

# **Dynamic Image Stitching for Panoramic Video**

Jen-Yu Shieh<sup>\*</sup>, Yu-Ching Liao, Guo-Jyun Liao, and Yu-Ting Liou

Department of Electro-Optics Engineering, National Formosa University, Yunlin County, 632, Taiwan.

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## **Abstract**

The design of this paper is based on the Dynamic image stitching for panoramic video. By utilizing OpenCV visual function data library and SIFT algorithm as the basis for presentation, this article brings forward Gaussian second differenced MoG which is processed basing on DoG Gaussian Difference Map to reduce order in synthesizing dynamic images and simplify the algorithm of the Gaussian pyramid structure. MSIFT matches with overlapping segmentation method to simplify the scope of feature extraction in order to enhance speed. And through this method traditional image synthesis can be improved without having to take lots of time in calculation and being limited by space and angle.

This research uses four normal Webcams and two IPCAM coupled with several-wide angle lenses. By using wide-angle lenses to monitor over a wide range of an area and then by using image stitching panoramic effect is achieved. In terms of overall image application and control interface, Microsoft Visual Studio C# is adopted to a construct software interface. On a personal computer with 2.4-GHz CPU and 2-GB RAM and with the cameras fixed to it, the execution speed is three images per second, which reduces calculation time of the traditional algorithm.

**Keywords:** image stitching, panoramic image, image matching, SIFT algorithm, OpenCV visual function library

## **1. Introduction**

Currently, video conferencing with panoramic function is rarely observed on the market. Normally, projects that promote panoramic view conference are usually achieved by camera equipped with stepping motor that can conduct 360 degree circular movement. Even though with 360 degree movement any given corner in the conference venue can be seen, but the limitation of one camera making it to be restricted to around 40 degrees. At the same time, the other 320 degree parameter cannot be observed instantaneously. In the turning process of the camera, the observing person can sometimes suffer from visual dizziness, tiredness and various other defects. To improve on such imperfection, this system brings forward the utilization of 1 ~ 6 wide-angle cameras to observe the entire venue of the conference. Six dynamic cameras with image stitching software can achieve the effect of panoramic vision and provide a panoramic display. A number of cameras required can also be adjusted to follow the actual seating arrangement. Not only the panoramic video conferencing have the effect of presence, simple operation and management, but most importantly, the construction cost is far lower than the panoramic view video conferencing product from other providers.

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<sup>\*</sup> Corresponding author. E-mail address: reed@nfu.edu.tw

Tel.: +886-9-56169985; Fax: +886-5-6365348

## 2. Mechanics of Static Imagery

### 2.1. Preface

To make the dynamic image stitching technology from happening it is necessary to start from static image stitching, finding highly stable method that is not affected by outside source to suit dynamic image stitching. The purpose of this section is to prove that the use of Scale Invariant Feature Transform (SIFT) method is enough to cater the variation in human movement image during video conferencing, then conduct matching based on the matched feature points between images and then stitching them.

### 2.2. System framework

(1) Hardware requirement: two video conferencing video and two customized support bracket structure. The cameras are supported by two customized bracket supports. The base of the supports is circular and the distance between the two is 3 to 5 centimeters in distance to conduct filming and reserve around 10 to 15% image overlap, which would allow a maller likelihood for error.

(2) Software requirement: Microsoft Visual Studio C#.

### 2.3. The theoretical foundation of feature description of SIFT algorithm

SIFT (Scale Invariant Feature Transformation) is an algorithm of computer vision for the detection of partial characteristic of the image described. It is brought forward by David Lowe [1], and it searches for the extreme points in the spatial scale and bring forward its position, scale, and rotation invariants. The purpose of the SIFT is to improve the corner detection method [2] brought forward by Chris Harris and Stephens, which cannot solve the shortcoming of scale invariability. With this method, all calculation is established within the scale space, with four categorization procedures:

(1) Detecting extreme value within the scale space

Using the scale space brought forward by Witkin [3] in 1983 which has the implication of simulating the change in distance, allowing single image file to be transformed into more identifiable data which can be used to find stronger features. Koenderink[4] (1984) and Lindeberg[5] (1994) have broughtforward the function of Gaussian scale space, with scale space function  $L$  as follows:

$$L(u, v, \sigma) * I(u, v) \quad (1)$$

$$G(u, v, \sigma) = \frac{1}{2\pi\sigma^2} e^{-(u^2+v^2)/2\sigma^2} \quad (2)$$

where,  $*$  is convolution,  $I(u,v)$  is the image input,  $\sigma$  is a parameter of Gaussian function, the larger this value, the more fuzzy the image will become.  $u$  is the horizontal more fuzzy the image will become.  $u$  is the horizontal coordinate and  $v$  is the vertical coordinate of the image. To construct a dimensional space, the method of realization is Difference of Gaussian Filter (DoG). The main concept is that using two different variances of the Gaussian Filter to process the original image, resulting in two images with different level of fuzziness. Then let these two images to subtract each other, which is known as the Difference of Gaussian Image, which is shown by figure 1.

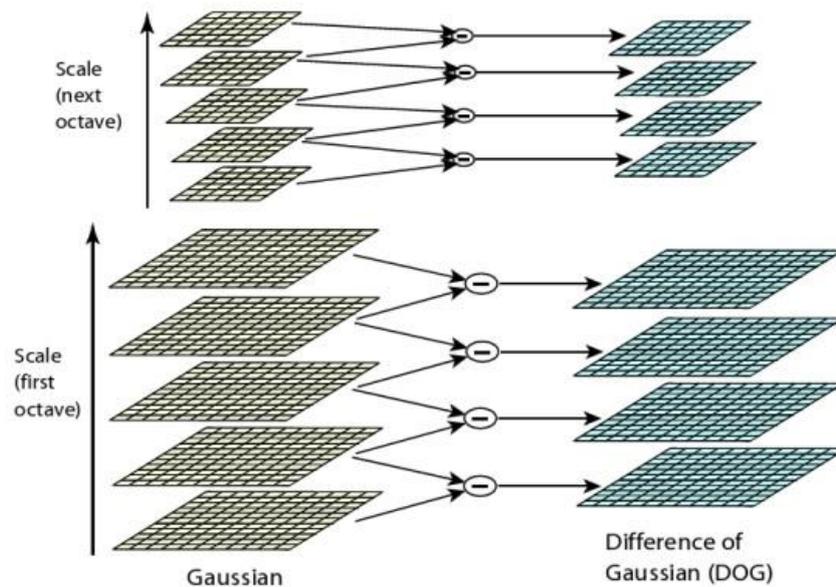


Fig. 1 Scale space diagram with different variance and resolution

After Scale space is generated, all extreme points that can be the feature points should be found. The method of searching for extreme point is shown by Figure 2. Within the diagram, the position of the pixel of X, after being processed by the Difference of Gaussian Filter, a contrast of the extreme values is made to 26 points which are in the neighborhood of a different scale space to this position. If such stands, they are then the extreme points.

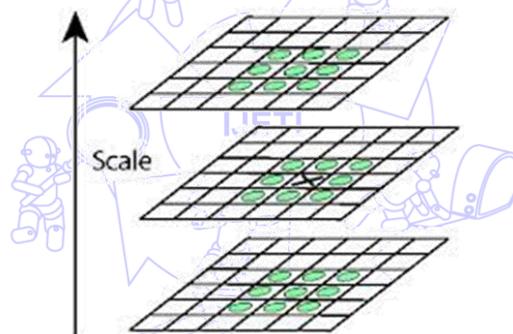


Fig 2 Illustration of search for regional extreme value

Mikolajczyk [6] brought forward the concept of using Laplace function to find feature point with the same stability, but would take up a much longer time frame. Whereas Lowe used Difference of Gaussian value to replace the Laplace function. Even though there is a small difference but saved quite a lot of time. Algorithm of the Difference of Gaussian Function is as follows:

$$D(u, v, \sigma) = (G(u, v, k\sigma) - G(u, v, \sigma)) * I(u, v) = L(u, v, k\sigma) - L(u, v, \sigma) \tag{3}$$

where, K is a multiple of parameter  $\sigma$  in the control scale space, while L is scale space which is the result from the convolution of the image and Gaussian Function, indicating the fuzzy image can be generated by conducting low-pass to the image. D is the Gaussian Function. As for the image generated by Difference of Gaussian function, it is generated by letting fuzzy images of different value to subtract each other. The difference of each image is k, which means that if more images are taken in each level, the difference in every scale space will become smaller. If the number of images taken from each level is s+3, assuming that every level is preset to six images, k, then  $\sigma$  of every level increases by k times every time.

## (2) Direction assignment

Assign a range in the scale space whether the feature point is located, quantify the pixels of the range, and input the value of each scale space of the pixels to gain the size and direction of the gradient. Firstly, calculate all the border direction and size of the pixels that are nearby the feature points, as shown by equations (4) and (5); count all the directions in that particular region, and use the majority vote method to determine the main border direction of that feature point. If the border direction is to be contrasted with other images, the original image is transformed into this type of partial image for the purpose of matching in order to achieve the aim of rotation without change.

$$m(u,v) = \sqrt{m(u,v) = \sqrt{(L(u+1,v) - L(u-1,v))^2 + (L(u,v+1) - L(u,v-1))^2} / (L(u,v+1) - L(u,v-1))} \quad (4)$$

$$\theta(u,v) = \tan^{-1}((L(u,v+1) - L(u,v-1)) / (L(u+1,v) - L(u-1,v))) \quad (5)$$

where,  $L$  is the scale space, and  $(u,v)$  is the coordinate of the space where it is located. Find out the size and direction the gradient of the feature point's neighborhood, the primary direction of the feature point by using statistical method, and cut up the angle into 36 grids with 10 degrees per grid. Such is the horizontal axis of the histogram. Use feature point as the center and calculate the size and direction of the gradient around it and obtain Gaussian weighting with accumulation method. The farther the point, the size of the gradient has to be multiplied by a smaller weighting, the  $\sigma$  of which is 1.5 times of the  $\sigma$  of the scale space where it is located.

## (3) Partial image descriptor

After the location, scale, and primary direction of the feature points are figured out, these features are further described by rectangular bar chart which takes direction as the target. With this method, the feature point and its 8x8 pixel neighborhood are cut up into four subsections of 4x4 pixels. The statistic chart of direction of each subsection is shown as Figure 3.

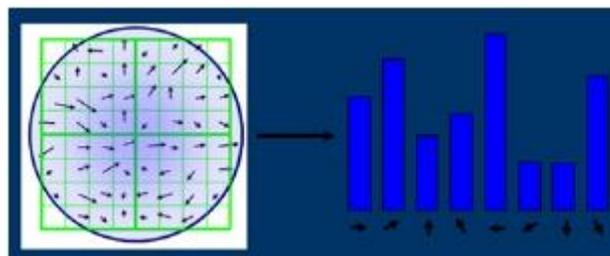


Fig. 3 Characteristic Point primary direction

## 2.4. Image matching and stitching

In the process of image connection, one image is firstly stabilized, using geometric transformation matrix to transform and adjust another image through horizontal moving, rotating, enlarging or reducing, so as to find the best position of connection for the stitching of the first image, in order to construct the mathematical relationship of the pixel coordinates between images. Transformation can be distinguished as affine transformation and transmission conversion. This study uses affine transformation as the model for the transformation of pixel coordinate between the images. Affine transformation model is a two-dimensional matrix  $A$  with 6 unknown parameters, as shown by equation 6, where the corresponding relationship of the pixel coordinates of the left and right images are presented by equation 7. In order to figure out the 6 unknown parameters [7], an equation with even number  $n$  is required, as shown by equation 8. To construct such equation, it is required that the point pairs obtained earlier are used, with at least 3 sets are input ( $n \geq 3$ ). When the system is over-determined, a method resolving the Eigen value should be used to figure out the minimum error. If the point pairs found are incorrect, then the quality of matching would be poor [8-9].

Table 1 2D Coordinaye transformation

name	matrix	#D.O.F	Icon
Horizontal Movement	$[I t]_{2 \times 3}$	2	
Rotation	$[R t]_{2 \times 3}$	3	
Enlarging/Reducing	$[sR t]_{2 \times 3}$	4	
Transformation	$[A]_{2 \times 3}$	6	

$$A = \begin{bmatrix} m_0 & m_1 & m_2 \\ m_3 & m_4 & m_5 \\ 0 & 0 & 1 \end{bmatrix} \tag{6}$$

$$x'_i = m_0x_i + m_1y_i + m_2 \tag{7}$$

$$y'_i = m_3x_i + m_4y_i + m_5$$

$$\begin{bmatrix} x_1 & y_1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x_1 & y_1 & 1 \\ x_2 & y_2 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x_2 & y_2 & 1 \\ x_n & y_n & 1 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & x_n & y_n & 1 \end{bmatrix} \times \begin{bmatrix} m_0 \\ m_1 \\ m_2 \\ m_3 \\ m_4 \\ m_5 \end{bmatrix} = \begin{bmatrix} x_1 \\ y_1 \\ x_2 \\ y_2 \\ \vdots \\ x_n \\ y_n \end{bmatrix} \tag{8}$$

2.5. Test result

First of all, Figure 4 shows two images taken by CCD films from different positions and find feature points. Secondly, Figure 5 shows the Matching relations line. Finally, Figure 6 is the stitching of the two images and Figure 7 will test SIFT stitched the number of seconds. Such static image stitching for the images were processed by the method brought forward by section 2.3 with the camera set up per the method accounted in section 2.2.



Fig 4 CCD filming two images from two different positions



Fig 5 Matching relations line



Fig 6 Two images stitched together



Fig 7 Test SIFT stitched the number of seconds

### 3. Reserch Methodology of Dynamic Image Stitching

#### 3.1. MSIFT algorithm

Even though SIFT algorithm is the faster method among similar type of algorithms, it is still short on dynamic image stitching. Currently, the research that focus on SIFT algorithm to improve speed mainly rest on the dimension number of the SIFT vector. At the same time of increasing the calculation speed, such would also lead to the reduction in accuracy of SIFT. When using a chart of pair DoG Gaussian Difference to reduce order, the result of the MoG is one layer less than that of the DoG, while by developing Gaussian Filter difference chart DoG to conduct one more differential function on Gaussian Filter Difference chart, the Gaussian Difference function below is generated.

$$L(u, v, k\sigma) - L(u, v, \sigma) = D(u, v, \sigma) \quad (9)$$

Conduct one more differential function to obtain second-order Gaussian Difference function.

$$D(u, v, k\sigma) - D(u, v, \sigma) = M(u, v, \sigma) \quad (10)$$

The Gaussian second-order difference function is used to simplify the pyramid structure and boost the speed of calculation, while the detection operator for the MoG feature is derived from DoG Gaussian Differential chart. According the theory of Geometry, the partial extreme value point of the original function is the zero point of this function's first-order derivative function. Hence it is clear that the maximum and minimum value obtained from the partial of the scale space diagram is in fact the zero point of this function's first-order derivative function. Due to the fact that the zero point feature is easier to detect than the extreme value point, hence, the zero point obtained from the first-order function of the scale space diagram serves to replace the partial extreme value point, and the zero point of Gaussian second-order difference function also substitutes for the extreme value point of Gaussian first-order difference function so as to confirm the feature point.

Subtract the neighboring two layers within the same order of the DoG pyramid to be a layer in MoG. The scale of that layer is that of the subtrahend in the scale of the DoG pyramid, hence, the counts of levels included by every level of the MoG pyramid is one level less than that of the DoG.

#### 3.2. Description and matching of the feature point

After the extraction of the feature point by the MoG feature point detection operator, this study utilized descriptive operator and matching algorithm same as the feature matching algorithm of SIFT to describe and match the feature points, which formed an improved feature matching algorithm of SIFT based on the MoG feature point detection operator. The advantage of the MoG lies in the ability in simplifying Gaussian Pyramid structure and increases the calculation speed. Due to the fact that the examination of extreme value is processed within  $3 \times 3 \times 3$  three dimensional space, while the zero point examination can be conducted in a two dimensional plane, hence clearly, when the MoG operator constructing the MoG pyramid, each order can neglect one layer of Gaussian filter image, which accounts for the reason of boost in calculation speed. Use MSIFT do the stitching time can be reduced to about 0.7 seconds although because of the capture of the feature points Less will lead to little error, but use Intuitive method is the correct judgment.

**3.3. Overlapping segmentation method**

First image one and image two divided into four equal parts ABCD to do cutting, extracted from BC to do stitching, reducing to find the feature points of time. BC was sutured to the use of images to Figure A Figure BC Figure C Figure do then, greatly improve the operating speed.

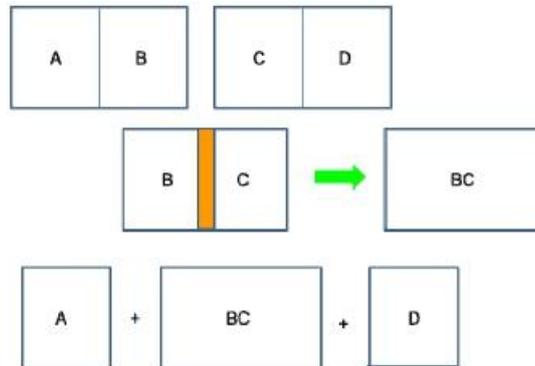


Fig. 8 MSIFT match overlapping segmentation method time test

By the experiment can be seen MSIFT with overlapping cutting to do the stitching time can be reduced to about 0.2 to 0.3seconds, than the SIFT algorithm significantly reduces the computation time.

**4. Testing Result**

This software program can be partnered with the cameras to solve the restriction on the field of vision of CCD camera angle when its development by utilizing Microsoft Visual Studio C# software is finished, it actually uses CCD camera to capture photographic images, and its feasibility is proved through examination. Some camera lens related work can be found on [10]-[11].

**4.1. Setup of cameras**

This study brings forward the method for camera setup, even with four average CCD and two IPCAM the desired effect can be produced The cameras are arranged in circular shape, the distance between the left and right cameras is between 3 to 5 centimeters; the overlapping area of the region is adjusted to 10 to 15%; each camera is set in circular diverging angle on an acrylic board. Figure 9 shows the actual camera setup.



Fig. 9 The actual setup of the camera

#### 4.2. Testing result

Through the use of the webcam to display the actual images, the interface program awaits the user to press the stitching button. After the stitching button has been pressed, the system will transform the image that has been stitched into AVI recording instantaneously and begin recording, and the actual test is shown by Figure 10.



Fig. 10 Illustration of actual test on panoramic view

## 5. Conclusions

### 5.1. Conclusion

This study brings forward the production of “Dynamic Panoramic Image Stitching System” based on feature contrast of SIFT. For the synthesis of images, this article proposes order reduction for Gaussian second-order difference based on the DoG Gaussian Differencing diagram, which simplifies the algorithm of Gaussian pyramid structure, MSIFT match overlapping segmentation method to simplify the scope of feature extraction in order to increase speed and improves on the time required for traditional image synthesis method and the shortcoming arising from being affected by the angle of the space. The result of the experiment shows that the feasibility of this research based on the methodology brought forward not only let the user benefits from the sense of presence and simple management as well as ease of operations, but most importantly, the cost of setup is way lower than that of other providers of panoramic conferencing product.

### 5.2. Characteristics of this study

The “Dynamic Panoramic Image Stitching System” brought forward by this study has the benefits of cost effectiveness, easy access, simple operation, plug-and-play and so on. This system uses a CCD camera that costs NT \$179, a 3D capable camera of NT \$599, and an IPCAM of NT \$1,600. The total amount is NT \$2,736. The setup of the three types CCD mix proves that even the CCDs have different brand, they can capture images. It is all simplified into the push of a button without complicated interface. The CCD that uses USB port is suited to the Windows XP and Windows 7 systems without other softwares.

Table 2 The distinguishing feature of this system

	Full view conferencing developed by Microsoft	IPCAM full view conferencing developed by Yi-Hua technology	180 degree adopted by Fung-Jia IT team	This system
Low cost	NT \$149,000	Around NT \$100,000	Not available	NT \$2,500
Easily accessible	Require specialized hardware	Require specialized hardware	Wide angle camera needs to be greater than 90 degrees	Average household camera applicable
Plug and play	Yes	Require setup by the company	Yes	Yes

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