

# Surveillance Video Inter-frame Forgery Detection: Review on Techniques

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## ABSTRACT

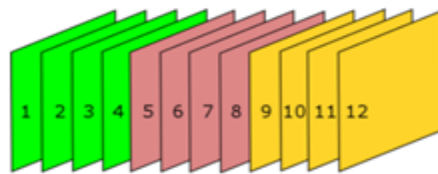
Coronavirus pandemic have changed the way humans being do things nowadays. A new normal have involve as a result of lockdown and strict measures from government and stakeholder. Communication is one area that experience great change. Video are now accepted as reliable and easy means of communication (Meetings, Lectures classes, Surveillance and etc.). This great acceptance of video data led to increase in video tempering as videos are the most accepted evidence. To mitigate the effect of video tempering, researchers have proposed techniques to detect forgery. The active video forgery detection inserts features that can be used to forged video during video creation. As majority of videos do not have features, passive technique that detects forgery based on footprint left by forgers becomes inevitable. In this research work, review on inter-frame detection scheme is done to highlight their strength, weaknesses, general problems and challenges of the schemes are stated.

**Keywords:** Passive forgery detection, Inter-frame forgeries, Inter-frame duplication, Inter-frame deletion and Inter-frame insertion forgeries.

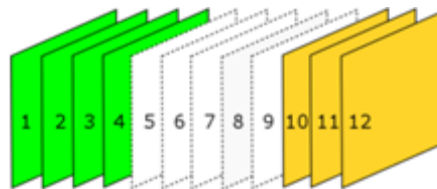
## 1.0 INTRODUCTION

The coronavirus (Covid-19) pandemic have catalyzed wide acceptability and usage of video data. Videos are now widely used in conferences, calls, campaigns preaching and normal day to day activities. Surveillance videos are now incorporated in security agencies as well as news and entertainments. The versatility and reliability of the devices that provides this medium led to the great acceptance of videos to achieve desired goal. Forgers temper with videos to conceal or convey false information (Buzzfeedvideo, 2024). Video attacks, can be carried out in three different ways: spatial, temporal, and spatio-temporal domains (Anas *et al.*, 2022). Copy-move or region duplication forgery occurs in the spatial domain. Because of its simplicity and efficacy, copy move forgery is the most commonly used video tampering technique, in which portions of the original video are copied, moved to a desired area, and pasted.

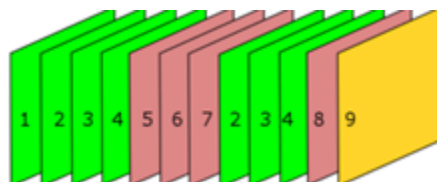
This is frequently done to hide or replicate particular details in a video. In the temporal domain, inter-Frame deletion, duplication, and insertion occur. The removal of an existing frame with the intent of hiding or concealing the existence of certain events is known as inter-Frame deletion. An example is shown in Figure 1(b) in which the dotted frames are deleted. Inter-Frame duplication is the copying of frames within a video sequence and putting them at another place in the video sequence as shown in Figure.1 (c) where frames 2 to 4 are copied and pasted after the 7th frame and no frames are deleted, the same can be performed with frame deletion to fill the gap of deletion. Inter-Frame insertion is the process of putting frame or frames between successive frames to hide content or make an object be part of the video sequence which is not as indicated red in Figure. 1(d); to a the target video;



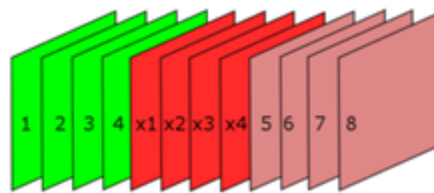
1(a) Original



1(b) Inter-Frame Deletion



1(c) Inter-Frame Duplication



1(d) Inter-Frame Insertion

The combination of both spatial and temporal occurs in spatio-temporal domains (Sitara and Mehtre, 2019). Tampered video can be detected by used of watermarks and digital signature that are inserted on to the digital video during creation (Bagiwa and Anas, 2021). Watermark is an identifying image or pattern that is embedded in a digital content having great invisibility to be used for tampering detection (Zhao and Wang, 2019). This is known as Active Detection. However, these features (i.e. watermarks and signature) can only be found on few cameras such as, Photo PC 700/750Z, 800/800Z, 3000Z and Kodak DC290 (Bagiwa and Anas, 2021). Therefore, the requirement for these features at the video origin makes active detection difficult. The limitations of active video forgery detection give rise to the need for the detection of forgery without relying on pre-embedded information (Signatures and watermark) which is called Passive or blind forgery detection method. Passive techniques for video forgery detection can be classified into three categories based on method used to detect trails of tampering; Statistical correlation of video features, the inconsistencies of various digital equipment and frame based for detecting statistical anomalies. The rest of this paper is categorized into three sections: review of related works, challenges and conclusion.

## 2.0 REVIEW OF RELATED WORKS

The wide use and acceptance of digital video as evidences in the court of law gives rise to the need for validation and authentication of digital videos. Researchers work abundantly in this area. The developed schemes in this research field (Digital Forensic, Multimedia forensic and Video forensic to be precise)

focused on the three aspects of inter-frame forgeries which are; inter-frame deletion, inter-frame duplication and inter-frame insertion.

### 2.1 Inter-frame Deletion

Inter-frame deletion forgery is a type of inter-frame forgeries that delete frames from a video to conceal object or remove the occurrence of an event. As a popular method of inter-frame forgery due to the acceptance of video in the court room, researchers have proposed methods to check the authenticity of videos by following the footprints left by forgers. These footprints led to the broad classification of inter-frame deletion techniques into two categories (Hong *et al.*, 2019 and Li & Hou, 2021). The first category is that which check for video compression artifacts and the second category is that of researches that check for anomaly in inter-frame continuity. Wang and farid (2019, 2021), Lou *et al.*, (2020), Vazquez-padin *et al.*, (202), Shanableh (2022), Gironi *et al.*, (2019), Feng *et al.*, (2019) and Hong *et al.*, (2019) All proposed schemes that detects inter-frame deletion by checking for artifacts left by double compression. However, scheme of this category have intrinsic flaw of un-ability to easily detect frame deletion point. Chao *et al.*, (2020), Yu *et al.*, (2020), Zhang, & Xu, (2020) earlier proposed schemes that checks for anomaly in inter-frame continuity. Recently Li and Hou (2021) proposed an inter-frame deletion scheme that utilizes the variation of optical flow orientation. The scheme detect low false alarm. However, the mathematical equation of the analytical mode is complex, thus requiring high computational time. The overview of Inter-frame forgery for deletion schemes are shown in Table 2.1 below

**Table 2.1 show Inter-frame forgery deletion**

S / N	Author s	Title	Methodology	Performance			Strength	Weakness
				Precision %	Recall	Accuracy		
1	Feng <i>et al.</i> (2019)	Motion Adaptive Frame Deletion Detection for Digital Video Forensics	fluctuation feature techniques	82.20 %	97%	89.01%	The scheme is based on frame motion residual to identify frame deletion point	The scheme could not detect other two forgeries (frame duplication and frame insertion).
2	Hong <i>et al.</i> (2019)	Detection of frame deletion in HEVC-Coded video in the compressed domain	sequence integrity detection on a group-of-picture basis	99.7%	100%	98.12%	The scheme identify discriminating coding patterns for use as features, which are classified by machine learning classifiers	The learning algorithm is inefficient
3	Yao <i>et al.</i> (2019)	An approach to detect video frame deletion under anti-forensics	low dimension scheme to ensures the real-time detection	90.1%	100%	99.12%	operation which is easy to realize as the scheme put forward an inter-frame interpolation as an anti-forensic	The information on how to set a threshold value is vague.



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4	Ulutas <i>et al.</i> (2019).	Frame duplication mirroring detection method with binary features.	FD/FM detection method	99.02 %	100%	99.04%	The scheme successfully detect FD/FM by yielding better execution time	The scheme fails to detect other aspect of frame forgery (Insertion and Deletion)
5	Wang & Farid (2019)	Exposing digital forgeries in video by detecting double MPEG compression.	Double compression method	33.02 %	76.06 %	57.09%	Extracting discrete cosine transform (DCT) coefficients and motion vector errors from videos	Special patterns only occur when different quantization step sizes are applied during double compression
6	Chao <i>et al.</i> (2020)	A novel video inter-frame forgery model detection scheme based on optical flow consistency	Optical flow consistency	89%	85%	87.92%	The scheme has good performance.	The scheme only performs better when the frame inserted has a different background scene
7	Lou <i>et al.</i> , (2020)	Complexity and Memory Efficient GOP Structures Supporting VCR Functionalities in H.264/AVC	G-Group and Binary Reference GOP Structure (BRGS)	62.0%	90.0%	72.03%	Achieve trick-play functionalities while keeping low decoder complexity	Computational complexity and memory requirement is drastically increased.
8	Wang & Farid (2021)	Exposing digital forgeries in video by detecting double quantization	Double compression using a special convex pattern of quantized DCT coefficients	45%	70.8%	49.20%	intra-frames is calculated and compared with the actual coefficients to detect deleted point	It require a lot of mathematical equations
9	Sharma <i>et al.</i> , (2021)	Video inter-frame forgery detection: Classification, technique & new dataset	Hu moment Features	95.02 %	100%	99.05 %	The scheme utilized gray value to extracting the deleted portion	Detects duplication Could not detects insertion and
10	Li & Hou (2021)	Frame Deletion Detection Based on Optical Flow	Pseudo flow orientation variation	98.12 %	100%	99.2 %	The scheme achieve high powerful discrimination than the conventional optical flow based methods	The scheme have a lot of mathematical equation
11	Vazquez -Padin <i>et al.</i> , (2022)	Detection of video double encoding with GOP size estimation	Variation of the macro block prediction	29.5%	82.0%	33.07%	Detected a video that has been compressed once or twice	The scheme has low accuracy

**2.2 Frame Insertion**

This is an inter-frame forgery technique, in which frames are inserted at a point between two successive frames to hide an object, reveal something which is not there or to delay the occurrence of an event. Table 2.2 show a comprehensive review of Inter-frame insertion techniques.

**Table 2.2 Show Inter-frame forgery insertion**

S / N	Authors	Title	Methodology	Performance			Strength	Weakness
				Precision	Recall	Accuracy		
1	Chetty <i>et al.</i> , (2019)	Digital video tamper detection based on multimodal fusion of residue features	Feature transformation in cross model subspace	87.05 %	90.09 %	89.70%	The accuracy improves as compared to single mode feature.	It only detect insertion forgery
2	Goodwin & Chetty (2019)	Blind video tamper detection based	Noise residue feature	79.0 %	94.0%	90.0%	The scheme achieve	Only copy-move tampering considered in the scheme

		on fusion of source features					multimodal fusion	
3	Chao <i>et al.</i> (2019)	A novel video inter-frame forgery model detection scheme based on optical flow consistency	Optical flow consistency	98.22%	95.01 %	87.92%	Achieves good performance	The scheme only performs better when the frame inserted has a different background scene
4	Sharma <i>et al.</i> (2019)	An Ontology of Digital Video Forensics: Classification, Research Gaps & Datasets	Review of video insertion forgery detection techniques	92.7%	97.9%	77.3%	The scheme not only presents a review of video forgery detection techniques, but also talks about different datasets developed for validation of these techniques.	The scheme required a lot of computational overhead.
5	Wu <i>et al.</i> (2019)	Exposing video inter-frame forgery based on velocity field consistency.	Extreme standardized deviate (ESD) to obtain velocity field sequence	90.01%	100%	96.70%	The scheme detects forged frames at insertion point	The scheme could not detect other two forgeries (frame deletion and frame duplication).
6	Gironi <i>et al.</i> , (2019)	A video forensic technique for detecting frame insertion.	localization of insertion point (LIP)	93.04%	100%	92.3%	Robustness to the use of different codecs.	The method has not been evaluated in Presence of global processing of the video.
7	Zhang <i>et al.</i> (2020)	Efficient video frame insertion and deletion detection based on inconsistency of correlations between local binary pattern coded frames	Inconsistency of QCCoL BP values at the tampered frames locations	75.8 %	100 %	95.01%	The method achieves both high detection accuracy and low feature computation complexity	The method can only report if forgeries exist but cannot distinguish frame insertion and frame deletion
8	Bidokhti <i>et.al.</i> (2021).	Detection of Regional Copy/Move Forgery in MPEG Videos using Optical Flow.	Optical Flow Consistency.	91.1 %	100 %	92.10%	Detection insertion Forgery in MPEG Videos using Optical Flow.	The scheme could not detect other two forgeries (frame deletion and frame duplication).
9	Bagiwa <i>et. al.</i> (2022).	Passive Video Forgery Detection Using Frame Correlation Statistical Features	Statistical correlation technique	75.8 %	100 %	95.01%	The scheme detects video in painting and chroma key in digital videos.	It only detect insertion forgery

10	Juan <i>et al.</i> (2023).	A Novel Video Inter-frame Forgery Model Detection Scheme Based on Optical Flow Consistency.	Optical Flow Consistency.	89.2%	85.7%	87.9%	The scheme detection is based on window rough and binary search based.	The scheme precisely detected only frame insertion forgery.
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### 2.3 Frame Duplication

This is another type of inter-frame forgery in which frames are copied and pasted within the same video to hide or replicate an event. This type of forgery is mostly done on surveillance video. Table 2.3 shows techniques that were proposed to detect inter-frame duplication. To detect inter-frame duplication, researchers can check similarity between frames. Two frames can be similar but not the same.

**Table 2.3 Show Inter-frame forgery duplication**

S/N	Authors	Title	Methodology Used	Performance			Strength	Weakness
				Precision	Recall	Accuracy		
1	Long <i>et al.</i> (2019).	A Coarse-to-fine Deep Convolutional Neural Network Framework for Frame Duplication Detection and Localization in Forged Videos	Siamese network based on ResNet architecture identifies fine-level correspondences	99.13%	100%	99.14%	The scheme develop an inconsistency detector based on the I3D network to distinguish the duplicated frames from the selected original frames.	The scheme fails to train on multiple manipulations and investigating the effects of various video codecs on algorithm accuracy.
2	Wang & Farid (2019)	Exposing digital forgeries in video by detecting duplication	Correlations introduced by de-interlacing algorithms, and show how duplication an object can destroy these correlations in interlaced video, the scheme measures the inter-field and inter-frame motions	38.5%	81.7%	65.8%	The scheme detects frame duplication forgery	The scheme cannot detect forgeries as a result of frame duplication and frame insertion
3	Lin & Chang (2019)	Detection of frame duplication forgery in videos based on spatial and temporal analysis	Blocked-based Algorithm	87.90%	100%	94.0%	The scheme detects frame duplication forgery	The scheme cannot detect (frame insertion and frame deletion).
4	Liao, & Huang (2019).	Video copy-move forgery detection and localization based on tamura texture features.	Tamura texture feature	99.6%	100%	99.8%	Efficiently in locating the copy-move sequences,	Higher precision and High accuracy but lower recall
5	Yang <i>et al.</i> (2020)	Using similarity analysis to detect frame duplication forgery in videos	Singular Value Decomposition (SVD)	92.3%	100%	91.2%	The scheme identifies those video sequences with high similarity as candidate duplications	The scheme fails to investigate the detection of other tampering, such as videos for which some of the frames have been

6	Singh & Kulbir (2020)	Video frame and region duplication forgery detection based on correlation coefficient and coefficient of variation	correlation coefficient and coefficient of variation.	94.4%	100%	96.6%	The scheme detect long length sequence Frame Duplication at large continues position as well as at many different positions in a video	taken off, some duplicated, and/or in Different subsequences. The scheme fails to investigate surveillance videos captured from static and moving cameras for a long time-interval at continue location as well as small and large time interval at different locations
7	Kharat <i>et al.</i> (2020).	A passive blind forgery detection technique to identify frame duplication attack	Scale Invariant Feature Transform (SIFT)	99.9%	99.7%	99.08%	The scheme identify frame duplication attack in Moving Picture Experts Group-4 (MPEG-4) video.	The proposed method needs average 33 seconds of simulation time
8	Fadl <i>et al.</i> (2020).	Frame duplication and shuffling forgery detection technique in surveillance videos based on temporal average and gray level co-occurrence matrix	FD and FDS detection method	94.0%	100%	99.27%	The correlation between similar feature vectors is performed for similarity matching with consideration of the size of detected shots to eliminate false Positives.	The proposed method needs to improve shot boundary detection to achieve higher accuracy because incorrectly shots lead to increase false positives.
9	Nagaraj & Channegowda (2021)	Detection of Frame Duplication Using Multi Scale Local Oriented Feature Descriptors	Multi scale local oriented feature descriptors	94.0%	100%	99.27%	The scheme achieved better performance in passive video forgery detection in terms of accuracy, sensitivity, f-score and specificity	The scheme fails to detect other forgeries.
10	Sharma <i>et al.</i> , (2021)	Video inter-frame forgery detection: Classification, technique & new dataset	Hu moment Features	87.7%	100%	92.3%	Detects duplication forgery with high detection accuracy.	Could not detects insertion and Deletion

## 2.4 Inter-frame Hybrid Forgery Techniques

Forgers nowadays do not apply one/single technique (Deletion, Duplication or insertion) to achieve their desired goal and come out undetected. They simply apply multiple techniques to detect such forgeries; techniques that can detect multiple forgery technique are required. Table 2.4 shows proposed techniques for detection of multiple forgeries.

**Table 2.4 Show Inter-frame Hybrid Forgery Techniques**

S/N	Authors	Title	Methodology	Performance			Strength	Weaknesses
				Precision	Recall	Accuracy		
1	Bestagini, <i>et al.</i> (2020)	Video forgery detection for detecting frame insertion and deletion based on structural similarity	Footprints for tampering a video sequence and localized it in the spatio-temporal domain.	92.04%	100%	97.01%	The scheme accurately detects frame deletion and frame insertion	Scheme could not detect (frame duplication and insertion).
2	Zhang <i>et al.</i> (2020)	Efficient video frame insertion and deletion detection based on inconsistency of correlations between local binary pattern coded frames	Inconsistency of QCCoLBP values at the tampered frames locations	75.8 %	100 %	95.01%	The method achieves both high detection accuracy and low feature computation complexity	The method can only report if forgeries exist but cannot distinguish frame insertion and frame deletion
3	Yang <i>et al.</i> (2020)	Using similarity analysis to detect inter-frame duplication and deletion forgeries in videos	(SVD) for obtaining the features of each frame and (ED) for calculating the features between of each frame and the reference frame	98.20%	100%	99.10%	The scheme detects two type of inter-frame forgeries (inter-frame and inter-frame deletion)	The scheme detects only inter-frame deletion and inter-frame duplication and requires a reference frame point for detection
4	Wei <i>et al.</i> (2021).	Video tamper detection based on multi-scale mutual Information	Normalized mutual information detection algorithm	97.2%	100%	99.04%	The proposed method is feasible and effective	However, the scheme fails to consider multi-lens tampering type.
5	Bakas <i>et al.</i> (2021).	Detection and localization of inter-frame video forgeries based on inconsistency in correlation distribution between Haralick coded frames.	Haralick coded frame correlation	96.0%	100%	94.09%	The scheme perform efficiently for Static as well as dynamic videos.	The scheme fails to focus on diverse forms of inter-frame video forgeries, such as frame reshuffling and replacement
6	Fadl <i>et al.</i> (2021).	Inter-frame forgery detection based on differential energy of residue.	Residue data extracted	99.30%	100%	99.16%	The scheme detect inter-frame duplication, insertion, and deletion forgeries	However, when some frames are deleted from a static scene, anomalies are not captured by the proposed method and detection fails

7	Zhao <i>et al.</i> (2022)	Inter-frame passive-blind forgery detection for video shot based on similarity analysis	HSV for color histogram comparison and SURF feature extraction together with FLANN matching for double-checking	98.07%	100 %	99.01%	The scheme detects all the three type of frame forgery (frame deletion, duplication and insertion)	The accuracy of the scheme is affected with existence of scene changes within the video shot.
8	Anas <i>et al.</i> , (2022)	An Inter-Frame Forgery Detection Technique for Surveillance Videos Based on Analysis of Similarities	Hue Saturation (HS) and Saturation Value (SV) for color histogram comparison	98.7%	100%	99.1%	The scheme detect all the three aspect of Inter-frame forgeries without being affected by scene change	The technique obtained a similar accuracy report to the benchmark during single shots video.
9	Tyagi & Yadav (2023)	A detailed Analysis of Image and Video Forgery Detection Techniques.	Editing Visual Media	92.09 %	100 %	87.03%	The scheme knows the part of video or image that can be manipulated	The scheme has a limit of detecting manipulated region.
10	Oliaei & Azghani (2024)	Video Motion Forgery Detection Using Motion Residual and Object Tracking	Motion Residual and Object Tracking	81%	100%	89%	The scheme locates the forged motion sequence.	Due to motion sequence the scheme has a lot of computational overhead.
11	Aktar, Hussain & Habib (2025)	Two-stage Detection and Localization of Inter-Frame Tempering in Surveillance Video Using Texture and Optical Flow	Texture and Optical Flow	83.7%	100%	97%	The scheme achieved and maintain high computational efficiency	The scheme fails to detect anomalies when the frames are removed from static scene.

### 3.0 CHALLENGES

Researchers have proposed several schemes for inter-frame forgery detections. However, these schemes face some generalized problem. These include:

#### i. Tools Box

A research tool box for inter-frame deletion detection, inter-frame duplication detection and inter-frame insertion detection forgeries should be developed to ease and enhance research in this area as researchers develop some required modules from the scratch.

#### ii. Benchmark values for evaluation parameters

There are no threshold values for acceptance of performance evaluation parameters. This affects the genuity of results. A particular threshold needs to be set.

#### iii. Replication

To successfully review and understand a particular scheme, the reported algorithm needs to be replicated and tested under several important conditions. Replicating a proposed scheme published on journal is very difficult or to say unfeasible. This happen because research give vague information about their scheme.

### 4.0 CONCLUSION AND FUTURE WORK

Real time video is on the increase. Nowadays these are high demand on online video due to availability of broadband network, capable devices such as Ip cameras, smart phone, and a lot of plethora of IoT devices. Therefore, scheme that detect real time should be investigated and investigated to catch up with the trend .in conclusion researchers proposed numerous inter-frame forgery detection schemes using different methods to achieve one particular goal. Therefore, a certain benchmark for the overall performance of the scheme

should be set as means of motivation and self-assessment.

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