Image Mosaicing with Strip Search Algorithm based on a Novel Similarity Measure

Kantilal P.Rane
Associate Professor
Godavari COE Jalgaon (India)

S.G.Bhirud
Professor
VJTI, Mumbai (India)

ABSTRACT
A novel mosaic technique based on Strip Search Algorithm is proposed that improves non-linearity, accuracy and vertical distortions possibly found in mosaic image. Strip Search Algorithm based on novel measure of Relative- Sum of the Squared Difference (R-SSD) is proposed to search particular strip of frame within its specified portion and it is used for normalization and simplification of some important steps of image mosaic. Steps like key frames selection, frames registration, their transformation and combination are suggested for mosaic creation. An optimal criterion is suggested for key frames selections. Hierarchical Seam Line Estimation and Vertical Strip Registration are introduced for precise image warping and distortion-less vertical transformation. Structural linearity, precision and non-deformation property reflects from mosaic results of proposed algorithm.

Keywords: Image stitching; Image registration; Similarity measure; Key frame selection.

1. INTRODUCTION
Combination of two or more images to get very big and high resolution image is called as Image Mosaicing. High resolution image of very large field of view cannot be captured by single shot of any camera as the camera's field of view is smaller than the human field of view, so it is required to get different snap of that scene and combination of those images will give us high resolution mosaic image. With this image mosaicing, we can go for video mosaicing. In video mosaicing we take video of that scene and the combination of all the frames of that video gives us panoramic high resolution image. Small spatial variations between every two consecutive frames of video are required to find for their combination. Instead of that we can find optimal variations between key frames of video for reducing high redundancy in number of frames.

Image mosaics includes many vision problems of image registration like feature extraction [1,2,3], correspondence matching [1,2,3,4,5]. It also includes spatial transform [6,7] and image blending [3,4,5,8,9]. All these were repeated recursively for all the pairs of consecutive frames for video mosaic.

To reduce redundancy and cumulative error with increasing the number of frames of video, automatic key frame selection is necessary.

More precise registration process is suggested through Hierarchical Seam Line Estimation. It includes Primary Seam Line Estimation, Approximate Seam Line Estimation and Exact Seam Line Estimation. Feature extraction and correspondence matching processes are included in Approximate Seam Line Estimation process. Accuracy and precision are maintained with Exact Seam Line Estimation. Vertical distortions between frames of video are removed with Vertical Strip Registration.

A novel measure of similarity is proposed to demand for unique, finite and non-spatial value of variations between two images. We modified the spatial measure of Sum of squared difference (SSD) between two images for fulfilment of required demand. This measure is utilized in many steps of mosaic methods.

2. METHODOLOGY
Basically more emphasis had been given on horizontal registration by most of the authors [1,2,3] for mosaicing of image frames. Seam line is the line across the overlapping portion of video frames. Obviously this line is vertical line and required to horizontally register properly for video taken in horizontal direction.

We mainly focus our attention on Hierarchical Seam Line Estimation and Vertical Strip Registration during our work.

Based on the study, a novel Strip Search Algorithm has been devised. Figure 1 shows the use of this proposed Strip Search Algorithm in various steps of image mosaicing.

2.1. Proposed Strip Search Algorithm based on a novel Similarity measure: R-SSD
Image mosaicing technique based on Strip Search Algorithm has been used by various researchers [10,11,12]. We implemented a novel algorithm under the Strip Search logic which is based on a new similarity measure between two strips as shown in Fig.1.

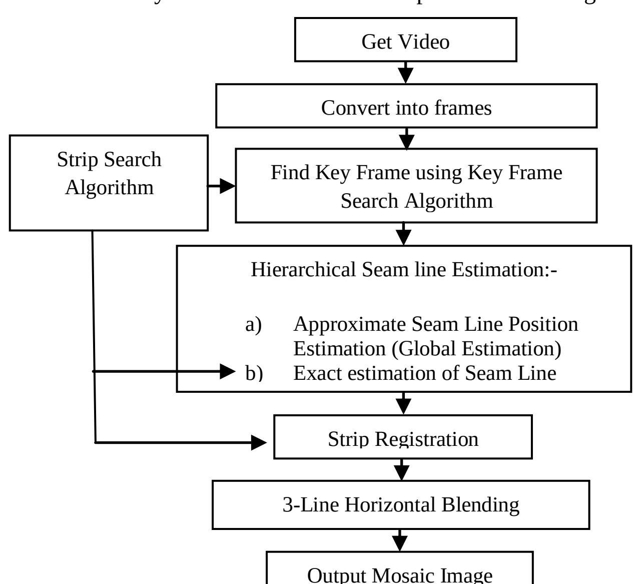

Fig 1: Flow diagram of mosaic process

Suppose a strip on key frame 1 is required to search between the different strips on key frame 2. The similarity model is defined by equation 1.

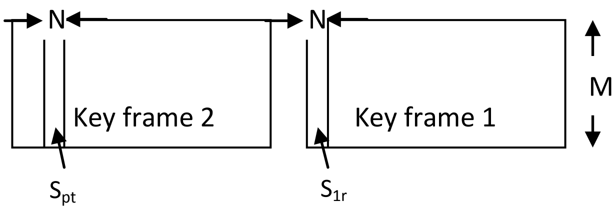

Fig 2: Frames demonstrating strip searching process

Let, $s_{1r}(m,n,l)$ *and* $s_{pt}(m,n,l)$, *for all*, $m = Y$ *to* $Y + M$, $n = X$ *to* $X + N$, $l = 1$ *to* 3, be the two strips of height M and width N at position [X,Y] of respective reference and target strips as shown in Fig 2. Objective strip $s_{1r}(m,n,l)$ is to be searched within the strips $s_{1t}(m,n,l)$, $s_{2t}(m,n,l)$ upto $s_{pt}(m,n,l)$ for optimal similarity.

Optimal Similarity ($Opt\_Similarity$) is calculated as,

$$Opt\_Similarity = Maximum\left(Similarity_{P=1:p}\left(\left(s_{1r}(1{:}\mathrm{M}, 1{:}\mathrm{N}, l),\ s_{pt}(1{:}\mathrm{M}, (\mathrm{p}-1)*\mathrm{N}{:}(\mathrm{p}*\mathrm{N})-1, l)\right)\right)\right)$$

$$for\ all,\ l = 1\ to\ 3, \qquad \text{----1}$$

We proposed Maximum of Relative Variation in sum of the Squared difference (R-SSD) of all the pixels of two images for similarity measurement.

Steps to find similarity between two images are as below:-

1) Find Sum of the Squared Difference (SSD)[12,13,14] for all the pixels of two images == $[N \times M]$.

$$SSD(i,j) = \sum_k \left(\left(s_{1r}(i,j,k)\right)^2 - \left(s_{pt}(i,j,k)\right)^2 \right),$$

$$for\ all\ i = 1\ to\ M,\ j = 1\ to\ N,\ k = 1\ to\ 3 \qquad \text{----2}$$

2) Find Horizontal Accumulation of the SSD, called HA_SSD.

$$HA\_SSD(i) = \sum_j SSD(i,j),$$

$$for\ all\ i = 1\ to\ M,\ j = 1\ to\ N. \qquad \text{----3}$$

3) Find Vertical Accumulation of HA_SSD at every row. This term is also called Cumulative-Difference (CD_SSD).
Initially set $CD\_SSD(0) = 0$,

Then find,

$$CD\_SSD(i) = CD\_SSD(i-1) + HA\_SSD(i),$$
$$for\ all\ i = 1\ to\ M. \qquad \text{----4}$$

4) Relative Variation in CD_SSD, called $RVCSD$, is calculated by off-set difference of CD_SSD.
Off-set is considered here as small patch of image.

Let $off\_set = K,\quad j = i + K,$

$$RVCSD(i) = CD\_SSD(j) - CD\_SSD(i),$$

$$for\ all\ i = 1\ to\ M - K. \qquad \text{----5}$$

5) Similarity is calculated as

$$Similarity = Maximum(RVCSD) \qquad \text{----6}$$

2.2. Mosaic Method

Steps for Mosaic creation using proposed strip search algorithm are shown in Fig 1. Proposed Strip Search Algorithm contributing R-SSD measure has been used in Key Frame Selection, Hierarchical Seam Line Estimation and Vertical Strip Registration during process of image mosaic.

2.3. Key Frame selection

Instead of combining all the frames of video, key frames can be selected and stitched. Two criteria for the selection of key frames have been suggested by Ging Li as follows.

1) The maximum information of non-selected frame should be present in selected key frame. This lead minimum overlapping portion between two consecutive selected frames [14].

2) Those consecutive frames should be registered properly for better mosaic. Maximum points of corresponds gives better registration [14]. This leads overlapping portion between two frames should be maximum for good mosaic generation.

Above criteria seems to be contradictory therefore optimal criteria has been suggested to select the key frames.

We proposed the technique to select the frames for mosaicing with the optimal criteria that the information at one end of a frame is shifted at middle of another frame and middle information of first frame is shifted at another end of second frame (Figure 2) for proper registration, mosaic and optimal information to be visualized.

Initially strips at start end and middle of first frame are selected as shown in Fig 3.

Let $s_{1s}(m,n,l)$ *and* $s_{1m}(m,n,l)$, *for all* $m = Y$ *to* $Y + M$, $n = X$ *to* $X + N0$, $l = 1$ *to* 3, be the two strips of height M and width N0 at position [X,Y] of respective start and middle position of first frame.

And similarly, $\boldsymbol{s_{fm}(m,n,l)}$ ***and*** $\boldsymbol{s_{fe}(m,n,l)}$, ***for all*** $\boldsymbol{m = Y\ to\ Y + M,\ n = X\ to\ X + N0,\ l = 1\ to\ 3}$, be the two strips of height M and width N0 at position [X,Y] of respective middle and end position of next f^{th} frame.

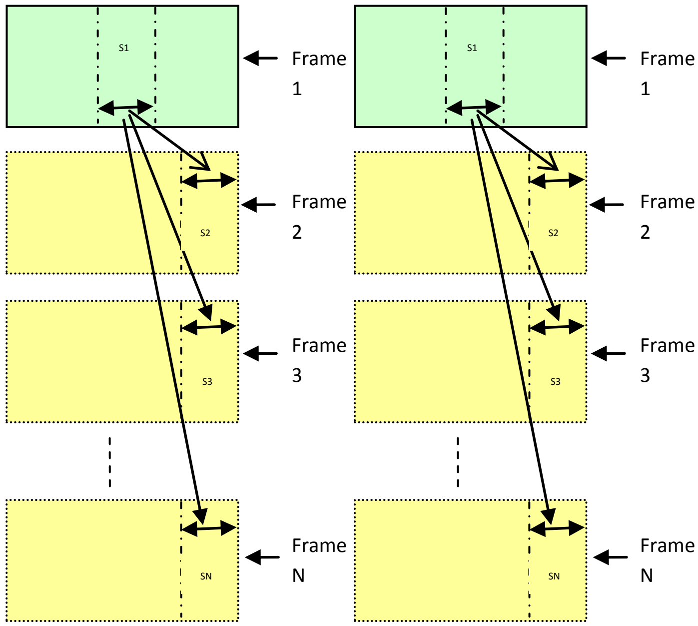

Fig 3: Optimal similarity search process using Strip Search Algorithm

Optimal Similarity MS_sm between the strips at the start of first frame and strip at the middle of all frames are calculated. Similarly, Optimal Similarity MS_me between the strips at the middle of first frame and strip at the end of all frames are calculated.

Frame with the identifier f of maximum of MS_sm and MS_me, is considered as optimal similarity frame of identifier $f = f_{max}$ and it is considered as reference frame for next frame to be selected.

2.4. Approximate Seam Line position Estimation using Global Motion Estimation

It is assumed that Key frame Estimation Technique points strip at the middle position as primary estimation of position of seam line.

$$Primary\ Estimation = \widehat{Pe} = \frac{N}{2} \qquad \text{----7}$$

Obviously more precise seam position can be estimated by estimating relative / global motion between those overlapping portions from the next frame.

Following steps are considered for global motion estimation:-

1) Corner detection (Harris corner detection [1]).
2) Initial matching (Correlation matching [15]).
3) Final matching (ransac [2,3]).
4) Local motion estimation (Distance vectors of matched corners [2,3]).
5) Global motion estimation (Distance vector having maximum frequency (v_{dx})).

Seam line position is then approximated by adding maximum distance vector to its primary position obtain using *equation (8).*

$$Approximate\ Estimation = \widehat{Xe} = \widehat{Pe} + v_{dx} \qquad \text{----8}$$

2.5. Exact Estimation of Seam Line Position

In order to estimate seam line position, strip at end portion of first frame is selected. The strip size is taken as small as possible. Its exact position in middle part of second frame may be some pixels forward or backward (defined by variance portion). This strip is moved physically along variance portion of second frame (Fig 4). Maximum similarity strip gives us exact position of seam line. The process is also carried out using proposed Strip Search Algorithm. Obviously this estimation of exact position of seam line implies horizontal registration of two frames.

Let MS_ev is the Optimal Similarity between end strip of first frame s_{1s} and strips along variance of second frames s_{2v} of width N and height M.

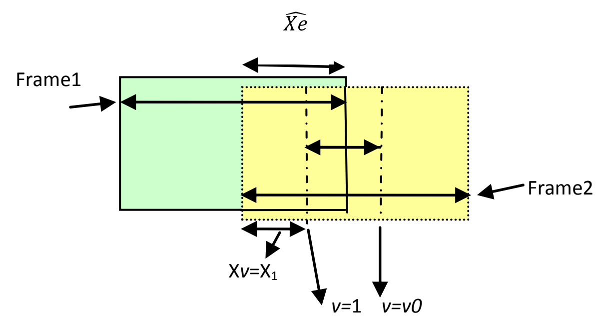

Fig 4: Process for Exact Estimation of Seam Line Position using Modified Strip Search Algorithm

Strip identifier $v = v_{max}$ of Ms_ev will give us Exact Estimation of Seam Line Position XXe.

$$XXe = \widehat{Xe} - \left(\frac{v0}{2}\right) + v_{max} \qquad \text{----9}$$

2.6. Strip Registration

Slight vertical displacement can take place while taking the video through camera in horizontal direction. Curve motion and slight slanted directional motion may also be obtained. It is necessary to consider vertical registration for panoramic mosaic process in all these cases. Strip search algorithm is again used here for vertical registration. Horizontally registered strip of first frame is cropped in half of the vertical size at middle of strip and it is moved from upper most to lower most portion of corresponding registered strip of second frame. Optimal similarity strip gives us vertical relative displacement (v_{dy}). It is assumed that this strip is vertically displaced by v_{dy} with respective to first frame. Second frame is then vertically transformed with amount of v_{dy}.

Vertical registration is shown in Fig 5. Strip S1 of height M and width N0 at end position of first frame (of width N) is horizontally registered with strip S2 of same height and width at position XXe of second frame during process of Exact Estimation of Seam Line Position. Strip S1 is cropped at middle in half of the vertical size, to get strip of S_{1h} and is moved along strip S2 in vertical downward direction. Optimal similarity in vertical registration (*MS_v*) is calculated.

Strip identifier $y=y_{max}$ of Ms-v will give us vertical displacement v_{dy}.

$$v_{dy} = \left(\frac{M}{2} - \frac{M}{4}\right) - y_{min} \qquad \text{-----}10$$

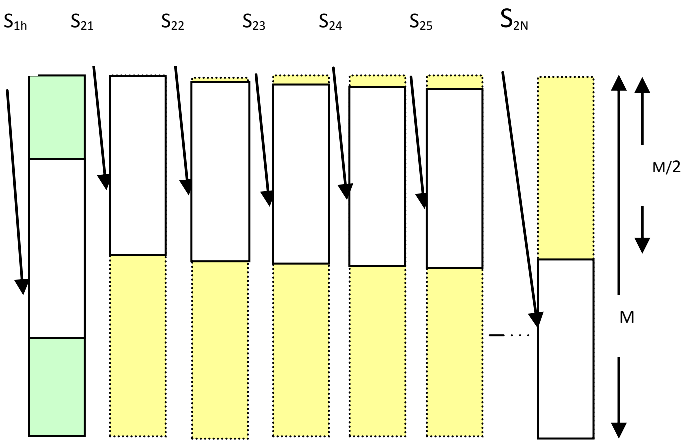

Fig 5: Process of Vertical Registration

2.7. Seamless blending

In the every pass of key frames, two registered frames are stitched horizontally. 3-Line Horizontal Blending Algorithm [33] is used here for this process. A multi-resolution technique is proposed for obtaining seamless blending.

The overall blending process consists of following steps:-

1) Create Laplacian pyramids of overlapping portion of two frames to different levels [17].
2) Blend two images at every level of Pyramids to get a new pyramid of blended images by using 3-Line Horizontal Blending Algorithm [18].
3) The blended pyramid is expanded to get resultant blended image [17].

All these processes are repeated recursively for all the pairs of selected frames to get panoramic mosaic image.

3. RESULTS

The proposed technique has been implemented on a video of Beach, consisting of 205 frames and video of train sequences consisting 345 frames.

Fig 6, Fig 7 and Fig 10 shows result of mosaicing on both the video using Space Time Manifold Technique, suggested by Wexler [10].

Figure 8 shows the mosaic result of video of Beach view by simple stitching horizontally registered frames. The method produces vertical lines (seam lines) in the mosaic image. The suggested multi-resolution blending process minimizes the effect of these vertical lines in mosaic image as shown in Fig 9. An object deformation problem occurs with the Space Manifold Technique [10] for different videos (at different speeds) of the same scene as seen in Fig 6 and Fig 7 with rectangle around moving person. Fig 9 shows that problem of object deformation is removed by applying the mosaic method suggested in this literature.

Fig 11 shows the mosaic image of Train Sequences after blending of horizontally registered frames (without vertical registration). Fig 10 and Fig 11 clearly points requirement of vertical registration in process of mosaic.

Mosaic image shown in Fig 12 is the result of proposed algorithm applied on Train Sequences. The distortion in the railings of bridge of railway line, observed in Figure 9 and Figure 10 are removed in Fig 12.

4. CONCLUSION

Result of mosaicing shows the comparatives of our algorithms with standard algorithmic processes. Used methodology is found powerful for mosaic creation. Linearity, non-deformation property is clearly visualized through the proposed mosaic method. Suggested new measure of similarity works well for total process and found effective for this work.

5. REFERENCES

[1] Gao Guandong Jia Kebin, "A New Image Mosaics Algorithm Based on Feature Points Matching", Second International Conference on Innovative Computing, Information and Control, 2007. ICICIC '07, 471 – 471, Sept. 2007.

[2] Lingjia Gu, JiLin Univ., Jilin, "An Automatic Target Image Mosaic Algorithm", The International Conference on "Computer as a Tool" EUROCON, 2007, 369 – 374, Sept. 2007.

[3] Wan, Yanli Miao, Zhenjiang Chen, Jing, "A Robust Image Mosaic Algorithm", Image and Signal Processing, 2008 Congress, 766 – 770, May 2008.

[4] Yanli Wan, Zhenjiang Miao, "Automatic panorama image mosaic and ghost eliminating", IEEE International Conference on Multimedia and Expo-2008**,** 945 – 948, April 26 2008.

[5] Yi Wang Camargo, A. Fevig, R. Martel, F. Schultz, R.R. "Image Mosaicking from Uncooled Thermal IR Video Captured by a Small UAV", IEEE Southwest Symposium on Image Analysis and Interpretation, 2008. SSIAI 2008, 161 – 164, March 2008.

[6] Melvin Sze-Ming Ni, Three-Dimensional Mapping and Navigation with Stereo Vision", Thesis of Aeronautics and Astronautics of Stanford University, December 2000.

[7] M.Brown, D.G.Lowe, "Recognising Panoramas" Proceddings of Ninth IEEE International Conference on Computer Vision (ICCV-03).

[8] Panli He, Xiaowei Han, Tianmin Deng, "A new method of color image mosaic", 7th World Congress on Intelligent Control and Automation, 2008. WCICA 2008**,** 7757 – 7761, June 2008.

[9] Yang, Guosheng -Zhang, Huanlong Yang, YuLin, "Study of Image Mosaic Based on the Method of Finite Difference", Image and Signal Processing, 2008 Congress, 436 – 440, May 2008.

[10] Wexler, Y. Simakov, D., "Space – time scene manifolds", Tenth IEEE International Conference on Computer Vision, 2005. ICCV 2005, 1, 858 – 863, Oct. 2005.

[11] Shmuel Peleg, Benny Rousso, Alex RAv-Acha, Assaf Zomet, "Mosaicing on Adaptive Manifolds", IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol 22, No. 10, PP 1144-1154, October 2000.

[12] Shmuel Peleg, Moshe Ben- Ezra, Yael Pritch, "Omnistereo: Panoramic Stereo Images", IEEE Transaction on Pattern Analysis and Machine Intelligence, Vol 23, No 3, PP 279-290, March 2001.

[13] Zhou Wang, Alan Conrad Bovik, Hamid Rahim Sheikh, Eero P. Simoncelli, "Image Quality Assessment: from error visibility to structural Similarity " IEEE transaction on image processing Vol 13, No.4, PP 600- 612, April 2004.

[14] Ging Li, quan Pan, Tao Yang, Stan. Z.Li, "Automated Feature Point management for video mosaic construction", proceeding of the third International Conference on Information Technology and Application (ICITA05), 2005.

[15] M.Brown, D.G.Lowe, "Recognising Panoramas", Proceddings of Ninth IEEE International Conference on Computer Vision (ICCV-03).

[16] Melvin Sze-Ming Ni, Three-Dimensional Mapping and Navigation with Stereo Vision", Thesis of Aeronautics and Astronautics of Stanford University, December 2000. [31] M.Brown, D.G.Lowe, "Recognising Panoramas", Proceddings of Ninth IEEE International Conference on Computer Vision (ICCV-03).

[17] Ming Shing Su, Wen –Liang Hwang, Kuo-Young Cheng, "Analysis of Multiresolution Mosaic Images", IEEE Transaction of Image Processing Vol 13 , no.7, July 2004, PP 952-959.

[18] Horizontal Blending Algorithm, http://www.eecis.udel.edu/~qili/ta/cis489/2/

Fig 6: Mosaic using Space time Scene Manifold technique [10] (Consists all 205 Beach sequences)

Fig 7: Mosaic using Space time Scene Manifold technique [10] (Consists 128 frames sampled from original Beach sequences, assuming frames captured with more speed. This leads deformation of objects shown in rectangle box within Fig 5 and Fig 6)

Fig 8: Mosaic using simple stitching of horizontally registered frames (from 35 registered frames)

Fig 9: Mosaic Image using Proposed Algorithm (35 registered frames)

Fig 10: Mosaic using Space time Scene Manifold technique [10] (Consists of all 345 Train sequences)

Fig 11: Mosaic using blending horizontally registered 58 Train Sequences (without vertical strip registration)

Fig 12: Mosaic using Proposed Algorithm (58 registered frames)