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Video Key Frame Extraction using Thepade's Transform Error Vector Rotation with Sine, hartley, Slant and Assorted Similarity Measures

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Abstract
A video is made up of frames. Generally video processing applications demand to process each video frame one by one, but processing each frame consumes lot of time; video content summarization helps in improvising the processing speed such applications. Key frames in video are considered for content summarization. Key frame is a frame in which there is a major change as compared to the previous video frames. Hence key frame extraction becomes very important in Video Content Summarization. In applications needing content summarization, like data storage, retrieval and surveillance, key frames extraction plays a vital role. In this paper, novel key frames extraction method is proposed with Thepade's Sine Error Vector Rotation (TSEVR), Thepade's Hartley Error Vector Rotation (TH_lEVR) and Thepade's Slant Error Vector Rotation (TS_lEVR) with ten different codebook sizes and assorted similarity measures. Experimentation done with help of the test bed of videos has shown that higher codebook sizes give better completeness in key frame extraction for video summarization. Experimental results are discussed for video content summarization with five assorted similarity measures like Euclidean Distance, Canberra Distance, Square-Chord Distance, Mean Square Error, Sorensen Distance with proposed TSEVR, TH_lEVR and TS_lEVR. Overall Euclidean distance gives better Keyframe extraction. The Thepade's Sine Error Vector rotation based keyframe extraction gives better performance with Euclidean Distance at codebook size 1024 among the considered variations in the paper.

Keywords— key frame; video summarization; vector quantization; Sine; Hartley; Slant

I. INTRODUCTION

Many research efforts have been done in field of key frame extraction from video since a long time. It started in early 90's with the emergence of video indexing, summarization and retrieval for fast browsing and efficient handling of video. With the day by day increasing amount of video data, it becomes increasingly difficult to browse and retrieve them for the purpose of selection of appropriate video element. Due to the uncertain length and formats of videos, accessing them still remains a challenge. Key frame extraction is an important step for processing of videos. Entire video can be mapped into a small numbers of representative frames called key frames [1].

Video summarization is one of the most important topics, which potentially enables faster browsing through large video collections and efficient content indexing and access. Essentially, this research area consists of automatically generating a short summary of a video, which can either be a static summary or a dynamic summary. Static video summaries are composed of a set of key frames extracted from the original video, while dynamic video summaries are composed of a set of shots and are produced taking into account the similarity or domain-specific relationships among all video shots [2].

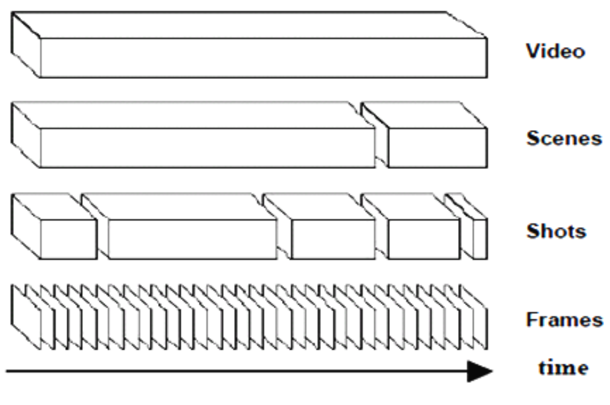

Fig. 1. **Structural hierarchy of a video Signal in terms of shots and scenes**

As shown in Fig. 1, videos are structured according to a descending hierarchy of video clips, scenes, shots, and frames.

Video structure analysis aims at segmenting a video into a number of structural elements that have semantic contents, including shot boundary detection, key frame extraction, and scene segmentation [3]. It is very important to understand the concept of Video Structure to do some improvement in the state of art of video processing.

II. LITERATURE SURVEY

As the name implies, video summarization is a mechanism for generating a short summary of a video, which can either be a sequence of stationary images (key frames) or moving images (video skims) [4]. Video summarization can be done by using key frames and video skimming. The detailed survey of video processing and video content summarization can be discussed with the few considerations as techniques.

A. Methods of Video Content Summarization

The Key frame based video summarization is sequence of still image abstract or static story board. It consists of a collection of salient images which are extracted from the video structure. These key frames are also called as representative frames. Video skim based video summarization is a sequence of moving- image abstract or moving story board. The original video is segmented into various parts which is a video clip with shorter duration. The trailer of movie is the best example for video skimming.

Video shot is retrieved among other similar frames. The key frame extraction is not only used for video summarization, but also applied in other video processing such as video annotation, video transmission, video shot detection, video segmentation, video indexing and retrieval etc. The work area of key frame extraction is so wide and rich. Many techniques for key frame detection have been reported and lots of work is done so far in video content summarization. With some relative research work done few things have been identified as basis for key frame extraction intended for video content summarization.

B. Video Content Summarization Using Key frame Extraction

Before A video summarization is a summary which represents abstract view of original video sequence and can be used as video browsing and retrieval systems. It can be a highlight of original sequence which is the concatenation of a user defined number of selected video segments or can be a collection of key frames. Different methods can be used to select key frames. Three different approaches for key frame extraction based video summarization are studied and for the proposed work the classification based sampling is considered.

- ***Classification based on sampling -***

It chooses key frames uniformly or randomly under-sampling, without considering the video content. The summary produced by these methods does not represent all the video parts and may cause some redundancy of key frames with similar contents.

- ***Classification based on scene segmentation-***

It extracts key frames using scenes detection, the scene includes all parts with a semantic link in the video or in the same space or in the same time. The disadvantage of these techniques is producing a summary, which does not take into account the temporal position of frames.

- ***Classification based on shot segmentation-***

It extracts adapted key frames to video content. They extract the first image as shot key frames or the first and the last frames of the shot. These methods are effective for stationary shot and small content variation, but they don't provide an adequate representation of shot with strong movements.

III. PROPOSED KEY FRAME EXTRACTION USING DIFFERENT CODEBOOK GENERATION ALGORITHM

Vector quantization (VQ) is one of the popular lossy data compression techniques which includes the process of clustering. In vector quantization, codebook is generated for each frame as signature which is calculated according to a specific VQ algorithm. In other words, Vector Quantization is mapping function that maps *k* dimensional vector space to finite set $CB = \{C_1, C_2 ... C_N\}$. The set CB is called a codebook consisting of N number of code vector and each code vector $Ci= \{c_{i1},c_{i2}....c_{ik}\}$ is of K dimension [5]. Here ten different Codebooks sizes like 2, 4, 8, 16, 32, 64, 128, 256, 512 and 1024 are used. The method most commonly used to generate codebooks is the Linde-Buzo-Gray (LBG) algorithm [6].

Vector quantization is used in many application like face detection, iris recognition biometric identification image retrieval etc. In LBG algorithm some drawbacks like cluster elongation and constant error vector addition are observed. To overcome this drawback Thepade et. al. [7] have desired codebook generated in spatial domain by clustering algorithms

A. Thepade's Sine Error Vector Rotation (TTEVR) Codebook Generation Algorithm

The Discrete Sine Transform (DST) is related to Discrete Fourier Transform (DFT). DST is used to represent signal in terms of a sum of sinusoids with its different frequencies and amplitudes [8]. However DST is not the imaginary part of FFT. To obtain DST of a digital signal, elements of the signal are reconfigured as an odd (anti-symmetric) extension of the input and then applying FFT. Total numbers of input as well as total number of DST coefficients are the same.

In Thepade’s Sine Error Vector Rotation (TSEVR) algorithm the positive and negative values of Discrete Sine transformation matrix are replaced respectively with 1’s and -1’s to obtain the Cosine error vector matrix. Where each row of Cosine error matrix E_i for i^{th} row will be error vector to be added and subtracted from the centroid of cluster and two vectors v1 and v2 are generated. This gives effective clustering. This algorithm performs very well at moderate bit rates and gives higher compression ratio. Fig. 2 shows Thepade's Sine error vector of size 8 x 8.

1	1	1	1	1	1	1	1
1	1	1	1	1	1	-1	-1
1	1	1	1	-1	-1	-1	-1
1	1	1	-1	-1	-1	1	1
1	1	-1	-1	-1	1	1	-1
1	1	-1	-1	1	1	-1	-1
1	1	-1	1	1	-1	-1	1
1	1	-1	1	1	-1	1	1

Fig. 2. **Thepade's Sine Error Vector of size 8×8**

B. Thepade's Hartley Error Vector Rotation (TH$_l$EVR) Codebook Generation Algorithm

The Discrete Hartley transform, was introduced by R. N. Bracewell in 1983. A Discrete Hartley transform (DHT) is a Fourier-related transform of discrete, periodic data similar to the Discrete Fourier transform (DFT), with analogous applications in signal processing and related fields. Its main distinction from the DFT is that it transforms real inputs to real outputs, with no intrinsic involvement of complex numbers. The DHT is the discrete analogue of the continuous Hartley transform, introduced by R. V. L. Hartley in 1942 [9],[10].

The positive and negative values of Discrete Hartley transformation matrix are replaced respectively with 1's and -1's to obtain the Thepade's Hartley error vector matrix which is to be used in proposed codebook generation algorithm Thepade's Hartley Error Vector Rotation (THtEVR), where each row of Thepade's Hartley error matrix E_i for i^{th} row will be error vector to be added and subtracted from the centroid of cluster and two vector v1 and v2 are generated. Although the DHT is defined for both real and complex sequences, its practical values arise from the way in which it takes advantage of the symmetry in DFT of real sequence. Thus DHT provides effective clustering. Fig. 3 shows Hartley error matrix of size 8 x 8.

$$E = \begin{bmatrix} e1 \\ e2 \\ e3 \\ . \\ . \\ . \\ . \\ e8 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & 1 & -1 & -1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \end{bmatrix}$$

Fig. 3. **Thepade's Hartley Error Vector of size 8×8**

C. Thepade's Slant Error Vector Rotation (TS$_l$EVR) Codebook Generation Algorithm

The slant transform was proposed by Enomoto and Shibata in 1971.The slant transform is a non sinusoidal orthogonal transform containing saw-tooth waveforms or 'slant' basis vector. A slant basis vector that is monotonically decreasing in constant steps from maximum to minimum has the sequence property and has fast computing algorithm. The lowest order slant matrix is 2 which is identical to 2 x 2 Haramard matrix. The higher order slant matrix can be generated by recursive relation [11].

In Thepade's Slant Error Vector Rotation (TS$_l$EVR) error vector is generated by replacing positive and negative values of Slant matrix are replaced with 1's and -1's respectively. In TS$_l$EVR codebook generation algorithm, where each row of Slant error matrix E_i for i^{th} row will be error vector to be added and subtracted from the centroid of cluster and vector v1 and v2 are generated. Slant transform is real and orthogonal i.e. $S=S^*$ and $S^{-1} = S^T$. It is a fast transform and provides good energy compaction. Fig. 4 shows Thepade's slant error vector of size 8 x 8.

$$E = \begin{bmatrix} e1 \\ e2 \\ e3 \\ . \\ . \\ . \\ . \\ e8 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \end{bmatrix}$$

Fig. 4. **Thepade's Slant Error Vector of size 8×8**

Steps for Thepade's Transform Error Vector Rotation with Sine or Slant or Hartley are explained as follow.

Step 1: Separate R, G, B components of the image are split into non overlapping blocks and convert each block to vector thus forming a training vector set Initialize i=1.

Step 2: Take a column wise mean of training vector and compute a centroid (codevector).

Step 3: Use Sine or Slant or Hartley transform matrix and form a Thepade's transform Error Vector E.

Step 4: Add and subtract error 'e_i' in codevector and form a two codevectors v1 and v2.

Step 5: Compute Euclidean distance between all the training vectors belonging to this cluster and the vectors v_1 and v_2 and split the cluster into two.

Step 6: Compute a centroid (codevector) for respective clusters obtained in the above Step 7.

Step 7: Increment 'i' by one and repeat Step 2 to Step 6 for each codevector and for desired codebook size is obtained

step 8: Stop.

D. Key Frame Extraction

A video consisting of 'N' number of frames is taken as an input with consecutive frames be 'Vn' and 'Vn+1' having feature vectors respectively for n^{th} and $n+1^{th}$ frame as 'FVn' and 'FVn+1'. The diff(n) be the difference between two consecutive video frame feature vectors. The feature vectors taken m proposed techniques are codebooks generated using TSEVR, TS$_l$EVR TH$_l$EVR with Sine, Slant and Hartley transform respectively. Here five similarity measures are used to calculate the diff(n) in proposed method as mean square error(MSE), Euclidean Distance, Canberra Distance, Squared-Chord Distance, and Sorensen Distance. Calculating diff(n) Mean(M) and standard deviation(SD) of all the video frames are calculated based on the five assorted similarity measures considered. The Threshold(T) value is computed by adding mean and multiplying constant 'a' with standard deviation. By comparing the threshold with the difference of consecutive video frames the key frames are computed as given in equation (1), (2) and (3).

$$Mean(M) = \frac{\sum_{n=1}^{N} diff(n)}{N-1} \quad (1)$$

$$SD = \sqrt{\frac{\sum_{n=1}^{N} (diff(n) - M)^2}{N-1}} \quad (2)$$

$$T = M + (a \times SD) \quad (3)$$

Here 'a' as a constant and after this calculate a key frame using If (diff (n) > T) output of n^{th} frame set as a key frame [12] [13].
Then, following similarity measures are used for calculate difference diff(n):

1) Mean Square Error (MSE)-
The Mean Square Error can be represented mathematically by the equation (4).

$$MSE = \frac{1}{N} \sum_{c=1}^{N} [V_c - V_{c+1}] \quad (4)$$

2) Euclidean Distance (ED)-
The Euclidean distance between two frame defined as an equation (5).

$$ED = \sqrt{\sum_{c=1}^{N} |V_c - V_{c+1}|^2} \quad (5)$$

3) Square-Chord Distance (SC)-
The equation (6) gives a representation of SC.

$$SC = \sum_{C=1}^{N} \left[\left[\sqrt{V_c} - \sqrt{V_{c+1}} \right] \right]^2 \quad (6)$$

4) Canberra Distance (CAB)-
Representation of Canberra distance is given in equation (7).

$$CAB = \sum_{c=1}^{N} \frac{|V_c - V_{c+1}|}{V_c + V_{c+1}} \quad (7)$$

5) Sorensen Distance (SD)-
The Sorensen distance between consecutive frames are calculated by equation (8).

$$Sorensen = \frac{\sum_{c=1}^{N} |V_c - V_{c+1}|}{\sum_{c=1}^{N} V_c - V_{c+1}} \quad (8)$$

Mean square error, Euclidean Distance from La family[14], Sorensen and Canberra are from L_1 Famiily[14] Square chord belong to the Fidelity family[14] and after using this follow the same process explain in key frame extraction.

IV. USING THE TEMPLATE

The key frame extraction using Thepade's Transform Error Vector Rotation (TTEVR) with Sine, Slant and Hartley is implemented with Matlab. The experiment is performed with Intel i5 with 4 GB RAM. In all 15 videos are taken with 150 initial frames per video for experimentation. The test bed used for experimentation of 15 videos is as given in Fig. 5.

Fig. 5. **Sample Video of Dataset Used**

V. RESULTS AND DISCUSSIONS

The proposed algorithm is used for key frame detection from videos and key frames are extracted. These frames are compared with the key frames extracted manually from the same videos. The completeness [12] [13] [15] of the algorithms is calculated by equation (9).

$$Completness = \frac{Actual\ correct\ extracted\ frames}{Total\ expected\ extraction\ of\ frames} \quad (9)$$

Actual correct extracted frames means correct key frames extracted from video using proposed algorithms. Total expected extraction means actual key frames present in videos.
In Fig.6 some key frame extracted of 'Direction number' video by the proposed algorithm are shown.

Fig. 6. **Key Frame Extracted for Proposed Algorithm of Direction Video**

Table I, shows the completeness for different codebook sizes for Thepade's Sine Error Vector Rotation (TSEVR) Table II shows for Thepade's Slant Error Vector Rotation (TS_lEVR) and Table III shows for Thepade's Hartley Error Vector Rotation (TH_lEVR) for the videos from the video test bed. Higher codebook sizes give better Completeness values. It also shows that the Euclidean distance gives better performance than that of other similarity measures used here. Sorensen also gives better completeness followed by that of Euclidean distance. Also in Fig. 7, Fig. 8 and Fig. 9 shows the graphical representation of completeness of different codebook sizes of TTEVR with Sine, Slant and Hartley respectively for key frame extraction algorithms with different similarity measures. Overall Euclidean Distance gives best Performance for the all codebook sizes and all Thepade's Transform Error Vector rotation (TTEVR) algorithm used in video key frame extraction. So in Fig. 10 results of all TTEVR algorithms with Euclidean Distance are compared. From That results it can be observed that TTEVR with Sine gives highest Percentage of Completeness than other TTEVR algorithms.

TABLE I. **PERCENTAGE OF COMPLETENESS FOR DIFFERENT CODEBOOK SIZES OF TSEVR DIFFEREN SIMILARITY MEASURES USED IN VIDEO KEY FRAME EXTRACTION**

	TSEVR with different Codebook Sizes									
Code book Sizes Videos	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**256**	**512**	**1024**
Canberra	54.67	51.24	58.25	52.95	52.50	54.81	53.12	39.89	32.35	18.68
Euclidean Distance	55.59	53.88	60.21	62.87	68.79	74.25	83.55	73.72	80.09	86.06
MSE	33.83	34.02	41.71	45.15	49.80	61.64	74.01	66.17	68.11	76.89
Square Chord	31.64	34.71	41.46	41.44	49.09	54.64	73.23	66.17	63.91	72.38
Sorensen	53.42	51.58	59.10	59.58	59.69	68.72	77.46	69.45	71.76	73.90

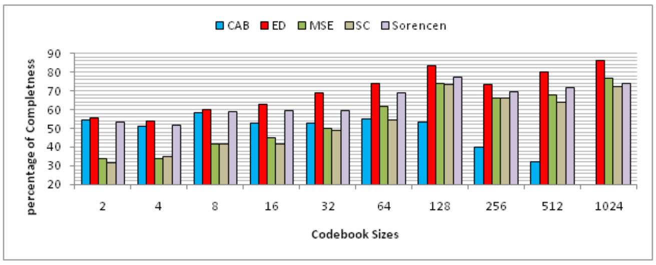

Fig. 7. **Percentage Completeness for Different codebook sizes of TTEVR with Sine algorithm (TSEVR) for Proposed Key frame Extraction Technique**

TABLE II. **PERCENTAGE OF COMPLETENESS FOR DIFFERENT CODEBOOK SIZES OF TS_lEVR DIFFEREN SIMILARITY MEASURES USED IN VIDEO KEY FRAME EXTRACTION**

	TS_lEVR with different Codebook Sizes									
Code book Sizes Videos	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**256**	**512**	**1024**
Canberra	54.67	51.24	58.25	52.95	52.50	54.81	53.12	39.89	32.35	18.68
Euclidean Distance	52.59	51.88	58.21	60.87	66.79	72.25	81.55	71.72	79.09	83.06
MSE	33.83	34.02	41.71	45.15	49.80	61.64	74.01	66.17	68.11	76.89
Square Chord	31.64	34.71	41.46	41.44	49.09	54.64	73.23	66.17	63.91	72.38
Sorensen	53.42	51.58	59.10	59.58	59.69	68.72	77.46	69.45	71.76	73.90

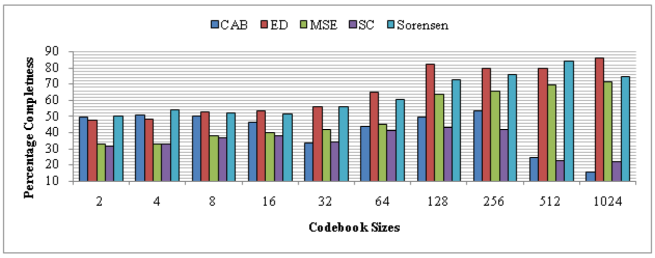

Fig. 8. **Percentage Completeness for Different codebook sizes of TTEVR with Slant algorithm (TS_IEVR) for Proposed Key frame Extraction Technique**

TABLE III. **PERCENTAGE OF COMPLETENESS FOR DIFFERENT CODEBOOK SIZES OF TH_IEVR DIFFEREN SIMILARITY MEASURES USED IN VIDEO KEY FRAME EXTRACTION**

	TH_IEVR with different Codebook Sizes									
Code book Sizes Videos	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**256**	**512**	**1024**
Canberra	52.21	58.35	60.80	62.37	60.70	67.45	52.82	50.79	42.47	24.52
Euclidean Distance	56.18	58.51	60.17	60.55	67.89	73.39	80.85	72.57	74.83	82.11
MSE	34.72	38.04	40.92	41.90	52.11	62.86	62.61	60.12	61.26	71.33
Square Chord	35.80	36.37	38.99	41.37	49.82	60.09	65.67	62.44	61.13	73.66
Sorensen	55.82	53.21	62.32	58.94	62.19	71.52	75.70	73.72	72.27	68.34

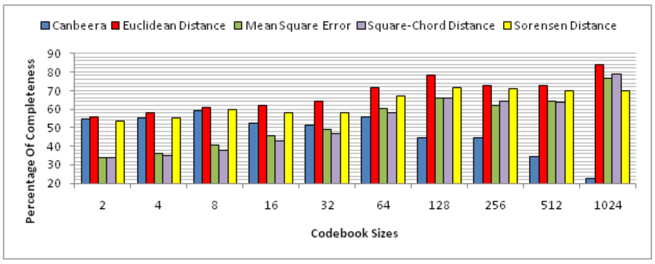

Fig. 9. **Percentage Completeness for Different codebook sizes of TTEVR with Hartley algorithm (TH_IEVR)for Proposed Key frame Extraction Technique**

Fig. 10. **Percentage Completeness Performance Comparison Betwwen LBG, TSEVR, TS_IEVR and TH_IEVR with Euclidean Distance and different Codebook Sizes**

VI. RESULTS AND DISCUSSIONS

In this paper a novel key frame extraction technique for video content summarization using Thepade's Transform Error Vector Rotation (TTEVR) with Sine, Slant and Hartley codebook generation methods of vector quantization is proposed and experimented for various codebook sizes and assorted similarity measures with a video test bed. The performance of the variations of proposed key frame extraction method is done using percentage completeness. The experimentation results have given better completeness percentage with higher TTEVR codebook sizes. For all TTEVR codebook of size 1024 Euclidean distance give better key frames for video content summarization followed by the Sorensen Distance.

Thepade's Sine Error Vector Rotation (TSEVR) gives better completeness than that other vector quantization algorithm i.e. Linde-Buzzo-Gray (LBG), Thepade's Slant Transform Error vector Rotation (TS_IEVR), Thepade's Hartley Transform Error vector Rotation (TH_IEVR) codebook generation algorithm.

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