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A Survey On Digital Image Processing From Enhancement To Advanced Security

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Abstract – This literature survey examines the current advancements and methodologies in digital image processing (DIP), focusing on its applications, challenges, and security measures. Digital image processing plays a vital role across various fields such as medical imaging, remote sensing, surveillance, and multimedia. The survey highlights key techniques like image enhancement, restoration, segmentation, and compression, emphasizing their contributions to improving image quality and facilitating analysis. Additionally, it explores the significance of security in digital image transmission, reviewing traditional methods including encryption, steganography, and watermarking. The survey also delves into innovative approaches like Chaotic Encryption with Dynamic Key Generation (CEDKG), which enhance image security through dynamic key generation and integration with steganography and watermarking. This comprehensive review provides insights into the evolution of DIP technologies and underscores the importance of robust security measures to protect digital images in an increasingly connected world.

Keywords: Digital Image Processing, segmentation, compression, restoration, machine learning, artificial intelligence, encryption, watermarking, security.

1. Introduction

Digital image processing (DIP) is a critical technology in the modern digital age, playing a pivotal role in various domains including medical imaging, remote sensing, surveillance, entertainment, and digital forensics. The primary objective of DIP is to process raw image data to enhance its quality, extract meaningful information, and facilitate further analysis or interpretation. With the rapid proliferation of digital images across diverse communication channels, ensuring the integrity, confidentiality, and availability of these images has become increasingly important. DIP encompasses a wide array of techniques and algorithms designed to manipulate images in different ways, such as image enhancement, restoration, compression, and segmentation. These techniques are employed to remove noise, correct

distortions, enhance visual quality, and identify specific features within an image. Furthermore, the advancements in machine learning and artificial intelligence have significantly expanded the capabilities of DIP, enabling automated and sophisticated image analysis and recognition systems.

However, the widespread sharing and transmission of digital images over the Internet and other networks pose significant security challenges. Ensuring the security of digital images is paramount to protect sensitive information, maintain privacy, and prevent unauthorized access or tampering. Traditional methods for securing digital images include encryption, steganography, and watermarking. Each of these techniques serves to achieve specific security goals: encryption for confidentiality, steganography for covert communication, and watermarking for ownership verification and copyright protection. Despite the effectiveness of these individual techniques, combining them can offer a more robust and comprehensive security solution. This is where innovative approaches like Chaotic Encryption with Dynamic Key Generation (CEDKG) come into play. CEDKG leverages the unpredictable behavior of chaotic systems to generate dynamic encryption keys, providing enhanced security by making it exceedingly difficult for attackers to predict or reproduce the keys. This approach, coupled with steganography and watermarking, offers a multi-layered defense mechanism that significantly strengthens the protection of digital images against various threats and attacks.

2. Literature Survey

1. Y. Ma (2020) et.al proposed Research on Digital Oil Painting Based on Digital Image Processing Technology. As society progresses and human civilization advances, the achievements we accumulate continually evolve. In the context of rapid development in computer networks and information technology, traditional text-based information transmission no longer meets the needs of the modern era. Consequently, in this age of extensive data and image processing technology, images have become an increasingly prominent means of information dissemination. To address the new era's challenges in digital oil painting research, this paper proposes utilizing digital image processing technology for this purpose. By analyzing the vast information contained in digital oil paintings through digital image processing and aligning with contemporary demands, a comprehensive and forward-looking plan for digital oil painting research and exhibition is formulated. The methodology proposed in this paper offers a novel approach, paving the way for innovative research and development in the field of digital oil painting.

2. L. Sanwei (2020) et.al proposed High Voltage Cable X-Ray Digital Image Depth Processing and Technology of Buffer Layer Defect Intelligent Recognition. Current research demonstrates the feasibility of digital X-ray imaging for non-destructive detection of power cable defects yet lacks in-depth digital image processing and defect recognition methods. This study addresses this gap by exploring advanced techniques for power cable X-ray digital image processing and intelligent recognition. By employing gray processing technology to enhance contrast and compress grayscale range, the original images are optimized for human recognition and defect identification. Training convolutional neural networks (CNN) and full convolutional neural networks (FCN) with image data facilitates intelligent identification of buffer layer

defects. Results indicate that the FCN outperforms traditional CNN, offering clearer and more intuitive defect recognition.

3. Y. Cheng (2021) et.al proposed Image Segmentation Technology and Its Application in Digital Image Processing. As science and technology advance, image processing technology in China matures, finding applications across various sectors. Particularly, image segmentation technology plays a vital role in transportation, biomedicine, remote sensing, and fire prediction and detection. Despite its significance, challenges such as data frequency, pressure, and processing speed limitations persist. Therefore, it's imperative for researchers to address these issues to enhance the implementation of digital image segmentation technology. Overcoming these challenges is crucial for advancing China's economic development in relevant fields.

4. C. Tang (2020) et.al, proposed Joint Regularized-based Image Reconstruction by Combining Super-Resolution Sinogram for Computed Tomography Imaging. In computed tomography imaging, the 2×2 acquisition mode improves projection assortment efficiency and reduces X-ray exposure time. However, it produces low-resolution projections and poor image quality. While the super-resolution (SR) method enhances the acquired projections, reconstructed image quality still suffers from signal-to-noise ratio issues due to evaluation errors. A combined regularization-based reconstruction technique was put out in this study. It incorporates stability terms from both 1×1 and 2×2 projection acquisition modes, enhancing image fidelity. By combining block matching and TV regularization, this approach enhances reconstructed image fidelity. The proposed model was solved using iterative alternating minimization. Experimental results on anthropomorphic phantom data demonstrated superior noise suppression and detail preservation compared to existing methods in CT image reconstruction from SR Sinogram.

5. P. Srujana (2021) et.al proposed Edge Detection with different Parameters in Digital Image Processing using GUI. The proposed work employs various edge detection algorithms to extract edges from digital images, utilizing a MATLAB GUI interface. Four different digital images, including Building, Flower, Finger Print, and Satellite, are analyzed using operators such as Sobel, Prewitt, Roberts, LoG, and Canny. The results, depicted in tables 1 to 4, illustrate variations in output across different operators. As seen in tables 5 to 8, the canny operator stands out as the most successful edge detection operator due to its low Mean Squared Error (MSE) and high Peak Signal-to-Noise Ratio (PSNR) and Signal-to-Noise Ratio (SNR). Real-time application models further confirm the superiority of the canny operator over others, demonstrating its practical efficacy in image analysis and processing.

6. V. B. Inchur (2020) et.al proposed Implementation of Blood Cell Counting Algorithm using Digital Image Processing Techniques. Blood, a vital connective tissue comprising RBCs, WBCs, and platelets, necessitates accurate cell counting for pathology diagnosis. Traditional manual counting, while accurate, is time-consuming. Hence, electronic minute blood counting, coupled with digital image processing, is adopted. RBC count accuracy varies; edge-based segmentation yields 66%, while Morphological operators reach 92%. Texture-based classification and CHT with morphological operators achieve 89% and 91%,

respectively. For WBC and platelet count, Morphological operators yield 60% accuracy, while Texture Object-Based classification achieves 100%. Consequently, Circular Hough Transformation improves RBC counting, while Texture Object-Based classification excels for WBC and platelet count accuracy.

7. J. R. González Montero (2020) et.al proposed Watermark Detection and Clearance in Video Using Simple Signal and Image Processing Techniques. This paper introduces two novel algorithms for detecting blend and overlaid watermarks in digital videos efficiently. The first algorithm employs a template matching approach in the HSV color model, followed by post-processing for refined detection. Notably, these methods offer exceptional speed compared to Machine Learning (ML) approaches. While a Convolutional Neural Network (CNN) model yielded slightly higher accuracy in blend watermark detection, it incurred significantly longer processing times. Our Algorithm-1, executed on a standard laptop, processed a video of approximately 46,000 frames in around 110 seconds, whereas the CNN model, running on a desktop with GPU support, took about 21 minutes. This vast difference in processing time underscores the efficiency of our CPU-based Algorithm-1 in blend watermark detection. Conversely, our Algorithm-2 for clear watermark detection outperformed the CNN model with a processing time of around 5 minutes, thanks to its streamlined analytical approach.

8. O. Bielova (2019) et.al proposed A Digital Image Processing Pipeline for Modelling of Realistic Noise in Synthetic Images. The proposed framework simulates realistic noise and various effects in synthetic images by replicating the image formation process of digital cameras. It operates with HDR images, synthesized in Blender or from real camera images in RAW format. Synthetic images offer control over camera, scene, and object parameters while providing ground truth values for factors like depth and albedo. This framework aims to create benchmark datasets for evaluating image-based algorithms. Unlike other approaches, noise is simulated at the raw data stage, prior to any processing. The model accounts for main, signal-dependent and signal-independent noise sources, allowing control over noise type and intensity. It encompasses essential processing steps of an in-camera imaging pipeline, offering flexibility in parameter settings and step selection.

9. G. Lu (2019) et.al proposed Deep Non-Local Kalman Network for Video Compression Artifact Reduction. Our approach to video compression artifact reduction draws inspiration from two key principles. Firstly, we leverage previously restored frames to enhance the current frame's recovery process, capitalizing on their more accurate temporal information compared to the original decoded frame. This allows us to construct a robust artifact removal system with superior performance. However, this reliance on past frames necessitates a dynamic recursive solution for artifact removal. Our method adopts a Kalman filtering approach, integrating several deep neural networks to predict states and estimates. By leveraging both the recursive nature of Kalman filtering and the representation learning capabilities of neural networks, we achieve effective artifact removal. Additionally, we incorporate non-local prior information to further enhance reconstruction quality. Our methodology extends to other low-level computer vision tasks like denoising, demonstrating superior performance compared to existing methods in experimental results.

10. C. Shao (2019) et.al proposed A Kind of Pavement Crack Detection Method Based on Digital Image Processing. Time-to-Digital Converters (TDCs) suffer from quantization noise inducing in-band phase noise. Prior research aimed to enhance TDC resolution through Vernier implementation. However, this method often necessitates intricate timing control due to the utilization of delay chains as core quantizers. Achieving high dynamic range (DR) proves challenging due to inherent jitter and nonlinearity, often traded off with signal bandwidth, power consumption, and area occupation. Using a digital-to-time converter (DTC) in conjunction with a high-resolution short-range TDC for phase shifting is another method. However, this may lead to varying situation increments per reference cycle, causing frequency deviation. This paper proposes a partial N digital PLL with low in-band phase noise, utilizing a high-resolution TDC. The achieved in-band phase noise aligns with the TDC's effective resolution. Additionally, a high-resolution, MOS-varactorless LC-DCO is proposed, alongside bridging capacitors to reduce quantization noise. The design blocks accommodating the TDC are also optimized. With the proposed TDC and DCO, the digital PLL achieves 110 dBc/Hz in-band phase noises at 3.625 GHz output, with 9.7 mW power consumption and 0.38 mm2 area. In summary, this work presents a high-performance digital PLL with meticulously designed TDC and DCO components.

Here is a comparison table summarizing the key points from the proposed works:

Author(s) and Year	Title	Summary	Merits	Demerits
Y. Ma (2020) et al.	Research on Digital Oil Painting Based on Digital Image Processing Technology	Proposes using digital image processing for analyzing and exhibiting digital oil paintings, aligning with contemporary demands.	- Enhances analysis and exhibition with detailed, accurate, and visually compelling presentations.	- Requires proficiency in digital image processing techniques, limiting accessibility and implementation.
L. Sanwei (2020) et al.	High Voltage Cable X-Ray Digital Image Depth Processing and Technology of Buffer Layer Defect Intelligent Recognition	Explores advanced techniques for X-ray digital image processing and intelligent recognition of cable defects using CNN and FCN.	- Enhanced defect recognition with FCN compared to traditional CNN.	- Lack of existing deep X-ray digital image processing methods hinders direct cable defect detection.
Y. Cheng (2021) et al.	Image Segmentation Technology and Its Application in Digital Image Processing	Discusses the importance and challenges of image segmentation technology in various sectors.	- Significant applications in transportation, biomedical, remote sensing, and fire prediction.	- Challenges in data frequency, pressure, and processing speed; images without denoising lack normal pinnacle and box of Dido value.
C. Tang (2020) et al.	Joint Regularized-based Image Reconstruction	Combines block matching and TV regularization to enhance	- Significant noise reduction and detail preservation using SART-TV and BMTV	- SART-TV method destroys image details in the skull of the phantom.

	by Combining Super-Resolution Sinogram for Computed Tomography Imaging	reconstructed image fidelity in CT imaging.	methods.	
P. Srujana (2021) et al.	Edge Detection with Different Parameters in Digital Image Processing using GUI	Analyzes various edge detection algorithms using MATLAB GUI, highlighting the Canny operator's superiority.	- Real-time application models show the Canny operator as the best due to low MSE and high PSNR/SNR.	- Edge detection method isn't separating images into various regions of discontinuity.
V. B. Inchur (2020) et al.	Implementation of Blood Cell Counting Algorithm using Digital Image Processing Techniques	Utilizes digital image processing for accurate blood cell counting, achieving high accuracy with different methods.	- Superior RBC count results with Circular Hough Transformation; Texture Object-Based Classification excels for WBC and platelet counts.	- Differential cells (Eosinophils, Basophils, etc.) can't be extracted.
J. R. González Montero (2020) et al.	Watermark Detection and Clearance in Video Using Simple Signal and Image Processing Techniques	Introduces efficient algorithms for detecting and clearing watermarks in videos, outperforming CNN models in speed.	- Exceptional speed compared to ML-based methods; CPU-based algorithms are significantly faster.	- Genuine negative rate and statistical comparison with CNN watermark detection not performed.
O. Bielova (2019) et al.	A Digital Image Processing Pipeline for Modelling of Realistic Noise in Synthetic Images	Simulates realistic noise in synthetic images for evaluating image-based algorithms, providing control over noise types.	- Accurate noise modeling and flexible processing chain.	- Most cameras don't directly record the intensities of the sRGB primaries.
G. Lu (2019) et al.	Deep Non-Local Kalman Network for Video Compression Artifact Reduction	Uses Kalman filtering and deep neural networks to reduce video compression artifacts, leveraging temporal information from previous frames.	- Effective for artifact removal and extends to other low-level tasks like denoising.	- Non-local prior information not integrated for reconstruction.
C. Shao (2019) et al.	A Kind of Pavement Crack Detection Method Based on Digital Image Processing	Proposes a high-performance digital PLL with meticulously designed TDC and DCO components for enhanced pavement crack detection.	- Accomplished in-band phase noise consistent with TDC's effective resolution.	- PLL achieves high in-band phase noise but compromises on power and area.

3. Conclusion

This literature survey underscores the significant advancements and methodologies in digital image processing, highlighting its crucial role in various fields such as medical imaging, surveillance, and multimedia. It reveals the importance of key techniques like enhancement, restoration, segmentation, and compression in improving image quality. Additionally, the survey emphasizes the critical need for robust security measures, reviewing traditional and innovative methods like encryption, steganography, watermarking, and Chaotic Encryption with Dynamic Key Generation (CEDKG). The insights provided demonstrate the evolution of DIP technologies and the essential role of comprehensive security measures in protecting digital images in an increasingly interconnected world.

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