delves into state-of-the-art simulation methodologies that have become essential for modeling and predicting system behavior in diverse applications. By leveraging these advanced computational approaches, engineers and researchers can navigate the complexities of imaging systems with greater precision, overcoming the constraints of conventional experimental techniques.

This narrative thoughtfully underscores how simulation serves as a catalyst for enhancing imaging device performance ultimately unlocking their untapped potential. As you turn these pages, I encourage you to immerse yourself in the depth of insight and expertise they contain. Whether you are an experienced professional, an emerging innovator, or simply intrigued by the frontiers of imaging science, this volume will undoubtedly expand your perspective and inspire you to advance the field.

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PREFACE

The field of engineering has always been driven by innovation and the ability to translate ideas into perceptible solutions. In recent years, one of the most transformative forces driving this innovation has been the advancement of imaging technologies. This book, Advancement of Imaging Application for Interdisciplinary Engineering, delves into this exciting intersection, exploring how cutting-edge imaging techniques are revolutionizing diverse engineering disciplines. Imaging applications in engineering have transcended their role in simply visualizing objects. They now offer powerful tools for non-destructive testing, material characterization, process monitoring, and design optimization. This book provides a comprehensive overview of these advancements, highlighting their impact on various engineering fields. Beyond the individual disciplines, this book underscores the importance of interdisciplinary collaboration. By fostering communication and knowledge exchange between imaging specialists and engineers, we can unlock the full potential of these technologies and accelerate innovation across diverse fields. Throughout the book, we explore the fundamental principles of various imaging techniques, delve into their practical applications in different engineering settings, and discuss emerging trends that promise to further revolutionize the field.

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CHAPTER 1

Investigation of the Imaging Algorithms in Artificial Intelligence

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Abstract: Artificial Intelligence (AI) is responsible for the transformation of image processing through cutting-edge imaging algorithms. This chapter delves deeper into AI-based imaging algorithms, such as image classification and pattern recognition. It provides a detailed review of the utilization of machine learning and deep learning models in imaging algorithms. Further, the applications of these AI-driven algorithms are also explored, thus emphasizing the advantages of these models in the real world. Key challenges and opportunities in AI-driven imaging are discussed, offering insights into emerging research directions.

Keywords: Deep learning, Feature engineering, Image classification, Machine learning.

INTRODUCTION

Imaging algorithms have always been indispensable for acquiring as well as exchanging information. These algorithms were earlier used for acquiring, transforming, restoring, enhancing, segmenting, and extracting edges of images, but now, with the inception of Artificial Intelligence (AI), there is a significant advancement in the technologies of image algorithms, such as image analysis, image classification, image generation, pattern recognition, and object detection. Despite being the older concept, AI was formalized only in the mid-twentieth

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century. The term "Artificial Intelligence" was coined by John McCarthy in 1956. Imaging algorithms in AI involve computer methods, such as processing, analyzing, and interpreting visual information. In the present day, AI-driven imaging algorithms have led to several innovations from healthcare to entertainment. These breakthroughs have become possible only because of the availability of data and computational resources [1 - 3].

The vital components of AI that are involved in these imaging algorithms are the Machine Learning (ML) and Deep Learning (DL) methods. These algorithms are basically designed to learn the features present in images for performing the tasks of classification, generation, recognition, and detection. In the AI-driven imaging algorithms, the ML and DL models, especially Convolutional Neural Networks (CNNs), are widely employed in various applications. These learning methods are capable of identifying patterns and features for several applications in the image processing domain, which primarily involve image segmentation, image classification and recognition, image enhancement, and image generation [2, 4].

Image segmentation is basically the division of images into meaningful regions, thus making it quite easy to analyze the particular image regions. ML and DL models, such as CNN, AlexNet, and GoogleNet, have gained prominence in performing segmentation, which is important for diagnosis in medical imaging [5, 6]. These algorithms are capable of getting a detailed analysis by segmenting the regions of interest (ROI), thus enhancing the performance metrics. The classification of the images or recognizing the patterns is another field in which the ML and DL models are capable of performing the classification into different categories for the datasets. It can be employed in the majority of imaging applications, such as face recognition, forgery detection, disease detection, *etc.*, which are used in real-time scenarios [7 - 9].

Further, DL-based superresolution algorithms, such as CNN and residual neural networks, are used for performing the enhancement of images. It involves the enhancement of image resolution, thus making the details prominent. It is beneficial in the case of medical and remote sensing images, in which details are required for performing the analysis to make significant decisions [10, 11]. Further, Generative Adversarial Networks (GANs) are utilized for generating as well as enhancing images, such as the generation of defective images from non-defective images, and performing image-to-image translation for medical images [12 - 14].

Thus, ML and DL are extensively employed for imaging algorithms in several sectors to increase their efficacy. The capability of the imaging algorithms increases to interpret the data with higher accuracy, thus paving the way for advanced applications. This chapter delves deeper into the historical evolution of AI in imaging algorithms before discussing the ML and DL approaches in imaging algorithms. Afterward, the AI-driven imaging algorithms are explored in various sectors in the subsequent sections before concluding.

HISTORICAL PERSPECTIVE

In the past, the imaging algorithms were focused on simpler applications, such as edge detection and enhancement, based on mathematical approaches, such as transforms. The realization of imaging algorithms using AI dates back to the mid-twentieth century during the exploration of computer vision. Artificial Neural Networks (ANN) and ML models came into the picture at that time to find the optimal solutions for the problems [15, 16].

Towards the end of the twentieth century, learning-based approaches, such as Support Vector Machines (SVM), were introduced. These methods were based on the features considered by the individuals, thus limiting the flexibility. Further, a significant breakthrough was made with the development of the CNN model, which led to the automatic analysis and accurate detection of patterns. A CNN-based method was proposed for recognizing the handwritten characters, which was a solution to the real-world problem. Further, they proposed the Modified National Institute of Standards and Technology (MNIST) dataset for handwritten character recognition [16, 17].

With the advent of DL in the past few decades, particularly with the inception of AlexNet, VGG, ResNets, GoogleNet, *etc.*, there has been rapid advancement in the AI-based applications of image processing in several fields. It has further led to devising solutions for the problems of face recognition, object detection, and disease detection in real-time. In the last decade, the advent of Generative Adversarial Networks (GANs) has further increased the possibilities of more advanced methods not only for performing image analysis, synthesis, and enhancement but also for creating realistic images from scratch [16, 18].

Thus, the evolution of AI-driven imaging has led to a shift from rule-driven approaches to data-driven approaches based on learning. These significant developments have led to the expansion in the implementation of AI across multiple scenarios, ranging from healthcare to industry.

BUILDING BLOCKS OF AI IN IMAGING ALGORITHMS

In broader terms, AI usually refers to the approach that mimics the intelligence of humans. Traditionally, AI was based on two directions, namely, connectionism

CHAPTER 2

Broadband Photodetection through Few-Layer Graphene/ZnO/Si Dual-Heterojunction and its Comparative Study with Machine Learning

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Abstract: The pursuit of highly efficient photodetectors has garnered substantial interest recently, driven by their wide-ranging applications spanning environmental monitoring, communication systems, and imaging technologies. This chapter examines how combining few-layer graphene (FLG), zinc oxide (ZnO), and silicon (Si) in a dual heterojunction design can create a photodetector that captures light across a wide range, from ultraviolet (UV) to near-infrared wavelengths. Utilizing the exceptional properties of graphene, the wide-bandgap nature of ZnO, and the scalability of Si as a substrate, the dual-heterojunction is optimized for UV-to-NIR light absorption and efficient carrier transport. A comprehensive simulation and analysis of the photodetector's characteristic parameters, including biased and unbiased operation, is conducted using the Silvaco Atlas TCAD software. The results show enhanced performance, with a least dark current density (Jdark) of 2.7×10–15 A/cm2, superior photocurrent density (Jlight) of 0.26 μA/cm2, along with a remarkable Jlight/Jdark ratio of 9.77×107, a 3-dB cut-off frequency of 7.36 THz, and a rapid rise (fall) time of 0.47 (0.88) ns at –1.0 V. Under illumination conditions, the photodetector exhibits a peak external quantum efficiency of 69.3%, photocurrent responsivity of 0.26 A/W, detectivity of 8.12×1015 cmHz1/2/W, and noise equivalent power of 7.79×10–20 W at –1.0 V bias. This

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research advances photodetection capabilities by demonstrating that combining p^+-FLG, n-ZnO, and n-Si in a dual-heterojunction design enables effective light detection from UV-to-NIR wavelengths. The findings suggest this integrated approach could lead to improved sensors and imaging devices. Moreover, a comprehensive comparative analysis is performed, utilizing the power of different machine learning (ML) regression models to evaluate their predictive performance in modeling the photodetector's behavior. The main goal is to determine the effectiveness of each ML regression model in accurately forecasting the photodetector's characteristics. This will be achieved by evaluating model performance across varying test set sizes using a range of metrics such as mean squared errors, root mean squared errors, mean absolute errors, and R^2 scores. The findings highlight the utility of machine learning algorithms in modeling and optimizing optoelectronic devices, offering valuable insights into their potential applications in advancing photodetector research and development endeavors.

Keywords: Broadband, Dark current density, Dual-heterojunction, Few-layer graphene, Machine learning, Near-infrared, Noise current, Photocurrent density, Quantum efficiency, Ultraviolet, ZnO.

INTRODUCTION

Photodetectors, also called photosensors, are critical in optoelectronic applications by transforming optical energy into electrical signals. To fulfill the diverse demands of applications like space communication, military surveillance, imaging, optical communications, and environmental sensing, cutting-edge photodetectors are being developed. This involves leveraging advanced materials and pioneering device architectures. Conventional photodetectors are constrained by a narrow detection bandwidth, restricting their capabilities. On the other hand, broadband photodetectors can employ a single device design to sense light spanning the ultraviolet (UV), visible, and infrared (IR) spectrums. Enhancing a photodetector's detection range substantially widens the scope of applications where it can be utilized.

Numerous efforts have been made to develop single broadband photodetectors by different research groups [1 - 4]. Despite their capabilities, the photodetectors developed [1 - 4] face limitations in terms of narrow detection ranges and relatively poor response times [5]. Moreover, attaining high photocurrent responsivity and stability in the UV spectral range, similar to the visible and IR ranges, while maintaining a fast response time continues to be difficult [6]. Silicon (Si) is the favored choice for manufacturing photodetectors sensitive to visible and near-infrared (NIR) wavelengths due to several advantageous factors. Firstly, the well-established technology surrounding Si manufacturing processes ensures a mature and reliable production framework. Additionally, Si's widespread availability contributes to its cost-effectiveness, making it an economically viable option for large-scale production. Furthermore, the manufacturing methods associated with Si are optimized for efficient and cost-effective fabrication, further reinforcing its position as the preferred material for photodetectors operating within the visible and NIR spectral ranges [5, 7]. Still, Si-based photodetectors face limitations, including high noise current, low photocurrent responsivity (less than 0.1 A/W for wavelengths below 400 nm), low efficiency, and a restricted spectral range due to the Si's narrow bandgap (~1.12 eV), sensitivity to temperature variations, high reflection coefficient, and low absorption [6, 8 - 10].

To address these shortcomings, the formation of a heterojunction between Si and wide-bandgap semiconductor materials has been proposed as a promising approach [10]. Among the various wide-bandgap semiconductors investigated [11], Zinc oxide (ZnO) emerges as a highly attractive material among wide-bandgap semiconductors due to its exceptional properties [11]. These include a large energy bandgap, better optical transparency in the visible spectrum region, substantial exciton binding energy, strong absorption in the UV spectrum, low material cost, and excellent stability at room temperature. ZnO's intrinsic n-type character offers a significant advantage, allowing for the straightforward fabrication of direct p-n heterojunctions by combining it with p-type materials [10, 12, 13]. ZnO can be effectively synthesized using a variety of physical and chemical vapor-phase deposition methods [10, 12, 14]. The heterojunction formed by integrating ZnO with Si emerges as a favorable option for optoelectronic devices, owing to its low fabrication costs, capability for low-temperature deposition, and superior optoelectronic properties. This ZnO/Si heterojunction exhibits the ability to detect radiation spanning the UV-to-NIR spectral regions within a single device framework [10, 12, 15], hence reducing the cost and size of the photodetectors.

Among the various two-dimensional (2D) materials explored so far for photodetection, graphene has gathered significant attention due to its exceptional properties. These properties include high sensitivity, carrier mobility, current handling capacity, low resistivity, broadband light absorption, and adjustable Fermi level [11, 16]. Consequently, graphene has gained considerable attention as a promising candidate for forming effective heterojunctions with other semiconductor materials in optoelectronic devices [10, 17 - 24]. The strong built-in electric field in these heterojunctions efficiently separates light-generated charges without needing an external voltage. This self-powered capability is key for developing high-performing photodetectors [10, 17 - 21, 23, 24]. The graphene layer plays a pivotal role by facilitating efficient carrier separation, attributed to its adjustable Fermi level [16]. Additionally, it functions as an antireflection coating, significantly reducing light reflection in the visible and NIR regions [25]. Therefore, integrating graphene with ZnO and Si in a dual-

CHAPTER 3

The Advancements in Imaging Applications for Nanomaterials

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Abstract: Nanotechnology has significantly revolutionized numerous fields, including materials science, medicine, and diagnostics, with its ability to manipulate materials at the nanoscale. Central to these advancements is the development of cutting-edge imaging techniques that offer enhanced visualization and characterization of nanomaterials. This paper focuses on recent innovations in imaging technologies for nanomaterial analysis, examining both the evolution of conventional methods and the integration of novel approaches to meet the growing demands of high-resolution and high-sensitivity imaging. Additionally, by providing better resolution, targeting specificity, and signal enhancement, the use of nanoparticles as contrast chemicals in healthcare imaging modalities, such as magnetic resonance imaging, computed tomography, ultrasonography, PET, and SPECT, has improved illness detection and diagnosis.

Nanoparticles' ability to exploit passive and active targeting mechanisms, such as the enhanced permeability and retention (EPR) effect, and functionalization with ligands for receptor-specific targeting, has revolutionized imaging in oncology, cardiovascular diseases, and neurological disorders. This chapter further highlights the development of multimodal imaging platforms, where nanoparticles are designed to integrate multiple imaging modalities, such as MRI-fluorescence or PET-CT, providing a more holistic diagnostic capability. These multimodal platforms enable the simultaneous acquisition of anatomical and molecular data, improving diagnostic accuracy and allowing for real-time monitoring of therapeutic responses. The integration of machine learning

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algorithms for image analysis and interpretation is another area of exploration, with the potential to automate and enhance the accuracy of nanomaterial imaging. While nanoparticle-based imaging holds great promise, challenges remain in ensuring their biocompatibility, biodistribution, and long-term safety. This chapter emphasizes the need for continued research into the optimization of nanoparticle design, surface functionalization, and toxicity profiles to advance their clinical translation. By reviewing the current state of imaging technologies and their applications, this research outlines the critical role that advanced imaging techniques play in pushing the frontiers of nanotechnology, ultimately paving the way for significant breakthroughs in science, medicine, and engineering.

Keywords: CT scan, EPR, MRI, PET scan, Ultrasound.

INTRODUCTION

An essential component of the healthcare system is the prompt identification and diagnosis of illnesses, including cancer. Studies have shown significant improvements in survival rates for patients who benefit from early detection. For instance, gastrointestinal cancer patients with early detection have demonstrated a two-year survival rate of 92.3%, compared to 33.3% for those without [1]. Similarly, breast cancer patients with early detection have seen a reduction in ten-year mortality rates by 17-28% [2]. Advanced diagnostic techniques in healthcare rely heavily on medical imaging to identify diseases in their early stages and monitor treatment efficacy. The field encompasses a range of sophisticated technologies, each offering unique insights into the human body. These include radiographic methods like traditional X-rays and the more detailed computed tomography (CT) scans [3]. Magnetic resonance imaging (MRI) provides high-resolution images of soft tissues, while ultrasound (US) uses sound waves for real-time visualization [4]. Nuclear medicine techniques such as positron emission tomography (PET) and single photon emission computed tomography (SPECT) offer functional imaging capabilities. Additionally, fluorescence imaging has emerged as a valuable tool in certain medical applications [5]. Together, these diverse imaging modalities form the cornerstone of modern diagnostic medicine, enabling healthcare professionals to visualize and analyze internal structures and physiological processes with unprecedented clarity.

In order to provide more accurate structural and physiological details, contrasting chemicals are used to distinguish between normal cells and pathological lesions [6]. Despite advancements in medical imaging, current contrast agents face limitations due to hardware constraints. For instance, contrast-enhanced CT can only detect liver tumors down to 3 mm in size [7]. Most conventional contrast agents are small molecules, which present challenges such as quick metabolic clearance, non-targeted distribution throughout the body, and potential safety issues. The efficacy and clinical usefulness of conventional imaging contrast materials are limited by these considerations taken together. These drawbacks show how better contrast agents are required to improve early illness identification and detection. Nanomaterials have emerged as promising candidates for improving medical imaging and detection capabilities. Their unique properties enable passive, active, and physical targeting mechanisms [8]. The increased permeability and retention (EPR) action of nanoparticles can cause them to concentrate in tumour tissues, raising the local amounts of contrast chemicals. The size of nanoparticles is a critical factor in their effectiveness for tumor imaging [9].

It influences several key aspects of their behavior in the body, including biodistribution patterns, duration of circulation in the bloodstream, uptake by cells, ability to penetrate tumor tissues, and overall targeting efficiency [10]. These size-dependent characteristics make nanoparticles particularly interesting for developing advanced imaging contrast agents. Research has shown that nanoparticles smaller than 10 nm, which is the average size of renal filtration pores, are quickly eliminated through the renal excretion system [11]. Conversely, nanoparticles larger than 100 nm are more easily recognized by macrophages and tend to accumulate in organs associated with the mononuclear phagocyte system (MPS), such as lymph nodes, liver, spleen, and lungs [12]. Multiple reviews have consistently reported that nanoparticles with sizes ranging from 10 to 60 nm demonstrate enhanced cellular uptake [13]. This size range appears to offer a balance between avoiding rapid renal clearance and minimizing recognition by the MPS, making it particularly promising for tumor imaging applications [14]. These findings highlight the importance of carefully considering nanoparticle size when designing contrast agents for medical imaging, particularly in the context of tumor detection and diagnosis. Nanoparticles in imaging have evolved beyond passive targeting, incorporating active targeting strategies through surface modifications [15]. By attaching specific ligands, these nanoparticles can bind to particular receptors, enhancing their accumulation at target sites within lesions. Two approaches, such as CT imaging of prostate cancer, and gold nanoparticles, have been functionalized with RNA aptamers that recognize prostate-specific membrane antigens. This modification resulted in improved contrast density at tumor sites [16].

For MRI applications in lung cancer, superparamagnetic iron oxide (SPIO) nanoparticles have been coupled with anti-EGFR antibodies. This design allows for targeted visualization of lung tumors expressing high levels of EGFR [17]. These developments show how customised nanoparticle architectures can greatly improve therapeutic imaging's specificity and effectiveness across a range of modalities and illness types. Nanoparticle-based imaging agents can be enhanced

CHAPTER 4

3d Local Descriptor-Based Abnormality Detection in Traffic Surveillance Videos

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Abstract: This research work is focused on detecting visual anomalies/abnormal events in video surveillance systems. In such situations, human attention may wander, and abnormal situations may be more challenging to note. So, to avoid such situations, an automated system is needed that can analyze such a huge amount of data and trigger alarms in abnormal events. Nowadays, the automation of surveillance systems is a major research area. This chapter presents a 3D local descriptor-based anomaly detection method for traffic surveillance videos, capable of extracting information about the appearance and motion of objects. Appearance information is extracted by 3D Histogram of Gradients (HOG), and motion information is extracted by 3D Histogram of Optical Flow Orientation (HOOF). Finally, these features are fed to a combined classifier for the detection of abnormality. Appearance information plays an important role when different types of objects are in the scene, like in traffic surveillance videos. This algorithm is tested on the YouTube video due to the unavailability of a publicly available standard traffic surveillance dataset.

Keywords: Abnormality detection, Histogram of gradients, Optical flow orientation, Surveillance systems, Traffic surveillance.

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INTRODUCTION

With the rapid development of video surveillance technologies in recent years, a greater number of smart video surveillance systems are being deployed in smart transport systems [1 - 4]. Traditional visual surveillance systems looking at roads or intersections have human intervention, which is not so effective. On the other hand, a smart transport system has very little human intervention. When something abnormal happens on roads, like road work, accidents, or jams, abnormal event detection systems detect the event and issue warning information [5 - 8]. So, automatic and timely detection of abnormal events will make our transportation system work efficiently and also reduce the workload of persons involved in the management of traffic [9 - 13].

PROPOSED METHOD

The block diagram of our proposed algorithm for the detection of abnormality in traffic surveillance systems is shown in Fig. (**1**). It is very important that extracted features are able to describe the scene properly. In this algorithm, the input video is described by a local feature descriptor, *viz.* 3D Histogram of Gradients (HOG) as proposed [1 - 3] and 3D Histogram of Optical Flow Orientation (HOOF). Both appearance and motion information are embedded in the feature vector. 3D HOG is used for extracting information about the appearance of different objects present in the scene. 3D HOOF feature extractors are based on optical flow, which provides information about the motion of objects. Finally, these extracted features are fed to the classifier for classification.

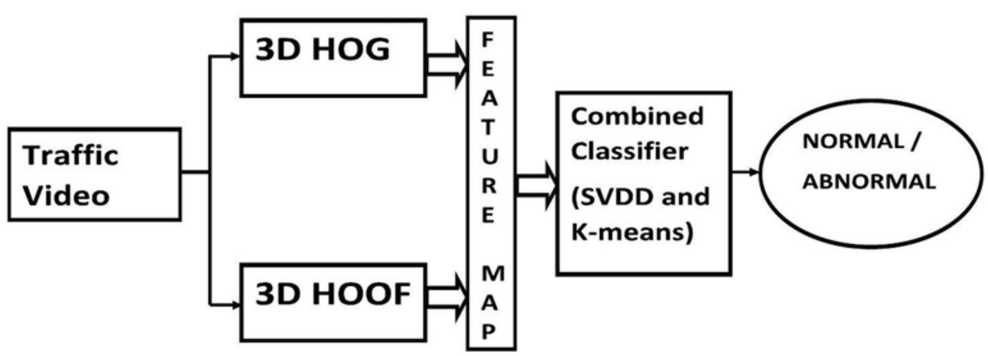

Fig. (1). Block diagram of our proposed algorithm.

Local Feature Extraction

In traffic surveillance video, the traffic scene is visually complex, with a large number of different types and sizes of cars, trucks, pedestrians, and objects (buildings, trees, *etc*.) that are unrelated to traffic. Fig. (**2**) shows the two scenes at different locations, both of which have a very large field of view.

Fig. (2). Images of traffic scenes.

Therefore, when using global image descriptors to describe such scenes, it becomes very challenging to accurately classify traffic scenes and identify individual objects within them. In a scene with a large field of view, an abnormal situation might occupy only a small portion, and the global descriptor may fail to capture it. For instance, if an accident occurs on the road, various events can happen simultaneously in different parts of the traffic scene. Some individuals might exhibit normal behavior, while others might attempt illegal U-turns, causing disruptions. Generally, accidents lead to traffic slowdowns in the affected lane and can also impact the flow in adjacent lanes [14 - 16].

To solve the above-mentioned problem, the feature descriptor needs to be calculated in local regions of the image or video. First, this algorithm divides the surveillance video into a number of video cubes. Then, a descriptor is calculated for each video cube, and the final scene is described by fusing the descriptor of each video cube [17 - 20].

Let A is a traffic video which is divided into N video cubes, also called cells, and expressed as follows:

$$A = C_1 \cup C_2 \cup \ldots \cup C_N \quad \textbf{(1)}$$

$C_k (1 \leq k \leq N)$ is k^{th} video cell of surveillance video A. The total number of video frames in each cell is kept the same. Further, each cell is sub-divided into a number of blocks as represented in Fig. (**3**).

CHAPTER 5

Estimating the Energy of Low-Quality Images Using Kinetic Energy and a Hybrid Model

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Abstract: Many applications rely on the correct analysis of low-quality photographs, yet effective interpretation is sometimes hampered by the inherent constraints of degraded image settings. We present a novel approach to estimating the energy content of low-quality images. We create a framework for measuring the dynamic features of these images by applying physical rules, particularly those governing motion. To preprocess the photos for precise energy estimation, we use image enhancement techniques and motion features. Following that, we calculate the energy of the objects' motions in the images using kinetic energy principles, considering characteristics, such as mass and velocity. Our proposed method accurately calculates energy levels from low-quality pictures, as demonstrated experimentally with synthetic and real-world datasets. This methodology has applications in environmental monitoring, robotics, and surveillance, all of which rely on insights into energy dynamics for analysis and decision-making. It also increases our understanding of the dynamics involved in such imaging.

Keywords: Energy estimation, Hybrid model, Image enhancement, Kinetic energy, Low-quality images, Motion features.

INTRODUCTION

Image analysis relies heavily on high-quality input data to produce accurate and reliable results. However, there are many practical applications that rely on interpreting low-resolution images, which pose significant challenges due to their inherent limits. Extracting valuable information from these images, often degraded by factors like poor lighting, blurred movement, or poor resolution,

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requires ingenuity. Crucial to this study is the estimation of the energy content of these images, which may shed light on the depicted scenes' dynamics [1].

Traditional methods for calculating image energy rely heavily on high-quality visual data and can fall short when confronted with intricate picture degradation configurations. We propose a novel method to fill this void by applying the principles of kinetic energy to estimate an object's energy content in low-resolution images. To ensure precise energy estimations, our system preprocesses and refines the visual input using a combination of motion feature analysis and image enhancement techniques [2 - 4].

Our methodology is based on the principles of kinetic energy laws, which govern the general laws of motion. By examining the mass and velocity of the objects in the images, we can precisely ascertain their energy levels. This hybrid model does double duty: it increases the interpretability of low-quality photos and broadens their typical uses [5 - 8].

To rigorously test our proposed method on both synthetic and real-world datasets, its efficacy in various contexts is demonstrated. Possible uses of robotics, surveillance, and environmental monitoring for accurately measuring energy from low-quality images are substantial. Because knowledge of energy dynamics is critical to analysis and decision-making in various domains, our method represents a major advancement in the field. The sections that follow provide a detailed explanation of our framework, including its motion feature analysis, image enhancement techniques, and kinetic energy principles. Also, the effectiveness of our technology is demonstrated through experiments, and its potential uses are discussed. We aim to enhance energy estimation in low-quality images, enabling more dependable and robust analysis across diverse technical and scientific fields.

IMAGE ENHANCEMENT TECHNIQUES

Features from low-quality photos are difficult to extract because of common issues like noise, poor contrast, and blurring. Our approach to resolving these issues is based on a set of picture enhancement methods targeted at raising the overall quality of the images. To minimise noise while preserving important information, we use state-of-the-art denoising methods such as non-local means (NLM) and Gaussian filtering. We improve object-to-background separation by increasing contrast through adaptive histogram equalisation. To enhance the photographs, we also use sharpening filters, such as unsharp masking, to emphasize the edges and finer details. By changing parameters such as the kernel size and the sigma of the adaptive histogram equalisation, we can achieve a good balance between removing noise and preserving features. Reduced noise, improved contrast, and better fine-tuning yield a more suitable set of photos for processing and motion feature extraction [4 - 8].

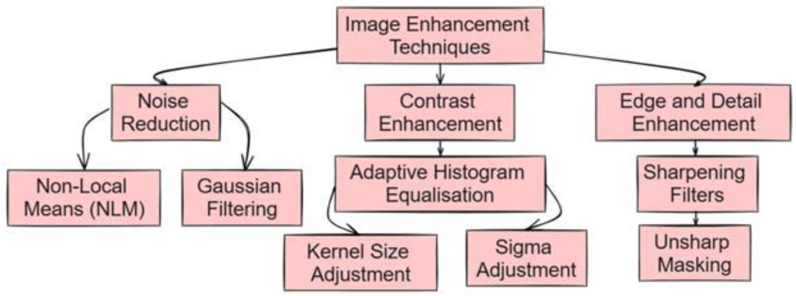

Fig. (1). Image enhancement techniques for low-quality photographs, illustrating various methods such as noise reduction, contrast adjustment, and edge sharpening to improve image clarity before kinetic energy estimation.

Low-quality photographs often exhibit noise, poor contrast, and blurring; these shortcomings make it difficult to extract features from the images. Our approach to solving these issues begins with a series of image enhancement techniques designed to improve the overall image quality. We employ the most advanced denoising techniques, such as non-local means (NLM) and Gaussian filtering, to reduce background noise while keeping crucial information, as shown in Fig.**1** [9 - 13]. Using adaptive histogram equalisation, we can improve object-to-background separation by increasing contrast. To bring out the best in the photos by emphasizing edges and minute details, we also apply sharpening filters, such as unsharp masking. By adjusting parameters, such as the sigma and kernel size of the adaptive histogram equalisation technique, we can effectively balance noise reduction and feature preservation. The final collection of images improves with reduced noise, increased contrast, and finer details, making it suitable for motion feature extraction and processing [14 - 16].

The dataset contains a wide range of low-quality images with varying levels of brightness, contrast, and noise, which makes feature extraction challenging. We assign a unique Image ID to each image based on its initial values for sharpness (Very Blurry, Blurry, Slightly Blurry), contrast (Very Low, Low, Medium, High, Very High), and noise level (High, Medium, Low), as shown in Table **1**. To enhance these images, we employ advanced denoising techniques, such as non-local means (NLM) and Gaussian filtering, as well as fine-tuning parameters, such as sigma and kernel size, to strike a fair balance between minimizing noise and maintaining clarity. We use adaptive histogram equalisation to enhance contrast and improve object-to-background separation by adjusting the clip limit and grid

CHAPTER 6

Quantum Imaging: Principles, Techniques, and Applications

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Abstract: Quantum imaging is an emerging field based on quantum mechanics and imaging technology, capable of unique capabilities in resolution, sensitivity, and information processing. An extensive review of the concepts, methods, and uses of quantum imaging is given in this chapter. The main ideas of quantum mechanics that are relevant to imaging, including superposition, entanglement, and quantum measurement, are introduced in this chapter. Following this, the various quantum imaging techniques, including quantum entanglement imaging, ghost imaging, and quantum lithography, illuminating their operational mechanisms and advantages over classical methods, are explored. The role of advanced photonic systems, single-photon detectors, and quantum dots in enhancing image quality are discussed. Additionally, the incorporation of quantum computing and machine learning with quantum imaging is examined, highlighting how these interdisciplinary approaches are pushing the boundaries of what can be visualized and analysed. Quantum imaging applications are varied, groundbreaking, and innovative, ranging from medical diagnostics and biological imaging to quantum communication and fundamental physics research. By harnessing the exclusive properties of quantum states, these applications achieve higher precision and new capabilities that classical imaging techniques cannot match. The challenges and future directions of quantum imaging, considering both the technical hurdles and the potential for groundbreaking discoveries, are discussed as well. In a nutshell, the chapter aims to offer the readers an in-depth insight into quantum imaging, its current state, and its future prospects by providing a holistic view of how quantum imaging is composed to revolutionize various scientific and technological fields.

Keywords: Entanglement imaging, Ghost imaging, Mechanics, Quantum imaging, Quantum lithography.

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INTRODUCTION

The art of imaging has gone through a significant transformation since the inception of the first camera. From capturing the visible spectrum to detecting the invisible, imaging has revolutionized numerous disciplines, including medicine, astronomy, and materials science. The quest for higher resolution, sensitivity, and contrast has driven innovation in imaging technology, yielding remarkable advancements. However, classical imaging techniques are ultimately bound by the constraints of classical physics, limiting their potential. Quantum mechanics, a realm where the rules of classical physics no longer apply, offers a tantalizing prospect: the possibility of transcending classical limitations. Quantum imaging, an escalating field, gets the most out of the peculiarities of quantum-based mechanics to explore new frontiers of imaging technology. By harnessing the superposition, entanglement, and coherence principles of quantum imaging, it defies classical constraints, enabling unprecedented resolution, sensitivity, and contrast [1].

Historical Context

The foundations of quantum imaging emerged from quantum optics in the 1950s and 1960s. Seminal works by Roy Glauber on quantum optics coherence theory laid the groundwork for understanding light's quantum nature in imaging contexts [1, 2]. However, it was not until the 1990s that the field of quantum imaging began to take shape, driven by advances in the generation and recognition of non-classical modes of light [3 - 5].

From Classical to Quantum Imaging

Classical imaging techniques, governed by the laws of classical optics, have been the mainstay of scientific observation for centuries. However, they are bound by fundamental limits:

1. **The Diffraction Limit**: Ernst Abbe's discovery in 1873 established that the optical system's resolution is primarily limited by the light's wavelength that was utilized [6]. Abbe discovered that the resolution of an optical arrangement is basically restricted by the wavelength used for imaging. This limit can be expressed as:

$$d = \lambda / (2n \sin \theta) \quad \textbf{(1)}$$

Where:

d is the minimum resolvable feature size

λ is the wavelength of light

n is the refractive index of the medium

θ is the half-angle of the maximum cone of light that can enter or exit the lens

This principle was further reinforced by Lord Rayleigh's work in 1879 [7], which provided a slightly different formulation of the same concept. The diffraction limit has long been considered an insurmountable barrier in classical optics, setting a fundamental constraint on the resolution of microscopes, telescopes, and other imaging systems.

1. **The Shot Noise Limit**: In low-light conditions, the discrete nature of photons leads to statistical fluctuations that limit the signal-to-noise ratio. Another crucial limitation in classical imaging, particularly in low-light conditions, is the shot noise limit. This phenomenon, rooted in the discrete nature of light (photons), was first described by Walter Schottky in 1918 [8].

The stochastic variations in the number of photons observed during a measurement are the source of shot noise. In the classical framework, light behaves as a stream of particles (photons) that arrive at the detector arbitrarily. The uncertainty in the figure of photons N detected in a given time interlude trails a Poisson distribution, with a standard deviation of $\sqrt{N}$.

This leads to a fundamental limit in the signal-to-noise ratio (SNR) in classical imaging:

$$SNR = N / \sqrt{N} = \sqrt{N} \qquad \textbf{(2)}$$

As a result, to improve the SNR enhancement by a factor of 2, one needs to increase the number of photons by a factor of 4. This poses significant challenges in scenarios where increasing light intensity is not feasible, such as in biological imaging, where excessive light can damage the specimen, or in long-distance imaging, where light intensity is inherently limited.

The Quantum Approach

Quantum imaging aims to circumvent these classical limits by harnessing the quantum characteristics of light. The arena emerged from the broader discipline of quantum optics, which was pioneered by works, such as Roy Glauber's papers on the quantum theory of optical coherence in 1963 [1, 2].

CHAPTER 7

Machine Learning Prediction for Air Quality Index

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Abstract: Air Quality Index (AQI) forecasting is vital for environmental monitoring and public health management. Hence, in this chapter, a machine learning (ML) algorithm, *i.e.*, Facebook Prophet Algorithm (a well-liked, flexible, and user-friendly time series forecasting tool), Auto Regressive Integrated Moving Average (ARIMA), and exponential smoothing are used in AQI forecasting. The ML model is created for Insights and future prediction for environmental policy formulation and decision-making by utilizing past AQI data. The procedure entails gathering past AQI data from online sources, handling missing values and outliers in the data through pre-processing/cleaning, and then training a Facebook Prophet model. Nonetheless, the model's performance is evaluated using common metrics like root mean square error (RMSE) and mean absolute error (MAE). The suggested method is effective in predicting AQI levels, as evidenced by the results. The ARIMA, Exponential Smoothing, and Facebook Prophet algorithms anticipate accuracy with their corresponding performance metrics falling in the range between 97 and 99.

Keywords: Air quality index, Facebook prophet algorithm, Machine learning, Mean absolute error, Root mean square error.

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INTRODUCTION

The unseen combination of gases that envelops Earth is called air, and it is among the Earth's most essential elements. Without water, humans can endure for several days, but they only need oxygen to breathe for a short while. Our ability to live a healthy and fulfilling life is largely dependent on the quality of the air we breathe. Low quality of air is mainly responsible for health issues. For example, it can lead to lung cancer and, respiratory illnesses, such as pregnancy outcomes, birth defects, TB, pneumonia, bronchitis, and asthma, as shown in Fig. (**1**). Research indicates that over 7 million individuals globally pass away as a result of air pollution each year (UN press report). In addition, global warming, a process in which heat is trapped in the atmosphere and results in increased temperatures, rising sea levels, heat-related illnesses, and infectious disease transmissions, is another effect of air pollution. Air maintains a livable temperature on the planet's surface by circulating hot and cold air.

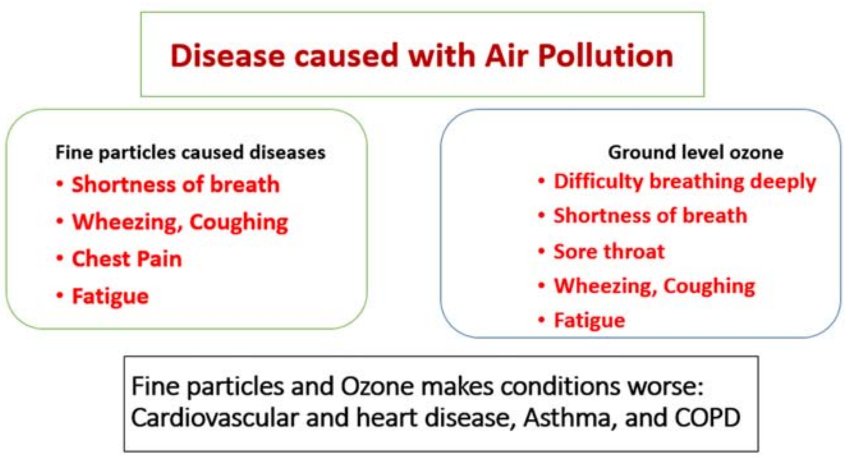

Fig. (1). The images depict various diseases caused by polluted air.

The rate of population growth has been significantly affected by the release of hazardous gases brought on by fast industrialization. The source of air pollutions are shown in Fig. (**2**). Hazardous compounds are contaminating the air, seriously harming our health. The unregulated pollution has caused a dramatic decrease in air quality. Air pollution levels are measured and communicated using AIQ.

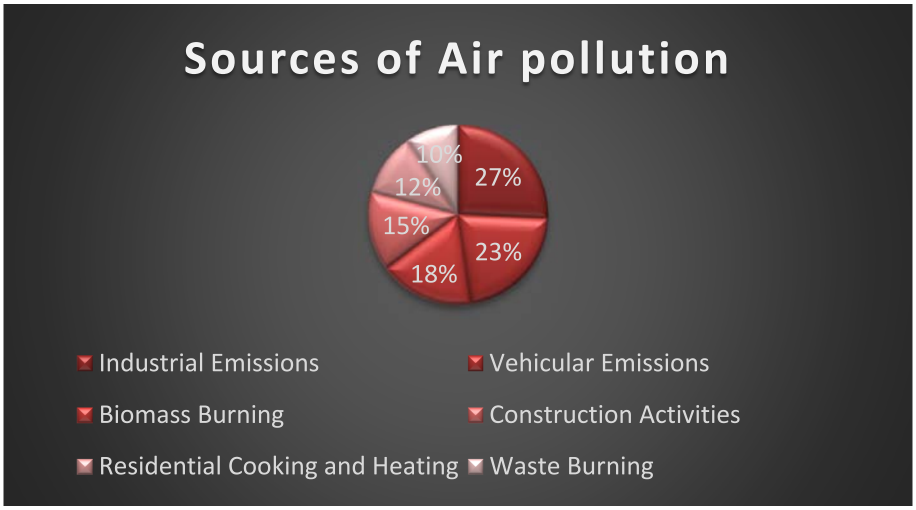

Fig. (2). Here is an illustrated depiction of various sources of air pollution.

There are 12 air pollutants, such as ammonia (NH_3), nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), ozone (O_3), PM10 (< 10 microns), PM2.5 (< 2.5 microns), and benzene, that are used to calculate the AQI [1]. The six pollutants PM10, O_3, SO_2, NO_2, PM2.5, and CO are mainly used to calculate the AQI [1]. Further, based on its AQI, a place can be categorised as tolerable, satisfactory, moderately polluted, or extremely poor or severe. Another way to describe an "Air Quality Index" is as a single number that indicates the state of the air and how it affects human health. Over the past three decades, AQI has been created and utilised in many industrialised nations as a means of classifying the ambient atmosphere. The daily AQI is used to report on the area's air quality, including how clean or dirty it is and the consequences it has on local health [2]. The Central Pollution Control Board (CPCB), the Government of India, created the National Air Quality Index and the Ministry of Environment and Forests (MoEF) in order to enhance the public's awareness of and involvement in air quality management [3].

An extremely reliable approach for determining the state of air quality is the breakpoint concentration method for measuring the AQI for particular contaminants, as established by the CPCB. Due to their ability to provide precise concentrations of air pollutants along with information on their degree of pollution and impacts, PSI and AQI are crucial tools for studying air quality. An average person needs around 12 kg of air every day, according to studies. The type of air quality we breathe directly influences our health and life [4]. In order to enable vulnerable populations to take precautionary measures, the US

CHAPTER 8

Health Chain: Unlocking the Potential of Blockchain in Healthcare

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Abstract: The systematic application of blockchain in the healthcare environment will likely change the conduct, retrieval, and dissemination of health records. Blockchain technology has attracted global attention as an innovation with the potential to disrupt several industries. In this research, the application of blockchain in healthcare is explored, and 'Health Chain' is positioned as an invention that addresses the challenges of existing healthcare systems. Health Chain leverage the Internet by incorporating innovative technology like blockchain for the secure storage of EHRs, management of patients' consent, enhancement of marketing channels for drug distribution, use of IoT devices for tracking, and improvement of ease of use and efficiency. This study investigates the prospects of deploying this technology, highlighting the development of a recommended framework and directions for further research. It aims to assess the potential of utilizing blockchain in healthcare settings for more efficient information management, integration of multiple functions, and provision of services to patients in a more effective manner through the proposed framework.

Keywords: Blockchain, Data management, Decentralized networks, Electronic health records, Healthcare, Interoperability, Patientc, Pharmaceutical supply chains, The internet of things.

INTRODUCTION

An Overview of Blockchain Technology

Unlike other technologies, blockchain provides a new approach to handling transactions and records. Essentially, it is a cryptographic security system based on a chain of blocks containing chronologically ordered signed documents. These blocks are arranged in a way that prevents unauthorized alteration. The concept

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was first proposed by Satoshi Nakamoto in 2008, leading to the creation of Bitcoin. Blockchain technology quickly began finding applications in other industries. It has certain distinctive properties, often referred to as the “blockchain,” such as decentralization, security, and others, which make it possible to reduce reliance on “middlemen” like banks, lawyers, or other intermediaries in certain types of transactions, as shown in Fig. (**1**).

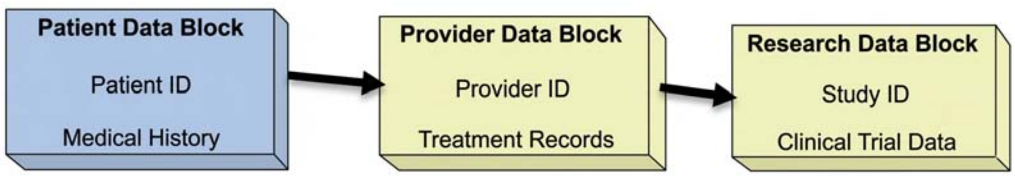

Fig. (1). Interoperability chain in healthcare data management.

The advent of blockchain technology can be described in terms of several evolutionary stages, which significantly translate into the upper layer of use for digital currencies, smart contracts, and various industries like healthcare, governance, and science, complemented by Artificial Intelligence as it develops. Operating in a distributed system, blockchain employs consensus techniques for transaction verification and cryptographic linking to secure the blockchain. This design architecture has several strengths, which enhance the security and transparency of transactions and improve the speed of processing and recording transactions. In the future, there is a high chance that blockchain will introduce radical changes in current transaction practices and data management. This technology continues to advance and shows promise of transforming many areas of activity by creating a new, effective, and safe way of communicating and exchanging information and conducting transactions.

Current Healthcare Challenges

Within the healthcare sector, a number of difficulties have arisen regarding data management and the application of data among health organizations in order to improve the quality of services rendered to patients and reduce the costs of providing those services. These difficulties include technical challenges, organizational issues, and ethical concerns. In some healthcare systems, there is no standardization of data formats, coding systems, or terminologies, which has led to the emergence of siloed health information systems and data repositories. This fragmentation makes it difficult to share information or exchange data efficiently. Additionally, fundamental aspects for smooth data exchange, such as security, privacy, and consent, are often poorly addressed, which limits the extent to which data can be shared and used.

To be sure, resource limitations, such as funding, technical manpower, and infrastructure, tend to hinder the effective use, integration, and maintenance of optimal health information systems. In addition, health professionals within the healthcare settings in the scope have a high level of illiteracy in digital devices, consequently reducing the productive use of health information systems. In more mature healthcare systems, predictive modeling of disease processes and targeted treatment with desirable effects can be implemented using techniques such as artificial intelligence, machine learning algorithms, and others. However, implementation of the proposed models is limited due to several reasons: data quality, protection of patients' privacy when using their health data for research and other purposes, and the lack of a coherent governance scheme along with proper coordination across all stakeholders involved.

Purpose of Case Study

This case study seeks to explore how this new healthcare blockchain technology has the potential to transform the sectors that use it through the innovative solution known as the Health Chain. This is because blockchain utilizes the decentralized and highly secure nature of its environment to address profound difficulties in areas such as data fragmentation, privacy concerns, and interoperability gaps within the healthcare system. It emphasizes improvements in the treatment, availability, and transfer of EHRs that blockchain technology will bring about, along with enhanced patient consent management, pharmaceutical supply chains, and even IoT devices for continuous health monitoring. All these aspects are featured in the structure and subsequent directions for further studies highlighted in the paper, showing the promise that blockchain holds for a more efficient, reliable, and patient-centric healthcare ecosystem.

BACKGROUND AND LITERATURE REVIEW

Historical Context of Healthcare IT

Health information technology (IT) has been evolving since the 1960s, when mainframe computers were first implemented to streamline hospital administration. During the 1970s and 1980s, departmental systems began to emerge, focusing on specialized applications such as laboratory information systems and radiology information systems. Early systems were very isolated and contributed little toward interoperability. The early 1990s marked a critical transitional period, with the development of electronic health records (EHRs) and hospital information systems designed to integrate separate departmental systems.

CHAPTER 9

Physico-Chemical and Spectroscopic Analysis of Municipal Solid Waste Compost in Pathankot, Punjab

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Abstract: Indian cities nowadays have very poor waste management. Rapid industrialization has caused the intensification of Municipal Solid Waste (MSW) at a very progressive rate. Alternative solutions are required because disposing of waste material in open landfills and using only incineration techniques increases environmental damage. The present study conducted the physico-chemical and spectroscopic characterization of municipal solid waste compost in Pathankot city of the Punjab region to analyze its appropriateness for various purposes. The compost was prepared collectively from the college hostel mess waste and from the dry leaves available in the proximity of the college campus. The compost pit was constructed with dimensions of 4*4 feet in the college campus area. The study revealed the examination of nutrient concentration and structural behaviour during the entire process of waste degradation. The study concluded that the region's waste is rich in organic materials and, hence, composting is an appropriate option for processing and minimizing waste.

Keywords: Compost pit, Compost, Pathankot, Physico-chemical, Punjab, Solid waste, Waste characterization.

INTRODUCTION

The current scenario of solid waste management in India is highly inadequate [1, 2]. According to reports, 1,35,198 tons of municipal solid waste are produced daily (TPD) in India [3]. However, only around 70% of this waste is collected,

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and the proportion of treated waste is reported to be about 12%. The main factor behind the lower collection efficiency is the inadequate availability of transportation vehicles [4, 5]. The economic conditions of cities and towns in any state significantly affect waste generation [6, 7]. Currently, Indian cities produce between 0.4 and 0.7 kilograms of garbage per person per day [8], making it extremely difficult to manage solid waste generation in most cities [9]. Poor municipal solid waste management, particularly open dumping, remains a major challenge in developing nations like India [10 - 12].

In terms of waste minimization, composting is one of the easiest and most cost-effective ways to reduce the burden of waste. Aerobic composting using the windrow method is documented as a cost-effective technique that can be employed as a soil amendment. This method is relatively simple, and its by-product significantly enhances soil fertility. Additionally, composting can complement incineration and recycling efforts, thereby reducing the overall amount of waste in urban areas [13, 14]. Furthermore, it is less expensive than other waste management options and represents an environmentally friendly alternative [15].

Zero Waste refers to designing and managing products systematically to avoid and eliminate the volume and toxicity of waste and materials [16]. It is a goal that is ethical, economical, efficient, and visionary. To achieve this, the main focus is to provide the college campus with a sufficient number of color-coded garbage bins. The process begins at the source, with mini-dustbins placed in offices and classrooms according to different types of waste. The aim is proper source segregation of municipal solid waste. Providing dustbins across the campus and establishing a composting site will help train students in waste segregation and composting practices.

The present study presents a case study of the waste management scenario at a college campus located in Pathankot city, Punjab. Punjab generates 4,376 tonnes of waste per day, with almost half treated and the remainder dumped illegally in open landfills. A similar problem of open dumping, rather than segregated disposal, was identified within the college campus. Additionally, burning of dry leaves was practiced, which can directly harm the environment and contribute significantly to air pollution. The open dumping of waste on campus is shown in Fig. (**1**).

Fig. (1). Open dumping of mixed waste.

Due to inadequate dumping of waste, groundwater, air, and land may become contaminated. To prevent this worsening situation, it is very important to ensure proper segregation of dry and wet waste and to avoid illegal burning of waste, which can release harmful gases. In this regard, the study comprised the physical characterization of solid waste generated in the area. Additionally, to assess the nutrient content and structural changes during the composting process, the study also included the physico-chemical and heavy metal characterization of compost made from garden and college mess waste in the Pathankot, Punjab, campus.

STUDY LOCATION

Pathankot is located at a latitude of 32.2733° North and a longitude of 75.6522° East, with a population of 148,937. The study location comprised the SSGI College campus area. The compost was prepared collectively from the college hostel mess waste and dry leaves from gardens within the campus.

CHAPTER 10

Assessment of Groundwater Indices and Physico-Chemical Characterization of Leachate in Pathankot, Punjab

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Abstract: Open dumpsites are one of the major causes of environmental degradation, and their impact on groundwater largely depends on leachate concentration. The environment can be severely polluted by leachate percolation if it is not properly managed. The present study examines the effect of leachate percolating into aquifers and soil in the vicinity of dumping sites in the study region of Pathankot, Punjab. The study primarily focuses on the evaluation of groundwater characterization, leachate characterization, and heavy metal analysis for quality assessment. In this context, the leachate pollution index is used to categorize the toxic potential of leachate so that immediate remedial actions can be implemented at dumping locations. Higher concentrations of leachate pollutants increase the likelihood of toxicity and, in turn, the pollution of groundwater and soil. From this perspective, groundwater pollution is an impending environmental issue that requires urgent consideration. In a nutshell, the current study endorses the construction of engineered landfills and effective leachate management to ensure the sustainability and conservation of groundwater aquifers and soil quality.

Keywords: Groundwater, Leachate, Pathankot, Physico-chemical characterization, Pollution index, Punjab, Water quality.

INTRODUCTION

Open dumping practices in Indian cities are recognized as one of the major threats and critical issues to groundwater reserves. This problem is prominent not only in

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India but throughout the world (United States Environmental Protection Agency, US EPA). It has been observed from the literature that more than 80% of solid waste is directly abandoned on the ground in an illegal manner [1, 2]. During rainfall, dumped solid waste comes into contact with water, and the decomposed water in the form of leachate infiltrates into the ground and hence pollutes the groundwater [3]. This leachate percolates through soil voids and contaminates groundwater aquifers to a greater extent [4, 5]. The level of groundwater pollution due to filtration of leachate is influenced by many factors, such as rainfall, depth, and the physical and chemical composition of solid waste [6]. However, sometimes the pollutants may not exceed drinking water limits, but still there may be a significant threat to human health and the environment [7 - 9]. The leachate pollution index and water quality index have been evaluated by many researchers to categorize the toxic potential of leachate so that immediate corrective actions can be executed at the dumping location [10, 11]. Higher values of the leachate pollution index indicate a greater probability of leachate toxicity and, in turn, pollution of groundwater and soil [12 - 14].

The environment can be eminently polluted by means of leachate percolation if not handled properly [15, 16]. The present evaluation study comprised the influence of leachate percolated into the aquifers and soil near the vicinity of dumping sites in the study region of Pathankot, Punjab. The study focused on the evaluation of groundwater characterization, heavy metal analysis, and leachate characterization for the quality assessment of leachate and groundwater.

From this viewpoint, groundwater pollution is an impending environmental issue and needs to be addressed. The water quality index is a tool to evaluate the quality of water and soil, which is substantially beneficial for policymakers for the ecological and efficient supervision of groundwater reserves [17 - 21]. In a nutshell, the study recommends the construction of engineered landfills and proper management of leachate so that groundwater reserves and soil quality may be maintained and preserved.

STUDY LOCATION

Pathankot is located at 32.2733° N (Latitude) and 75.6522° E (Longitude) and has a population of 148,937. The study area includes a large dumpsite near the city. The dumpsite receives waste from Pathankot on a daily basis. The current scenario of the dumpsite near Pathankot city is shown in Fig. (**1**).

Fig. (1). Current Scenario of the dumpsite near Pathankot City (Study location).

MATERIAL AND METHODOLOGY

The preliminary visit and survey of the dumpsite were conducted on a frequent basis. The physical characterization of municipal solid waste was analyzed in the dumpsite area. The analysis and literature study revealed that the study region is rich in organic waste, followed by plastic waste, as plastic is not banned in Punjab; hence, a huge amount of plastic waste was observed in the dumpsite, which may be a source of many harmful pollutants. The physico-chemical characterization of groundwater was analyzed to determine the possible contamination levels due to the percolation of leachate. The pre-survey of the dumpsite is shown in Fig. (**2**).

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