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An efficient post-processing adaptive filtering technique to rectifying the flickering effects

Anudeep Gandam[1☯], Jagroop Singh Sidhu[2☯], Sahil Verma[3☯]*, N. Z. Jhanjhi[4☯], Anand Nayyar[5,6☯], Mohamed Abouhawwash[7,8☯]*, Yunyoung Nam[9☯]*

1 Department of Electronics and Communication Engineering, IKG-Punjab Technical University Jalandhar, Punjab, India, **2** Department of Electronics and Communication Engineering, DAVIET Jalandhar, Punjab, India, **3** Department of Computer Science and Engineering, Chandigarh University, Mohali, Punjab, India, **4** School of Computer Science and Engineering, SCE Taylor's University, Subang Jaya, Malaysia, **5** Graduate School, Duy Tan University, Da Nang, Viet Nam, **6** Faculty of Information Technology, Duy Tan University, Da Nang, Viet Nam, **7** Department of Mathematics, Faculty of Science, Mansoura University, Mansoura, Egypt, **8** Department of Electrical and Computer Engineering, Michigan State University, East Lansing, Michigan, United States of America, **9** Department of Computer Science and Engineering, Soonchunhyang University, Asan, Korea

☯ These authors contributed equally to this work.
* ynam@sch.ac.kr (YN); abouhaww@msu.edu, saleh1284@mans.edu.eg (MA); sahilverma@ieee.org (SV)

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Abstract

Compression at a very low bit rate($\leq$0.5bpp) causes degradation in video frames with standard decoding algorithms like H.261, H.262, H.264, and MPEG-1 and MPEG-4, which itself produces lots of artifacts. This paper focuses on an efficient pre-and post-processing technique (PP-AFT) to address and rectify the problems of quantization error, ringing, blocking artifact, and flickering effect, which significantly degrade the visual quality of video frames. The PP-AFT method differentiates the blocked images or frames using activity function into different regions and developed adaptive filters as per the classified region. The designed process also introduces an adaptive flicker extraction and removal method and a 2-D filter to remove ringing effects in edge regions. The PP-AFT technique is implemented on various videos, and results are compared with different existing techniques using performance metrics like PSNR-B, MSSIM, and GBIM. Simulation results show significant improvement in the subjective quality of different video frames. The proposed method outperforms state-of-the-art de-blocking methods in terms of PSNR-B with average value lying between (0.7–1.9db) while (35.83–47.7%) reduced average GBIM keeping MSSIM values very close to the original sequence statistically 0.978.

Introduction

Various international standards have widely adopted Block-based Discrete Coding Technique (BDCT) have widely adopted block-based discrete coding technique (BDCT) like motion JPEG, MPEG-1, MPEG-2, and MPEG-4 for moving frames [1–3]. It is proved to be the most efficient yet simplest and fastest technique for compression to reduce the cost of transmission and storage issues. Although compression solves the problem of bandwidth scarcity issue at

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the same time, it also produces artifacts. One such artifact is blocking artifacts, and the other one is temporal artifacts commonly known as flicker artifact. MPEG-4/AVC standards are based on a hybrid coding technique that utilizes block-based coding and transform coding. Furthermore, it helps in maintaining the quality of the perceived data (image or video) without any significant loss of information. The main objective of the BDCT technique is that it bundles information into (NxN) blocks. At a very low bit rate, each block is predicted, quantized, and transformed independently, resulting in blocking artifacts across vertical and horizontal block boundaries. Flicker comes into existence because the video encoder could not able to processed co-located blocks consistently of consecutive frames. It leads to an increase in the difference between inter-frames w.r.t original video sequence. The de-blocking algorithm's main objectivede-blocking algorithm's main objective is to alleviate such artifacts and improve the visual quality parameters of compressed images [4, 5].

Blocking artifacts and flickering generally occurs in moving frames with intricate details when processed at low bit rate coding are very annoying artifacts that degrade the frames' visual quality. It is critical to address and provide an efficient solution to extract and remove such artifacts.

Problem statement

The problem associated with the video artifacts significantly degrades the overall subjective quality of the sequences. Flicker removal has been a relevant topic of research with the evolution of video standards from the last decade. However, a concrete solution to this problem has not been found yet. Due to the inadequate response of encoder during video compression, other artifacts occur, commonly called flicker artifacts [6, 7].

At the same time, researchers used a fixed threshold approach in their work [8]. None of the researchers introduce the concept of reduction of PSNR loss while designing flicker artifact detection and removal techniques. The selection of these artifacts is to find the most profound way to identify and rectify the root cause problem of perceptual quality of image/video frames. Adaptive filtering tools that will increase the accuracy of proposed algorithm for the providing a better solution.

Literature review

Although extensive work is carried out in image and video compression since the last two decades, it causes degradation in the subjective quality of decoded frames. De-blocking algorithms are broadly classified as in-loop processing and post-processing. At a higher compression ratio, it has been observed that the correlation between adjacent pixels decreases. Due to a one-dimensional filtering approach, the in-loop processing method enhances the coding efficiency by reducing blocking artifacts amongst adjoining pixels or frames but is unable to process corner outliers. To alleviate blocking artifacts different post-processing approaches such as frequency domain analysis [8–31], Projection Onto Convex Sets (POCS) [9–13], wavelet-based techniques [8, 20–30], estimation theory [5, 9–13], and filtering approach [11–15] has been proposed in last few decades. The most common method is to apply a low-pass filter across block boundaries to remove artifacts. The main disadvantage of spatial filtering techniques is over smoothing due to its low pass properties. Kim et al. [14] presented a POCS based post-processing technique to remove blocking artifacts. POCS is more complex and requires high computations due to more iteration steps performed during discrete cosine transform (DCT) as well as inverse discrete cosine transform (IDCT). Wen et al. [8] produced a DCT based filtration method for the smooth region, but it has poor performance. Hu et al. [16] proposed a singular valued decomposition (SVD) technique. In [30–36] Fields of experts

(FoE) technique is used to remove blocking artifacts. The methods mentioned above are based on the principle of estimation theory which is again an iterative technique. Due to the iterative approach, such techniques are not useful in the real-time application in image/video applications. Filtration methods were initially developed by Wang P. et al. [31] for the smooth region. Wang [24] also explained an adaptive filtering technique depending upon different frequency modes to remove blocking artifacts. On the other hand, corner outliers, detection, and removal have been proposed by [15, 25]. During compression, the corner outlier pixels are either considerable value or very small value pixels concerning surrounding pixels [8, 17–33]. Later on, Wang J. et al. [37] presented an adaptive filter-based technique for compressed images of different regions. X. Xia Ji et al. [6] proposed three-stage algorithm, namely the training stage, coding stage, and decoding stage for SAR compressed images. Although the above technique is very fast. Still, it gave poor performance along edges as well as the textured region of compressed images. Moreover, Due to non-adaptive characteristics, most of the post-processing techniques result in blurring and over-smoothening. De-blocking approaches filter frames across blocks and could not cover corner points due to which information or details of images or frames lost.

Some of the literature solutions are based upon filtration done at the decoder side [7, 38, 39] but have a disadvantage where standard decoder must be required.

The rest of the paper is organized as follows: In Section III proposed PP-AFT method is introduced to detect and rectify the issue of blocking artifacts and flicker artifacts as follows, Initially, a threshold-based pre-processing approach is applied, before de-blocking which helps in removing the quantization signal error. In the later stage, four adaptive filters based deblocking system is implemented, and finally, flicker extraction and removal for frames have been developed. The PP-AFT method helps in improving discontinuities near block boundaries and also helps in removing flicker artifact among successive video frames efficiently. Experimental results signify the subjective performance of the PP-AFT method over other techniques.

Proposed PP-AFT methods

A. System model

Our proposed model's main objective is to develop a system that can detect and remove artifacts like blocking artifacts as well as flickering artifacts in low bit-rate coded mobile standard definition (SD) videos. In this paper, a multi-fold technique is used. Implementing the preprocessing method removes the abrupt variation in signals that are more sensitive to human eyes. Secondly, the region-based adaptive de-blocking filter algorithm is applied along with the removal of ringing artifacts; finally, the flicker detection and removal algorithm are countered and produce high quality decoded video frames. We propose a multi-step de-blocking scheme to resolve the glitches arising due to compression, as shown in Fig 1.

The flowchart of the PP-AFT method is as follows.

In Block based Transform Coding (BTC) the significant observations are as follows:

- In smooth regions, the blocking artifacts are more visible than in non-smooth regions.
- In non-smooth regions, de-blocking filters tend to blur image details, which are more sensitive to human visual systems. In video coding, discontinuities are predominated across block boundaries between consecutive frames when coded at a very low bit rate. The Motion Compensated Prediction (MCP) may propagate blocking artifacts that are more visible to human eyes, specifically more in flat regions than complex regions.

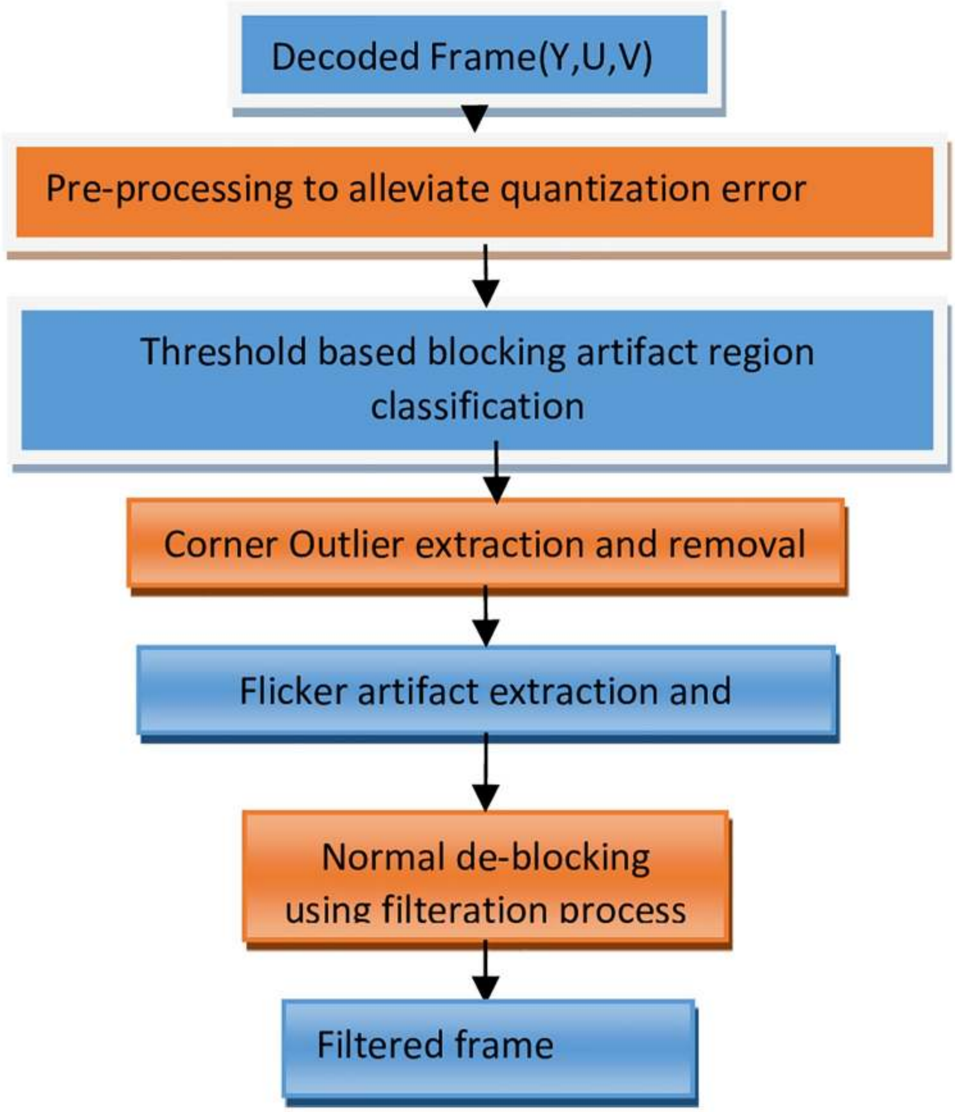
Decoded Frame(Y,U,V)
Pre-processing to alleviate quantization error
Threshold based blocking artifact region classification
Corner Outlier extraction and removal
Flicker artifact extraction and
Normal de-blocking using filteration process
Filtered frame

Fig 1. Flow chart of the PP-AFT technique.

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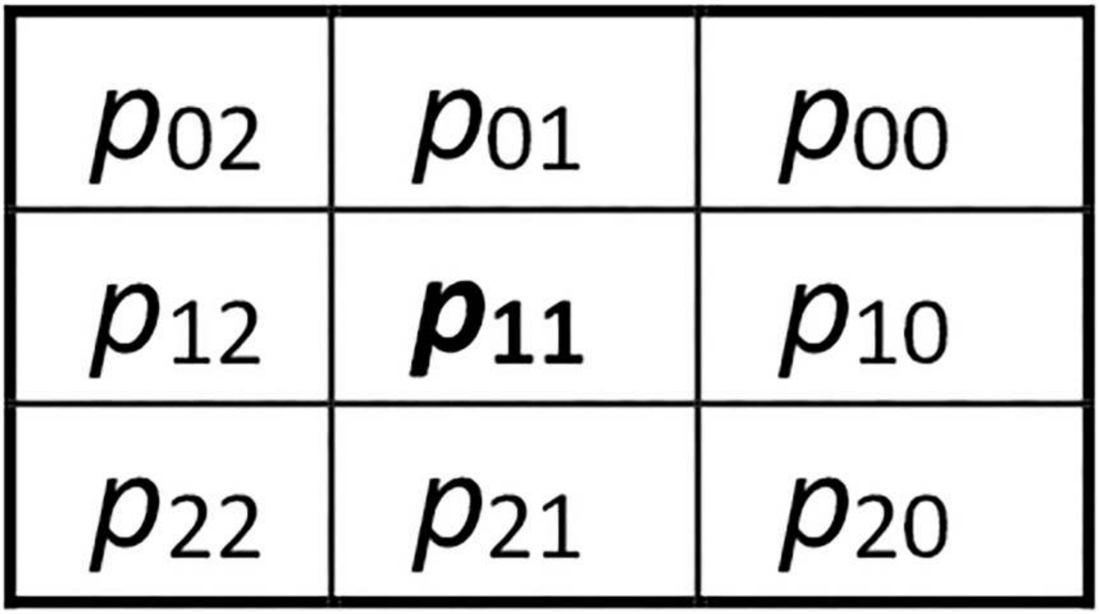
B. Pre-processing algorithm

The human Visual System (HVS) is more delicate to unexpected changes in signals (pixel estimation) of video outlines, specifical pixels with high or low differentiation esteems than its adjoining pixels. This sudden change diminishes the emotional nature of the casing and eventually upsets the total de-hindering activity. To eliminate such sort of discontinuities, one can apply mean channel. Fig 2 (p11) is the pixel getting looked at, and S characterizes a bunch of eight encompassing pixels.

Let (p_{11}) is abrupt signal; then its value should be near to $max(S)$ and the difference is always less than or equal to (Δ) and more significant than N pixels in set (S).



p_{02}	p_{01}	p_{00}
p_{12}	$\boldsymbol{p_{11}}$	p_{10}
p_{22}	p_{21}	p_{20}

Fig 2. Pixel with discontinuity in BDCT compression.

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Mathematically

$$max(S) \; - p_{11} \leq \; \Delta \tag{1}$$

$$M = \; \{p|p_{11} - p| > \; 1.41 \; * T_d \quad ,p\epsilon \mathrm{S}\} \tag{2}$$

$$|M| \; > \; \mathrm{N}, \qquad p\epsilon \mathrm{S} \tag{3}$$

We consider (N = 8), (Δ = 2.5), and (T_d = 6.5), where (T_d) is the threshold to calculate the dissimilarity that occur between two adjacent frames or pixels. If (1), (2) & (3) satisfied for (p_{11}), then it is observed as a pixel with considerable signal value, and it will be replaced with the mean of all the eight neighbouring pixels to remove undesired noise as in (4)

$$p_{11} \; = \; mean(S) \tag{4}$$

C. Post processing algorithm

The proposed strategy considers (16x16) pixels across level and vertical square limits as demonstrated in Fig 3. The proposed calculation ought to unmistakably recognize the square limits and lessen over-smoothening to accomplish a superior nature of casings. In light of pixels esteem, three districts were characterized relying upon the variety in antiques in the various locales. Consequently versatile channels have been presented. Diverse edge esteems are considered because of the explanation that the nearby properties of the video outlines change extensively. Consequently, these edges should neither have a fixed worth nor ought to be reliant just upon QP rather, it relies on BPP too.

The value of threshold will be large for smooth regions to preserve all edges of blocks and remove the artifacts only in the smooth regions. In contrast, in the non-smooth regions, QF should be small enough to maintain the images' vagueness effects.

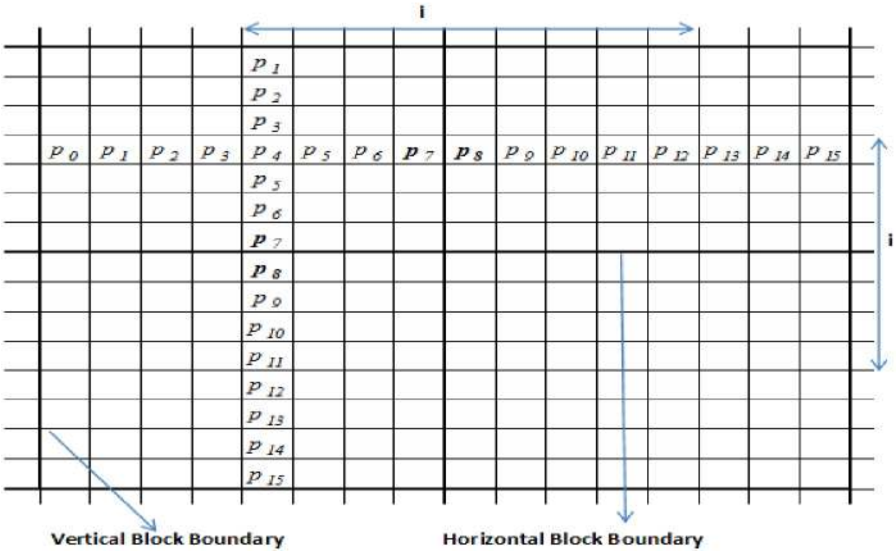

Fig 3. Pixel Vector (PV) and block boundaries for determining region using the activation function of symmetrical 8x8 block of a de-blocked video frames.

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I. Threshold generation. A limit is needed to counter discontinuities along block limits. We propose a limit worth to figure PV containing dissimilarities.

$$|p_7 - p_8| < T_i \tag{5}$$

Where (T_i = 173.5*QF $^{(0.05)}$) is utilized to catch edges of decoded video edges and 'i' got from ith Pixel Vector. Expecting obstructing curios are even across block limits (level just as vertical). Henceforth the vertical obstructing ancient rarities are likewise diminished by just pivoting the picture by 90^0.

II. Region classification. Regions categorizes primarily of three types, namely flat, intermediate, and non-smooth in view of the level of perfection. To confirm the attributes of the pixel vector, movement work (Ψ) has been acquainted with measure the nearby variety of PV.

$$\Psi = \sum_{k=0}^{N-3} (1 - \Re_C[(p_j(k))))$$
$$\Re_C[(p_j(k)) = \begin{cases} 1 & p_j(k)\hat{I}C \\ 0 & otherwise \end{cases} \tag{6}$$

Where ℜ (.) is the marker work, (C) is the inertia limitation set of PV with (jxj) squares to such an extent that $C = \{(\mathrm{p}_j(k)) : |(\mathrm{p}_j(k) - (\mathrm{p}_j(k+1))| \leq \text{ƛ}\}$, (ƛ) characterizes adjoining pixels relationship edge. Its worth is determined tentatively and set equivalents to "3" for best outcomes for locale grouping.

Isolation of districts is done with two separate limits (T_s)&(T_c) for the smooth area and complex locales, individually. The area arrangement is addressed in Fig 4. The estimations of (T_s)&(T_c) tentatively set to '1' and '2' for an effective differentiation between various districts.

- ***Smooth Region***

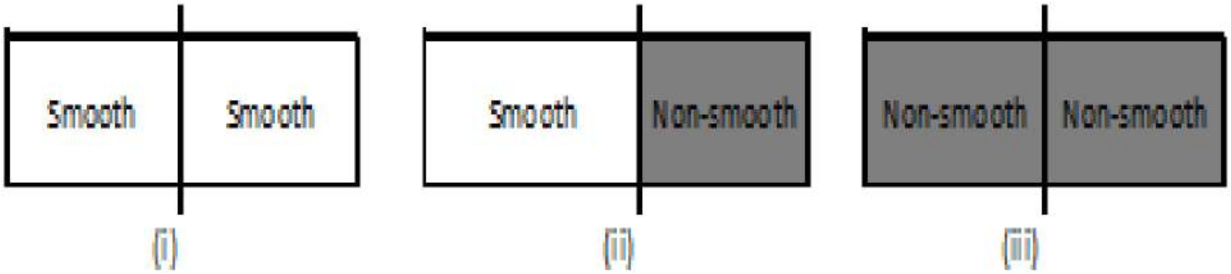

Fig 4. Different artifacts (i) ($\Psi < T_s$) (ii) ($T_s < \Psi < T_c$) (iii) ($\Psi > T_c$).

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Let R is flat region *(surrounded by similar pixel values)* if the activity functions (Ψ) is less than the threshold value (T_s) as shown in Fig 4(i).

$$\Psi = R_{smooth} \qquad for \;\; \Psi < T_s \tag{7}$$

If the above condition is true, calculate the absolute difference between boundary pixels. To verify whether the block is artifact-free or not, another threshold T_A is introduced.

$$if \;\; p_j(\frac{k}{2}) - p_j(\frac{k}{2} - 1) \leq T_{NA} \tag{8}$$

If Eq (8) is assured, the given pixel lies in the first even locale (no artifacts region), i.e., two adjoining pixels have similar recurrence parts. To lessen calculation intricacy as far as computational errand, no compelling reason to apply any de-hindering channel in this area and set T_{NA} = 0.035 T_i. In the event that (8) isn't fulfilled, another edge esteem is set to ascertain PV containing ancient rarities which are near the square limit to such an extent that

$$p_j(\frac{k}{2}) - p_j(\frac{k}{2} - 1) \geq T_{FE} \tag{9}$$

Where T_{FE} (T_{FE} = 0.56T_i) is the threshold for smooth edges, where smoothing filters are not suitable.

If the above condition is true, PV is altered by (10).

$$\begin{aligned}
p_4' &= p_4 + [(|p_7 - p_8|)/8] \\
p_5' &= p_5 \;\; + [(|p_7 - p_8|)/6] \\
p_6' &= p_6 + [(|p_7 - p_8|)/4] \\
p_7' &= p_7 + [(|p_7 - p_8|)/2] \\
p_8' &= p_8 + [(|p_7 - p_8|)/2] \\
p_9' &= p_9 + [(|p_7 - p_8|)/4] \\
p_{10}' &= p_{10} + [(|p_7 - p_8|)/6] \\
p_{11}' &= p_{11} + [(|p_7 - p_8|)/8]
\end{aligned} \tag{10}$$

Else the PV changes by (11).

$$\begin{aligned} p_4{}' &= p_4 - [(|p_7 - p_8|)/8] \\ p_5{}' &= p_5 \ \ - [(|p_7 - p_8|)/6] \\ p_6{}' &= p_6 - [(|p_7 - p_8|)/4] \\ p_7{}' &= p_7 - [(|p_7 - p_8|)/2] \\ p_8{}' &= p_8 - [(|p_7 - p_8|)/2] \\ p_9{}' &= p_9 - [(|p_7 - p_8|)/4] \\ p_{10}{}' &= p_{10} - [(|p_7 - p_8|)/6] \\ p_{11}{}' &= p_{11} - [(|p_7 - p_8|)/8] \end{aligned} \tag{11}$$

Where $p_4{}', p_5{}', p_6{}', p_7{}', p_8{}', p_9{}', p_{10}{}'$, and $p_{11}{}'$ are the eight changed pixels of PV. For a smooth area, every pixel in PV is reliant on different pixels. Henceforth smoothing channel planned in (10) and (11) is executed to finish a bunch of PVs (evenly just as vertically). On the off chance that (9) isn't fulfilled, to save picture subtleties across the edges, another level edge channel has been created and is given by (12).

$$p_i(j)\prime = \begin{cases} p_i(j) + \left[\dfrac{2}{1 + \sqrt{|(p_7 - p_8)|}}(|p_7 - p_8|)/8\right], & \mathit{if}\ \ i = \dfrac{2(N+1)}{4} - 2 \\ p_i(j) - \left[\dfrac{2}{1 + \sqrt{|(p_7 - p_8)|}}(|p_7 - p_8|)/8\right], & \mathit{if}\ \ i = \dfrac{N}{2} \end{cases} \tag{12}$$

$$\mathit{where} \qquad N = 0, 1, 2, 3, 4, 5, 6, 7$$

and the rest pixels unchanged.

Similarly, intermediate and non-smooth regions are determined and pixels have been changed. Filtering mode choice is utilized to deal with obstructing relics in the various locales. For the non-smooth locale, a straightforward channel is utilized while for a smooth area solid channel is utilized (all the more no. of pixels across block limits should be prepared). Interestingly, the middle channel is liked for the moderate locale, as clarified in Table 1.

D. Directional filter

In packed pictures or casings, blocks across edges contain outwardly irritating curios most popular as a ringing antique. The ringing relics are delivered because of the deficiency of high-recurrence segments or loss of accuracy in high-recurrence parts. It debases the perceptual nature of picture or video edge somewhat as far as Peak Signal to Noise Ratio, and it is difficult to outperform ringing impact with 1-D channel. We apply a 2-D directional filter, as demonstrated in Fig 5.

Table 1. Pixel filtering modes.

Artifact type	Activity region type	Pixel to be filtered	Mode of filtering
Fig 4(i)	Smooth-Smooth	$\{p_4, p_5, p_6, p_7, p_8, p_9, p_{10,}\ p_{11}\}$	1
Fig 4(ii)	Smooth–Non-smooth	$\{p_5, p_6, p_7, p_8, p_9, p_{10}\}$	2
Fig 4(iii)	Non-smooth- Non-smooth	$\{p_7, p_8\}$	3

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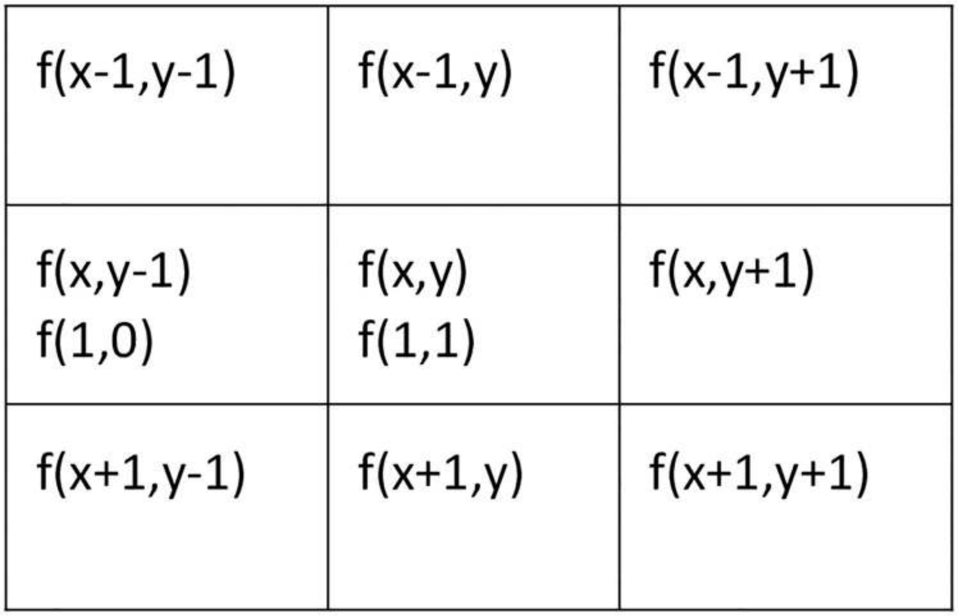

f(x-1,y-1)	f(x-1,y)	f(x-1,y+1)

f(x,y-1)
f(1,0)
	f(x,y)
	f(1,1)
		f(x,y+1)

f(x+1,y-1)	f(x+1,y)	f(x+1,y+1)

Fig 5. Directional filter.

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Let f(x,y) the pixel with a ringing artifact and need to be adjusted. The updated pixel is defined by (13)

$$f'(x, y) = \sum_{(c,d)\in w_{x,y}} f(x + c, y + d)w(c, d) \tag{13}$$

Where $w(c, d)$ is weighted function given in Eq (14)

$$\begin{aligned} &w(c, d) = e^{-|f(x+c,y+d)-f(x-c,y-d)|}, \\ &(c, d) \in \mathrm{w}'_{x,y}\ , \\ &where \\ &\qquad \mathrm{w}'_{x,y} = \mathrm{w}_{x,y} - (x, y)_{0,0} \end{aligned} \tag{14}$$

E. Extraction and removal of flicker artifacts

To extricate flicker in the sequential edges and gauge bending because of gleam ancient rarities, a D-flicker metric is presented. The method to discover gleam block is clarified in Algorithm I

ALGORITHM-1: PSEUDO-CODE FOR FLICKER DETECTION ALGORITHM:

```
Input: Create data set of videos divided into frames ($I_i((y, u, v))$),
where $i \in [1 : nF]$;
  Input:
    Input video frames $V_i((y, u, v)$;
  Output:
    Extraction of flicker artifacts in video frames $V_F((y, u, v)$;
  Begin
    for i=2:nF
```

```
        Input: Current frame (IF), Next frame (IFnext), Current
          Processed
          Frame ($IF_p$), Next Processed frame ($IFnext_P$).
          DiffF = IFnext -IF;
          DiffF_P = $IFnext_P$ -$IF_P$;
          DFlicker = max {0, abs (DiffF_P -DiffF)};
    End
End
```

To eliminate flicker artifacts, we have proposed a 2-D worldly filter that is fit for controlling PSNR-B$_{loss}$ (μ) in de-hindered casings of decoder (MPEG-4). The estimation of (μ) is tentatively set to 0.56 for better execution. The flash expulsion channel calculation is characterized in the accompanying pseudo-code and is appeared in Algorithm II.

ALGORITHM-II: PSEUDO-CODE FOR FLICKER REMOVAL ALGORITHM:

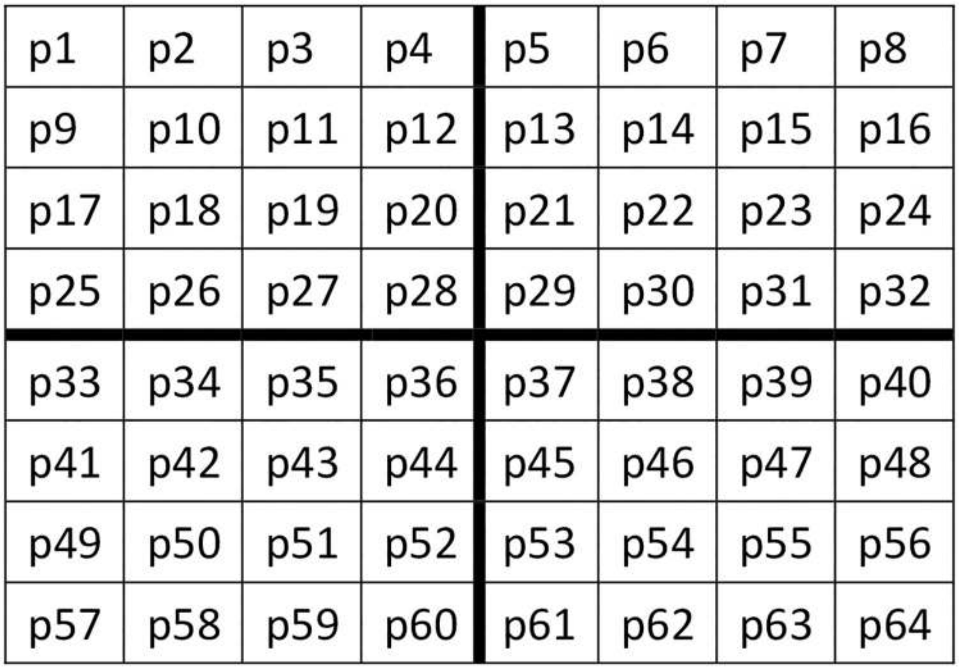
```
Input: Create data set of videos divided into frames ($I_i$((y, u, v)),
where $i \in [1 : nF]$;
  Input:
    Input DFlicker video frames
    $D_{Flicker}V_F$((y, u, v); (μ)=0.7;
  Output:
    Removal of flicker artifacts in video frames (IFfinal) = $V_p$((y,u,
v);
  Begin
  for i=2:nF
  1.    Input: Current frame (IF), Next frame (IFnext),
  2.    IF = double (IF); IFnext = double (IFnext);
  3.    IFn = (μ) .* IF + (1 − μ).* IFnext;
  4.    IFfinal = uint8(IFn);
    End
  End
```

Assessment metrics

To analyses the performance of the proposed method, we consider full-referenced performance metrics. In this paper, we consider the following metrics for performance analysis of de-blocked video sequences.

A. PSNR-B

The first parameter used for performance evaluation is a block sensitive image or video quality metric called Peak Signal to Noise Ratio-Blocking artifacts effect (PSNR-B) [40]. Blocking artifacts are more prominent with increasing the quantization parameter (QP). To calculate PSNR-B, let us consider an area containing a blocking artifact that is available in the x and y-axis simultaneously. Let V(x,y) is a video sequence where x and y are horizontal and vertical dimension pixels. Let $p_{i(x,y)}$ is the blocking pixels in a particular frame of V(x,y) video sequence as shown in Fig 6. Each frame is illustrated by (8x8) size pixel blocks such that N_H and N_v are equal to 8 and no boundary pixel on either side of horizontal and vertical block boundaries is similar to B = 4. The thick lines represent block boundaries. Let P_v are the pixels across the vertical block boundary. Similarly, P_h is the pixels across the horizontal block boundary. On the other hand, P_h^B and P_v^B are the set of pixels that are not lying across horizontal and vertical block boundaries, respectively.



p1	p2	p3	p4	p5	p6	p7	p8
p9	p10	p11	p12	p13	p14	p15	p16
p17	p18	p19	p20	p21	p22	p23	p24
p25	p26	p27	p28	p29	p30	p31	p32
p33	p34	p35	p36	p37	p38	p39	p40
p41	p42	p43	p44	p45	p46	p47	p48
p49	p50	p51	p52	p53	p54	p55	p56
p57	p58	p59	p60	p61	p62	p63	p64

Fig 6. Pixel block representation.

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The pixel set in Fig 6 is as follows

$$\begin{aligned} \mathrm{P_h} &= \{(\mathrm{p}_{25},\mathrm{p}_{33}),(\mathrm{p}_{26},\mathrm{p}_{35}),\ldots(\mathrm{p}_{32},\mathrm{p}_{40})\},\\ \mathrm{P_v} &= \{(\mathrm{p}_{4},\mathrm{p}_{5}),(\mathrm{p}_{12},\mathrm{p}_{13}),\ldots(\mathrm{p}_{60},\mathrm{p}_{61})\},\\ \mathrm{P_h}^{\mathrm{B}} &= \{(\mathrm{p}_{1},\mathrm{p}_{2}),(\mathrm{p}_{2},\mathrm{p}_{3}),\ldots(\mathrm{p}_{63},\mathrm{p}_{64})\}, \end{aligned}$$

and

$$\mathrm{P_v}^{\mathrm{B}} = \{(\mathrm{p}_{1},\mathrm{p}_{9}),(\mathrm{p}_{9},\mathrm{p}_{17}),\ldots(\mathrm{p}_{56},\mathrm{p}_{64})\},$$

After defining boundary pixels, we have to calculate mean squared difference (μ_d) for boundary pixels as well as pixels which did not lying near to block boundaries($\mu_d{}^B$) as

$$\mu_d(p) = \frac{\sum_{(p_x,p_y)\in P_h}(p_x - p_y)^2 + \sum_{(p_x,p_y)\in P_v}(p_x - p_y)^2}{16} \tag{15}$$

$$\mu_d{}^B(p) = \frac{\sum_{(p_x,p_y)\in P_h{}^B}(p_x - p_y)^2 + \sum_{(p_x,p_y)\in P_v{}^B}(p_x - p_y)^2}{96} \tag{16}$$

We can calculate the value of the effect of blocking artifacts, which is a function of block size by a factor termed as BAEF and calculated as

$$BAEF(p) = \beta[\mu_d(p) - {\mu_d}^B(p)]$$
$$where$$
$$\beta = \begin{cases} \dfrac{\log_2(8)(blocksize)}{\log_2(\min(8,8)block)} & if\ \ \mu_d(p) > {\mu_d}^B(p) \\ 0, & otherwise \end{cases} \tag{17}$$

Similarly, we can calculate BAEF for all the blocks of a given frame is calculated as

$$BAEF_{Total}(p) = \sum_{n=1}^{N} BAEF_n(p) \tag{18}$$

Therefore, the mean square blocking error (MSE-B) is calculated as

$$\mathrm{MSE - B(V_{(x,y)}) = MSE(V_{(x,y)}) + BAEF_{Total}(p)} \tag{19}$$

Where

$$MSE\left(V_{(x,y)}\right) = \frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)^2 \tag{20}$$

Where x, y represents pixel vectors of frame of a given video sequence. After calculating MSE-B we can finally calculate PSNR-B as

$$\mathrm{PSNR - B}(Frame_{(x,y)}) = 10\log_{10}\frac{255^2}{\mathrm{MSE - B}(x,y)} \tag{21}$$

B. GBIM

GBIM stands for Generalized Block-edge Impairment Metric [40, 41]. We can mathematically calculate the value of GBIM as follows.

Let us consider a DCT coded frame as shown in Fig 6 and is represented as P = {p_1, p_2. . . . . .p_cW_c} where p_{cj} is the j^{th} column of the video frame with W_c as the width of the frame. The interpixel difference across the vertical block boundaries is given by

$$P_v(x,y) = \begin{bmatrix} p_4 - p_5 \\ p_{12} - p_{13} \\ p_{N-4} - p_{N-3} \end{bmatrix} \tag{22}$$

Assume that frame is divided into (8x8) block size which is commonly used in standard video compression formats. Let the output of the prosed Human visual system (HVS) with local weights BM to generate Blocking artifact strength (BAS) and is given by

$$\mathrm{HVS(x,y) = BM(x,y) * BAS(x,y)} \tag{23}$$

The GBIM metric is calculated by using the HVS parameter as given below

$$GBIM_v = \left|\frac{|HVS_{output}(x,y) * BAS(x,y)|}{|HVS_{output}(x,y) * P_v(x,y)|}\right| \tag{24}$$

Where ||. . ..|| is normalized L2 function, $P_v(x,y)$ is an inter-pixel difference across vertical block boundaries. Similarly, Horizontal GBIM ($GBIM_H$) is calculated and the final value will be added for each frame.

$$\mathrm{GBIM}_{\mathrm{Total}} = \mathrm{GBIM}_{\mathrm{v}} + \mathrm{GBIM}_{\mathrm{H}} \quad (25)$$

C. MSSIM

MSSIM represent mean structural similarity indices [1–5, 8, 9–22, 37, 40] parameter for total frames (T_F) of a video is calculated as

$$\begin{gathered} \mathrm{MSSIM} = \frac{1}{T_F}\sum_{k=1}^{T_F} SSIM(x_k, y_k) \\ where \\ SSIM(Frame_{(x,y)}) = \frac{(2\mu_x\mu_y + C_a)(2\sigma_{xy} + C_b)}{({\mu_x}^2 + {\mu_y}^2 + C_a)({\sigma_x}^2 + {\sigma_y}^2 + C_b)} \end{gathered} \quad (26)$$

μ_x and μ_y are the mean values of pixel element x and y in a frame whereas σ_x and σ_y are the standard deviation of x and y respectively and C_a and C_b are stabilizing constant.

Result and discussion

To approve the presentation of the proposed strategy, video guidelines like MPEG-4 procedure were utilized. The PP-AFT strategy's exhibition is contrasted and existing methods Wang et al. [37] and MPEG-4 pressure. For target assessment we utilize a normal of obstructing (PSNR-B) [40]. Likewise, for emotional examination, we are utilizing two measurements specifically MSSIM (Mean Structural Similarity Indices Metrics) [40] and GBIM (Generalized Block-edge Impairment Metric) [40, 41].

This work has been executed on various video arrangements like meetings, akiyo, versatile, suzie taken from derf's assortment accessible without permit for research reason (https://media.xiph.org/video/derf/), with standard translating calculations like MPEG-4 just as Wang et al. [37]. The normal estimation of GBIM is fundamentally less when contrasted with condition of-workmanship procedures. The PP-AFT strategy gives around 47.7% less estimation of normal GBIM w.r.t MPEG-4 Standard pressure procedure and 35.83% less when contrasted with the technique created by Wang et al. [37].

Fig 7 portrays a graphical portrayal of the target examination of different video arrangements. It analyzes the exhibition measurements (PSNR-B) with the best in class strategy in particular MPEG-4 and Wang et al. [37]. The standard MPEG-4 codec utilizes BDCT, movement remuneration is utilized for every one of the recordings Fig 7(a) portrays PSNR-B esteems for Interview video grouping at different Bit Per Pixel (BPP) going from 0.20 to 0.50. At low estimation of BPP (i.e BPP = 0.20), PP-AFT strategy gives approx. 1.5dB more PSNR-B when contrasted with MPEG-4 norm and 0.3dB preferable worth over [37]. At BPP = 0.35, PP-AFT procedure gives 2.3dB and 0.8dB better outcome w.r.t to MPEG-4 technique and Wang et al. [37] separately. At a higher estimation of BPP (for example BPP = 0.50), the PP-AFT technique gives approx. 2.2dB and 0.7dB better outcomes once more.

Essentially, for Akiyo, Mobile, and Suzie video arrangement, we have determined the target investigation metric and discover better outcomes for low, medium just as higher BPP as demonstrated in Fig 7(b), 7(c) and 7(d) individually. Fig 7(a)–7(d) shows that the PP-AFT strategy

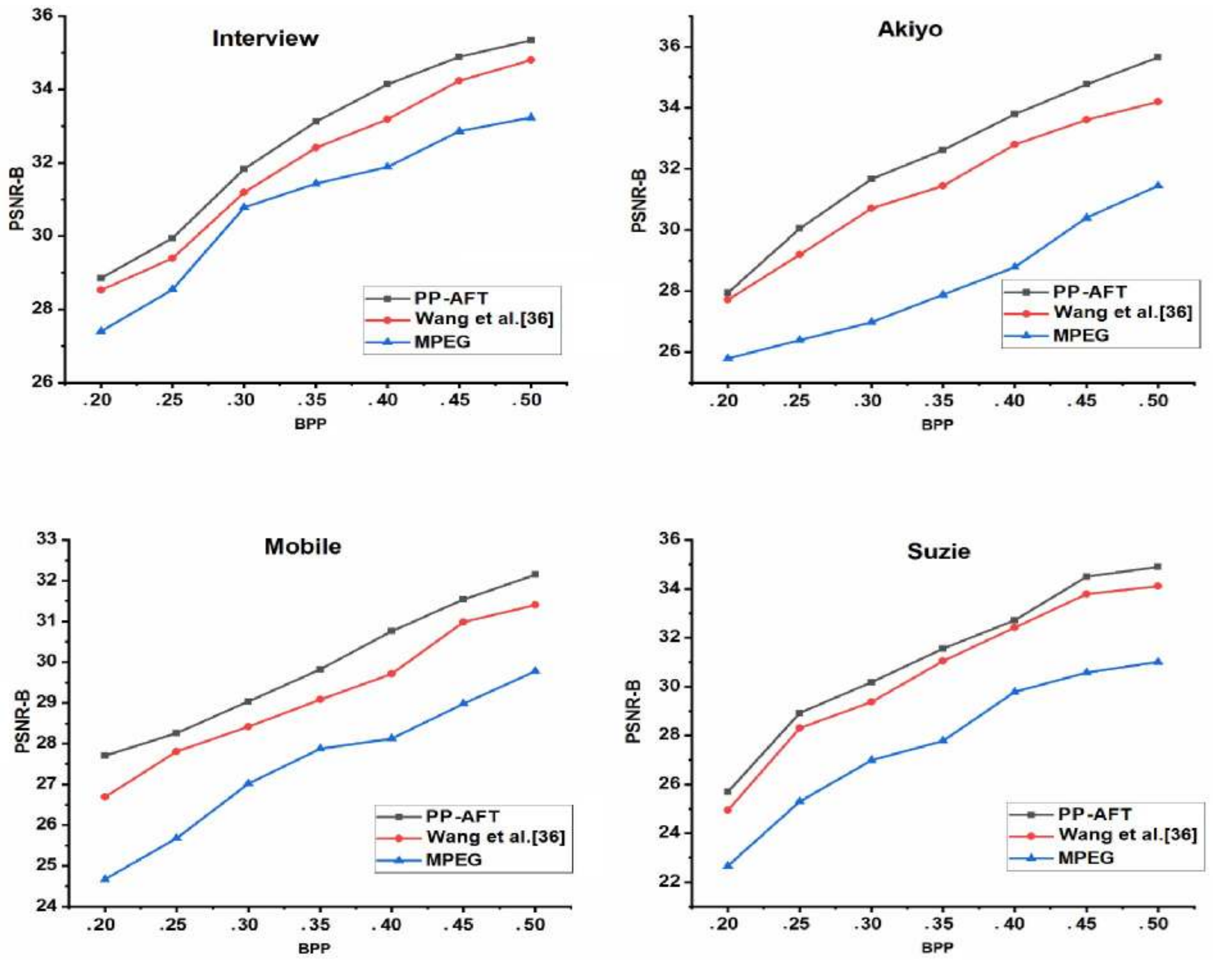

Fig 7. Objective analysis of different video frames sequence PSNR-B vs QP for (a) Interview, (b) Akiyo, (c) Mobile and (d) Suzie.

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beats regarding target measurements like PSNR-B with normal worth lying between (0.7–1.9db) concerning MPEG-4 and Wang et al. [37] strategies.

Fig 8 represents the average value of blocking peak signal to noise ratio (PSNR-B) of different techniques, and the PP-AFT method gives an average PSNR-B gain 2.93921 dB w.r.t standard MPEG-4compression technique and 0.74452 dB w.r.t Wang et al. [37].

Fig 9 delineates the abstract examination metric (MSSIM). As per [40], It is seen that the more will be the estimation of MSSIM, the better will be the de-hindering procedure. It is obvious in Fig 9 that the normal estimation of MSSIM of the PP-AFT technique is near unique worth measurably 97.89% when contrasted with 91.42% for MPEG-4and 94.67% for Wang et al. [37].

Fig 10 depicts various video sequences' subjective analysis, namely Interview, Akiyo, Mobile, Suzie, Coastguard, and Container using metrics Mean Structural Similarity index. Fig 10 clearly shows the robustness of the proposed algorithm w.r.t state-of-the-art method (MPEG-4) and the method, explained in Wang et al. [37].

Table 2 shows the estimation of MSSIM measurements in even structure. From Table 2 it is seen that the PP-AFT strategy got primary closeness record extremely near "1", measurably lies between 0.97–0.9885 as contrast with [37] which ranges between 0.9162–0.943 just as cutting

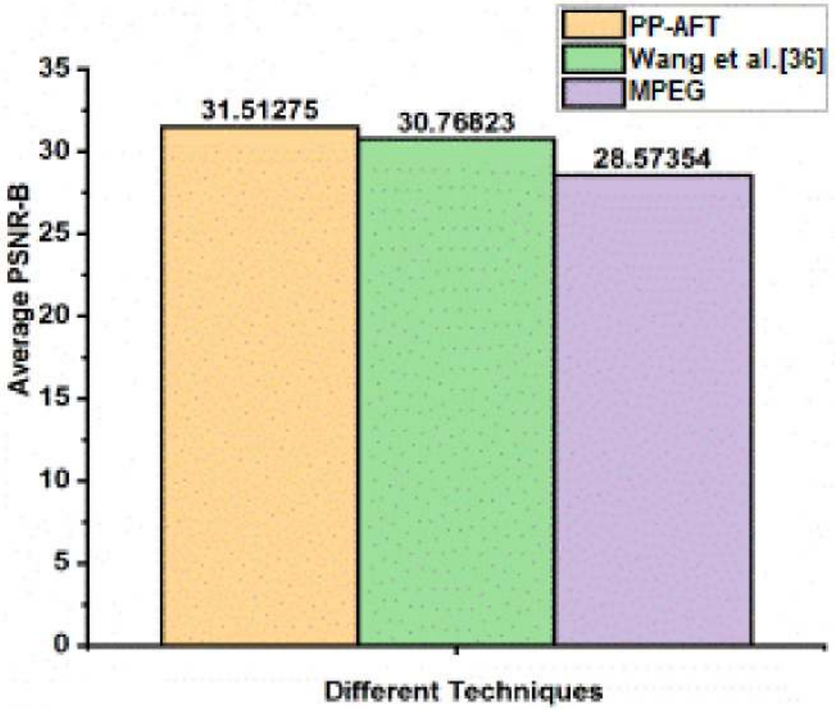

Fig 8. Average value of PNSR-B for different techniques.

https://doi.org/10.1371/journal.pone.0250959.g008

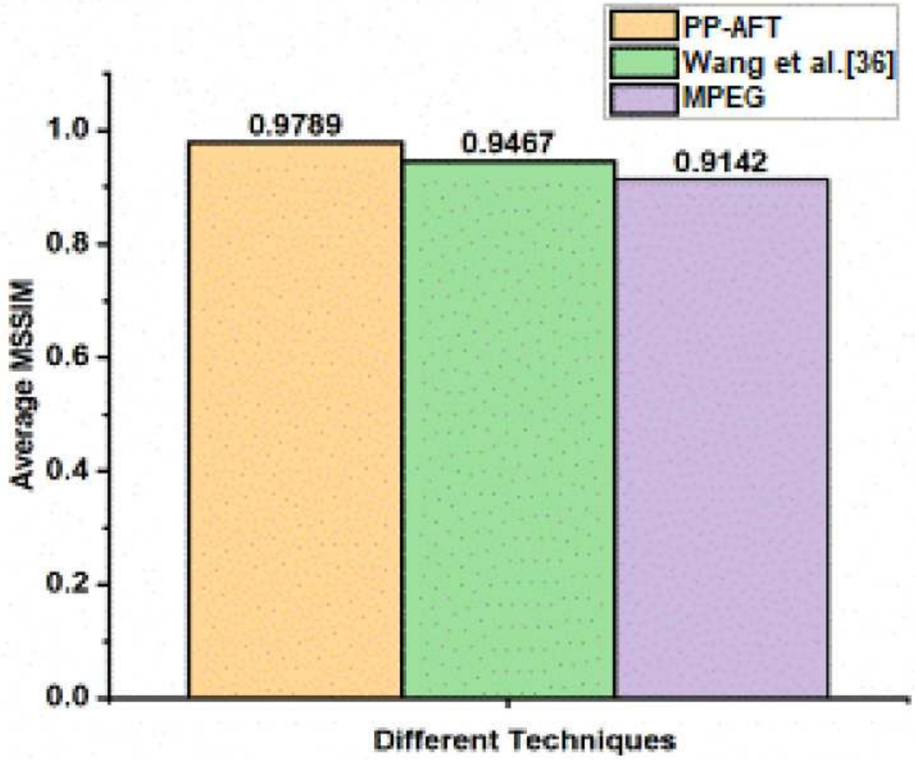

Fig 9. Average value of MSSIM for different techniques.

https://doi.org/10.1371/journal.pone.0250959.g009

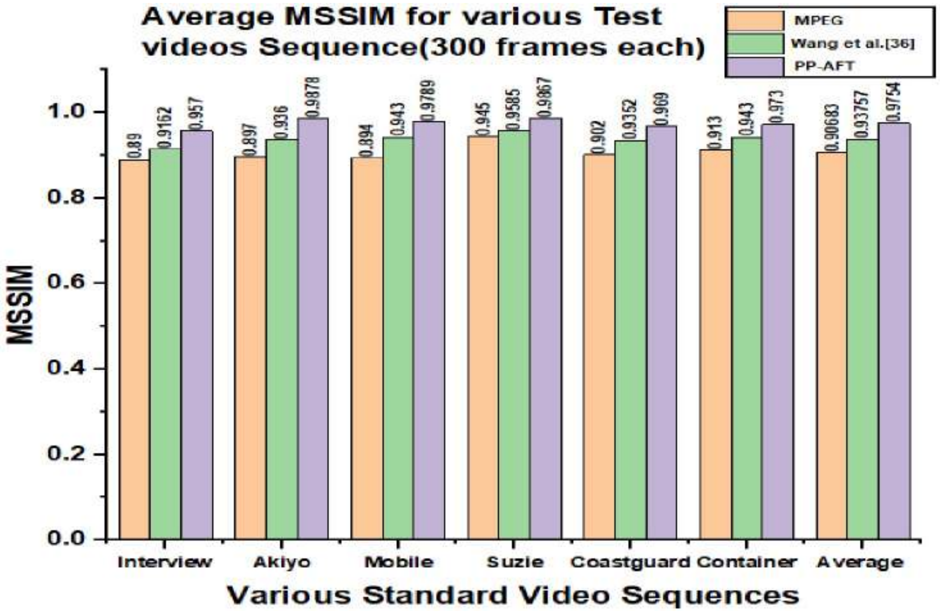

Fig 10. Average value of MSSIM for various video sequences.

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edge technique (MPEG-4), which acquire just 0.89–0.945. Fig 10 plainly shows the perceptual nature of pictures or casings. It proficiently eliminates impeding curios, and Table 2 plainly outlines the PP-AFT technique's strength for an alternate arrangement of standard video successions.

Findings

We summarize our contributions in this research work as below:

1. All images/frames have gone through the same process, but the quality is different due to the degree of complexity in different video sequences frames. Please note that the reconstructed images/frames have improved quality as compared to existing methods in terms of objectives and subjective assessment.
2. With general improvement, we eliminate the flicker artifact to a large extent. The framework creates a perceived quality of reconstructed video frames, that explicitly addresses the issues of blocking and flicker artifacts.

Table 2. MSSIM value for various test videos.

Name of Video Sequence	MSSIM		
	MPEG-4	**Wang et al. [37]**	**PP-AFT**
Interview	0.89	0.9162	0.97
Akiyo	0.897	0.936	0.98
Mobile	0.894	0.943	0.9789
Suzie	0.945	0.9285	0.9867
Coastguard	0.902	0.9352	0.9885
Container	0.913	0.943	0.973
Average	0.906833	0.937567	0.9754

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3. We evaluated the methods for overcoming the problem of flicker artifacts in video sequences mostly used for mobile multimedia communication. We use the Block Discrete Cosine Transform method to extract blocks from various test sequences into (8x8) blocks. These blocks are then pre-processed to eliminate quantization error. Blocking artifact detection and removal is addressed, and finally, a flicker detection and removal algorithm is introduced.

Limitations

Due to the lack of resources, some features on this research work are compromised that can add more strength to its functionality in terms of both time and cost.

1. High-definition videos need to be implemented with hybridization of the proposed algorithm, which will help to find more accurate results for HD contents.
2. One can apply soft computing techniques, which provides efficient approach to remove these artifacts with low complexity.

Conclusion

We have proposed a novel adaptive threshold-based pre- and post-processing technique to reduce artifacts in BDCT video frames. The PP-AFT method is based on a 2-D directional filtering approach to remove ringing artifacts while preserving the edges. The Human Visual System is also incorporated to improve the visual quality of the images or frames. The frames' characteristics across block boundaries are efficiently obtained by removing blocking artifacts using three filters based on three regions (smooth, intermediate, and non-smooth regions). The smooth region filtering has been achieved efficiently using a considerable threshold value. At the same time, the small threshold value is proposed for non-smooth regions, whereas for intermediate regions, two different filters are proposed using different thresholds to maintain a balance between smooth and non-smooth region.

Objective and subjective experiments, have been performed to validate the performance of the proposed work. To analyze the proposed technique, PSNR-B is evaluated for an objective, and for human visual perception, MSSIM and DBIM indices have been used. It is observed that the PP-AFT approach provides a significant improvement in the perceptual quality of images or frames and efficiently removes blocking artifacts. MSSIM values obtained from the PP-AFT method is very close to original images.

Future scope

The PP-AFT method is also suitable for real-time applications of frames decompression due to its low computational complexity shortly. Soft computing methods can also optimize the results. This work can be further extended by considering H.265/ HEVC decoding technique for High Definition Video sequences for high-speed internet network like 5G/LTE using DCT and Discrete Sine Transform (DST) with variable block size between (4x4) and (32x32).

Author Contributions

Conceptualization: Anudeep Gandam, Jagroop Singh Sidhu, Sahil Verma, N. Z. Jhanjhi, Anand Nayyar, Mohamed Abouhawwash, Yunyoung Nam.

Data curation: Anudeep Gandam, Jagroop Singh Sidhu, Sahil Verma, Anand Nayyar, Mohamed Abouhawwash, Yunyoung Nam.

Formal analysis: Anudeep Gandam, Sahil Verma, N. Z. Jhanjhi, Mohamed Abouhawwash.

Funding acquisition: Yunyoung Nam.

Investigation: Anudeep Gandam, Jagroop Singh Sidhu, Sahil Verma, N. Z. Jhanjhi, Anand Nayyar, Mohamed Abouhawwash, Yunyoung Nam.

Methodology: Jagroop Singh Sidhu, Anand Nayyar, Mohamed Abouhawwash.

Project administration: N. Z. Jhanjhi, Mohamed Abouhawwash, Yunyoung Nam.

Resources: Anudeep Gandam, Jagroop Singh Sidhu, Sahil Verma, N. Z. Jhanjhi, Anand Nayyar.

Software: Anudeep Gandam, Jagroop Singh Sidhu, Sahil Verma, N. Z. Jhanjhi, Anand Nayyar, Mohamed Abouhawwash, Yunyoung Nam.

Supervision: Jagroop Singh Sidhu, Mohamed Abouhawwash, Yunyoung Nam.

Validation: Anudeep Gandam, Sahil Verma, N. Z. Jhanjhi, Anand Nayyar, Mohamed Abouhawwash.

Visualization: Mohamed Abouhawwash, Yunyoung Nam.

Writing – original draft: Anudeep Gandam, Jagroop Singh Sidhu, Sahil Verma, Anand Nayyar.

Writing – review & editing: Anudeep Gandam, Jagroop Singh Sidhu, Sahil Verma, N. Z. Jhanjhi, Anand Nayyar, Mohamed Abouhawwash, Yunyoung Nam.

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