

Survey of Anomaly Detection Techniques in Intelligent Surveillance Systems

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Abstract

Smart surveillance systems are used to monitor specific regions such as houses, businesses, and borders. For a long time, abnormality detection in time-series data has been a significant study area. In today's society, unusual conduct signifies a threat or risk to others. An anomaly is something that deviates from what is anticipated, common, or usual. The most unexpected aspect of human behavior is determining if it is dubious or normal. It is extremely difficult to continually monitor public locations. Effective monitoring methods are critical to consistently increase the demand for successful inspection of open areas, handling difficulties such as traffic congestion, and ambiguities in crowded scenes.

Handling millions of people during Hajj, intruder detection, fall detection, and so on. Raising knowledge of intelligent video surveillance technology and improving the degree of intelligent video surveillance has resulted in a reduction in data observation time. And analysis time has been reduced by half. Technology had advanced far too quickly.

When introducing machine learning, artificial intelligence, and deep learning into the system, anomaly detection methods were developed using statistical models.

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The goal of the suggested review is to make a significant contribution to the study of activity analysis techniques in computer vision research issues.

Keywords: anomalous activity, anomaly behavior, intelligent surveillance video, classification, Computer vision, crowd scene, behavior analysis, activity analysis

مسح لتقنيات كشف الشذوذ في أنظمة المراقبة الذكية

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الخلاصة

تُستخدم أنظمة المراقبة الذكية لمراقبة مناطق معينة مثل المنازل والشركات والحدود. لفترة طويلة، كان اكتشاف الشذوذ في بيانات السلاسل الزمنية مجال دراسة مهم. في مجتمع اليوم، يشير السلوك غير العادي إلى وجود تهديد أو خطر على الآخرين. الشذوذ هو شيء ينحرف عما هو متوقع أو شائع أو عادي. أكثر جوانب السلوك البشري غير المتوقعة هي تحديد ما إذا كان مشكوكًا فيه أم طبيعيًا. من الصعب للغاية مراقبة الأماكن العامة باستمرار. تعتبر طرق المراقبة الفعالة أمرًا بالغ الأهمية لزيادة الطلب باستمرار على التفتيش الناجح للمناطق المفتوحة، والتعامل مع الصعوبات مثل الازدحام المروري، والغموض في المشاهد المزدحمة. التعامل مع ملايين الأشخاص أثناء الحج، واكتشاف الدخلاء، وكشف السقوط، وما إلى ذلك. أدى رفع المعرفة بتكنولوجيا المراقبة الذكية بالفيديو وتحسين درجة المراقبة الذكية بالفيديو إلى تقليل وقت مراقبة البيانات. وتم تقليل وقت التحليل بمقدار النصف. تقدمت التكنولوجيا بسرعة كبيرة جدًا. عند إدخال التعلم الآلي والذكاء الاصطناعي والتعلم العميق في النظام، تم تطوير طرق اكتشاف الشذوذ باستخدام النماذج الإحصائية. الهدف من المراجعة المقترحة هو تقديم مساهمة كبيرة في دراسة تقنيات تحليل النشاط في قضايا بحث رؤية الكمبيوتر.

الكلمات المفتاحية: سلوك شاذ، فيديو مراقبة ذكية، تصنيف، رؤية حاسوبية، مشهد جماعي، تحليل سلوك، تحليل نشاط.

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Introduction

Closed-circuit televisions (CCTVs) are becoming common, particularly in crowded areas. As a result, it is critical to employ machine learning to assist in detecting abnormalities in those locations. Without the assistance of artificial intelligence, this work will need a significant amount of human labor to monitor a large number of displays and detect these events, despite the fact that they are rare. [1] Monitoring is a critical part of safety. Security cameras are becoming an essential component of everyday life for security and safety [2]. One of the most seriously issues in today's society is crime. A Smart and sophisticated surveillance systems are required to reduce crime rates [3]. The most significant benefits of video monitoring are reduced labor needs and the capacity to audit and implement new security trends [4]. Detecting abnormalities in data is among the most analysis tasks. Because the occurrence fluctuates depending on its location, there is no set definition of anomalous events [1]. Anomalies are data points that deviate from the normal distribution of original dataset, and the technique used for discovering them named "anomaly detection". [5] Formal paraphrase However, due to the intricacy of the sceneries and the deceptive notion of irregular activities, detecting anomalies is a challenging task [6]. There are ways to classify the classification approaches that are unsupervised, supervised, and semi-supervised. Unsupervised classification is performed by a computer and does not require human intervention. To manual training and labeled data, supervised classification is required, the sort of learning named "Semi-supervised" that falls somewhere between no labeled training data (unsupervised learning) and labeled training data (supervised learning) [7]. This document categorizes and analyzes classic and sophisticated video anomaly detection techniques. Recent years have seen the development of methodologies for several algorithms in the field of machine learning. Because the integrity of the input-data representation is so important to an ML algorithm, for many years, ML has been involved in feature engineering, which has influenced numerous research initiatives. This method seeks to create features from raw data. [8]. in computer vision, deep learning architectures may effectively use effectively used for objectives beyond image classification, object identification,

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and activity recognition. Deep learning outperforms traditional approaches, according to studies. [9] Throughout the DL algorithms, feature extraction is accomplished automatically. Anomaly detection systems have applications in traffic monitoring, medical science, high-surveillance regions such as military bases and airports, population analysis, Automatic forensic video retrieval and criminal behavior recognition. Regardless of its potential uses, It is frequently utilized in training institutes, security alarms for schools surveillance systems or nursing systems at homes, intelligent transportation systems, and other applications. [10]. The main contributions gathered data on the most significant research on anomaly detection in surveillance films over the previous few years in the two axes of machine learning and deep learning, In addition to presenting the benchmark dataset used in the evaluation on these literature review. This paper's remainder is organized as follows. The (VSS) application facing a challenge, which are listed in Section 2. The section 3. Machine Learning-Based Models, feature extraction, classification. Section4 deep learning. The relevant literature and methods are covered in section5, section 6 Performance Analysis and discussion, related dataset in section 7. The conclusion is found in section eight.

Diverse video surveillance system application areas

Intelligent surveillance systems have the potential to be deployed in a variety of contexts and applications. The following are some examples of common applications Intruder detection (such as Identification of intrusion, Object monitoring, and Object detection in sparsely populated (uncrowded) areas), Counting (such as Statistical analysis, Marketing, Analysis and reporting on flow of traffic, and Great accuracy), Non motion detection (such as A scene's static updates are detected, Manage a crowded and bustling atmosphere, Can detect tiny objects, Can identify an undetectable item in scenes with low-contrast), and Crowd management (such as Crowd management, Traffic management, and Queue management) [11] [12]. The surveillance target is selected based on the system's use surveillance targets are often divided into five categories: automobile, human, event, object, and crowd. Because anomaly detection must be dealt with quickly, network slack and operational delays make cloud computing ineffective. In

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time-sensitive applications, for anomaly detection. Figure 1 depicts the relationship between surveillance, surveillance targets, and anomalies [13].

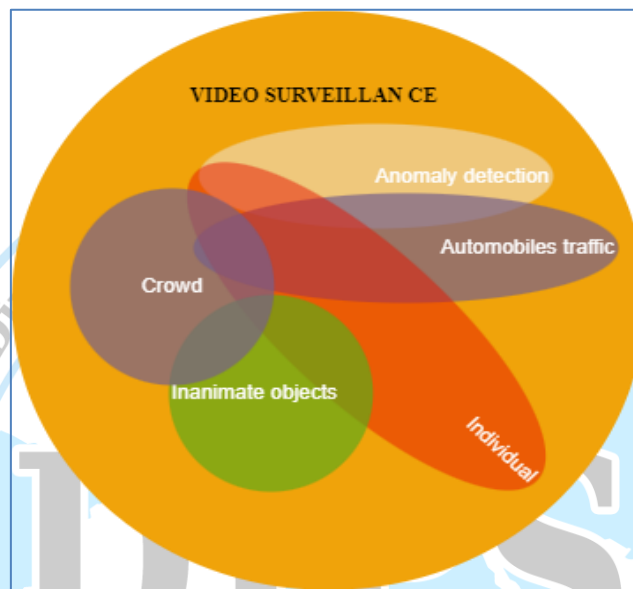


Figure 1: The correlation of (VSS) targets

It is also confronting or facing a number of challenges, which are listed below. [10]:

- Abnormal behaviors are hard to fully explain since it is very personal and varies widely among individuals. Furthermore, it is unclear how to classify abnormalities. Furthermore, due to a lack of appropriate instances of abnormality, anomaly detection is often addressed as a low likelihood pattern recognition problem rather than a classification challenge. [7]
- The distinction between normal and abnormal behavior is frequently unclear. Furthermore, in realistic situations, the same conduct might be normal or abnormal under various conditions [10]
- Noise in Video: In video analysis, noise can be a problem. Rain, dust, or the swaying of tree branches are all examples of noise. [12]

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- **Low Resolution:** When the pixel density of a face image to be recognized is less than $16 * 16$, a low-resolution problem emerges in a face recognition system, finding it challenging to categorize items since the boundaries of the objects are not very visible. [14]
- **Huge Crowd:** Detecting an object in a large crowd is quite challenging. Detecting aggression, stealing, slapping, and beating in more populated locations is a challenging task. [3]
- **Occlusion of Object Partially or Fully:** Identifying partially or completely blocked objects is quite challenging. Other objects might obstruct the faces at times. Some faces in photographs of groups of people may partially obscure others. [16]
- **Data labeled for training/validation models:** They are employed by anomalous detecting methods a tough mission is also the selection of characteristics that are used to characterize the item since it has a major influence on the description and analysis behavior. [17]
- **Processing at Real Time:** Developing a real-time system is the most difficult endeavor. When analyzing a video with a complicated backdrop, it may take longer, and object tracking may take longer [17].

Machine Learning-Based Models

Handcrafted features provide high-dimensional feature vectors for motion and appearance information by aggregating tiny local patches of successive video frames. However, in an uncontrolled environment, for huge video analysis, these feature vectors with several dimensions do not scale properly. [15]. the extraction of features in the spatio-temporal domain is critical to the handmade features approach. A bag-of-words is a grouping of low-level characteristics that may be used in both supervised and unsupervised learning contexts. The quality of the features picked determines their efficacy. The classification is then performed by using a trained machine learning classifier. [16]

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1. Feature Extraction

Feature extraction is the process of lowering the dimensionality of raw data to create a set of manageable categories. Methods that choose and/or integrate variables into features, successfully detect data redundancy, and provide an accurate and complete dataset are referred to as this. Feature extraction is a technique for identifying essential features in data and transferring them from one data set to another using valid key points. In a digital image or video, feature extraction algorithms are used to recognize features such as forms, edges, and movements. The most important phase in the model construction process is feature extraction. [17][18].

2. Classification

In Smart Video Surveillance System (SSVS), categorization is also a crucial stage. SVM, LSTM, Conventional Neural Network (CNN), Gaussian Mixture Model (GMM), and Recurrent Neural Network are examples of these approaches (RNN). There are two periods of the methodologies that have been outlined. In order to increase accuracy, I) supervised models were trained on labeled data. II) Because the model tries to extract patterns on its own, unsupervised models do not require labeled data. Both supervised and unsupervised environments have used a variety of classifiers [16]. A popular technique, Hierarchical Directed Process (HDP), Convolutional Neural Networks (CNN), and Hidden Markov Model (HMM), classifying of Image and video, processing of natural language, recognition of generic visual, recognition of faces, detection of pedestrian, and recognition of images are only few of the uses.[3]. The initial stage in video classification is extracting the frames from the supplied batch of clips, and this is the easiest approach to work with video data. Based on learning techniques, abnormality categorization is divided into categories [18].

Deep Learning-Based Models

Following deep learning systems' success in image classification, researchers investigated their ability to identify abnormalities. Deep learning algorithms do not require human participation

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since they bypass the manual feature extraction procedure and work directly with raw data. The quantity of learning is influenced by the quality of the data, which influences the ultimate product's quality. The effectiveness of a system will suffer if the data quality is low [9]. End-to-end deep learning is a "black box," and its predictions are challenging for humans to follow because of their layered structure. If it is employed as a counter, an issue will be difficult to solve. The researchers are therefore aiming to integrate deep learning with conventional methods [16].

Related Work

Several earlier researches have proposed various ideas and strategies. Regardless of the methods used, the given systems achieve the identification of normal and abnormal behaviors, but the essential objective of them remains to identify, monitor, and categorize objects and differentiate normal activity from irregular, several prior similar works are chosen:

In [2018] Waqas & et al [7], They demonstrate a MIL anomaly detection method based on only poorly labeled training footage, as well as using for a deep learning network a MIL ranking loss to learn video segment anomaly scores. AUC of the proposed technique without constraints (74.44) and with constraints (74.44) (75.41), dataset to assess suggested approach are UCF crime, which includes 13 real-world anomalies such as Abuse, Arrest, and so on. In [2018], Prakhar & Vinod [19]: uses a deep neural network (DNN) for modeling natural actions as well as predicting future frames from past frames of distortion-free data. The recommended technique was tested on the publicly offered UCSD Anomaly Detection Datasets4: UCSDPed1 and UCSDPed2. The outcomes for the proposed approach for very first metrics: Area Under Curve (AUC), it's achieve (74.8% in UCSDPed1) and (80.2% in UCSDPed2). In [2019], Divya Thakur et al. [20], This work proposes a CNN-based Anomaly Detection System (CNN-ADS), which is the organization of several layers of a hidden unit with the maximum MSER characteristic using a Genetic Algorithm (GA). The developed system's training and testing is evaluated using the UCF-Crime Dataset; the average error rate is 1.29 percent, and the average

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accuracy (AUC) is 98.71 percent. In [2020]. Waleed Albattah and et al [21]: They show a crowd control system that employs image classification and an alarm system to deal with the millions of people who attend the Hajj. This method is heavily reliant on the training dataset (CNN). The goal is to use mapped image data to train the CNN model, which will subsequently be used to classify crowds as ordinary, light crowded, semi-crowded, crowded, and severely crowded. Future study is a continuation of the approach to identify group behavior, which may also allow the group to be classified based on age, gender, and speed. In [2020] jwan [17], through a motion detection algorithm, the system suggests an abnormal classification of human activities (GMM). The FCM hash technique (a hybrid of two SIFT-Harris algorithms) is then used to extract features. The KNN method was eventually evaluated to identify the actions that correspond to three separate data sets: Weizmann, KTH, and Corridor Real. The results demonstrate the system's efficiency, as the test results revealed that the accuracy of data sets (97 percent), detection rate (97 percent), and false alarm rate (97 percent) were all within acceptable limits (4 percent). While real-time statistics show that the accuracy rate (91%), DR (detection rate) equal to (93%), and FAR (false alarm rate) are all high (12 percent). In [2020] Vishwajit & et al, [2], proposed Intelligent Surveillance System Using Deep Learning, CNN algorithm is used to extract features in a particular video clip. The LSTM rating then identifies the detection of violence in a particular video frame and sends an alert if violence is detected. This proposed algorithm gives best performance in spite of having hardware limitations. Time taken to process 5 seconds video clip is around 20 seconds, the results in the first part of the image showed violence with a percentage of 0.99 and a normal non-violent behavior with a percentage of 0.00. Later part is showed only non-violent behavior with a percentage of 1 so the system succeeded in detecting

In [2021] Shabana and et al [22], to recognize pilgrims from surveillance cameras, using this pilgrim's dataset, a lightweight CNN model is trained. The second phase involves passing these preprocessed significant frames to a lightweight CNN model for spatial feature extraction, and an LSTM is constructed in the third stage. They conducted several tests using two publicly

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available datasets of violent behavior, Surveillance Fight and Hockey Fight, and found that their suggested model had accuracies of 81.05 and 98.00, respectively. In [2021] Muthana S. Mahdi and et al [2]. The video is classified as abnormal or normal by the supplied system. In the event of unacceptable behavior, the authorities will be notified through SMS. In their method, they make use of YouTube, CAVIAR, and KTH scenes. The study's objective was achieved by using CNN to extract features from frames and the LSTM structure to categorize them as abnormal or normal. The accuracy was 95.3 percent.

In 2021, Faisal Abdullah and et al [8]: In this paper a new particle force model for multi-person tracking is presented Powerful fusion of global and local descriptors, along with a powerful entropy-optimized classifier for Detecting, understand and interpret the behavior of human masses required powerful feature extraction First distance algorithm was applied to remove background clutter, The performance of the proposed system was evaluated on the publicly available PETS2009 standard and UMN data set, it achieved results with an accuracy of 89.80% for multi-person counting and 86.95% for tracking people have achieved

Entropy 2021, 23, 628 22 of 26 Promising results on the publicly available standardized UMN data set. in 2022 Soheil Vosta & Kin-Choong Yow [23]: ResNet50 was used as a CNN for feature extraction in the proposed design. Following that, as a result of working with the video dataset, an RNN, ConvLSTM, was incorporated into the model's architecture, and the UCF-Crime dataset was utilized to obtain AUC 81.71 percent and Accuracy of ResNet101ConvLSTM 63.75 percent. This literature review is presented in table (1).

Performance Analysis and Discussion

This literature review is presented in table (1).by five columns, the researcher's first column, along with the publication year and citations the approach or algorithm employed, the dataset on which training and testing were done, the 2nd and 3rd columns, respectively, the outcomes according to the criteria used in each research, and certain drawbacks were mentioned in the last column.

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In Table No. 2, we provided the general description, and the type of events for the dataset used in the Related Work section, which provides an easy search for the name of the data set. The diversity of scenes, total number of actors, application domains, the sources of the data set, and the number of these anomalies are the most prominent features that were touched upon by many in previous work on the standard data set and the most common anomaly detection in video.

Table 1: Are used to present this literature summary

YEAR, AUTHOR(S), REFERENCE	TECHNIQUES USED	DATASET USED	RESULTS	DRAWBACKS
2018, Waqas Sultani et al.[7]	C3D& MIL ranking loss	UCF Crime dataset	AUC (74.44) without constraints. AUC with constraints (75.41)	Videos are long unprocessed surveillance videos with a lot of intra-class diversity. As a result, the dataset is a difficult dataset for detecting unusual behaviour
2018, Prakhar & Vinod [19]	DNN	UCSD PAD1 UCSD PAD2	AUC (74.8% in UCSDPed1) and (80.2% in UCSDPed2) /False Alarms (33/4 in UCSDPed1) & (11/1in UCSDPed2)	proposed approach does not perform as well as the state-of-the-art techniques in terms of AUC
2019, Divya Thakur et al.[20]	CNN MSER-CNN	UCF Crime dataset	98.36% 95.06%	—
2020 Jwan Jamal Ali[17]	GMM, KNN	Weizmann, KTH and Corridor Real.	Dataset: ACC (97%), DR (97%) with FAR .(%4) Real time: ACC (91%), DR (93%) with FAR .(%12)	Preserve the identity of human and isolating into individual trajectories is a difficult Task, blurring cluttered background is difficult in the activities Identifying.
2020 Vishwajit & et al[2] ,	CNN LSTM	Hockey Dataset Movie Fight Scenes Real Life.	the results in the first part of the image showed violence with a percentage of 0.99 and a normal non-violent behavior with a percentage of 0.00	_____

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2020 Waleed Albattah and et al[21]	CNN	During the 2018 Hajj season, crowds on the route to Jamrat. "Free Video from JPG Convert"	ACC 98%	This model's efficiency must be increased by using drone cameras and supercomputers for algorithm computation.
2021 Shabana and et al[22]	CNN&LSTM	Hockey Fight, Surveillance Fight datasets	ACC 96% (Hockey Fight). ACC 81.05% (Surveillance Fight datasets)	Violent activity is recognized from a single view. They cannot cover the full 360 coverage of activity.
2021, Muthana S. Mahdi and et al[2]	VGG16 & LSTM	CAVIAR, KTH, and YouTube scenes.	ACC 95.3	pure deep Learning is better for real-time anomaly detection, it may not produce as good of results as other techniques.
2021, Faisal Abdullah and et al [8]	entropy classifier with spatio-temporal and particles gradient motion descriptors. K-nearest neighbors searching algorithm	UMN data set PETS2009 Dataset	Mean Accuracy = 89.80% Tracking Accuracy (%) = 86.9	
2022 Soheil Vosta & Kin-Choong Yow[23]	CNN & RNN, CONVLSTM	UCF-Crime (four major groups)	AUC is 53.88%, Precision is 22.93%, Recall is 24.31%, F1-score is 23.60%, and Accuracy is 22.72%.	The dataset utilized in diverse topics, lighting, speed, The anomalous events may occur in one or two seconds, and even in 10-second recordings, more than 80% of the video duration demonstrates normal behavior

Datasets in literature review

Data set is one of most important components to evaluate the performance of any system. Evaluating the proposed algorithm against a standard dataset is one of the challenging tasks in video surveillance system. In the recent years, a number of standard datasets are available in different field of abnormal activity recognition. We will talk about the most common datasets,

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and they are listed in the table (2). It shows a brief for available dataset. As mentioned in Part VI of the **"Performance Analysis and Discussion."** [9], [23] [1] [24]

Table 2: Description of the public datasets containing anomaly events [1]

Dataset	Description	Type of event
University of California, San Diego (UCSD)	Peds1: 5 minutes Clips of individuals going towards and away from the camera, with some perspective distortion. Peds2: 5 minutes Scenes in which pedestrians travel in a straight line parallel to the camera plane.	moving across pathways, Bicyclists, and tiny carts
University of Central Florida (UCF) Ucf-crime	A new, 1st large-scale dataset encompassing 128 hours of footage was created. It is made up of 1900 lengthy and uncut real-world surveillance recordings, with an average frame count of 7247.	arrest, assault, collision, burglary, fighting, Abuse, robberies, shooting, arson, exploding, shoplifting, theft, and, Explosion, Stealing, Shoplifting, and Vandalism
CAVIAR	To act out the many scenarios of interest, a number of video clips were generated. Individuals strolling alone, Leaving a package in a public area is an instance of this. All video clips were shot with a broad camera lens. The resolution is PAL regular half-resolution (384 288 pixels, 25 frames per second) and MPEG2 compressed.	meeting people, Walking around, window shop, entering stores, arguing, and giving out packages
Weizmann standard dataset	The Human Action Dataset includes 90 films of nine performers doing ten distinct actions.	video recordings show nine distinct persons, each of which executes ten fundamental actions
KTH	The KTH is the most popular publicly available dataset for human activity. It has six different sorts of video activities with a 160 * 120 resolution The average number of frames used for video classification is around 100 per video.	Six human acts were repeated by 25 individuals in four different contexts. Walking, hand waving, jogging, sprinting, hand-clapping, and kickboxing are all examples of physical activities. It totally contains 2391 sequences.
Avenue	Used to detect unusual events with a range of 30652 frames, the Sixteen training and 21 testing video clips were taken on CUHK Central Avenue (15328 training, 15324 testing).	The collection contains anomalies such as a person strolling with a suspicious object, a random individual jogging, and any discarded object.
The movie-fight dataset and Hockey-fight	Two well-known datasets on violence. The first dataset is made up of 200 action movie clips taken in a variety of settings and qualities. The second dataset comprises 1000 action clips categorized as fights or non-fights.	Videos showing anomalous interaction between groups of individuals are included in interaction datasets.

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Conclusion

Many studies have been conducted in the last 40 years on the difficulties of surveillance systems, and substantial studies have been performed in this field. Intelligent video surveillance relies on two important components: event detection and person behavior recognition. Understanding human behavior automatically is a challenging task. This evaluation includes both handcrafted and deep learning-based techniques. A number of phases are involved in anomalous detection methods (preprocessing, feature extraction, classification, decision making). Each step is in charge of a specific activity that has an influence on the overall system's outcomes. We also gathered the databases utilized in this field of study. Finally, there are still some difficulties in this research field, and experts are continually coming up with new answers.

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