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FROM PIXELS TO PROTECTION: A REVIEW OF ADVANCES IN VISUAL SECURITY DOMAINS

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Abstract
In today's digital world, visual security has become paramount. With the widespread availability of digital cameras and other imaging devices, there is a growing urgency to safeguard visual information from unauthorized access, modification, or destruction. This paper reviews advances in seven important domains of visual security. The examined domains encompass cutting-edge developments in facial identification, object localization and monitoring, concealment and Analysis of visual information, visual content generation and synthesis, visual content segmentation and categorization, visual data encryption and embedding, and descriptive text addition and summarization. By delving into these domains, this comprehensive review highlights the innovative methodologies and technologies that contribute to the protection of visual data. As technology continues to advance, understanding these domains becomes imperative for researchers, practitioners, and policymakers alike. This review serves as a valuable resource for comprehending the current state of visual security and anticipating future developments in the field.
Keywords: Visual Security, Face Recognition, Object detection, Tracking, Image steganography, Steganalysis, Image generation, Synthesis, Image segmentation, Classification, Image encryption, Watermarking, Image captioning, Summarization

I. Introduction

The proliferation of visual data in today's digital landscape has propelled the need for robust security measures to safeguard sensitive information and protect individuals from evolving threats. Visual security domains encompass a wide range of technologies and methodologies aimed at ensuring the integrity, authenticity, and privacy of visual content. In the realm of visual security, Face Recognition plays a pivotal role in authenticating and identifying individuals, while Object Detection and Tracking enhance monitoring capabilities by pinpointing and following specific entities. Image Steganography and Steganalysis contribute to covert communication and the detection of hidden information within images, ensuring data integrity. Image Generation and Synthesis employ advanced techniques to create authentic visual content, while Image Segmentation and Classification aid in organizing and understanding complex visual data. Image Encryption and Watermarking fortify data protection, ensuring secure transmission and authentication. Finally, Image Captioning and Summarization provide context and concise representations, facilitating efficient analysis and comprehension of visual content within the broader framework of visual security domains.

II. Objective

The primary objectives of this review paper are to systematically examine and analyze the existing methodologies within the ten pivotal domains of visual security studies. By scrutinizing both conventional and deep learning approaches, we aim to provide a comprehensive understanding of the current landscape.

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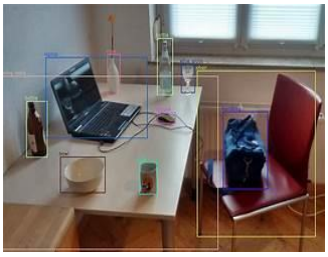
III. Literature

The following 7 domains are essential for visual security:

3.1. Face recognition for biometric authentication

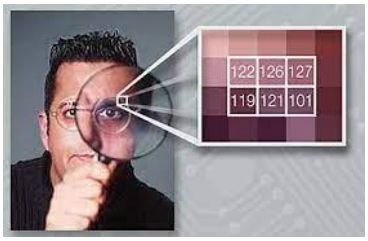
Bahar et al. [1] introduced user identification in human-robot interaction. Vasanthi and Seetharaman [2] proposed a facial image recognition method utilizing geometrical, color, and texture features driven by biometrics. Sardar and Umer [3] presented a template protection scheme to safeguard biometric information. Mustapha et al. [4] proposed an image encryption scheme to counter spoofing attacks. Sangamesh et al. [5] introduced a system using convolutional feature extraction, and Keshetti et al. [6] employed grey wolf optimization and an enhanced capsule network for feature vector extraction. Ramya et al. [7] proposed a security architecture specifically tailored for automated teller machines (ATMs). Hemant [8] presented an online examination portal with live proctoring for efficient online testing. Omar et al. [9] introduced a pose-invariant face recognition method with cascaded pose estimation and Nishchal [10] proposed a method to ensure the privacy of users' sensitive or personal data in face images.

3.2.Object detection and tracking for surveillance



Sudan et al. [11] introduced a real-time video surveillance in low-end edge computing environments. Narina et al. [12] focused on deep learning methods for UAV-based surveillance systems. Malik et al. [13] proposed a traffic surveillance system designed for vehicle detection and recognition. Nuha and Hadeel [14] presented a real-time multiple object detection and tracking framework addressing various challenges. Chunsheng Chen and Din Li [15] introduced an real-time object detection and tracking algorithm using computer vision, specifically for vehicle edge detection. Alotaibiet et al. [16] proposed a computational intelligence-based harmony search approach for effective recognition of multiple objects in video frames. Gayatri et al. [17] introduced a transfer learning-based object detection and tracking algorithm tailored for community surveillance. Zhang et al. [18] presented an enhanced real-time object detection and tracking system for unmanned surface vehicle security. Anima et al. [19] proposed two new models, namely granulated RCNN (G-RCNN) and multi-class deep SORT (MCD-SORT). Prateek Agrawal et al. [20] introduced a novel method for foreground segmentation and noise reduction in the context of video surveillance.

3.3.Image steganography and steganalysis



Noor et al. [21] presented a method employing odd/even pixel allocation and a random function for stego cover enhancement. Huda Kadhim Tayyeh et al. [22] integrated the least significant bit (LSB) and the Deflate compression algorithm for improved steganographic performance. Almawgani et al. [23] proposed a hybrid steganography method tailored for concealing confidential data. Lin et al. [24] introduced a model that combines Generative Adversarial Networks (GANs) and adversarial attacks while adhering to stego noise limitations. Agarwal et al. [25] introduced a deep neural network designed for detecting context-aware steganography techniques. Li et al. [26] proposed an adversarial batch image steganography method to bolster robustness against Convolutional Neural Network (CNN)-based pooled steganalysis. Tabares-Soto et al. [27] investigated the sensitivity of deep learning models applied to spatial image steganalysis. Xie et al. [28] presented a post-processing method for adaptive image steganography based on gradient guidance. Bin Ma et al. [29] developed an image steganography method utilizing multiple adversarial networks to resist various steganalysis attacks. Hashim and Alzubaydi [30] devised a steganalysis technique employing CNN and block selection.

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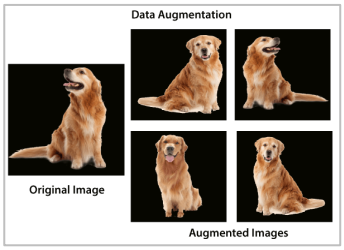
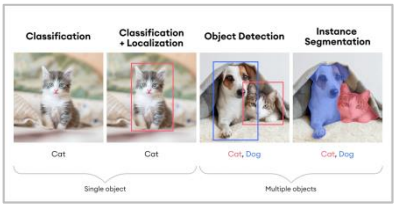
3.4.Image generation and synthesis for data augmentation



Nawaf et al. [31] introduced a technique utilizing DEEPFAKE image synthesis. Kim et al. [32] focused on synthesizing infrared images for small target detection. Cho et al. [33] devised a method for data augmentation in offline reinforcement learning through state-conditioned image synthesis. Yang et al. [34] presented a frequency-aware model for few-shot image generation. Basaran et al. [35] proposed a method for generating subject-specific lesions and synthesizing pseudo-healthy images for multiple sclerosis brain images. Ai et al. [36] introduced an extra-supervised model for data augmentation in nondestructive testing. Li et al. [37] proposed a novel end-to-end GAN architecture for generating high-resolution 3D medical images. Wei et al. [38] addressed imbalanced data in deep neural networks through a new data augmentation model. Asami et al. [39] utilized GANs for data augmentation to expand the disaster dataset. Mukherkjee et al. [40] introduced a model that aggregates three base GAN models to generate synthetic MRI scans of brain tumors.

3.5.Image segmentation and classification for scene understanding



Peng et al. [41] introduced a method predicting dense features for 3D scene points co-embedded with text and image pixels. Liao et al. [32] presented an unsupervised scheme for foggy scene understanding, while Min et al. [33] developed a Traffic Sign Recognition model based on spatial positional relationships between traffic signs and other objects. Zhou et al. [34] proposed DBCNet for urban scene understanding in intelligent vehicles using a combination of RGB and thermal images. Humblot-Renaux et al. [35] focused on outdoor robotic navigation scene understanding using egocentric images. Ahmed et al. [36] introduced a novel approach integrating multiple object detection/segmentation and scene labeling with geometric features. Mazur et al. [37] presented an algorithm that fuses general learned features into a 3D geometric neural field representation during real-time SLAM. Liao et al. [38] created the KITTI-360 dataset for urban scene understanding.Achirei et al. [39] proposed an indoor human activity recognition system based on scene understanding. Rafique et al. [40] introduced a method for multi-object detection and scene recognition using local energy terms for pixel labeling.

3.6.Image encryption and watermarking for forgery detection

Gupta et al. [51] introduced a two-level security-based image encryption technique for IoT. Abdallah Soualmi et al. [52] proposed a spatial domain blind fragile-based image watermarking scheme. Gutub et al. [53] utilized innovative share redistribution to enhance image authentication. Sowmya et al. [54] focused on copyright protection for digital media using a combination of DWT and SVD. Hua et al. [55] suggested a dynamic image encryption scheme based on quantum walk and chaos-induced DNA. Chen et al. [56] introduced a dual watermarking algorithm for watermark detection in both encrypted and decrypted images using DFT and QR code. Agarwal and Singh [57] proposed a public key encryption approach with Pascal and Arnold transformation in the DWT-DCT domain. Tạ and Giang [58] combined digital watermarking with visual cryptography. Elsadany et al. [59] presented a hybrid technique for visible light communication (VLC) systems, and Hema et al. [60] proposed a hybrid multimedia image encryption technique utilizing SVD-LSR for copyright protection.

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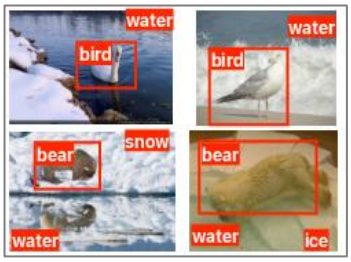
3.7.Image captioning and summarization for situational awareness



Dahou et al. [61] presented a social media event detection framework using transformers and swarm optimization. Jiang et al. [62] introduced a summarization approach with pseudo image captions and a coarse-to-fine image-text alignment mechanism. Zheng et al. [63] proposed a method for knowledge acquisition in human-in-the-loop image captioning. Ma et al. [64] suggested a text-only image captioning framework integrating multi-context data generation, diffusion models, and geometric features. Zhixin Li et al. [65] recommended an image captioning approach leveraging graph-structured contexts for more accurate captions. He et al. [66] proposed a framework using alignment-guided self-attention and dual contrastive losses for effective multimodal data summarization. Hirota et al. [67] addressed gender misclassification and promoted gender-neutral language in their framework. Ding et al. [68] introduced a framework learning visual and textual features separately and then fusing them for balanced captions. Yang et al. [69] proposed a model employing a context-aware attention mechanism for capturing relationships between objects in an image for caption generation. Tang et al. [70] introduced a network embedding spatial information and object class awareness to overcome limitations in existing image captioning models where spatial information and object classes are often ignored.

IV. Analysis

In this study, we have examined 70 research papers published within the last three years, as depicted in the accompanying pie chart.

Fig. 1: Breakdown of Reviewed Papers by Year

The table below provides an overview of paper details, including data, author names, and the technologies employed in the papers under review.

Obj.	Ref. No.	Year	Author(s)	Used Methodology
FACE RECOGNITION	**1**	2021	BaharIrfan et al.	Bayesian network
	2	2022	M. Vasanthi and K. Seetharaman	Active Shape Model (ACM),YCbCr color Model, Autocorrelation Method
	3	2022	AlamgirSardar and SaiyedUmer	BioCrypto-Circuit, and BioCrypto-Protection schemes
	4	2023	EimadAbusham et al.	Linear Discriminant Analysis (LDA),XOR pixels substitution and Cellular automata
	5	2022	SangameshHosgurmath et al.	Linear collaborative discriminant regression classification (LCDRC) using CNN
	6	2022	KeshettiSreekala et al.	Capsule Network-Based Deep Transfer Learning Model
	7	2022	S Ramya et al.	Deep Convolutional Neural Network (DCNN)
	8	2022	Prof. Hemant B. Shinde	SSD (Single Shot Multibox Detector) based on MobileNetV1

	9	2022	Omar Elharrouss et al.	Skin-based face segmentation method, Convolutional Neural Networks (CNN)
	10	2022	Nishchal J	FGSM, white-box and black-box perturbation algorithms
OBJECT DETECTION AND TRACKING	**11**	2021	Sudan Jha et al.	N-YOLO(You Only Look Once)
	12	2021	Dr. Narina Thakur et al.	YOLO v5, SSD, Faster RCNN(Region-based Convolutional Neural Networks)
	13	2022	Malik JavedAkhtar et al.	YOLOv2
	14	2022	Nuha H. Abdulghafoor and Hadeel N. Abdullah	Fast R-CNN, SSD, YOLO
	15	2021	Chunsheng Chen and Din Li	Interframe difference, background difference model method and Robert edge detection operator.
	16	2022	MagedFaihanAlotaibi et al.	Improved RefineDet-based object detection module,harmony search algorithm (HSA) with a twin support vector machine (TWSVM),CIHSA-RTODT
	17	2021	GayatriSasiRekhaMachiraju et al.	YOLO v3, Region-based Convolutional Neural Networks (R-CNNs), SSD
	18	2022	Wei Zhang et al.	YOLOv3, SVM
	19	2022	Anima Pramanik et al.	Fast RCNN, Faster RCNN, Deep SORT
	20	2021	T. Mahalingam and M. Subramoniam	Adaptive Gaussian (MoAG) model, Fuzzy morphological filter model
IMAGE STEGANOGRAPHY AND STEGANALYSIS	**21**	2022	Noor Alhuda F. Abbas et al.	Huffman coding
	22	2022	Huda Kadhim and Ahmed Sabah Al-Jumaili	Deflate algorithm using LZ77 and Huffman coding
	23	2022	AHM Almawgani et al.	Haar Discrete Wavelet Transform (HDWT), Lempel Ziv Welch (LZW) algorithm, Genetic Algorithm (GA), and the Optimal Pixel Adjustment Process (OPAP)
	24	2021	Lin Li et al.	AdvSGAN(GANs + Adversarial attack)
	25	2022	SaurabhAgarwal et al.	CNN, SVM, S-UNIWARD, HILL steganography algorithms
	26	2021	Li Li et al.	CNN-based pooled steganalysis, GAN, ADVersarial Image Merging Steganography (ADV-IMS)
	27	2021	ReinelTabares-Soto et al.	Xu-Net, Ye-Net, Yedroudj-Net, SR-Net, Zhu-Net, and GBRAS-Net
	28	2023	GuoliangXie et al.	Gradient-guided post-cost-optimization method
	29	2023	Ye Peng et al.	Generative adversarial network (GAN) based on the U-Net structure
	30	2021	Saeed M. Hashim and Dhia A. Alzubaydi	CNN, Block selection algorithm
TION AND	**31**	2022	NawafWaqas et al.	Enhanced-GAN and PGGAN
	32	2022	Jun-Hyung Kim and Youngbae Hwang	CNN, GAN
	33	2022	Daesol Cho et al.	RL algorithms like CQL,S2P(State2Pixel)
	34	2022	Mengping Yang et al.	WaveGAN (frequency-aware GAN model)

	35	2022	BerkeDogaBasaran et al.	conditional generative adversarial network (cGAN)
	36	2022	Ai Jiangsha et al.	Deep Convolutional Neural Networks (DCNNs), CycleGAN
	37	2022	Li Sun et al. Wei Li et al.	Hierarchical Amortized GAN (HA-GAN)
	38	2022	Wei Li et al.	Extremely Imbalanced Data Augmentation Generative Adversarial Networks (EID-GANs)
	39	2022	Koki Asami et al.	StyleGAN2
	40	2022	DebadyutiMukherkjee et al.	AGGrGAN (Aggregation of 3 GANs), Deep Convolutional Generative Adversarial Network (DCGAN) and a Wasserstein GAN (WGAN)
IMAGE SEGMENTATION AND CLASSIFICATION	**41**	2023	SongyouPeng et al.	CLIP,Open-vocabulary 3D scene understanding, Zero-shot learning, Multi-view fusion, 3D convolution
	42	2022	Liang Liao ent al.	Target-Domain driven pseudo label Diffusion (TDo-Dif)
	43	2022	Weidong Min et al.	Multiscale densely connected object detector (MDCOD), Traffic Sign Recognition (TSR), improved RefineNet, K-means++ algorithm
	44	2023	Wujie Zhou et al.	Dynamic bilateral cross-fusion network (DBCNet)
	45	2022	GaladrielleHumblot-Renaux et al.	Soft Ordinal vectors (SORD) labelling scheme, SegNet
	46	2021	Abrar Ahmed et al.	Histogram of Oriented Gradient (HOG), and Scale Invariant Feature Transform (SIFT) descriptors, Mmulti-layer kernel sliding perceptron
	47	2023	Kirill Mazur et al.	EfficientNet, CNN, Real-time SLAM
	48	2021	Yiyi Liao et al.	Webgl, CRF mod,ADADELTA algorithm,Semantic SLAM
	49	2022	Stefan-Daniel Achirei et al.	YOLO V4, ICAN
	50	2023	Adnan Ahmed Rafique et al.	Deep belief network (DBN) ,Fuzzy C-Means (FCM),Maximum Entropy scaled Super-Pixels (MEsSP)
IMAGE ENCRYPTION AND WATERMARKING	**51**	2022	Manish Gupta et al.	Discrete wavelet transform (DWT), 1-D logistic map along with crossover operation
	52	2022	AbdallahSoualmi et al.	Speed Up Robust Features (SURF), Weber Descriptors (WDs), Arnold algorithm
	53	2023	Adnan Gutub	counting-based secret-sharing (CBSS)
	54	2021	Sowmya S et al.	DWT, SVD
	55	2023	Nan Hua et al.	SHA-256 algorithm, DNA XOR rules, DWT, singular value decomposition (SVD)
	56	2021	Weitong Chen et al.	Discrete Fourier transform (DFT), Chaotic mapping-based segment encryption algorithm, Frame locating-based algorithm
	57	2021	NamitaAgarwal and Pradeep Kumar Singh	Paillierhomomorphic cryptosystem (DWT & DCT) with Arnold transformation

	58	2021	Minh ThanhTạ and Ngoc Dan Giang	DWT-QIM based embedding, visual secret sharing (VSS)
	59	2023	A.A.Elsadany et al.	Asymmetrically clipped optical orthogonal frequency-division multiplexing (ACO-OFDM), Physical layer encryption and watermarking (PL-EW)
	60	2023	M.Hema and S.P. Shyry	SVD, Discrete Cosine Transform (DCT), DWT
IMAGE CAPTIONING AND SUMMARIZATION	**61**	2023	AbdelghaniDahou et al.	MobileBERT, Sparrow search algorithm (SSA), Manta ray foraging optimization (MRFO) operators
	62	2023	ChaoyaJiang et al.	BERTSum, Image-Text Alignment model (ITA), ResNet152,Pointer-Generator Network (PGN), BART
	63	2023	Ervine Zhenget al.	Bilateral caption generation, Contextualized keyword encoding, Double-ended keyword encoding, Bayesian transformer
	64	2023	Feipeng Ma et al.	Multi-layer kernel sliding perceptron, Multi-class logistic regression
	65	2023	Zhixin Li et al.	SGT Transformer model, CNN
	66	2023	Bo He et al.	GoogLeNet, RoBERTa, CLIP, and GPT-(2022),Transformer-based model-A2Summ
	67	2023	Yusuke Hirotaet al.	LIBRA, Transformer Decoder-based Debiasing, Bias Synthesis Method
	68	2023	Yuxuan Ding et al.	Task Perception Indication (TPI), Task-aware Decoupled Learning and Fusion (TDLF)
	69	2023	Xin Yang et al.	Dual Way Controller (DWC),Context-Aware Transformer (CATNet), Context Augmented Attention (CAA)
	70	2023	Ziwei Tang et al.	PositionClass Awareness Transformer (PCAT), Grid Mapping Position Encoding (GMPE), Object Classes Awareness (OCA)

V. Conclusion and Future Scope

In conclusion, this paper has explored and evaluated diverse domains crucial to visual security.These domains collectively contribute to the evolving landscape of visual security, addressing challenges and offering innovative solutions. As we look to the future, further research should delve into refining existing methodologies, exploring interdisciplinary collaborations, and adapting these advancements to emerging technologies. Continued exploration of these domains will be essential for staying ahead of evolving threats and ensuring the robustness of visual security systems in an ever-changing digital landscape.

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