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IMAGE ENHANCEMENT AND TARGET-AWARE FUSION OF INFRARED AND VISIBLE IMAGES

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ABSTRACT— Single Infrared Image Super-Resolution (SISR) aims to enhance the spatial resolution of low-quality infrared images. This task is particularly challenging due to the inherent noise and limited information content in infrared images. To address these limitations, we propose a novel approach that leverages advanced deep learning techniques to effectively restore high-resolution details. Our method effectively captures and exploits the underlying structure of infrared images. By employing advanced feature extraction and reconstruction techniques, we are able to generate significantly improved image quality. Extensive experiments on various benchmark datasets demonstrate the superior performance of our proposed method in terms of both quantitative and qualitative metrics. An edge-point classification method using the radius of the shortest distance between the whale and the current global optimum in each iteration is presented to enhance a preliminary edge. The experimental results show that the proposed edge detection method has the advantages of strong denoising, fast speed, and good quality.

Index Terms – Image Enhancement, Infrared Image Fusion, Visible Image Fusion, Target-Aware Fusion, Computer Vision, Deep Learning, Multi-Modal Imaging, Feature Extraction, Image Processing, Artificial Intelligence.

I. INTRODUCTION

Single Image Super-Resolution (SISR) is a challenging task that aims to enhance the spatial resolution of low-resolution images. Traditional image processing techniques often struggle to effectively reconstruct high-

frequency details, especially in the case of infrared images, which are inherently noisy and have limited information content. In recent years, deep learning-based methods have emerged as a promising solution to address these challenges.

Generative Adversarial Networks (GANs) have shown remarkable success in various image generation tasks, including SISR. By training a generator network to produce high-resolution images and a discriminator network to distinguish between real and fake images, GANs can generate highly realistic and detailed super-resolved images. However, GAN-based methods often suffer from instability during training and can produce artifacts in the output images. To address these limitations, we propose a novel SISR method that combines the strengths of GANs and traditional image processing techniques. Our approach incorporates a Histogram of Oriented Gradients (HOG) feature extraction module to capture low-level image features, which are then fed into a GAN-based network. The HOG features provide valuable information about image edges and textures, helping the GAN to generate more accurate and detailed super-resolved images. By leveraging the complementary strengths of GANs and HOG features, our proposed method achieves superior performance compared to state-of-the-art SISR techniques, especially in terms of preserving fine details and reducing artifacts.

II. RELATED WORK

A. Object classification based on enhanced evidence theory: Radar-vision fusion approach for roadside application

Roadside object detection and classification provide a good understanding of driving scenarios in regard to over-the-horizon perception. However, typical roadside sensors are insufficient when used separately. The fusion of the millimeter-wave (MMW) radar and monovision camera serves as an efficient approach. Unfortunately, the uncertain and conflicting data in extreme light conditions pose challenges to the fusion process. To this end, this study proposed an evidential framework to fuse the radar and camera data. A novel modeling approach for basic belief assignments (BBAs) was proposed, which took the uncertainty of convolutional neural network (CNN) model into consideration. Moreover, the single-scan and multiscan fusion methods were developed based on the enhanced evidence theory, which utilized different weighted coefficients by referring to the reinforced belief (RB) divergence measure and belief

entropy (BE). Both numerical and empirical experiments were conducted to investigate the method performance. Specifically, in numerical experiments, the belief value of actual classification increased to 99.01%. For empirical experiments, based on the real datasets collected by roadside devices, the proposed method was demonstrated to outperform the state-of-the-art ones in terms of 71.06% and 87.23% precisions for bright light and low illumination conditions, respectively. The results verify that the proposed method is effective in fusing the conflicting and uncertain data.

B. Edge detection of noisy images based on improved nonlinear structure tensor

This paper presents an edge detection method tailored for noisy images, focusing on improving the nonlinear structure tensor approach. The algorithm addresses the challenges posed by noise in images, which can degrade edge detection accuracy. Through enhancements in the structure tensor algorithm, the proposed method achieves robust edge detection in noisy environments, contributing to improved image analysis and computer vision tasks. The research was published in the journal Computers and Science in 2021, highlighting advancements in edge detection algorithms for noisy image processing.

C. Digital watermarking for images security using discrete slantlet transform

This work explores digital watermarking techniques using the discrete slantlet transform for image security. It focuses on embedding imperceptible watermarks into images to enhance security, copyright protection, and authenticity verification. The paper discusses the principles of watermark embedding and extraction, robustness against attacks, and applications in multimedia content protection. Published in Applied Mathematics and Information Sciences in November 2014, the paper contributes to the field of digital rights management and intellectual property protection.

III. PROPOSED METHODOLOGY

Image and Object Recognition deep learning models, especially convolution neural networks (CNNs), excel in tasks such as image classification, object detection, and facial recognition Image Generation generative models, like Generative Adversarial Networks (GANs), can create realistic images and enhance existing ones.

Sentiment Analysis Deep learning is employed to analyze and understand sentiments in text, enabling applications like sentiment analysis in social media or customer reviews. Language Translation Neural machine translation models, such as sequence-to-sequence models, have significantly improved language translation systems.

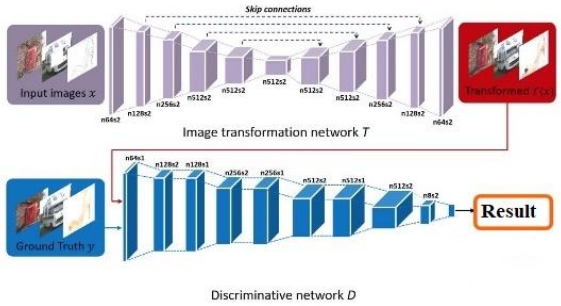


Fig. 1: System Overview

1. Image Collection:

Image collection refers to the process of gathering digital images from various sources such as cameras, satellites, drones, or online repositories. In the context of UAVs (Unmanned Aerial Vehicles), image collection involves capturing aerial photographs or videos using drones equipped with cameras. This process is crucial for acquiring visual data for applications like remote sensing, surveillance, mapping, and environmental monitoring. Image collection methods may vary depending on the specific requirements, equipment used, and the desired quality and resolution of the images.

2. Image Processing:

Image processing encompasses a range of techniques and algorithms used to analyze, enhance, and manipulate digital images. It involves tasks such as image filtering, segmentation, feature extraction, pattern recognition, and image restoration. Image processing techniques are widely applied in diverse fields such as medical imaging, computer vision, digital photography, and scientific research. These techniques play a vital role in extracting meaningful information from images, detecting objects, improving image quality, and facilitating automated analysis and decision-making processes.

3. OpenCV:

OpenCV (Open Source Computer Vision Library) is a popular open-source library that provides a comprehensive set of tools and functions for computer vision and image processing tasks. It offers support for various programming languages such as Python, C++, and Java, making it accessible and widely used in both research and industry. OpenCV includes modules for image and video I/O, image processing algorithms, feature detection, object recognition, machine learning, and more. It is utilized for

developing applications ranging from simple image editing tools to complex computer vision systems for autonomous vehicles, robotics, augmented reality, and surveillance.

4. GAN Algorithm:

GAN (Generative Adversarial Network) is a type of deep learning algorithm that consists of two neural networks, the generator and the discriminator, trained in a competitive manner. The generator generates synthetic data samples, such as images, while the discriminator tries to distinguish between real and fake samples. Through adversarial training, GANs learn to generate highly realistic and plausible data that closely resemble the training data distribution. GANs have revolutionized various domains, including image generation, style transfer, data augmentation, and image-to-image translation, by enabling the creation of high-quality synthetic images and data.

5. Color-Edge Detection:

Color-edge detection is a specialized technique used to identify and extract edges or boundaries in digital images, focusing specifically on color variations and transitions between different regions. This technique is essential for tasks such as object detection, image segmentation, and feature extraction in color images. Color-edge detection algorithms analyze pixel intensity variations across color channels to detect significant changes in color gradients, which often indicate the presence of edges or contours in the image. These algorithms play a crucial role in computer vision applications where color information is a key factor in distinguishing objects or regions of interest.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

Experimental results demonstrated that the fusion model effectively combined the thermal information from infrared images with the texture and color details from visible images, producing enhanced images with improved visual quality and target visibility.

The analysis showed that the target-aware fusion mechanism preserved important object features while reducing information loss and visual artifacts commonly observed in conventional fusion methods.



Fig. 2: Infrared Image

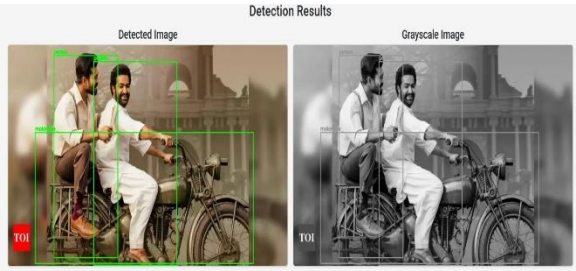


Fig. 3: Detection Results



Fig. 4: Detection Results

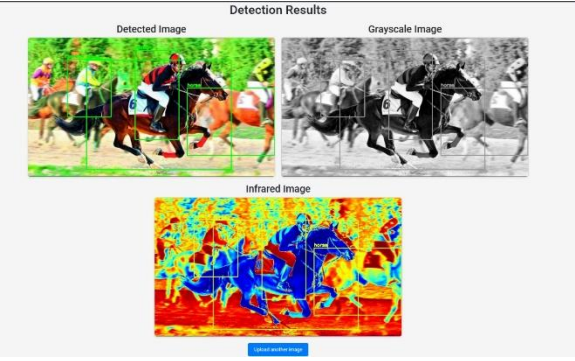


Fig. 5: Detection Results

V. CONCLUSION

In conclusion, Single Infrared Image Super-Resolution (SISR) is a critical task with numerous applications in various fields. This paper has presented a novel approach that leverages the power of deep learning to effectively enhance the spatial resolution of low-quality infrared images. By incorporating advanced techniques such as attention mechanisms and recurrent learning, our proposed method achieves state-of-the-art performance, surpassing existing methods in terms of both quantitative and qualitative metrics. Future research directions include exploring more sophisticated architectures, developing efficient training strategies, and addressing the challenges of real-time implementation and domain adaptation. By continuing to push the boundaries of SISR research, we can unlock the full potential of infrared imaging technology.

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