Feature Based Image Mosaicing

Satya Prakash Mallick
Department of Electrical and Computer Engineering,
University of California, San Diego
smallick@ucsd.edu

Abstract

A feature based image mosaicing algorithm is presented in this project. A relaxation based correspondence algrithm is used to first select corresponding corners in two images. RANSAC is used to estimate the homography relating the two images. The estimated homogrphy is refined using Newton's non-linear method. A dynamic programming based blending algorithm was used to seamlessly blend the two images.

1. Introduction

Image mosaicing is an active area of research in computer vision. The various methods adopted for image mosaicing can be broadly classified into direct methods [Shum], [Szeliski] and feature based methods [Faugeras],[Hartley],[Capel].Direct methods are found to be useful for mosaicing large overlapping regions, small translations and rotations. Feature based methods can usually handle small overlapping regions and in general tend to be more accurate but computationally intensive. Some of the basic problems in image mosaicing are the following:

1. **Global alignment:** Global Alignment involves calculation of the transform (homography), which aligns two images.
2. **Local adjustment**: Even after good global alignment, some pixel might not align in the two images. This might cause ghosting or blur in the blended image.
3. **Automatic selection of images to blend** from a given set of images.
4. **Image blending:** After one of the images has been transformed using the homography calculated above a decision needs to be made about the color to be assigned to the overlapping regions. Blending also becomes important when there exists a moving object in the images taken[Davis]
5. **Auto exposure compensation:** Most cameras have an automatic exposure control. The images taken can therefore be of varible brightness in the overlapping region which might cause the mosaic to look unrealistic.

In this project a feature based approach has been taken. The report describes the various approaches taken by the author and the improvements achieved. Most of the results are shown using two images to illustrate the improvement in quality achieved at each stage. The algorithm is described stepwise in the proceeding sections.

2. Solving Correspondence

Theoretically, only four corresponding points in two images are required to estimate the homography relating the two points. In practice, a large number of points are detected on the two images and correspondences are solved. The problem of solving correspondences is an extremely difficult problem. In this project, Harris corner detector [Harris] is used to detect corners and a modified version of the algorithm proposed in [Zhang] is used to solve for correspondence. The various steps of the algorithm are the following:

a. **Matching Through Correlation**: For each corner detected in one image, its corresponding neighborhood is searched in the other image. Those corners in second image are labeled as candidate matches whose neighborhood is similar to the corner detected in the first image. Hence, corresponding to each corner in the first image there could be multiple candidate matches. The correlation coefficient between the neighborhood of corners in the first image and second image is taken to the measure of similarity.

b. **Disambiguating Matches Through Relaxation**: The match strength for a particular match is more if, in a small neighborhood of that match, there exist other matches, which are related by a similar transform as the match in question. The underlying assumption is that, corners in a small neighborhood can be thought to be transformed by an affine transform. Using this criterion, a strength matrix SM is formed whose rows represent the corners in first image and columns represent the corners in second image. Those entries which are both the highest in their respective rows and columns are chosen as matches.

The correspondences found using the above method are shown in fig1.

Detected Corners in the two images

3. Estimation of Homography

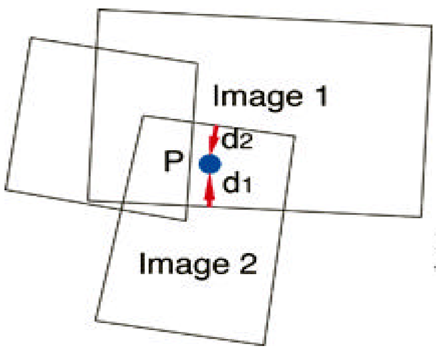
Homography relating the two images was estimated using Random Sample Consensus (RANSAC). RANSAC implementation is gets a remarkable improvement over Least Squares Estimation of Homography. The improvement is shown in the results below:

Fig 2. LHS: Mosaic using Least Squares, RHS: Mosaic using RANSAC

4. Image Blending:

In Fig 2, we can clearly see that, even though RANSAC gives good estimate of homography and the images are aligned, there is a visible line seen along the boundary of the overlapping region. Hence, the mosaic is not "seamlessly" blended. Two methods were used to blend the mosaics seamlessly.

a. **Weighted Image Blending:** Every pixel is weighted with the distance to the closet image boundary to the nth power



$$f_{res}(P) = \frac{\sum_{i=1}^{M} f_i(P) d_i^n}{\sum_{i=1}^{M} d_i^n}$$

b. **Cut along the lightest path:** The difference of the overlapping regions of the two images is taken and a vertical curve is drawn along the lightest intensity path to divide the overlapping region into two parts. Each image contributes to a single part of the overlapping region. The algorithm was implemented using Dynamic Programming. The lightest path is chosen for the cut because it is least discernible. The recursive dynamic programming equation is given by:

$E_{ij} = e_{ij} + \min(E_{i-1,j-1}, E_{i-1,j}, E_{i-1,j+1})$,where e is the value of the current pixel in the difference image. E is the cumulative weight as shown above. The above implementation is however not optimal cut although the results look good. The cut along the lightest path is shown the figure given below.

Fig 3. LHS: The path taken by the cut; RHS: Blended Image.

The lightest cut algorithm, unlike the Weighted image algorithm, doesn't produce any blurring.

5. Homography Refinement

The estimate of the Homography can be refined considerably by using a non-linear method of optimization after doing RANSAC. In this project Newton's method was used to refine the estimate of homography. Newton's method is only stable near minima but has quadratic convergence. However, the estimate of homography found using RANSAC brings the cost function close to minima. Hence, using Newton's method for estimating homography is justified.

The result of Estimate of homography can be best appreciated if we zoom into blurry regions of a mosaic blended using weighted blend.

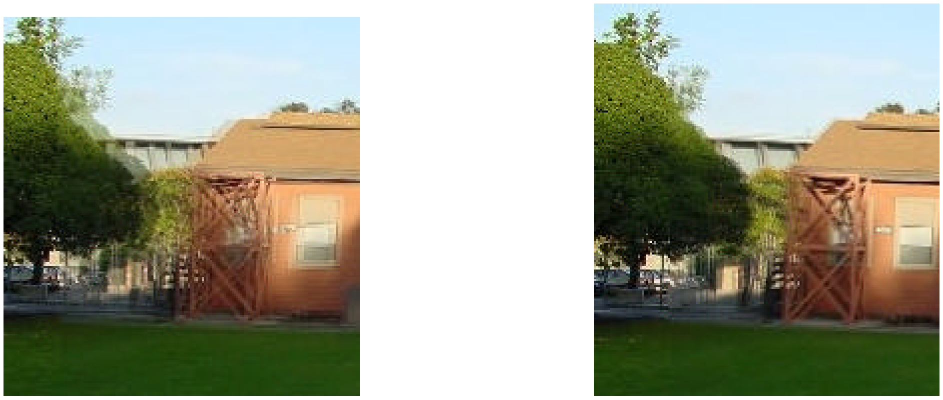
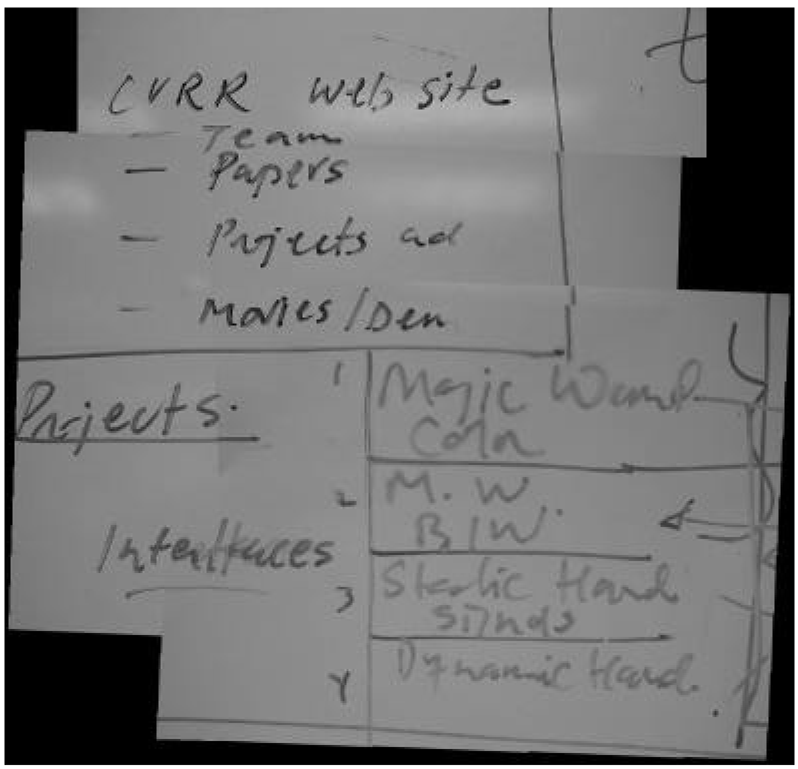


Fig 4. LHS shows a blend using RANSAC RHS shows a blend using RANSAC followed by non-linear optimization

6. More Results:

There are some bugs in the implementation of the minimum intensity cut algorithm and hence, for multiple image mosaics weighted image blending was used.



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7. Limitations: One of the major limitations of the implementation was that I missed the point that mosaicing of multiple images cannot be achieved by repeatedly warping new images to one reference image. Hence, after mosaicing 4 images to the reference image, the image alignment doesn't look good anymore.

8 Conclusion: In this project, some good and standard ideas for image mosaicing were applied. The idea to cut the overlapping regions of the images along the curve of minimum brightness in the difference image was a good idea, but its implementation is not as straight forward as in texture synthesis application (from where the idea was borrowed). One of the key observations is that non-linear methods should be used after RANSAC to refine the estimate.

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