Camera Arrays for Laparoscopic Surgery

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May 2, 2016

1 Abstract

We attempt to offer an improvement over the traditional single camera set ups currently used in laparoscopic surgery. Our laparoscope array offers an improved field of view over traditional systems and thus will offer a hands free vision system for surgeons attempting the procedure. The system uses a four camera array that expands out from the surgical port to give a panoramic view of the surgical area. In this paper, we discuss the challenges and goals of an improved laparoscope system. We have implemented a basic image stitching algorithm to combine the video feeds from our camera array into a single video feed and a basic projection based view interpolation algorithm to showcase the benefits our system offers over a traditional laparoscope.

2 Introduction: What is your problem?

Laparascopic surgery is a method of minimally invasive surgical procedure where the entire surgery is performed through a small incision. To avoid making a larger incision, the surgeon must rely on a live camera feed for vision of the surgical area. Currently, the cameras used for laparascopic surgery have a single camera at the end of a probe. Due to the limited field of view (FOV) of the single camera, The surgeon can not keep the entire surgical area in frame at any given time.

To solve this problem, We will look at replacing the camera used for laparascopic surgery with a camera array. By replacing the single camera with an array, we can potentially greatly increase the FOV of our vision system, but we introduce new challenges and open up new possibilities for our problem.

We will assume that we have a 2x2 array of cameras attached to the surgical port that we are using to survey the surgical area. We have to now consider how we can best visualize our scene to help the surgeon.

For this project we have several goals.

1. Combine multiple video feeds from a 2x2 video camera array into a single mosaicked video feed.

2. Re-project images to a new viewpoint to allow surgeons to focus on specific portions of the surgical area.

3. Give surgeons depth perception by either real stereo vision, or approximated stereo vision using image morphing and view morphing techniques

3 Background/Related Work: Relevant literature and the state of the art

3.1 View Systems for Laparoscopic surgery

The current standard for laparoscopic surgery is the use of a single small digital camera is attached to the end of a long telescoping rod that is then inserted into the patient in order to gain a view of the surgical area. [4] offers a good overview of the challenges involved in designing a vision system for the laparoscopic surgical setting. However, where [4] relied on a single camera, structured light system, we look at using a multi camera array to improve field of view and coverage of the viewing area.

3.2 Image Stitching

Our image stitching approach is based off of the RANSAC method first proposed by [3] in 1981. This method attempts to match keypoints from different images in such a way that it is more robust to outliers and incorrectly matched features than a simple least squares fit would be. [11] offers a good overview of the RANSAC algorithm and its implementation which we used in this project.

3.3 3D visualization

There are many existing methods for recreating a 3D scene from 2D images. Structured light methods such as the methods proposed by [7],[5], and the method used by the Microsoft kinect use a light source to project a pattern onto the scene. If we know the location of the light source relative to the camera, we can use basic triangulation techniques as outlined in [7] to determine a depth map of the scene.

Structure from motion algorithms such as are used in [10] do not need any external light source. Instead, they attempt to match points between multiple images and use those to estimate the relative position of the two cameras. Once those positions have been calculated, the same triangulation methods can be used to calculate the depth mapping of the scene.

On this project, we will attempt a method more similar to [12] where we can cut down on computation times by using a camera array with known relative pose to simplify the calculations necessary for 3D scene reconstruction.

3.4 View Morphing

The view morphing technique proposed by [9] seems like it could potentially allow for the creation of intermediate viewpoints without fully calculating the depth information of the scene. Seitz proposes that the procedure can generate realistic intermediate views of an object.

4 Your Approach: Detail the framework of your project. Be specific, include equations, figures, plots, etc.

4.1 Stitching

The first challenge on this project is using an image mosaicking algorithm at each frame of the video to combine the 4 video feeds into a single feed. To achieve this, we can use a fairly standard Image mosaicking algorithm. First we need to find corresponding feature points in the two images. We used the SURF (Speeded up Robust Features) is it was faster than SIFT but offered improved feature detection over algorithms like ORB and FAST.

Once we have our corresponding feature points. We use a RANSAC method to compute the best homography for warping the images. Now that we are dealing with a 2x2 array of images, we have to decide how we want to warp images onto each other.

Finally, we apply our homography, and blend the resulting images together. We may choose to sequentially warp new images onto the existing mosaic. Alternatively, we could try to perform warping procedures in parallel to reduce computation time.

4.2 View Interpolation

Our view interpolation algorithm does not take the same approach as proposed in [9]. Instead, we use the assumption from our stitching algorithm that all the image points lie on approximately the same plane. Since our choice of scale is arbitrary, we place this plane at $[X, Y, 1, 1]$. We consider the camera center of the stitched image to be the point [0,0,0] in the world coordinate system.

5 Conclusion: What have you learned? future works?

6 Resources

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