EE 5358

COMPUTER VISION
MEDICAL IMAGE REGISTERATION

FrameWork for Machine Vision assisted Cholecystectomy (Gallbladder removal)

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INTRODUCTION

In Computer Vision, sets of data acquired by sampling the same scene or object at different times, or from different perspectives, will be in different coordinate systems. Image registration is the process of transforming the different sets of data into one coordinate system. Registration is necessary in order to be able to compare or integrate the data obtained from different measurements.

METHODS USED

- Affine transformation
- Optical flow based image registration
- Image morphing based registration

AFFINE TRANSFORMATION

- In geometry, an **affine transformation** or **affine map** or an **affinity** between two vector spaces (strictly speaking, two affine spaces) consists of a linear transformation followed by a translation.
- In general, an affine transform is composed of zero or more linear transformations (rotation, scaling or shear) and translation(shift).

AFFINE TRANSFORMATION

- The general affine transformation is commonly written in homogeneous coordinates as shown below:

$$\begin{vmatrix} x_2 \\ y_2 \end{vmatrix} = A \times \begin{vmatrix} x_1 \\ y_1 \end{vmatrix} + B$$

- Rotation matrices are of the form

$$\begin{bmatrix} \text{Cos}(w) & -\text{Sin}(w) \\ \text{Sin}(w) & \text{Cos}(w) \end{bmatrix}$$

where w is the angle of rotation. This is practically the *definition* of the sine and cosine functions

BASIC STEPS

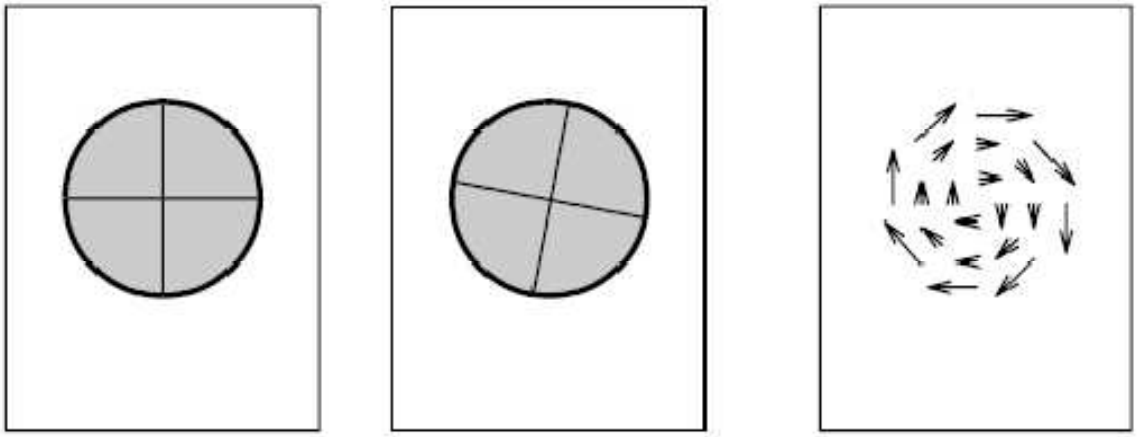
- Divide the entire video into number of frames.
- Define a dissection line for the surgeon to perform the operation.
- Calculate the affine matrix based on the changes from frame to frame.
- Apply the Affine matrix to the dissection line.
- We observe that it moves according to the movements in the frame.

OPTICAL FLOW METHOD

- Optical flow is the distribution of apparent velocities of movement of brightness patterns in an image. Optical flow can arise from relative motion of objects and the viewer. Consequently, optical flow can give important information about the spatial arrangement of the objects viewed and the rate of change of this arrangement . Discontinuities in the optical flow can help in segmenting images into regions that correspond to different objects .Attempts have been made to perform such segmentation using differences between successive image frames.

OPTICAL FLOW METHOD

- It is the velocity field that represents the three dimensional motion of an object points across a two dimensional image.
- Optical Flow reflects the image changes due to motion during a time interval *dt*.



(a) Time t_1, (b) time t_2, (c) optical flow.

OPTICAL FLOW METHOD

- There are two measures of similarity that are commonly used for optical flow vectors. One is **sum of squared differences** (SSD) between an image patch centered at a point , which is a location at time and various other candidate locations where that patch could have moved between two frames at time and The goal here is to find a displacement in the image plane , which minimizes the SSD criterion:

$$SSD(\delta x, \delta y) = \sum_{(x,y)} (I(x, y, t) - I(x + \delta x, y + \delta y, t + \delta t))^2$$

- where the summation ranges over the image patch centered at the feature of interest. The optical flow of the chosen point feature is

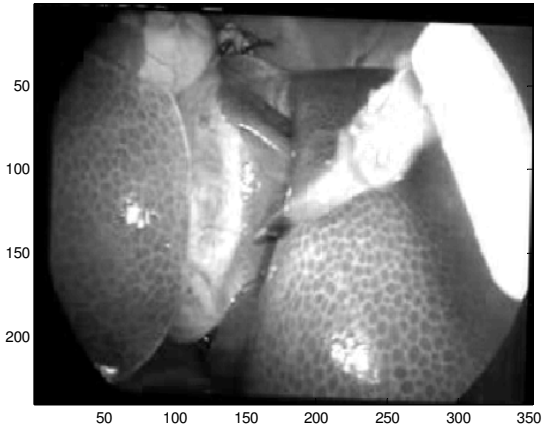
$$(v_1, v_2) = \left(\frac{\delta x}{\delta t}, \frac{\delta y}{\delta t}\right)$$

BASIC STEPS

- Divide the entire video into number of frames.
- Define a dissection line for the surgeon to perform the operation.
- Calculate the motion vectors based on the changes from frame to frame.
- Apply these motion vectors to the dissection line .
- We observe that it moves according to the movements in the frame.

Medical Image Registration using Global Affine Transformation

- We have investigated a general-purpose registration algorithm for medical images. The transformation between images is modeled as locally affine.
  - S. Periaswamy and H. Farid “Medical Image Registration with Partial Data”, Medical Image Analysis, 10:452-464, 2006.
  - S. Periaswamy “General-Purpose Medical Image Registration”, Ph.D. Dissertation, Department of Computer Science, Dartmouth College, 2003.



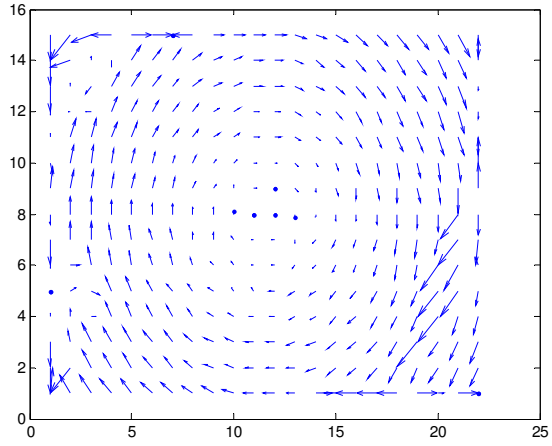
a) Original b)Rotated 2 deg CW c) Reconstructed by Affine Tranformation

Medical Image Registration using Optical Flow

- Instead of using a 'Global' motion model we investigate a 'Local Motion' model using Optical Flow.
  - Ref: Minyou Wang, et al. "Non-rigid medical image registration using optical flow and locally-refined multilevel free form deformation." Page(s): 4552-4555, IEEE Nuclear Science Symposium, Oct 2007.
  - S. Kodipaka, et al. "Kernel Fisher discriminant for shape-based classification in epilepsy", Medical Image Analysis, Vol 11, Pages 79-90, Feb 2007.
  - B. C. Vemuri et al. "An Efficient Motion Estimator with Application to Medical Image Registration ", Medical Image Analysis, Vol 2: Pages 79-98, 1998.

a) Original

b)Rotated 2 deg CW



c) Optical flow of the motion

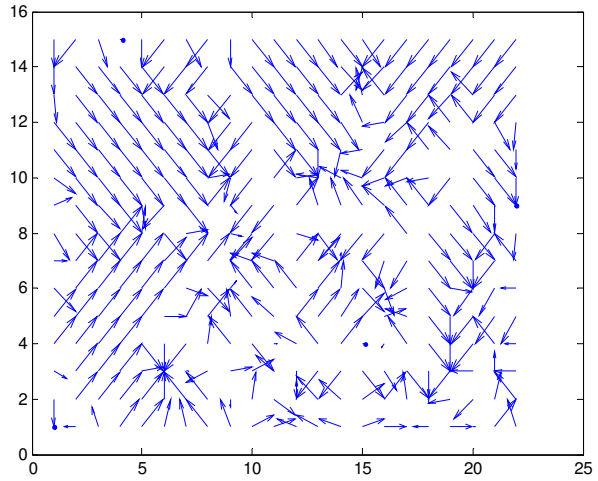
Effects of Illumination on Registration

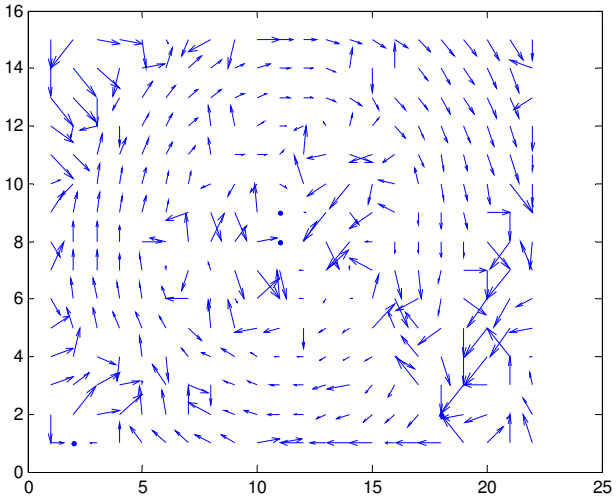
- We have studied algorithms that
  - Z. Wang, A. C. Bovik, H. R. Sheikh and E. P. Simoncelli, "Image quality assessment: From error visibility to structural similarity," *IEEE Transactions on Image Processing*, vol. 13, no. 4, pp. 600-612, Apr. 2004.
  - The SSIM Index for Image Quality Assessment

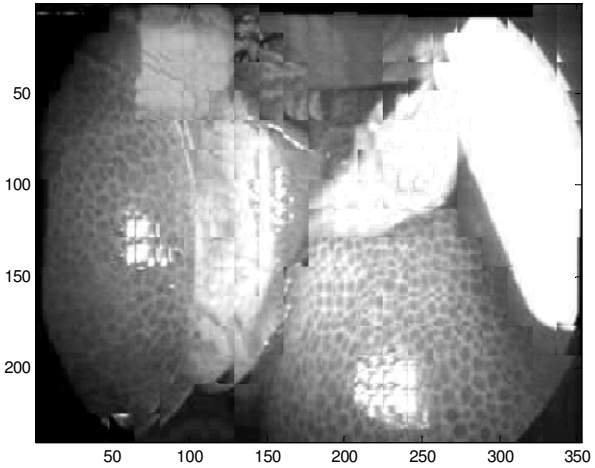
a) Original

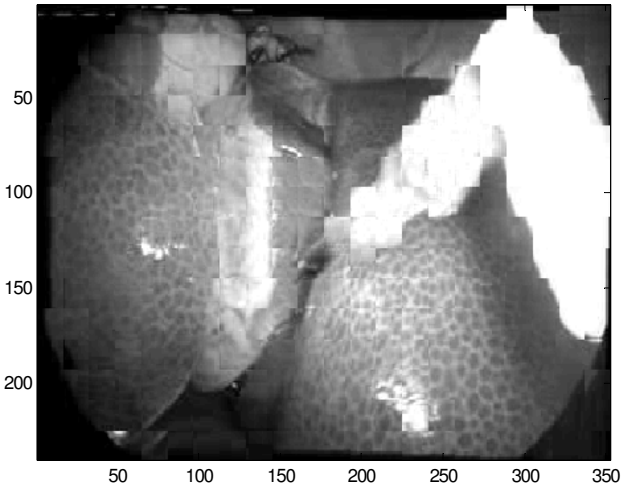
b)Rotated 2 deg CW with illumination change

Optical Flow MSE based vs SSIM





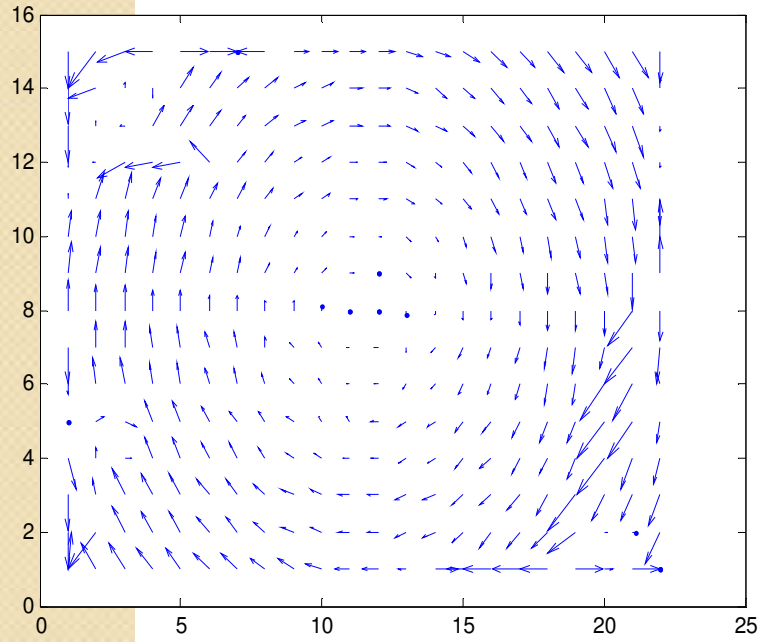


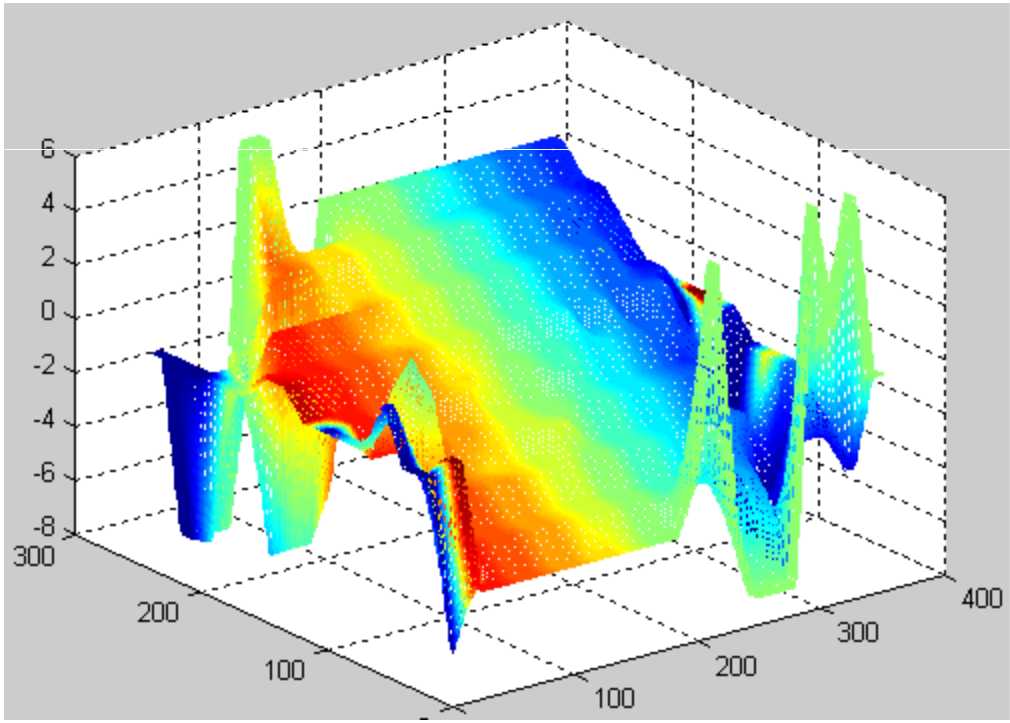


- Optical flow between two frames with illumination changes and rotated 2 deg CW

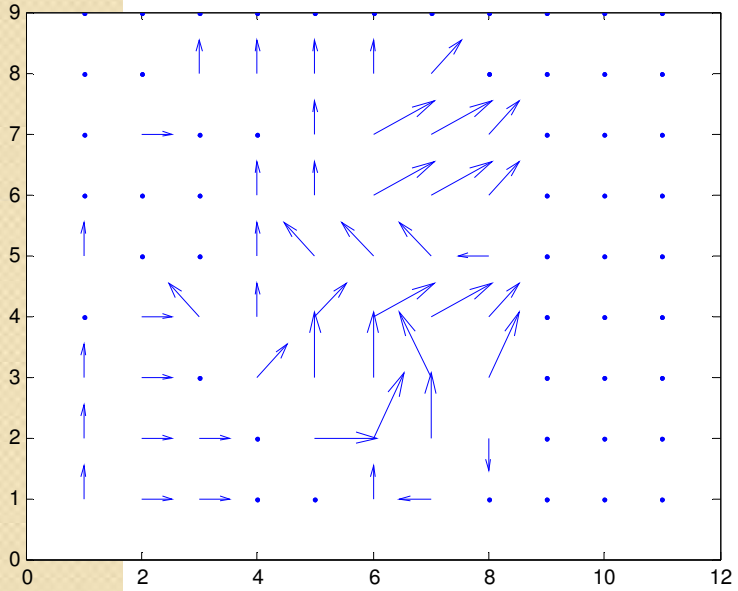
Motion Vector to Geometric Morph

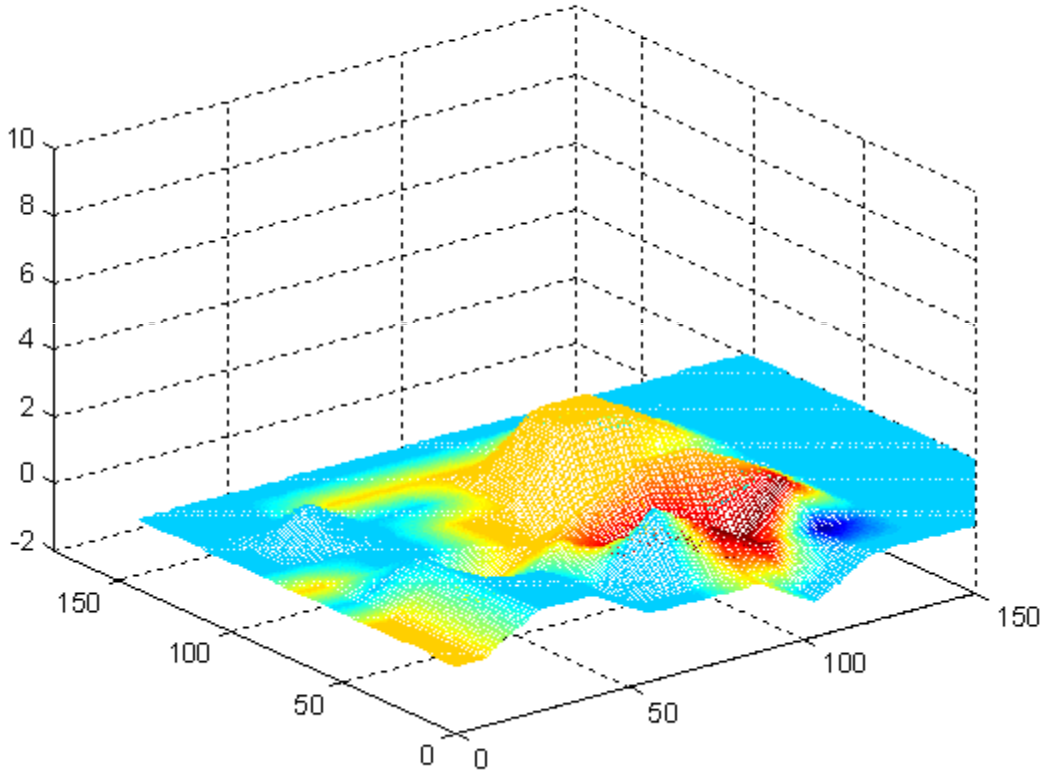
- Content-Based Watermarking by Geometric Warping and Feature-Based Image Segmentation. In *IEEE/ACM Proceedings of International Conference on Signal-Image Technology & Internet-Based Systems*, 17 - 21. 2006, Hammamet, Tunisia.
- LEE S.Y. , CHWA K.Y. ,SHIN S.Y. *Image morphing using deformable surfaces,* Proc. Computer Animation (1994) , vol 200, pp. 31-39.





Motion Vector to Deformable Surface Morph

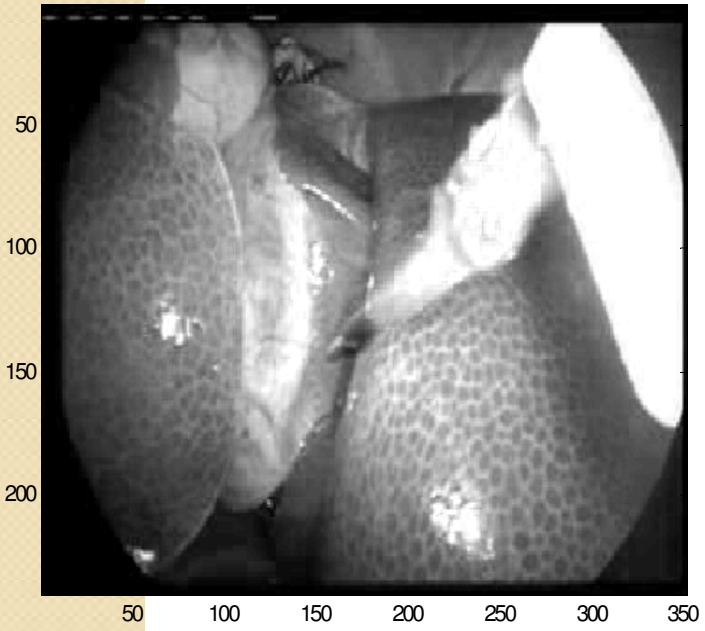




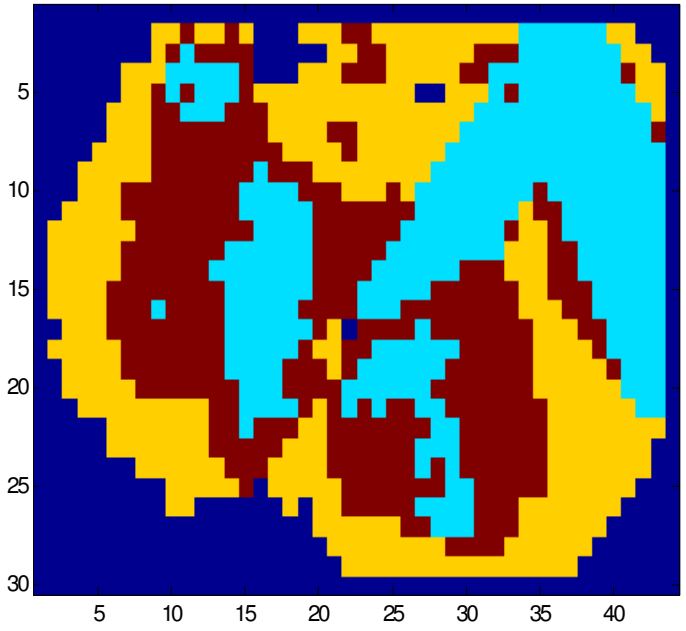
Clustering based Segmentation

Reference:
Zhang, P. Wang: **A New Method of Color Image Segmentation** Based on Intensity and Hue Clustering. **ICPR** 2000: 3617-3620.

Original Sequence Frame

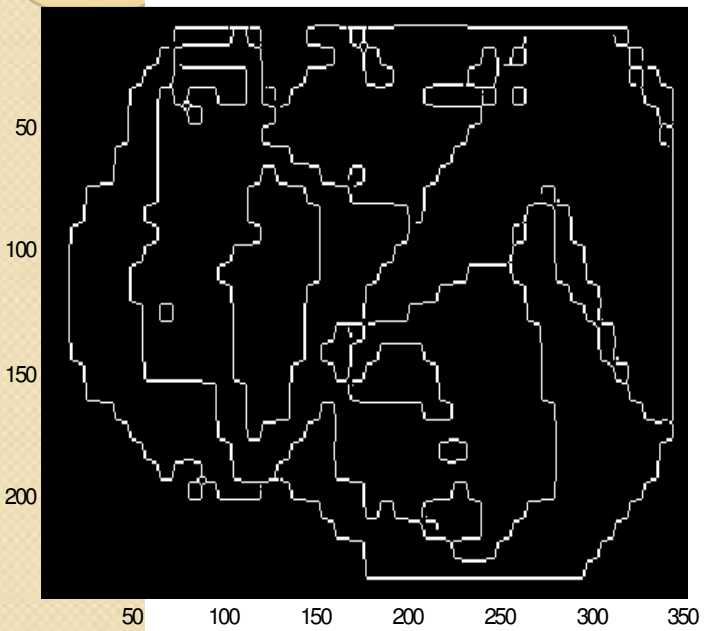


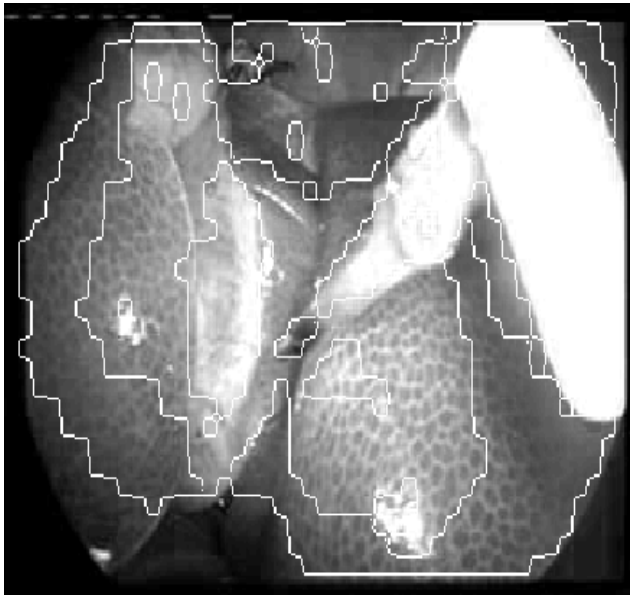
Original input Segmented into 4 Clusters



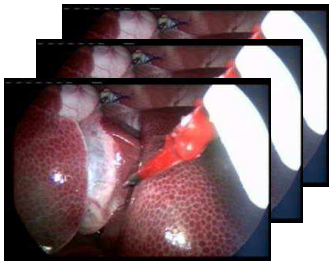
Clustering based Segmentation (contd)

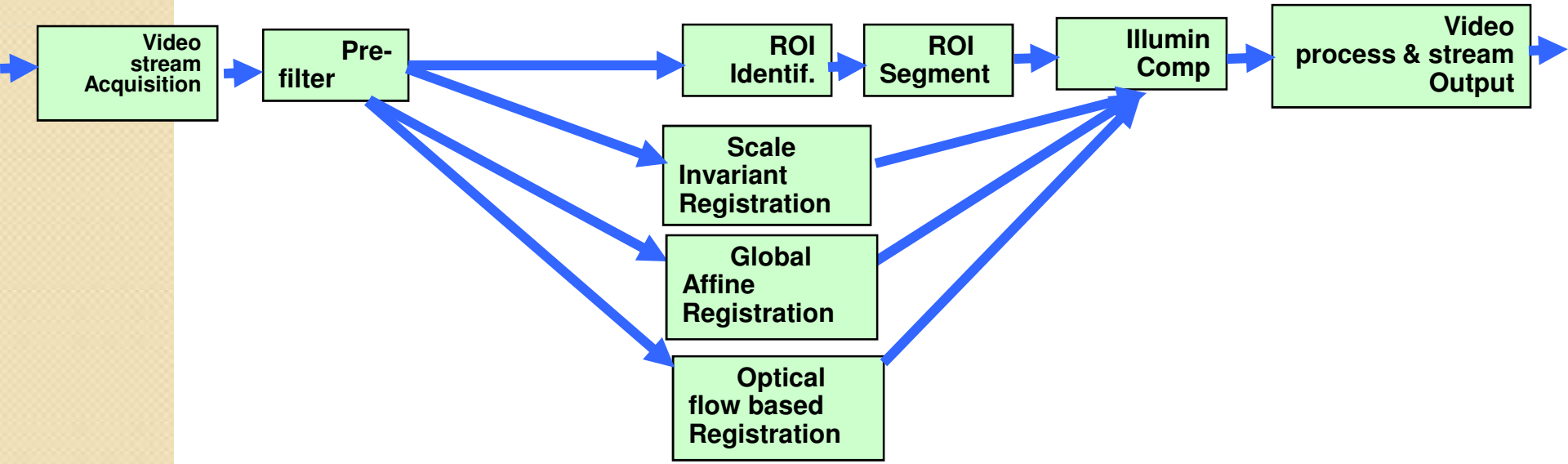
Edge detected after Segmentation and Superimposed on the input





High Level Block Diagram

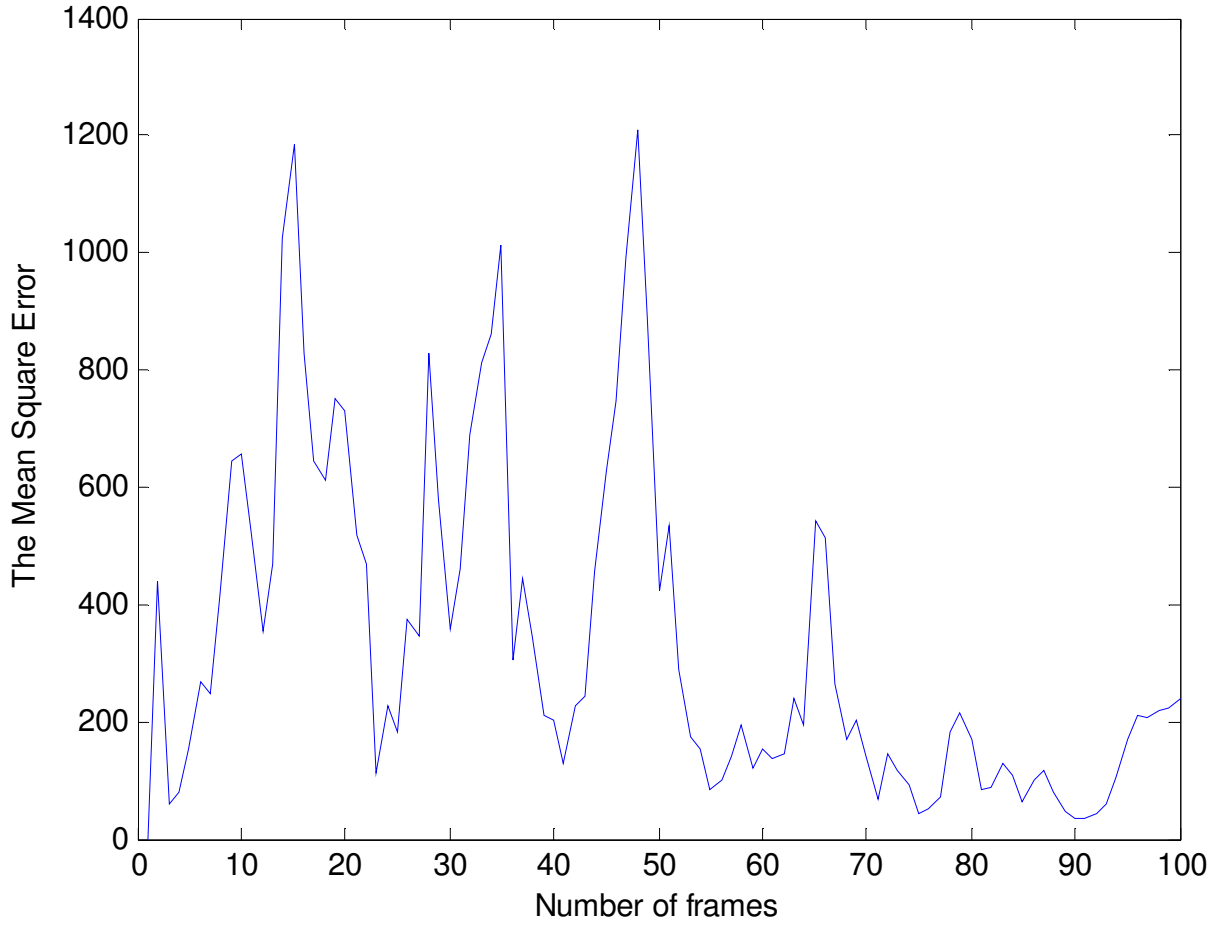




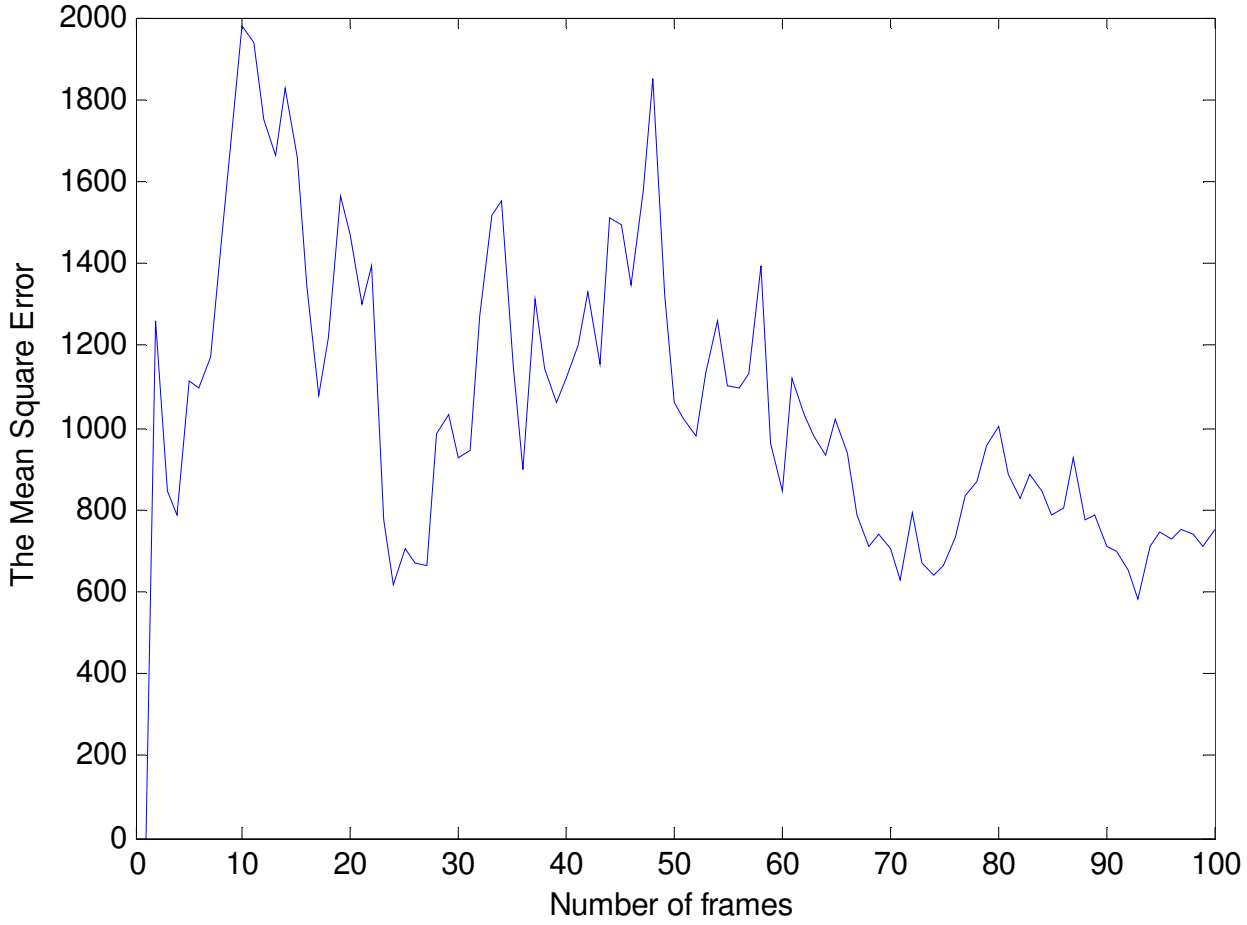
Results

- The estimated flow velocities are depicted as short lines, showing the apparent displacement during one time step.

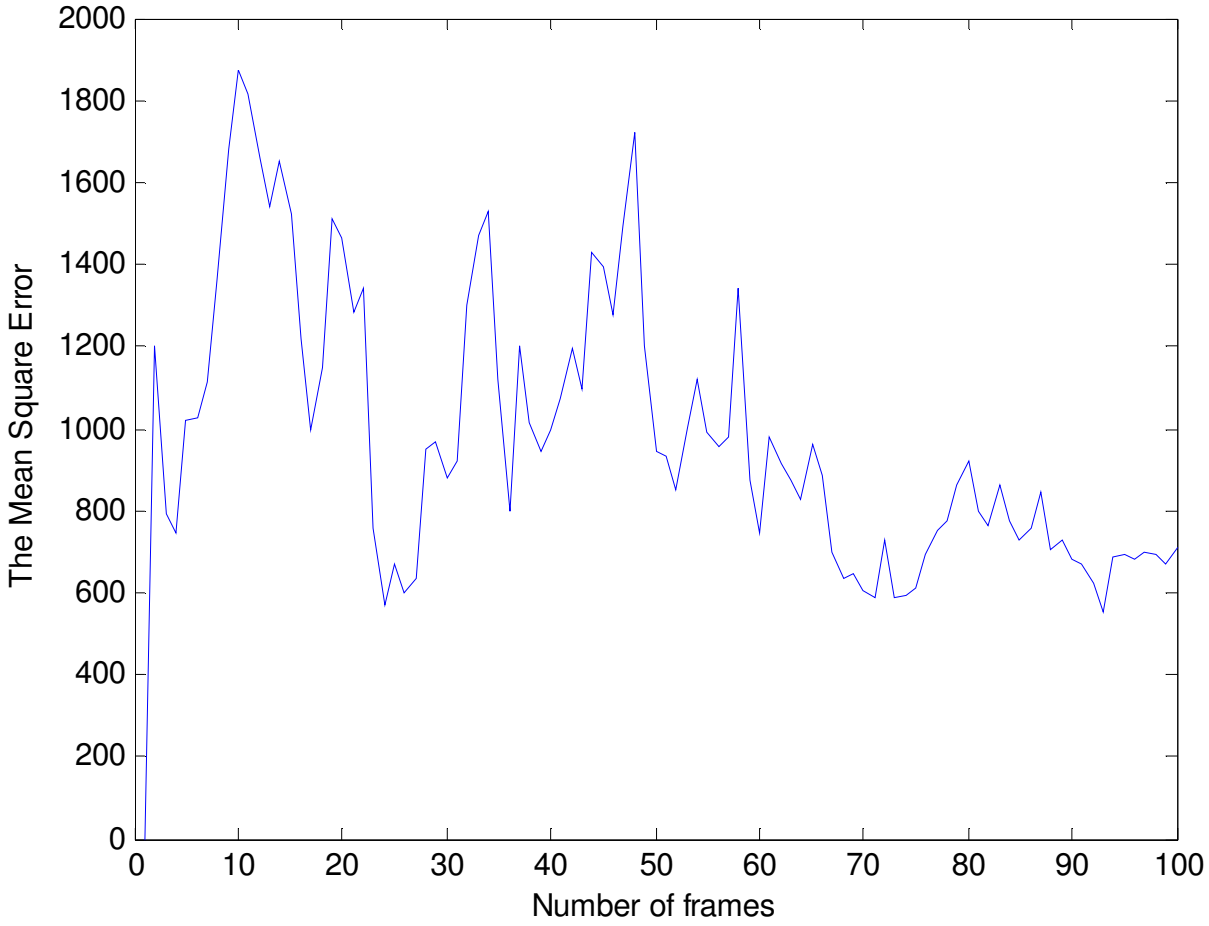
MSE GRAPH FOR AFFINE TRASNFORM



MSE GRAPH FOR OPTICAL FLOW METHOD



MSE GRAPH FOR THE IMAGE MORPHING METHOD



REFERENCES

- S. Periaswamy and H. Farid "Medical Image Registration with Partial Data", Medical Image Analysis, 10:452-464, 2006.
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