

# Automatic Stitching Method in Surgical Robot System to enhance the Surgeon's View

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**Abstract:** Panoramic mosaic is stitching pictures, taken from one scenery image in multiple degrees, into one. This technique can provide surgeon with wider range of view during laparoscopic surgery. To implement this, affine transformation with six degrees of freedom which needs three corresponding points is used. Corresponding points are obtained using SIFT(Scale Invariant Feature Transform) which gets hundreds of corresponding points, and then RANSAC(RANdom SAMple Consensus) picks three corresponding points. The panoramic mosaic images are stitched through these processes, and when a laparoscopy moves, an Icon pops up in the view. There are two methods of stitching each frame image. First method compares compiled image and new image, and the second method compares prior image and new image. The application of panoramic mosaic can be located within the whole view or the exterior location with the central laparoscopic view.

## 1. Introduction

Obtaining panoramic picture from mosaic is done by taking pictures of one scenery image in multiple degrees and combining them into one. This method is called panoramic mosaic[1]. Panoramic mosaic can be applied to console screen of surgical robot system to improve surgeon's view.

Surgical robot is in "Master and Slave" structure. Surgeon can control Slave's laparoscopy and robotic arm, by looking at Master's screen. Screen displays image obtained from laparoscopy[2-4]. However, due to limited range of laparoscopy, only some parts of surgery scenes can be viewed. Therefore, to obtain images of other organs, laparoscopy needs to rotate.

During a surgery, real-time input laparoscopic images can be stitched to each frame using a panoramic mosaic technique to compose full display. If marking a present display in full display and also interest organ, we can overcome the problem of narrow view with laparoscopic surgery.

## 2. Method

Stereo laparoscopy provide real time surgical image, which consist of I1 (left part of image), and I2 (right part of image). I1 and I2 can provide 3-D real time image to the surgeon. When laparoscopic moves, I1 and I2 are changed in according to position and direction of laparoscopy.

Therefore, as variation of position and direction of laparoscopy, difference between images can be aptly modeled to provide panoramic mosaic.

As position of laparoscopy changes from  $t$  to  $t+1$ ,  $I1(t)$  and  $I1(t+1)$  can be modeled by using, translation transformation with offset in  $x$  and  $y$  direction, geometric transformation with 4 degrees of freedom, affine transformation with 6 degrees of freedom, perspective transformation with 8 degrees of freedom[5]. We used affine transformation with 6 degree of freedom and needs three corresponding points. This can be represented as Eq.(1).

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a_1 & a_2 \\ a_3 & a_4 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} \quad (1)$$

Where  $(x,y)$  and  $(x',y')$  represent corresponding points from the image. Affine transformation can be calculated using least squared method when there are three corresponding points. If we define parameter vector as an 'a', then this can be represented as Eq.(2).

$$a = (a_1, a_2, b_1, a_3, a_4, b_2) \quad (2)$$

We also define matrix  $X_i, Y_i$  as Eq.(3).

$$X_i = \begin{bmatrix} x_i & y_i & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x_i & y_i & 1 \end{bmatrix}, \quad Y_i = \begin{bmatrix} x'_i \\ y'_i \end{bmatrix} \quad (3)$$

By using least squares method, we can calculate this parameter as Eq.(4)[6].

$$a = \left( \sum_i X_i^T X_i \right)^{-1} \left( \sum_i X_i^T Y_i \right) \tag{4}$$

For a frame where motion is detected by laparoscopy, the affine transformation is calculated, and the frame is used to obtain panoramic mosaic. The initial position converts according to Eq.(5).

$$x_n = f_n(x_{n-1}) \tag{5}$$

Where n is natural number,  $f_n$  is the affine transformation between the order of n and the order of n-1 frame.

To obtain three corresponding points, specific characteristic points need to be extracted uniformly and located from between  $I(t)$  and  $I(t+1)$ . It is important to extract specific characteristic points to obtain accurate transformation. Otherwise, organ's boundary line will appear blurry and structures like blood vessel will be selected too many as an important points. The specific characteristic points are extracted using SIFT(Scale Invariant Feature Transform)[7]. SIFT extracts key points by building pyramid and DOG(Difference Of Gaussian) according to image's size and selects location of each key point. Besides, local direction of image change in important point is found to be included in character of important point, and be used to calculate corresponding points.

Several hundreds of corresponding points can be obtained using SIFT, but only three of them are used to calculate affine transformation. RANSAC(RANdom SAMple Consensus) is used to calculate useful affine transformation[8].

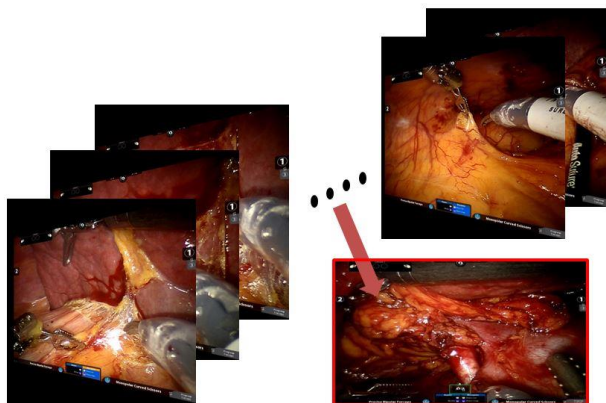


Fig 1. A Movement of Laparoscopy with Icon

In actual robotic surgery, the image gets complex as surgical tool overlaps with surgical site in multiple degrees of angle. When position of laparoscopy changes, surgeon is just repositioning to get better view, so surgical tools remain in the same position. Therefore, image that gets connection is only limited to one that is taken when position of laparoscopy changed. The tested image was

successful in building panoramic mosaic using da Vinci surgical system from Intuitive Surgical Operations. For this test, as green line box in Fig1 represents, an icon appeared at the bottom representing the movement of laparoscopy.

There are two methods of connecting images. Figure 2(a) shows a method that compares accumulated and newly obtained image than building a new mosaic image. Advantage for this method is that error does not accumulate. Figure 2(b) show a method that compares previous and newly obtained image then calculates transformational matrix. This newly formed matrix is multiplied with previous matrix to obtain mosaic image. For this method, error gets accumulated so the resulting image might not be accurate, but the corresponding relationship with prior image can be stably calculated.

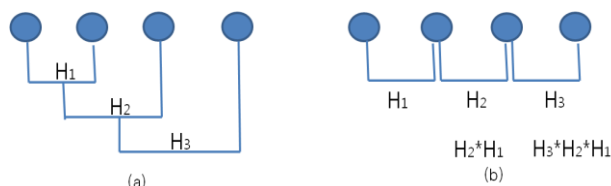


Fig 2(a). The method of comparing compiled image and new image

Fig 2(b). The method of comparing prior image and new image

Both methods were used to build mosaic image. First, image gets accumulated as it is shown in Fig 2(a). When error occurs, the system starts using Fig 2(b) method. To explain this using Fig 2(a) and Fig 2(b), if an error occurs while transforming Fig 2(a), system changes to Fig 2(b) mode. In Fig 2(b) mode, it multiplies H2 with previous transformational matrix, H1, and stitches it.

Also, as surgical tool moves and may appear multiple time while making mosaic. So, all surgical tools need to be removed from the image. Method for locating the surgical tool is based on color. First, RGB is transformed into 'Lab' space and then k-means clustering is performed in 2-D 'ab' space to locate the tools[9].

Surgeon performs surgery while the laparoscopy is moving. So while stitching the images, accumulated image may not contain information of organ that changed its position. Meaning that, in Fig 2(a), if shape of organ is changed between H2 and H3 after continuous H2 transformation is stitched, which will not appear in the new image. So before stitching H3, previously attached image from H2 needs to be replaced with newly stitched organ image. This is possible because mosaic is done only when laparoscopy changes position.

For surgical image, data for left and right direction gets imported simultaneously. So it is possible to obtain wider range of view by combining left and right image. When connecting left and right image, ghosting (or artifact) might appear due to parallax from the object with depth difference[10]. However, from the current system, surgical tool is only object that can cause this. So, it is possible to affine transform left and right image.

### 3. Result

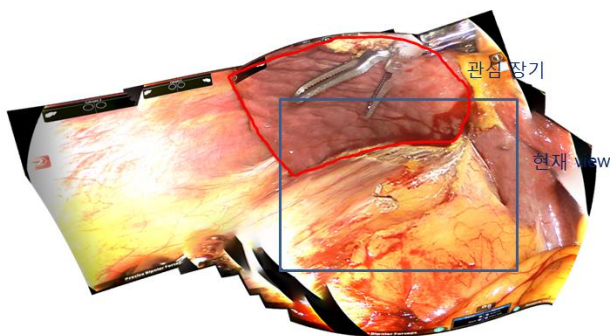
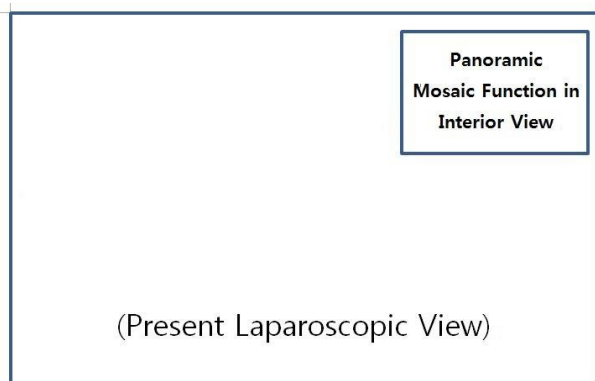


Fig 3. Panoramic Mosaic View in Surgical Robot System

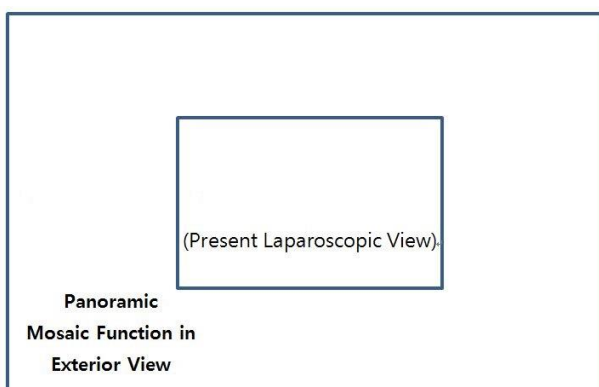
Figure 3. represents panoramic mosaic view in surgical robot system. A red region means interest organ, and a blue region means present laparoscopic view. This view can provide overall surgical situation, due to the wider range of view during laparoscopic surgery.

### 4. Discussion



Console View

Fig 4. Panoramic Mosaic Function in Interior View



Console View

Fig 5. Panoramic Mosaic Function in Exterior View

Figure 4. and Figure 5. show specific example of how this technique can be applied. In case of Fig 4, by placing Fig 3 in top right corner, surgeon can get whole view. In case of Fig 5, real-time laparoscopic image can be displayed in the

middle, and panoramic mosaic image can be displayed around the laparoscopic image.

Also, it is possible to scan the surgical site and build panoramic mosaic image before the surgery, if it is difficult to display image of abdominal cavity. If there is change in surgical site, between repositioning of laparoscopy, the changes can be marked. This can be calculated using local change in motion vector or non-rigid deformation. So, even if organ deforms while tracking organs, it is possible to keep tracking the selected organ while building the mosaic image.

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