Computational Method to Extract the Keyframe from Angiogram video

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Abstract: Extraction of keyframes from the coronary angiogram video is an essential task in the medical community to analyze the image and proceed for further treatment. There are different medical modalities such as MRI, CT, X-ray, etc. to capture the images. This research focuses on coronary artery disease which is identified by the X-ray coronary angiogram test. The process of acquiring images in X-ray angiogram data is generally capturing the video at 15-30 frames per second. During the analysis of the coronary angiogram video the cardiologist often manually pauses the video at a regular interval frame to examine the artery. Such a frame which represents the vessels or artery with complete visual content is a keyframe. In this paper a method to extract the keyframe automatically from the angiogram video is proposed. This proposed method has three phases, In the first phase video is converted into frames. In the second phase frames are pre-processed to improve the quality of the frames. In the third phase, by comparing connected components properties of each frame, keyframes are extracted. This keyframe is used for further processes like segmentation and detection of the stenosis in the artery and the results of the proposed method is compared with the existing method.

Keywords: Video, key frame extraction, Angiogram, Coronary Artery disease, Histogram

1. INTRODUCTION

Coronary artery disease is one of the common heart disease, which is caused by the presence of stenosis in the wall of the heart artery. Stenosis is a deposition of calcium or fatty material in the artery. This stenosis will narrow the artery, so the blood flow to the heart muscles will reduce and it leads to severe heart problems such as heart attack. Cardiologists are using X-ray coronary angiogram tests to identify such medical conditions. X-ray coronary angiogram is a [1] benchmark medical imaging technique used to find the coronary artery status such as blockage in the artery. Among all different medical imaging modalities, X-ray is proven to be the best imaging technique to treat such conditions further.

During an angiogram test a catheter is injected into the wrist and guided up to the heart, when it reaches the position a dye is dispersed among the heart arteries and then spread over the entire artery through it. The X-ray device will start capturing the image in different angles such as, right anterior oblique (RAO) 0°, RAO 90°, Left anterior oblique (LAO) 0°, LAO 90°, etc simultaneously. The captured Angiogram data is in video format so finding the correct / optimum frame is essential for diagnosis, thus a keyframe extraction is very important. Artery shape will alter over time due to heart beat. It's difficult for doctor to select the particular frame where the artery is visible. To solve this problem a method is proposed to find the key frame from the Angiogram video. Once the keyframe is found its easy for the cardiologist to detect the coronary artery disease. In this proposed method, first angiogram video is split into different frames. Then from that frame, a keyframe can be detected and extracted. Keyframe is the frame where the blood vessel is fully visible, upon the visual inspection the doctor(s) can verdict the degree of the stenosis. Keyframe extraction is the major part in detection of the stenosis in the angiogram video.

2. RELATED WORK

Usually Video Keyframes are extracted using [2] different technique like motion-based information collection, shot detection, visual information basic detection, video frames clustering. Here some existing method and techniques in video frame extraction are discussed. Yannis S et al. developed [3] a framework to extract important information from the video. Using colour and motion segmentation technique few features are extracted from the frames. Extracted features all unified using fuzzy feature vector. Through cross correlation and features trajectory, keyframes are chosen from MPEG video.

Antonis Ioannidis et al. implemented [4] a method where the author used three diverse datasets in the research work. In this method divergent combination of descriptor are used to find the keyframe in the video. Author patterned a method, where the keyframes should contain maximum information and it should not have similar information. Each descriptor is weighted separately and combined to get specific video shot. Spectral clustering algorithm is applied in this method toward group the frames from the shots.

Walid Barhoumi et al. proposed [5] a method to detect the keyframe based on object in the videos. Here visual content plays a main role to select the keyframe in the videos. Visual dictionary is used in this method to check the relevant object in the frames. According to the relevant of the object present in the video the keyframes are extracted.

Kuanar SK et al. implemented [6] a dynamic Delaunay graph clustering method to excerpt the keyframe. Videos are pre-sampled using segmentation method. From that pre-sampled image two features are extracted. First colour feature is extracted using 256 bins, after that second feature edge is extracted by 80 bins. Here author merged both colour and edge feature. By clustering frames and by comparing the connected component of the graph, keyframes are selected from the video.

Ayumu Ishijima et al. proposed [7] an algorithm where intensity variance among the frames is calculated, to find the similarity in it. From that few frames are selected and entropy for frames is calculated, to detect the focus of the image. Entropy helps to identify few frames from the selected frames and by using SURF algorithm feature point in the frames are calculated. The frames that have maximum feature point is preferred as a keyframe from the micro endoscopy video.

K.S. Thakre et al. proposed [8] an algorithm to find best clips in the video. In this algorithm frames are separated into blocks and wavelet transforming is applied in each block of the frames. Distance between each block is computed and stored in vector format. Mean value for the distance is computed and compared with the local minima and maxima of each vector. From this calculated value keyframes are identified.

In [9] C. V. Sheena et al. presented a technique to extract the keyframe from the video through analysis of the histogram using statical method. This method starts with split the frame one by one in the video. Then Convert all frames into grayscale format. Calculated the histogram difference between the following frames and compute the mean and standard deviation for that value. select the keyframe comparing the [10] threshold value with the Absolute difference of the histogram of the frames.

Rachida Hannane et al. implemented [11] a system to segment and selected the keyframes from video. This system has two phases. In first phase video is segmented into shots by finding the boundary using adaptive threshold method. In second phase keyframes are selected by using entropy based singular values.

Ling Chen et al. developed [12] a technique to identify the keyframe in On-site video recording. In this technique three different descriptor like colour, texture and gradient are used to identify the keyframe properly. In colour descriptor RGB, YUV, HSV, CIELUV colour spaces are used for the work. In gradient descriptor weighted average gradient and histogram of gradient magnitude are used in this work. In texture descriptor Gabor filter bank is used for the research. Dissimilarity is checked by the Euclidean distance method. By combining these three descriptors a method is implemented to detect the keyframe in real time videos.

Aditi Jahagirdar et al. developed [13] a technique to identify the keyframe for action recognition. In first level frames are separated from the video and convert it into grayscale images. Histogram of difference frames algorithm is applied to find threshold value and by comparing the threshold salient frames are extracted. In second level salient frames are read one by one and applied difference wavelet coefficient algorithm. By comparing the threshold value final keyframe is chosen.

Hana Gharbi et al. experimented [14] a method to find the keyframe from video summarization. In this local attention point descriptor and iterative graph clustering are used to set the candidate key. The resulted keyframe in this method has important event of the video.

Shaoyan Xia et al. developed [15] a framework to extract the artery from the sequence of image. In this by considering the artery area as a motion part and background as a static part of the image in matrix decomposition model. In this model first the background is removed and the artery region are enhanced by the Hessain matrix. The spatiotemporal energy function is used to fine tune the artery structure. There is considerable work on frame selection, shot boundary detection and shot detection, but this method is for selecting the keyframe from the general video. [16] Angiogram video images are mostly low intensities with unevenly the same intensity histogram irrespective of the content being shown. So, these general videos shot detection methods are not applicable for the angiogram video. In this research work a new method is proposed to extract the keyframes form the X-ray coronary angiogram video.

3. MATERIALS AND METHODS

A. Dataset Description

X-ray coronary angiogram video used in this experiment is provided by Rahavendar Hospital Madurai. After assessing the ethical aspects, the hospital ethical committee granted the permission to collect the data in Cath Lab. The data are collected from the device Philips Allura Xper FD20 X-ray system. 50 patient data are collected from the hospital. For each patient 3 to 8 videos are there in the data. From collected dataset, a set of videos are used for experimentation for the current research.
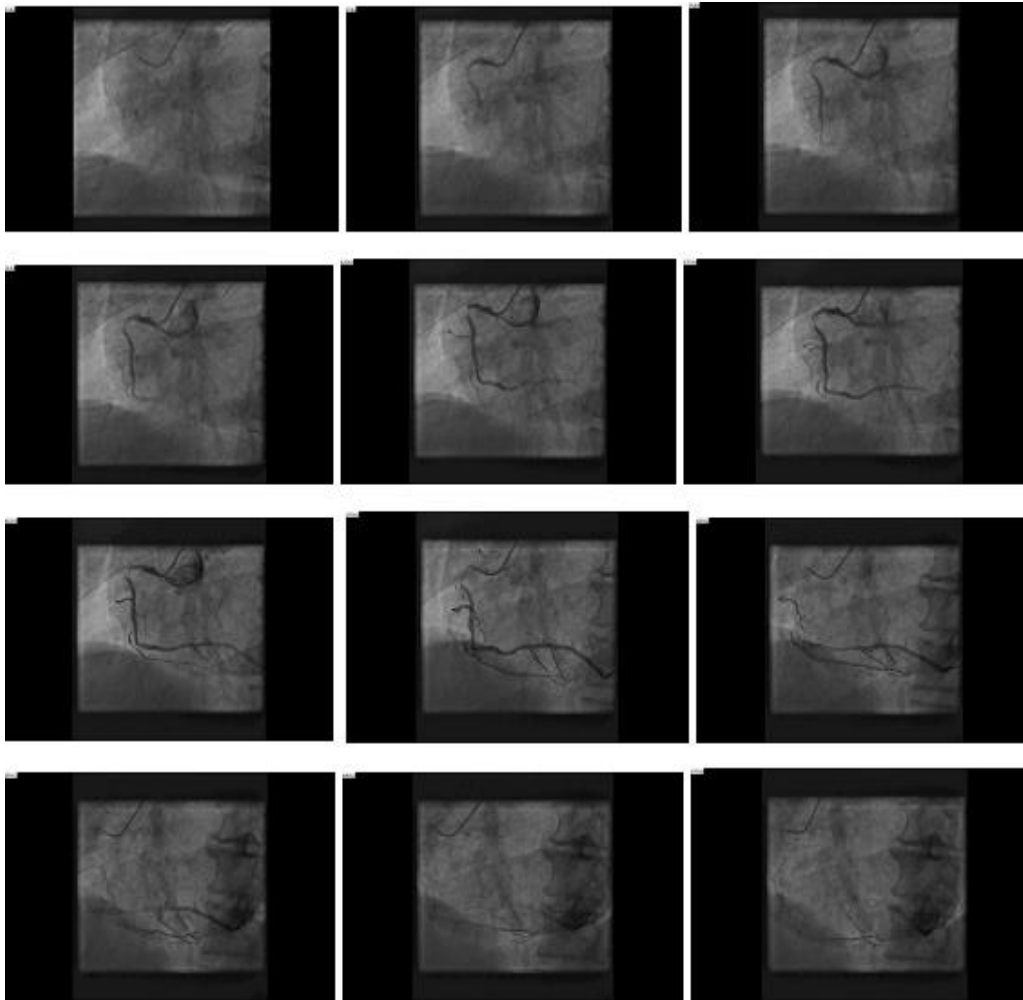

Figure 1. Sample Frames extracted from the video

B. The Proposed Method

Keyframe extraction was executed in this research to identify the high-quality frame[17] which has full shape of artery for next analysis. The current proposed method consists three phases, in first phase the video is captured and it is converted into various frames. Here frames are extracted from the angiogram video one by one and stored. Second phase is pre-processing the frames, where the black background region in the frames is removed by checking the gray threshold value of the image using these equations (1).

$$F = I > th \qquad (1)$$

F - pre-processed frame
I - Original frame
th – Gray threshold value

3090

In this method th is assigned as 60, the pixel intensity greater than the th is stored in F pre-processed frame. Now the black region in the frame are removed.

Then second pre-processing methods morphological operation is used to enhance the contrast and quality of the frames. The Top-hat operation is used to improve the contrast of the frame. In this operation it first calculate the opening morphological operation , then subtracts the output image from this operation to the frame itself [18]. In this morphological operation disk shaped structuring element is used with the 150 radius value. The equation used in this stage is shown below.
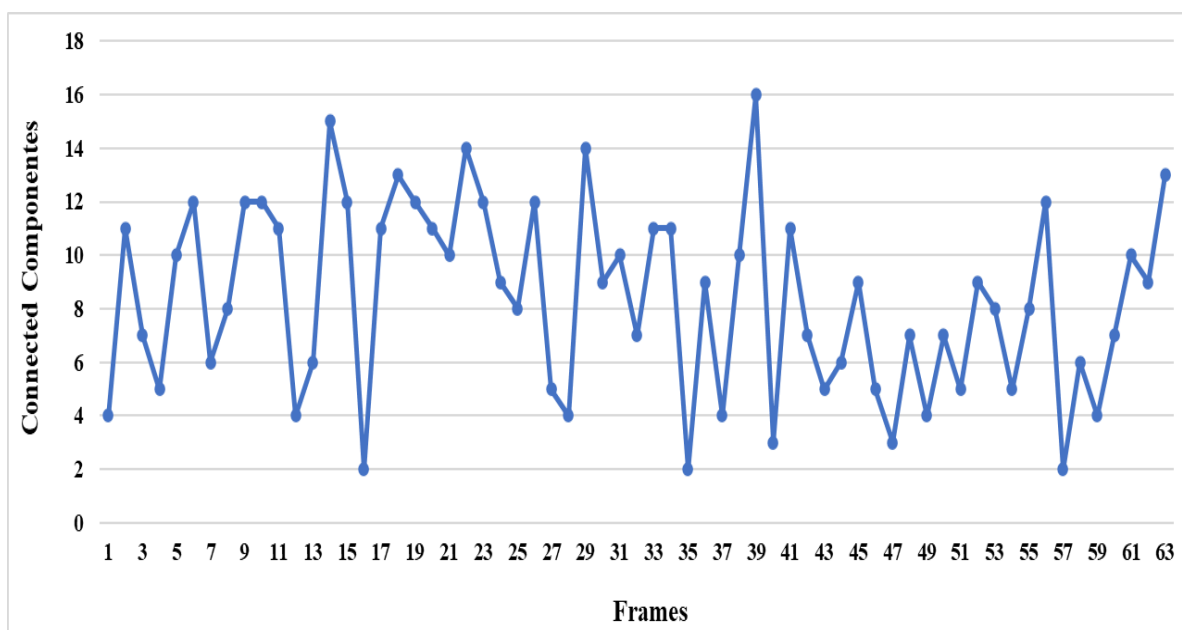
$$Top - Hat(A) = A_{TH} = A - (A°B) \qquad (2)$$

Figure 2. Connected Component in each Frames are shown in the graph

In third phase connected component properties in each pre-processed frames are calculated and stored in the variable. Set of pixels linked to all other pixels is called connected component[19]. This connected component is used to find the object in the image and also to count number of objects in the image. By using this properties, artery area connection are calculated and shown in the Figure 2. Number of connected components in the frame is calculated and stored. Then the number of connected components of each frame is compared with the maximum number of connected components of the frames. By applying the equation (3) the keyframe is identified.

$$Keyframe = Ncc > Max \qquad (3)$$

Ncc - Number of connected components in the frame.

Max – Maximum number of the connected component.

If Ncc is larger than Max then that frame is selected as a keyframe. In This resulted keyframes the visibility of the artery is clear and complete structure is present in the image, compare to the existing method.

Pseudocode: *Proposed Method algorithm*

Input = Video
Output = Keyframes

Begin

Read_video

nFrames=Total Number of Frames

For T= 1 to nFrames

      GrayImage=RGB_Gray (Frame $_T$)

      Image= GrayImage > threshod $_{value}$

End

For j= 1 to nFrames

      filtered_image= Tophat(Frame $_j$)

End

For z=1 to nFrames

      CC(z) = bwconncomp(Frame $_z$);

      No_of_component(z) = CC(z).NumObjects

      Max $_{value}$=max(No_of_component(z))

      If No_of_component(z) > Max $_{value}$

            Keyframe= Frame $_z$

      End

End

Steps :

1)   Read the video and convert into frames

2)   Calculated the total number of frames in the video.

3)   For loop is used to navigate & process from frame '1' to 'last' frames.

4)   Convert the frame into grayscale format.

5)   Frames are preprocessed using threshold value.

6)   Frames are enhanced further by Morphological transformation operation.

7)   From that enhanced image connected component in the frame is calculated to check the maximum information is available in the frame.

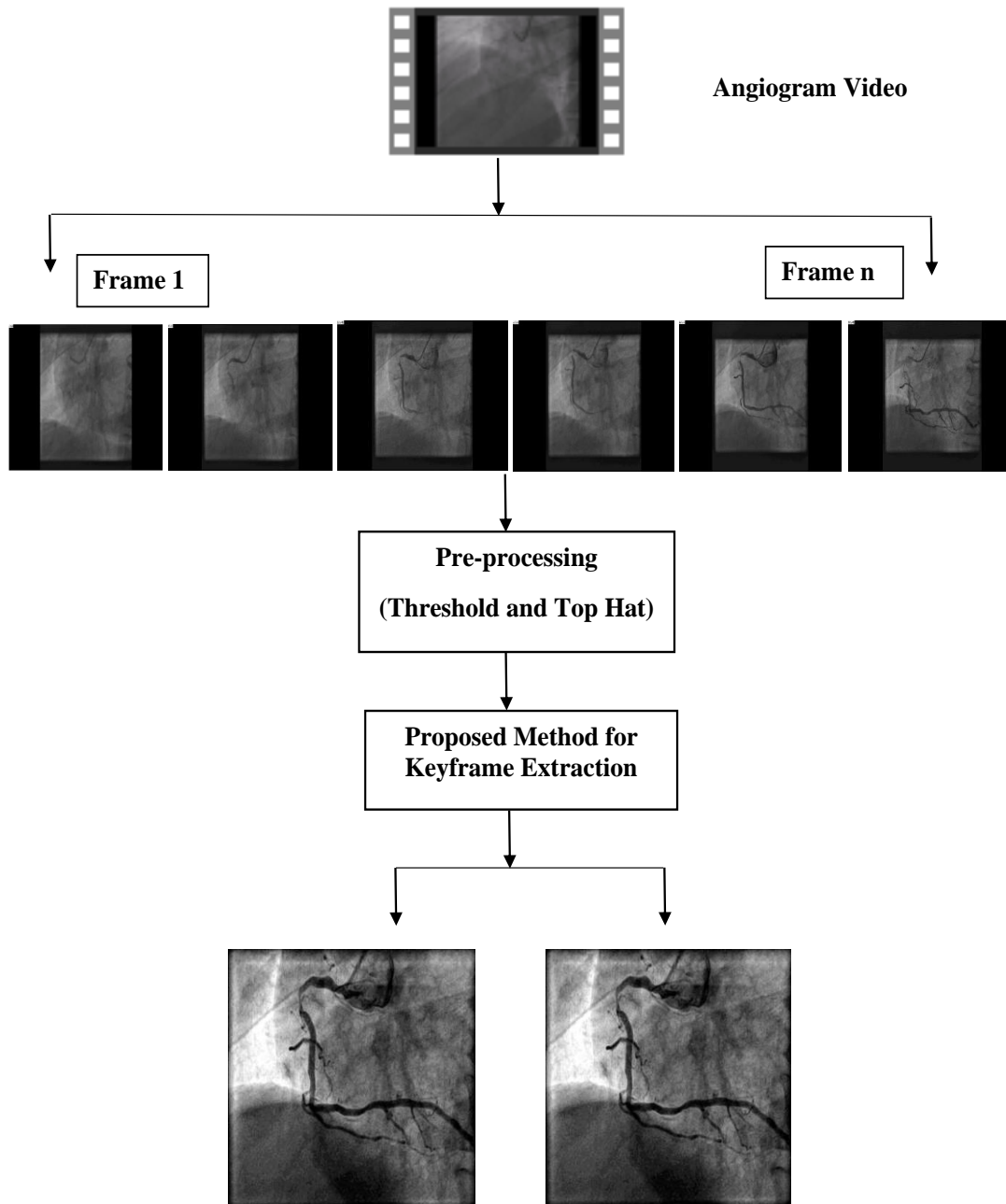8)   The frame which has maximum value of connected component is consider as a keyframe in this method.

Figure 3. Flow Diagram of the proposed method

4.   EXPERIMENTAL RESULTS AND ANALYSIS

From the collected set of videos absolute difference of histogram method [9] and proposed methods are experimented. In absolute difference of histogram method frames are separated from the video. Then modify the frames into grayscale. Number of frames in the video is calculated to execute it using for loop. Absolute difference is calculated among two frames. By using that value mean and standard deviation is calculated. Finally, by comparing the threshold value with the frame, Keyframes are identified in this method. Next Proposed method is experimented on the Dataset. In this proposed method video is fragmented into frames and stored. Threshold method is used to remove the black area in the frames and using Top hat morphological operation frames are enhanced. By using connected component properties of the frames and comparing the highest connected component Keyframes are extracted.

In in Figure 4 keyframe extracted from coronary angiogram video using absolute difference of histogram method is shown. From the existing method six keyframes are selected and in Figure 5 extracted keyframe using proposed keyframe

extraction method is shown. Here two keyframes are extracted and its quality also better compare to the exiting method output.
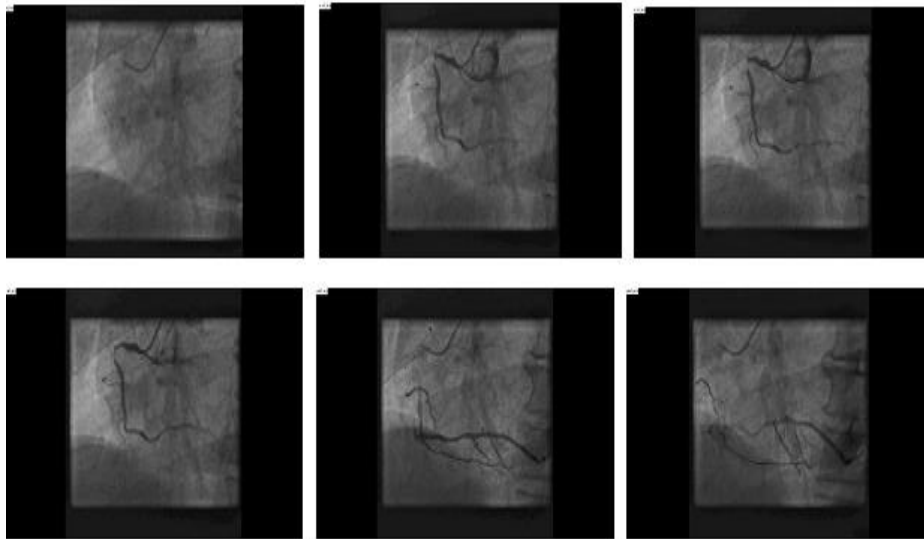

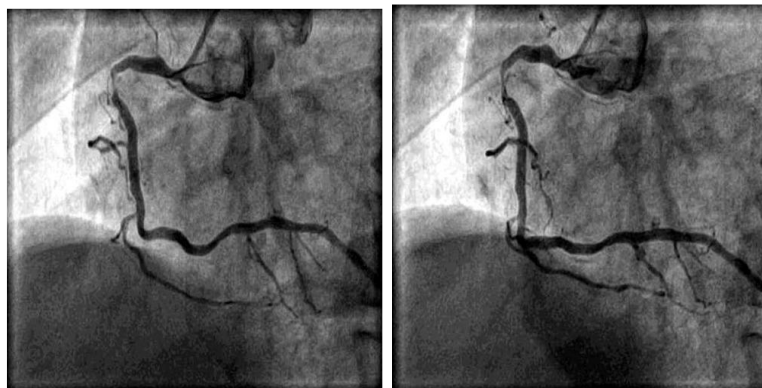**Figure 4. Extracted Keyframe from the video using absolute difference of histogram method**

Figure 5. Extracted Keyframe from the video using proposed method

Table 1. Evaluation of the Absolute Difference of Histogram Method

Video ID	Video size	Frames	Keyframes
Video_1	27.5 MB	63	6
Video_2	22.4 MB	50	5
Video_3	18.7 MB	51	6

    Table 1 summarizes the video size, Frames and Number of keyframe extracted using absolute difference of histogram method. Video size are different for each video: video_1 is 27.5MB, video_2 is 22.4MB and video_3 is 18.7MB. According to the video size the number of frames and keyframes also varies. Number of frames riven from the video_1 is 63, video_2 is 50 and video_3 is 51. The keyframe extracted from the video_1 is 6, video_2 is 5 and video_3 is 6.

Table 2. Evaluation of the Proposed Keyframe Extraction Method

Video ID	Video size	Frames	Keyframes
Video_1	27.5 MB	63	2
Video_2	22.4 MB	50	2
Video_3	18.7 MB	51	2

Table 2 summarizes the video size, Frames and Number of keyframe extracted using proposed method. The keyframe extracted from the video_1 is 3, video_2 is 2 and video_3 is 2. So, our proposed method resulted 2 Keyframes for video_1, 2 keyframes for video_2 and 2 keyframes for video_3 that is a lesser number of keyframe extracted from the existing method. Extracted Keyframes has complete structure of artery, which helps to go for further process like detect and recognize the blockage in the frames.

5. PERFORMANCE EVALUATION

Keyframes are generally specifies the prominent content of the entire frame; the information in this keyframe obtained from the angiogram video must have the clear vision of the artery. To evaluate the proposed method and to make sure that keyframe extracted deserves to present the entire artery, compression ratio and fidelity measure are Figured. Compression ratio (CR) is used to know the compactness of the frame due to the number of frames from angiogram video and number of extracted keyframes from angiogram video. Compression ratio is calculated by the equation.

$$CR = \frac{Total\ number\ of\ frame\ in\ angiogram\ video}{Number\ of\ keyframes\ extracted} \qquad (4)$$

The comparison of compression ratio presented in Figure 6 for keyframe extraction. Proposed method gives high CR value compare to absolute difference of histogram method. If the compression ratio value increases, then the quality of the image is good.
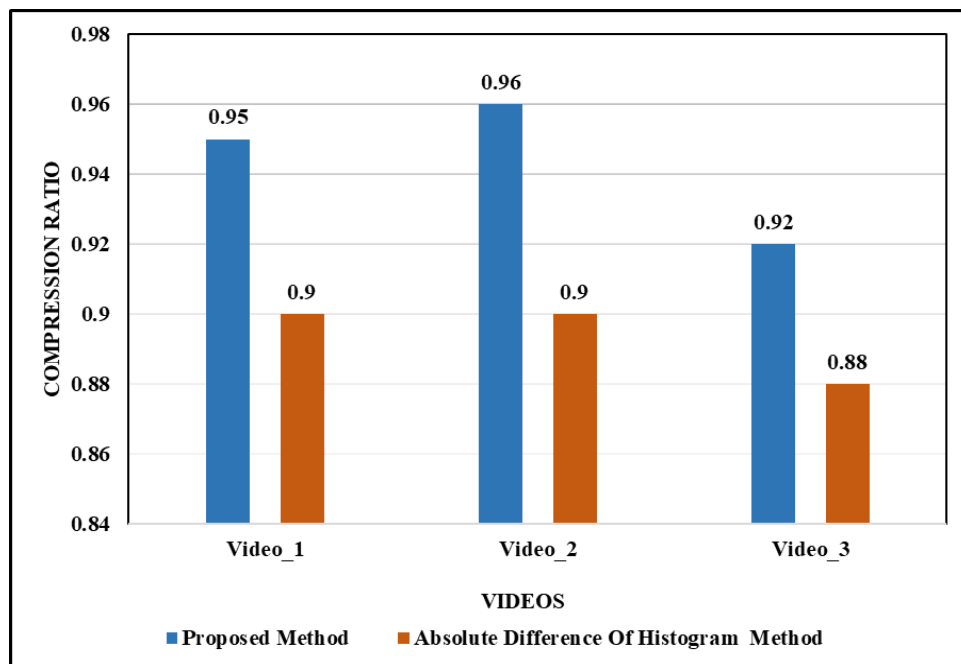

Figure 6. Comparative analysis in terms of Compression Ration
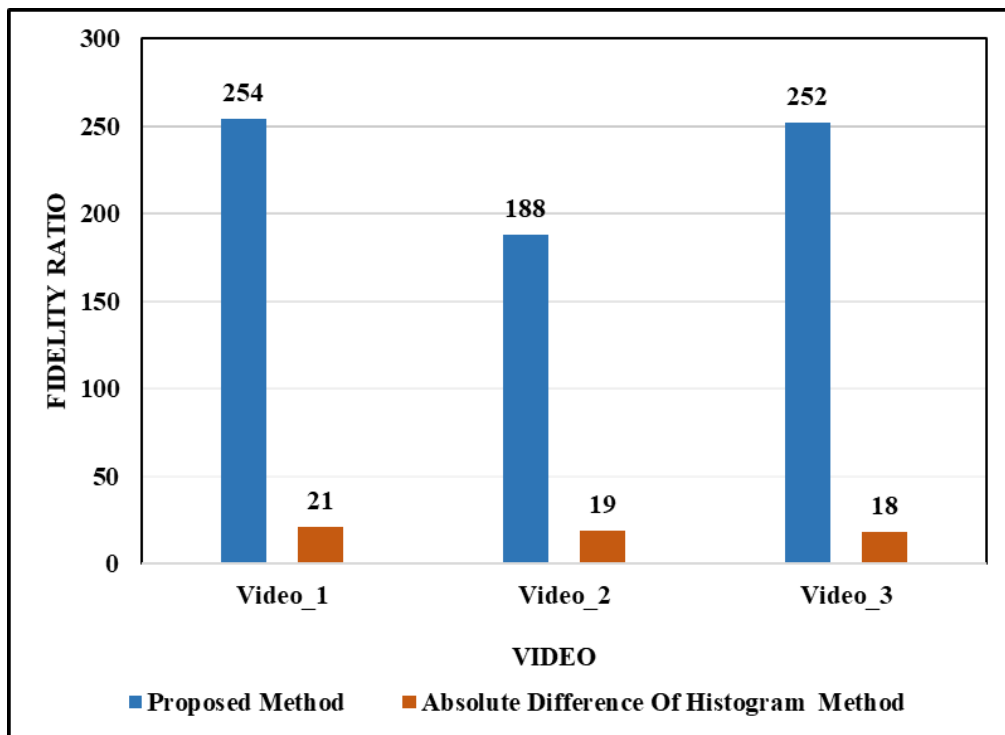
Figure 7. Comparative analysis in terms of Fidelity

Fidelity measure[20] is calculated as the maximum of the minimum distance between the keyframe set and the angiogram video frames set. The Fidelity is calculated by using following equations.

$$d_j = mini(dis(V, R)) \tag{5}$$

V – Frames obtained from angiogram video
R – Extracted keyframes from the angiogram video
dis – distance between V and R
Semi-Hausdorff distance between R and V is

$$d_{sh} = \max(d_j) \tag{6}$$

$$Fidelity = \frac{(1 - d_{sh})}{\max(\max(d_j))} \tag{7}$$

Fidelity shows that the keyframe extracted has a whole picture among the angiogram video sequence.

The comparison of Fidelity from the extracted keyframes is presented in Figure 7. In this Proposed method gives high fidelity value compare with the absolute difference of histogram method. The values of Fidelity and compression ration illustrate that the keyframes obtained by this research work was optimum.

6.   CONCLUSION

In this paper a proposed method for automatic keyframe extraction for angiogram video is implemented. Extracting keyframe is a time-consuming technique, it helps to do further processing like segmentation and recognition. In this proposed method frames are riven from the coronary angiogram video. In pre-processing, first black area in the frame is removed using threshold method, then frame is enhanced by Top hat Morphological operation. By calculating the

connected components properties and comparing the Maximum connected component in the frames, keyframes are selected from the angiogram video. Also, existing absolute difference of histogram method is implemented in these angiogram videos to compare proposed method. Keyframes extracted using proposed method are clear view comparing to existing method. Complete structure of the artery is visible in the keyframes, these keyframes help the cardiologist and radiographer to detect the stenosis in the artery.

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