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An Inter-Frame Forgery Detection Technique for Surveillance Videos Based on Analysis of Similarities

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Abstract

***Background**: In video forgeries, the insertion, duplication and deletion of frames are the most common forgeries that are used by attackers to alter targeted videos for malicious intent. Researchers have proposed the use of active and passive technologies for detecting video forgeries over the years. Active approaches are used to detect the occurrence of alterations in digital video with the use of embedded features such as digital signature and watermarks. However, techniques that are based on active approaches are only applicable to specialized hardware devices. A passive technique, on the other hand, detects forgery using the behavioral cues encoded in a video. In this paper, a passive video forgery detection system based on frame similarity analysis is presented.Inter frame forgeries (Insertion, Deletion, and Duplication) were detected using the proposed technique, which was unaffected by scene changes.The technique has the overall performance of 98.07% precision, 100% recall and 99.01% accuracy.*

Keywords:*Digital video, forensics, passive technique, Inter-frame forgery, Surveillance videos, HSV colour histogram*

1. Introduction

The technological advancement of the 21st century has led to the availability of digital devices that grant easy creation, acquisition and saving of digital videos (Bagiwa, 2017). The need for better digital videos in terms of digital perception and scientific analysis has also led to the development of much video editing software that can be used to fine-tune and enhance the content of digital videos. The availability of these video editing software's has over time simplifies how tampering is performed on digital videos. Digital video tampering can be as minor as removing the sound of a video to removing or replacing an object within the video content. Tampering of a digital video can be done through deleting, duplicating and insertion of frame or frames in the target video (Sawant and Sabnis 2018). These tampered videos (insertion,deleted and/orduplicated frames), physically appear same as the original videos to the naked eyes and may be accepted as the true occurrence of events especially when submitted in a court of law as admissible proof. Hence, the needs for the development of robust techniques that will help determine the integrity and trueness of digital videos. Digital video attacks can be carried out in three different ways: spatial attack, temporal attack, and spatio-temporal attack domains (Sawant and Sabnis 2018). Frame deletion,insertion andduplication are frame tampering which occurs in temporal domain. Removal of an existing frame with the intent of hiding or concealing the existence of certain events is known as frame deletion. Frame

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duplication is the process of replicating frames from one video sequence and placing them in another video sequence. 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.

Wang &Farid (2006 & 2007), Bestagini, Milani, Tagliasacchi&Tubaro (2011), Feng*et al.* (2011), Ling & Chang (2012), Wu, Jiang & Wang (2014) have proposed techniques that detect only one aspect of the frame forgery (deletion,insertion, or duplication). Yang et al. (2016) proposed a technique for detecting duplication and deletion. Zhao et al. (2018) proposed an approach for detecting all three types of frame forgery: insertion, deletion, and duplication. In the presence of a scene change, however, the technique's accuracy degrades.This paper proposes an inter frame forgery detection technique for surveillance videos based on analysis of similarities that is unaffected by scene change.

2. Related Works

The widespread usage and acceptance of digital video as evidence in court has necessitated the necessity for digital video verification and authentication.Techniques for inter frame forgery detection are meant to focus on the three aspects of the frame forgeries. However, majority of the proposed techniques in the existing literature only focus on one aspect of frame forgery that is either; frame insertion, frame deletion or frame duplication while some focus on addressing two aspect of frame forgeries, and only a few addresses all the three aspect of frame forgery.

2.1 Theoretical Review

In literature, techniques were proposed to detect different video tampering methods. Wang &Farid (2006), Ling & Chang (2012) and Sharma *et al.,*(2021) proposed techniques that detects frame duplication. Wang &Farid (2007), Feng*et al.,*(2011) and Bakas*et al* (2019) proposed frame deletion techniques. Wu, Jiang & Wang (2014) proposed frame insertion techniques. To enhance the performance of forgery detection, techniques to detects different aspects of video tampering were proposed, Bestagini*et al.,* (2011), Yang *et al.,* (2016). Zhao *et al.,*(2018) proposed a technique which detects all the three aspects of frame forgery. However the accuracy of the scheme is affected by scene change. Table 1 presents the summary of the review of literatures showing, methodology, strength and weakness of each solution.

Table 1 Summary of Literatures

S/N	Author	Methodology	Forgery Type	Strength	Weakness
1	Wang &Farid (2006)	Doubly composed MPEG video sequence	Duplication	Detects duplicated region & frames	Could not detects insertion and deletion
2	Lin & Chang (2012)	Histogram difference	Duplication	Detects duplication	Could not detects insertion and deletion
3	Sharma *et al* (2021)	Hu moment Features	Duplication	Detects duplication	Could not detects insertion and deletion
4	Feng*et al*, (2011b)	Fluctuation feature technique	Deletion	Detects deletion	Could not detects insertion and duplication
5	Wang &Farid (2007)	Correlation in interlaced and de-interlaced video	Deletion	Detects deletion	Could not detects insertion and duplication
6	Bakas*et al* (2019)	Haralick Coded frames correlation	Deletion	Detects false positives	Could not detects insertion and duplication

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S/N	Author	Methodology	Forgery Type	Strength	Weakness
7	Wu, Jiang & Wang (2014)	Extreme Standardized Deviate	Insertion	Detects insertion	Could not detects deletion and duplication
8	Bestagini*et al* (2011)	Statistics of motion vectors	Deletion & Insertion	Detects 2 aspects	Could not detect duplication
9	Yang *et al*, (2016)	Euclidean Distance features	Deletion and duplication	Detects two aspects	Could not detect insertion and require reference point
10	Zhao *et al* (2018)	HSV histogram	All the tree	Detects all the three aspects	Scene change affects overall accuracy

3. Proposed Technique

To mitigate the effect of scene change on the benchmark technique(Zhao *et al*.,(2018) technique), a pre-check is introduced to detect scene change and segment the affect video into shots. Figure 1 shows the graphical framework of the proposed technique for inter-frame forgery detection on surveillance videos based on similarity analysis that incorporate scene change detection and segmentation before analysis.

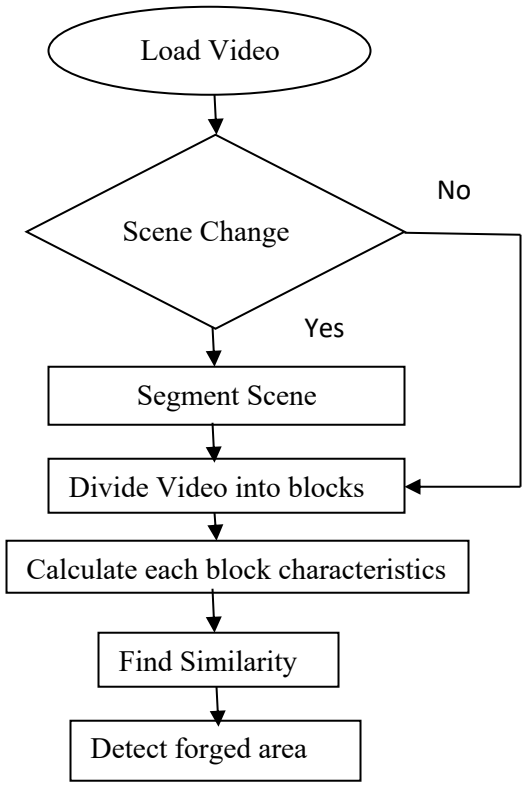

Figure 1: Proposed AIFDT-SV-BAS Scheme Diagrammatic Description

The framework of the proposed technique is presented in Algorithm 1 for the scene change detection and segmentation.

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Algorithm 1: *Proposed AIFDT-SV-BAS Scheme*

1. **Input:** set of surveillance videos
2. **Input:** forged area of the videos
3. **Procedure:**
4. Load the video
5. Test for scene change
6. **If** scene change = YES
7. Segment the scene in to single shot
8. **Else**
9. NO segmentation
10. Divide the video into a single blocks
11. Calculate each block characteristic
12. Find the similarity
13. **End if**
14. **End else**

The proposed technique checks for scene change in the suspected video. If there is scene change, the technique splits the video into shots of different scenes. The shots are then fed into the technique proposed in zhao*et al.,*(2018) for forgery detection. If there is no scene change, the splitting is not done. The proposed techniques utilize the HSV saturation value feature for forgery detection. HSV correlation statistic method was used to calculate characteristics of each block. To detect specific changes in HSV, color histogram are used. Between video frames, HSV marks significant statistical changes. In surveillance videos camera captured clip has unchanging background especially with single complete shot. In such shots, the frames are either uniform or have a very wide variation. For the frames similarity analysis, histogram differences between the two adjacent frames in a shot were adopted.

3.1 Dataset

To provide a convincing morally acceptable support on the efficacy of the proposed AIFFDT-SV-BAS technique, a total of 2064 frames from 10 distinct obtained test videos from the datasets were used in a set of experiments (CASIA 2 and NC 16 datasets). Table 2 shows the test videos summary with the number of frames for autonomous video as well as frame resolutions. The proposed technique's robustness was tested using ten (10) videos having different durations and resolutions.

Table 2: Dataset Summary.

No	Names of Files	Arrangement	E&S	Resolution	Length
1	Bike.mp4	MP4	MP4V	1920x1080	253
2	Sajeed and Kayo.AVI	AVI	DIVX	320x240	266
3	Walking Man.AVI	AVI	MJPG	640x480	111
4	Peoples in Group.MP4	MP4	MP4V	720x404	273
5	Street.MP4	MP4	MP4V	640x480	324
6	Table Tennis.MP4	MP4	MJPG	320x240	304
7	Ball.AVI	AVI	MJPG	1920x1080	294
8	Walking Teacher.AVI	AVI	DIVX	320x240	248
9	Room.AVI	AVI	DIVX	640x480	119
10	Nawwal Riding Bike.AVI	MP4	MP4V	720x404	215

Table 3 Simulated experiment result

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No	O/L	IF (Insertion)	DF (Deletion)	DF (Duplication)
1	253	N=37, K=44	M=40,S=5	P=40, Q=5, R=44, T=1
2	266	N=45,K=67	M=35,S=179	P=1, Q=75, R=75, T=45
3	111	N=35, K=233	M=45,S=251	P=35, Q=102, R=236, T=1
4	273	N=30,K160	M=25,S=38	P=1, Q=276, R=276, T=35
5	324	N=25,K=88	M=30,S=127	P=45, Q=89, R=183, T=1
6	304	N=40,K=96	M=40,S=52	P=1, Q=127, R=127, T=40
7	294	N=45,K=55	M=35,S=56	P=30, Q=71, R=100, T=1
8	248	N=30, K=202	M=30,S=154	P=1, Q=243, R=243, T=30
9	119	N=40, K=187	M=50,S=83	P=35, Q=5, R=79, T=1
10	215	N=25, K210	M=25,S=140	P=1, Q=168, R=168, T=25

Frame insertion, deletion and duplication were simulated randomly at choosing locations within each shot to create a synthetic dataset for the experiments. Figure 2 presents examples of different inter frame video forgery mechanisms.

(a) After 4th frame, 44th-80th frame of another were inserted in to shot 1 (Source Rao*et al (*2020))

(b) Deleted frame from 5th-44th (Source Rao*et al (*2020))

(c) 5th frame copied 40 times and inserted after 5th frame. (Source Rao*et al (*2020))

(d) Frame 5th-4th copied and inserted after frame 44th. (Source Rao*et al (*2020))

Figure 2: Examples of different inter frame video mechanism

4. Result and Discussion

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This section presents and discusses the findings of the proposed inter frame forgery detection technique for surveillance videos based on the similarity analysis.On the H-S and S-V histograms, Figures 3 and 4 demonstrate two yellow peak values. These peaks are caused by a low degree of resemblance between two neighboring frames.The first peak determines the beginning of the insertion and the second peak determines where the last frame is inserted.

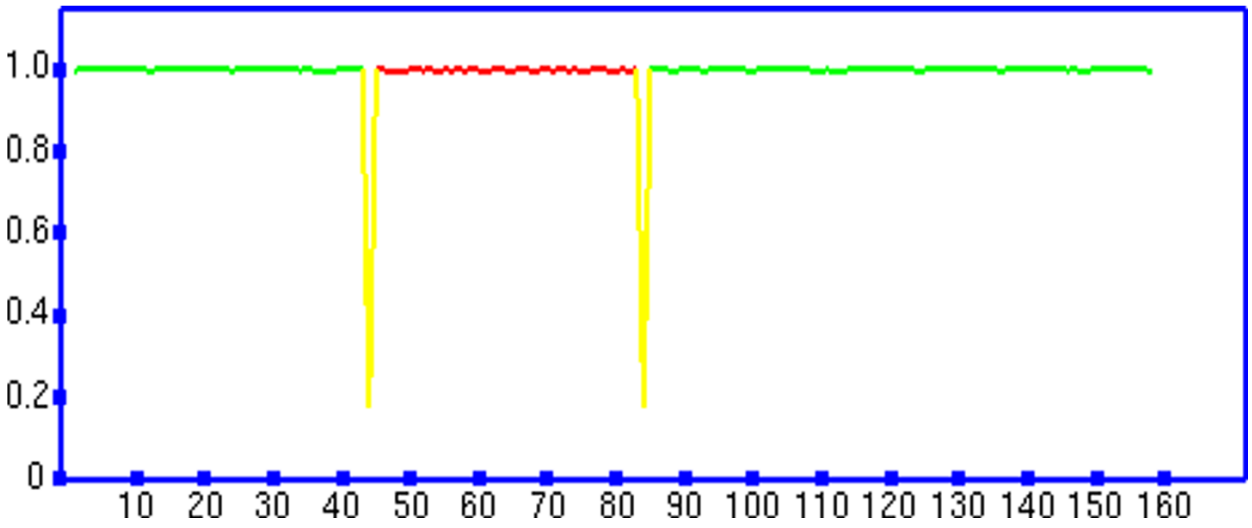

Figure 3: H-S histogramsframe insertion Detection

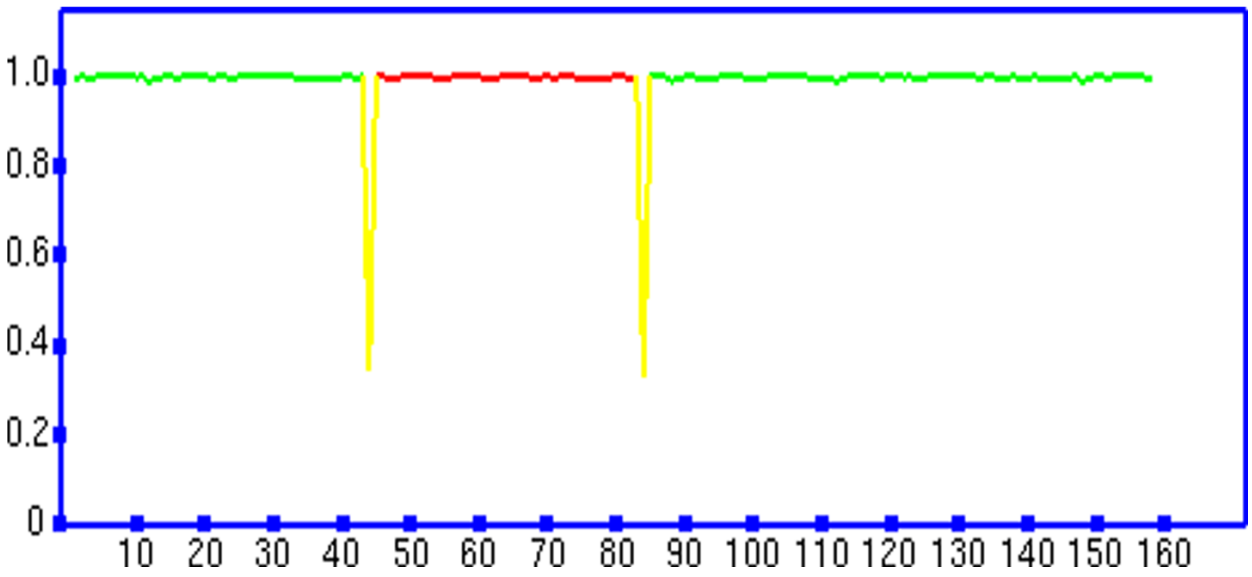

Figure 4: S-V histogramsframe insertion DetectionFigures 5 and 6 of the H-S and S-V histogram shows a peak fall on the similarity of two adjacent frames, this peak is as result of similarity gap that exists between non adjacent frames. A single peak fall signifies missing frame/frames. This confirmed frame deletion.

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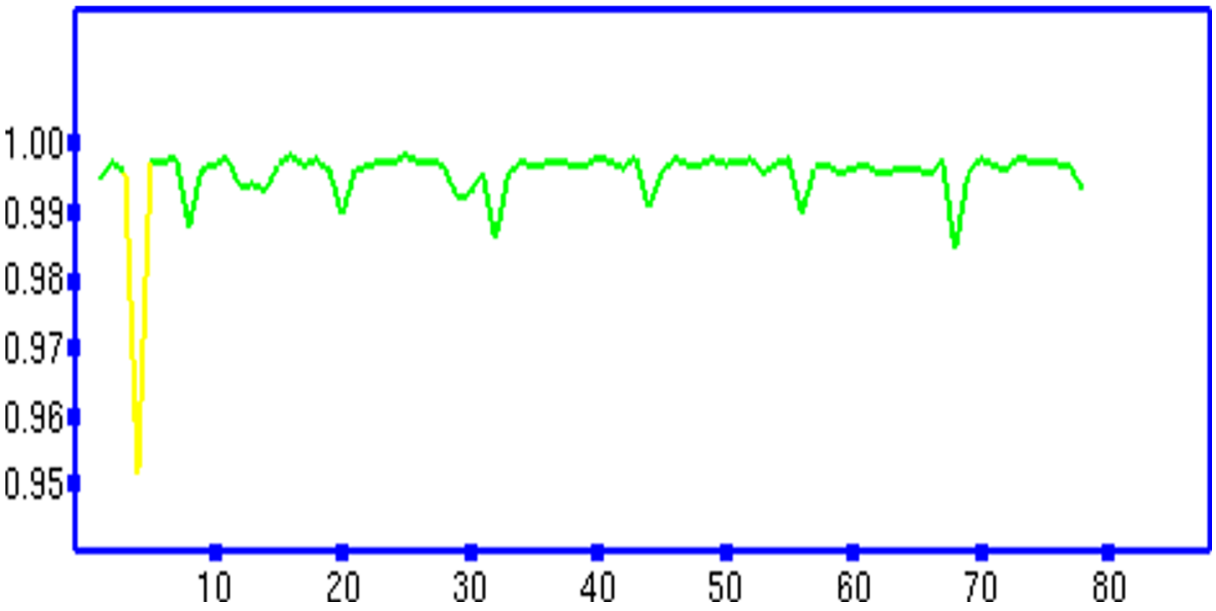

Figure 5: H-S histogramsframe deletion Detection

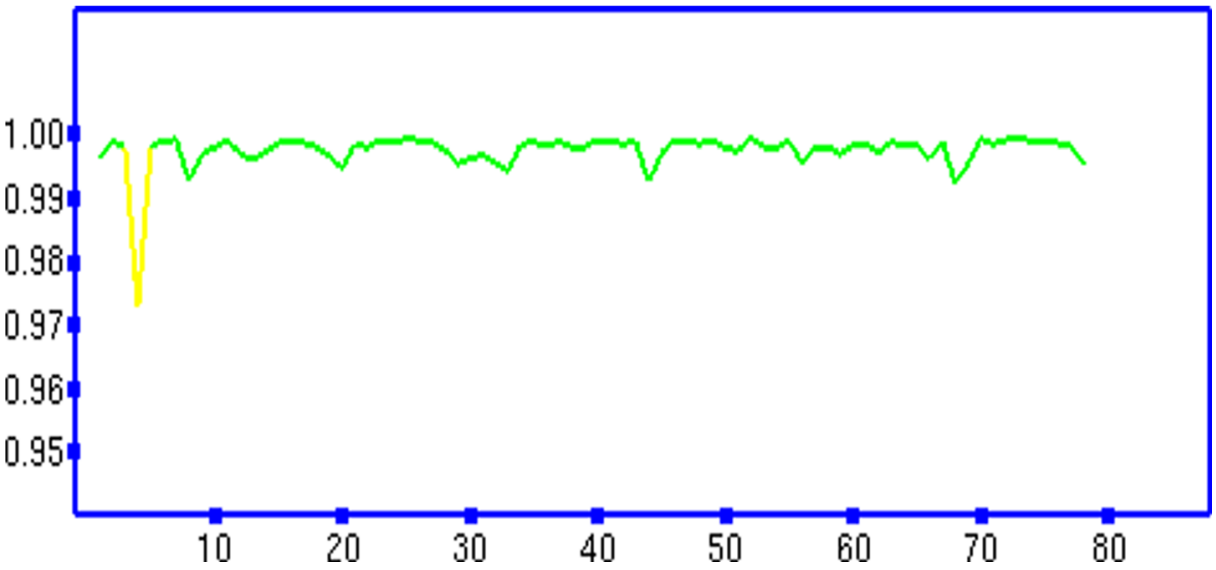

Figure 6: S-V histogramsframe deletion Detection

Finally, even though the frame of the same shots are similar, they are not identical in the sense that they have some minimal variation. H-S and S-V show exact (identical) frames exist. This confirms frame duplication as shown in Figures 7 and 8.

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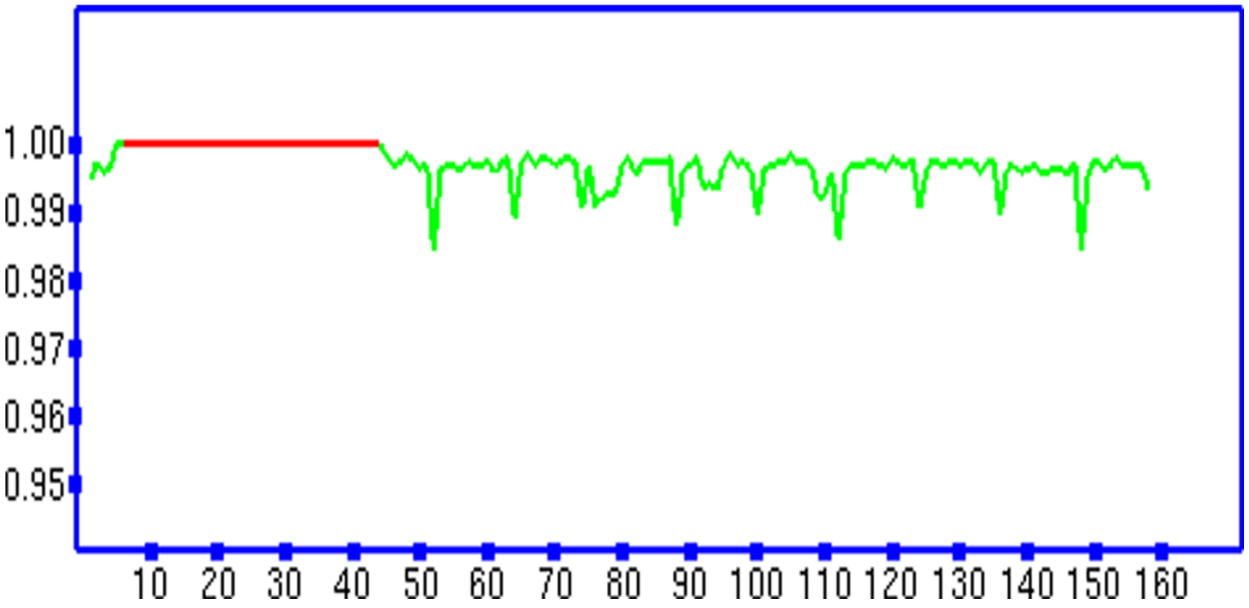

Figure 7: Frame duplication detection using H-S histograms

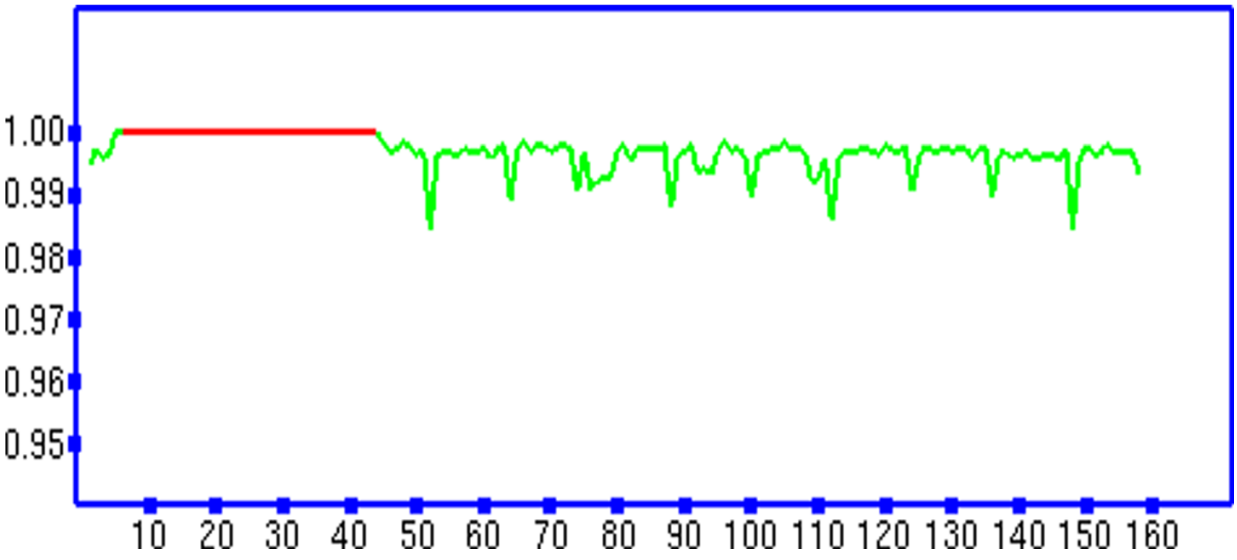

Figure 8: Frame duplication detection using S-V histograms

The result of the histogram similarities is presented in Table 3 for the three inter fame forgery mechanism.

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Table 4: HSV color histogram maximum and minimum similarities

Method	Maximum similarity	Minimum similarity.
H-S insertion	0.984551	0.183462
S-V-insertion	0.983397	0.381470
H-S deletion	0.998611	0.986297
S-V deletion	0.999833	0.931389
H-S duplication	0.996392	0.983249
S-V duplication	0.979232	0.922627

4.3 Comparison with existing scheme

Three difference performance metrics which include precision (P), recall (R) and detection accuracy (D) were used to determine the efficacy of the proposed scheme. These metrics are defined as in equation 1:

$$p = \frac{TP}{TP + FP}, R = \frac{TP}{TP + FN}, D = \frac{TP + TN}{TP + TN + FP + FN}$$

Tp denotes the count of authentic frames correctly detected as authentic, TN represents the count of forged frames correctly detected as forged frames, Fp represents the count of incorrectly authentic frames detected as forged, and FN otherwise. Figure 9 compares the proposed technique's performance to that of (Zhao et al., 2018).When there is no scene change in the video, both techniques perform equally. However, when the input video has a scene change, the performance of the proposed techniques supersedes that of the (Zhao *et al.,* 2018) as shown in Figure 10.

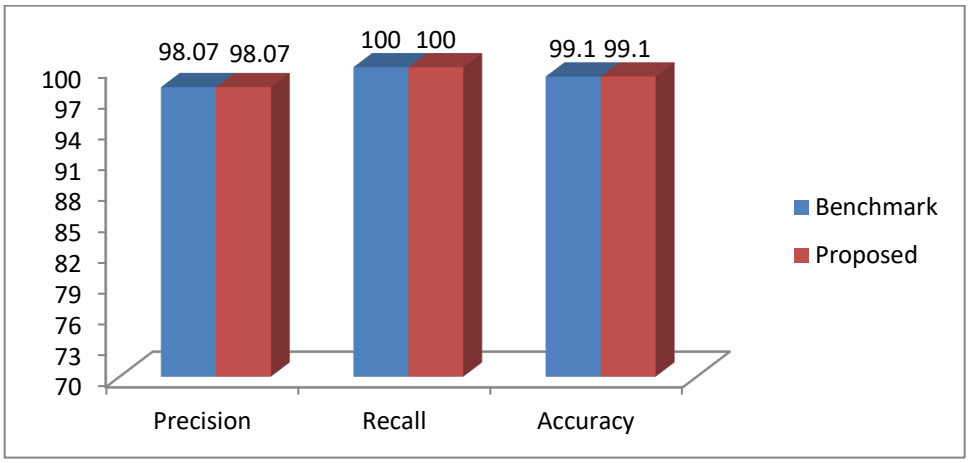

Figure 9: Comparison using single scene

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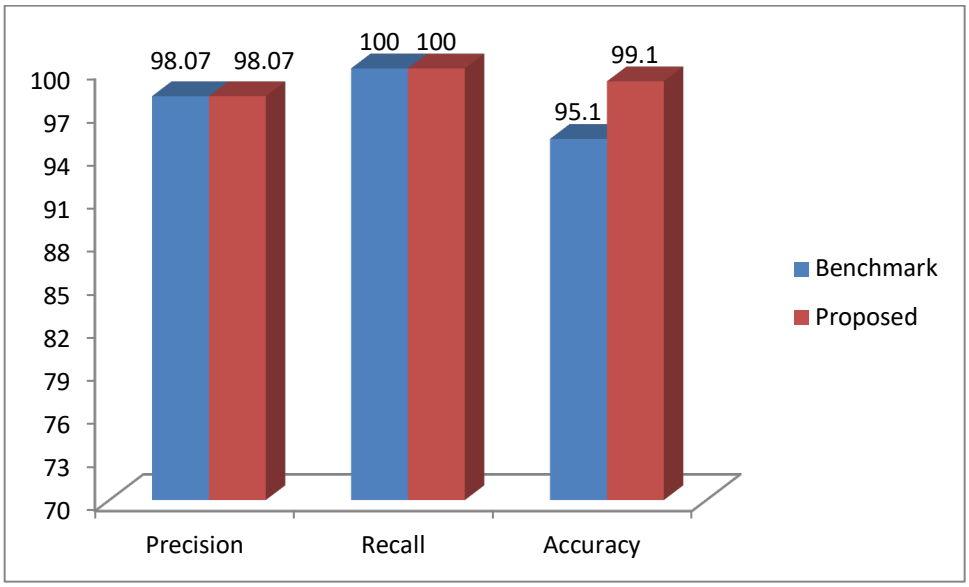

Figure 10: Comparison using multiple scenes

6. Conclusion

An inter frame video forgery detection technique for surveillance videos was proposed in this paper, which can handle both multiple scene and single scene videos.The proposed technique has shown to give high precision, recall and accuracy. The goal is to provide measure in which the multiple scenes cannot affect the accuracy and overall performance of the scheme. The proposed AIFDT-SV-BAS detection technique was evaluated using CASIA 2 and NC 16 datasets. The datasets were chosen because they are frequently used as benchmark data in video forensic investigations. To ascertain its robustness, the performance of AIFDT-SV-BAS technique was evaluated using three effective different performance metrics namely: precision rate, recall and accuracy based on the selected datasets. The analysis result vividly shows the performance of AIFDT-SV-BAS provides a significant improvement on the performance of the technique proposed in Zhao *et al.,* (2018). The capability of scene change detection and segmentation of the videos before checking for forgery has resulted in an increase in accuracy.

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