

**Final Report on an Investigation of Image Processing  
Techniques for the Problem of Automatic Counting  
of Sea-lions from Aerial Video**

**Prepared by :**

**Dr R.G. Gosine, Dr L. Gamage  
Industrial Automation Laboratory  
Department of Mechanical Engineering  
University of British Columbia  
2324 Main Mall  
Vancouver, V6T 1Z4**

**Prepared for :**

**Dr A. Trites  
Northwest Pacific Universities Marine  
Mammal Research Consortium  
c/o Royal Society of Canada, Research Evaluation Unit  
Room 18, Hut B-3  
6248 Biological Sciences Road  
Vancouver, V6T 1Z4**

## BACKGROUND

A coalition of North Pacific fishing industry groups has been working to address pending restrictions on the Gulf of Alaska and Eastern Bering Sea commercial fishery as a result of possible decline of the Steller sea lion population. A component of the research into this problem is the investigation of techniques to automate the counting of sea lions from aerial video of the Alaska coast. Currently, sea-lion counts are completed manually from 35mm slides, and there is some concern regarding the accuracy and repeatability of such an approach.

It is proposed that computer-assisted counting from video tape or digitised slides (CD-ROM) could provide a better alternative to manual counting in terms of improved spatial coverage, improved reliability/consistency and reduced labour costs.

## METHODOLOGY

From June 1993 - October 1993, image processing techniques were investigated for reliable and accurate counting of sea lion population from aerial video images. In consultation with Dr A. Trites the following six sites were specified as representative haulouts or rookeries,

- (1) Ugamak
- (2) Pinnacle Rocks
- (3) Cape Morgan
- (4) Vsevidof
- (5) Kagalaska
- (6) Cape Yakak

Initially, only a second generation HI-8 video tape of these sites was available, and the colour quality of this tape was very poor. Toward the end of the study a Kodak CD-ROM containing high resolution, colour images was made available.

Appendix A illustrates the system used for this study. Basic image data for the system is provided by either a Hi-8 video editor or a Kodak CD-ROM player. Images from these sources are processed using an SD-512 image processing computer which extracts image features that are useful in identifying sea-lions using knowledge-base software on a PC.

In view of the difficult nature of the sea-lion counting problem, it is proposed that some degree of human interaction will be necessary in the final system. A promising approach would see an operator manually indentifying the sea-lions in the first image frame of a scene. Note that since one image frame corresponds to 1/30 second of time, a 5 second scan along a beach corresponds to 150 image frames that would need to be analysed. With the proposed approach the computer would scan 149 image frames using the human expertise on the initial frame as a basis for automatic counting. Also, some operator intervention is anticipated in the case of overlapping sea-lions when automated counting may be difficult.

The following issues were addressed during this study,

(1) Basic techniques were developed to discriminate sea-lions from background image information. The second generation Hi-8 images produced very poor colour images, and it was decided to pursue grey-scale analysis techniques in the feasibility study. The techniques developed in this phase appear to give good segmentation of the sea-lions, although other objects having similar features to the sea-lion, such as rocks or logs, are also segmented.

(2) The segmented image is further analysed in order to verify the location of sea-lions in the image. A more detailed analysis of the local greyscale variation in the vicinity of potential sea-lions provides a basis for positive sea-lion identification.

(3) An algorithm for tracking sea-lions between successive image frames was developed and tested on a limited number of scenes. This algorithm, or a refined version, will be needed in a final system to ensure that a sea-lion is only counted once although it may appear in a number of successive image frames.

(4) The techniques developed during this investigation were applied to *typical* image sequences for a range of terrain (ie. sandy beach, rocks) and the performance was measured in comparison with manual sea-lion counts.

## SEA-LION COUNTING ALGORITHM

In this section the algorithm for automated counting of sea-lions is detailed. A flowchart of this algorithm is found in Appedix B, while sample images at various intermediate stages of processing are found in Appendix C.

Once an image is captured from the HI-8 editor or the CD-ROM, the operator is asked to input the average size of a sea-lion in the scene. This size is later used in the program in order to eliminate unwanted objects from the image. The image is then smoothed using a low-pass filter, and the edges of the resulting image are enhanced using a Sobel edge detection operator.

A suitable threshold value is selected by trial and error, and the image is binarized. The binary image, in general, consists of a large number of objects, which may or may not be sea-lions. Since the average size of a sea-lion is known, the objects that are very small or very large can be eliminated. It is necessary, therefore, to compute the area of each object. In order to compute the area, each object must be segmented and objects within a range of acceptable area are dilated so that the dilated area covers the complete area of the original object in the image. This is carried out in order to extract the areas corresponding to the objects from both the original image and the edge enhanced image for computing features that lead to accurate sea-lion identification. The dilated objects are labelled so that they can be uniquely identified. The following steps are crucial to computing the object features.

The first step is to box all objects found by the dilation procedure. Boxing is a process which finds the least rectangle that encloses the object of interest. The results of the boxing process is a set of top left and bottom right coordinates of each object in the image. The reason for finding these coordinates is to compute some morphological features

of the objects. Also, once the object boundaries are known, processing can be limited to an area of interest which results in a tremendous reduction in computation cost.

The next step is to extract the corresponding object areas from the original image in order to compute the the mean value and the standard deviation of the pixel intensities of the original objects and to compute the object area. The objects from the original image are extracted by setting up a dyadic look-up table which operates on two images and outputs a value only if the conditions specified by the look-up table are satisfied by both images at corresponding locations.

The other crucial feature for accurate identification of sea-lions is the change in intensity gradient across the sea-lion body. It was clear from most of the sea-lion images that the brightness gradient across the body of a sea-lion changes from a high value at the edge to a low value (almost zero) at the center. This particular feature distinguishes sea-lions from other objects 90% of the time provided that the sea-lions are of a reasonable size. In order to obtain the gradient values across a body of an object, several operations must be performed. First, it is necessary to extract the corresponding areas of objects from the edge enhanced image (gradients) by a process similar to extracting original objects described above. Second, in order to find the gradients across the body, it is necessary to find the orientation of the object. The orientation of an object is given by the direction of its major principle axis and therefore the direction of across body is given by the direction of the minor principle axis. The principle axes of object can be found by computing its second moments of area and the cross moment of area. Finally, a value for the gradient can be computed by taking a cumulative value of the gradients of the objects extracted from the edge enhanced image along a line parallel to the minor principle axis of the object through its centroid. The centroid of the object can be computed by the first moment of area of the object. Two other gradient values were computed in directions parallel to the minor principle axis, although the lines cross the major principle axis 5 pixels from either side of the centroid.

After computing features from all objects, the object coordinates are saved in an array in order to match them in the next frame. This is necessary to avoid double counting of sea-lions. The matching process is carried out by taking each object in the previous frame and correlating it with an object in the current frame. If the value of correlation (normalized) is close to one then there is a strong possibility that the two objects are identical.

A data-base of features is established using the information in an image that has been manually analysed. This data-base then serves a nearest-neighbour classifier that makes a decision regarding positive identification of a sea-lion based on the degree of similarity between the features of an unknown image object and those of knowns sea-lion in the initial image frame.

## **DISCUSSION OF RESULTS**

The results from this study are summarised in Appendix D. The results for the HI-8 video indicate a good agreement between the computer and manual counts for each of

the six sites. Note that for the HI-8 results the manual counts were completed by Dr L. Gamage, and these counts were made from a television monitor which displayed the same image that was used for the computer count. Also, overlapping sea-lions were not considered for the HI-8 results. Grey-scale images were used in this study since the colour quality on the second generation HI-8 video tape was very poor.

For the CD-ROM results, the manual counts were completed by Dr A. Trites, and these counts were made from slides projected onto a white screen. The computer counts were made from the CD-ROM image corresponding to the projected slide. The colour CD-ROM image was converted to grey-scale prior to processing in order to use the software developed for the HI-8 video. As indicated in the recommendations section of this report, colour processing would have been preferable. Colour processing, however, was not possible within this study due to hardware limitations on the available equipment for processing the CD-ROM.

Again, there is good agreement between the computer and manual counting for the non-overlapping sea-lions at each of the six sites. The results for the CD-ROM images highlight the difficulty in counting overlapping sea-lions, and further work is needed on this problem.

Overall, the results of this study indicate promise for the use of computer vision techniques for automated counting of sea-lions. The primary advantage of computer vision is that it provides a consistent sea-lion count. Unlike a human, an automated system will not become distracted from the task, it will not fatigue as it performs a boring and repetitive task, and it can rapidly track large amounts of image data in a scene spanning many image frames or slides. The computer system, however, will only perform as well as the information in its data-base, and ensuring accurate data-base development is critical.

## RECOMMENDATIONS

The following recommendations are provided based on the results obtained in this study,

(1) The average size of a sea-lion should be at least 400 pixels in a  $512 \times 512$  image. This sea-lion resolution was found to provide reliable features for positive identification of sea-lions.

(2) The basic image processing operations used or developed in this study should be extended to improve the system performance. In particular, the sea-lion tracking algorithm, which avoids double counting of a sea-lion in successive image frames, must be tested further. Also, an algorithm to identify overlapping sea-lions must be developed.

(3) It was clear from the CD-ROM images that colour is a valuable feature in discriminating sea-lions from the other objects. Further work is necessary to incorporate this feature.

(4) More sophisticated classification schemes should be investigated. The nearest-neighbour classifier used in this study could be modified to include feature weightings that are selected based on optimal performance on the data-base (initial image frame).

(5) When a large number of sea-lions are overlapping user interaction should be incorporated into the system. In order to provide an useful interactive system further work is needed in the development of an appropriate user interface.

In terms of data gathering techniques, the following recommendations are made,

(1) Image distortion should be minimised. For example, eliminate the time/date stamp and avoid recording through glass.

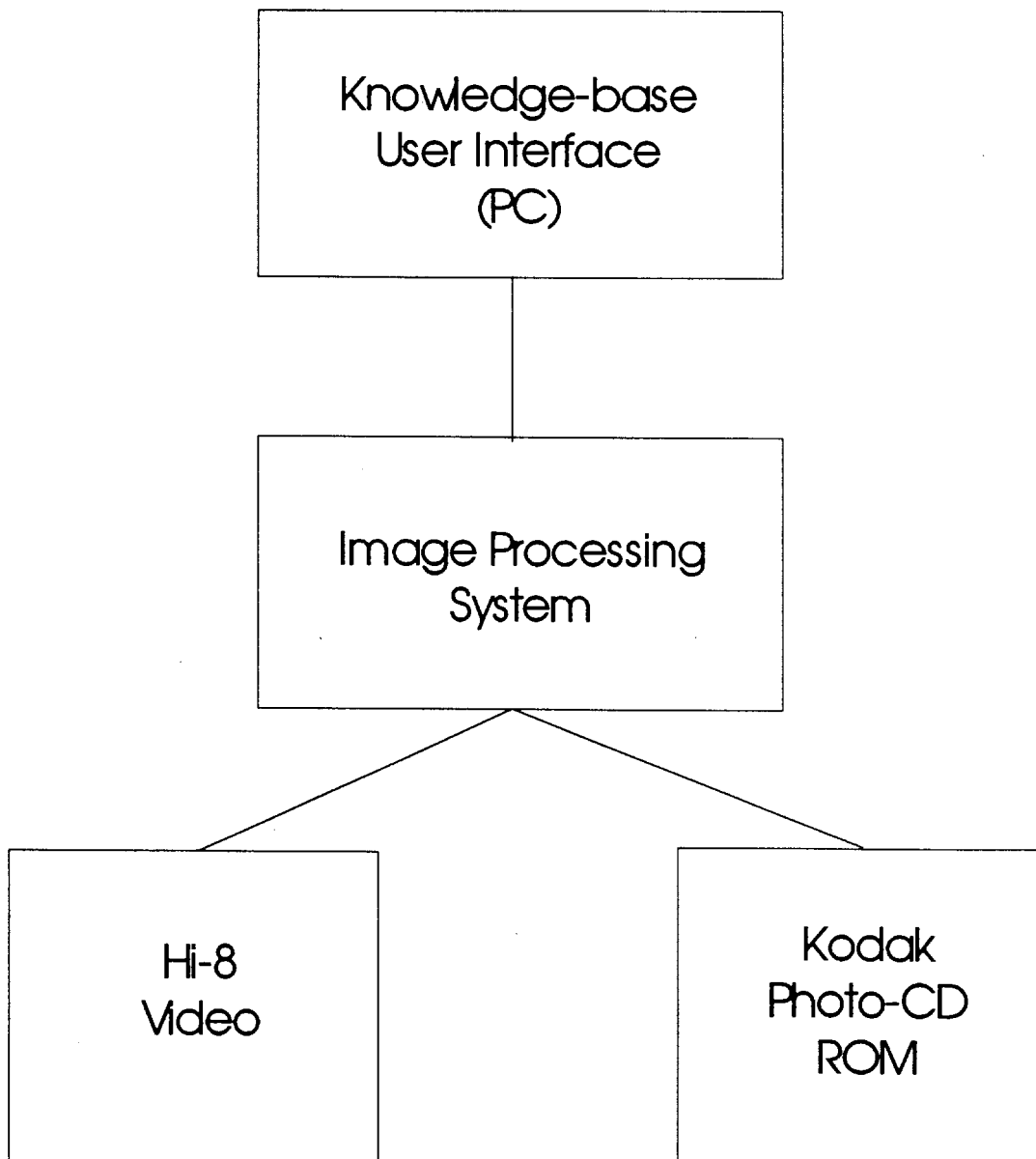
(2) The camera should be stabilised. This may require the design of a camera mount.

(3) The audio track on the HI-8 video recorder should be used during data gathering to provide a specific demarcation to separate different scenes.

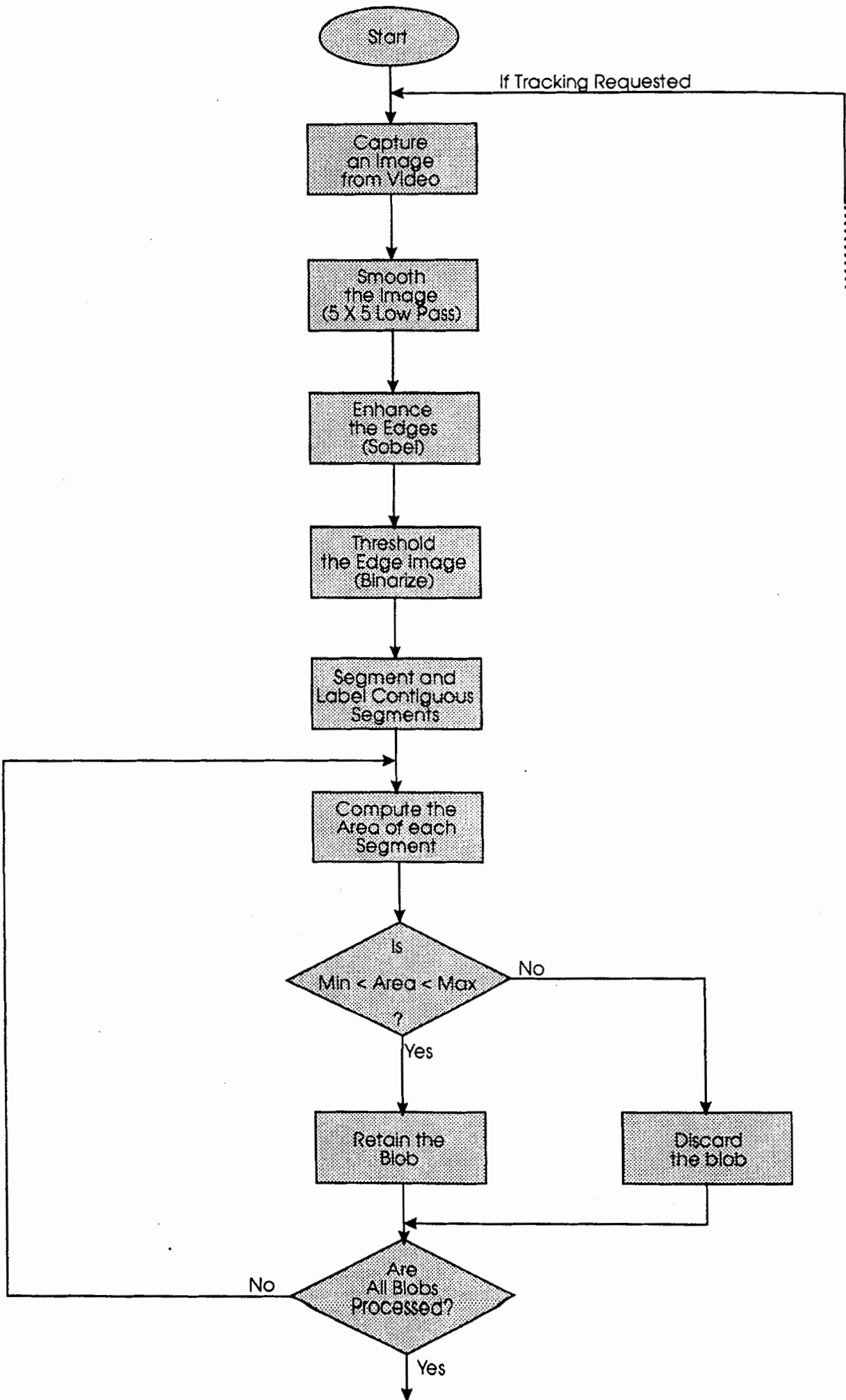
(4) The analysis would be simplified if the camera operator focused on one scene for an extended period of time (say  $\sim 10$  Sec.). This would help distinguish sea-lion scenes from other scenes.

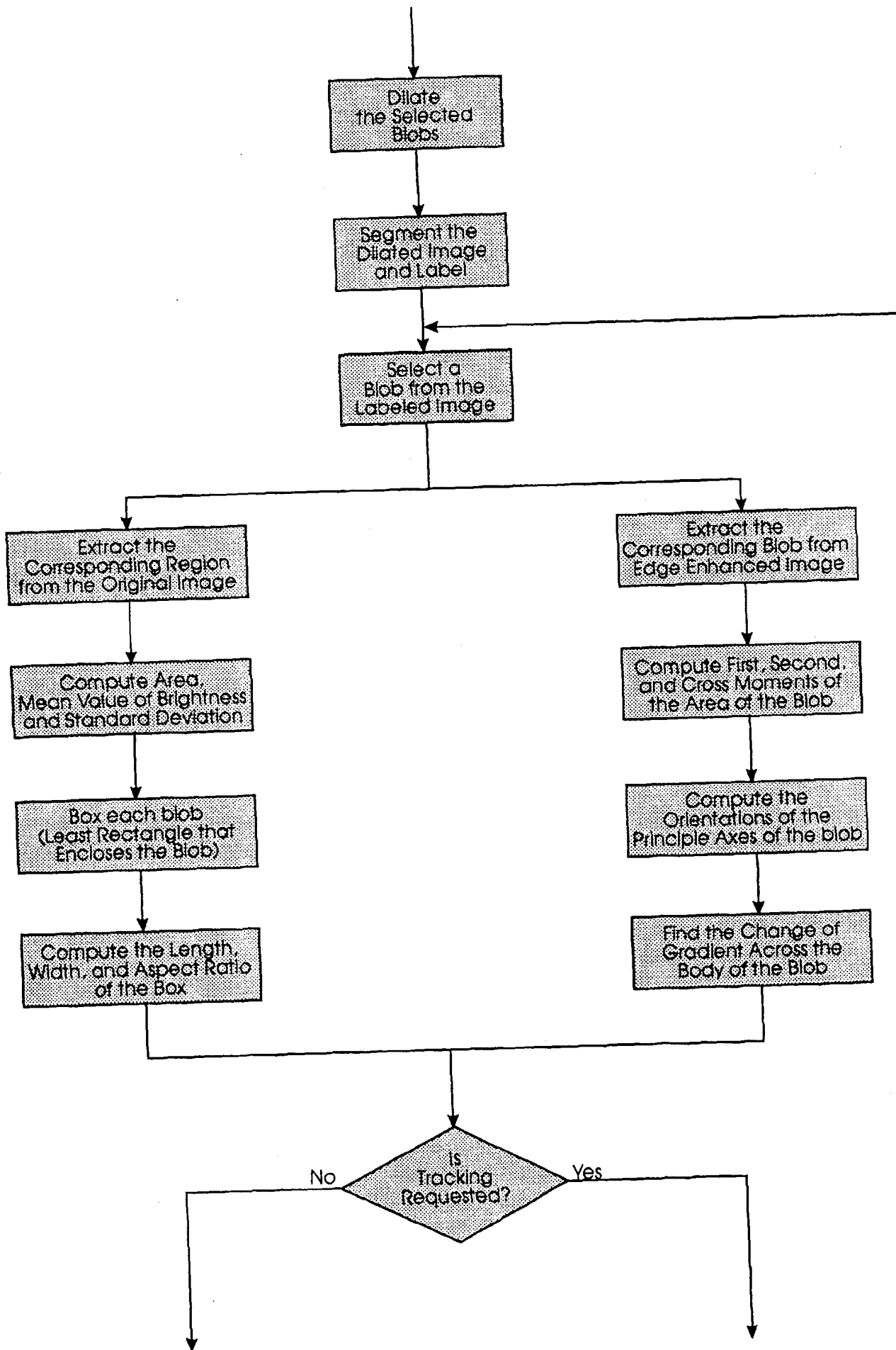
## **APPENDIX A - SYSTEM OVERVIEW**

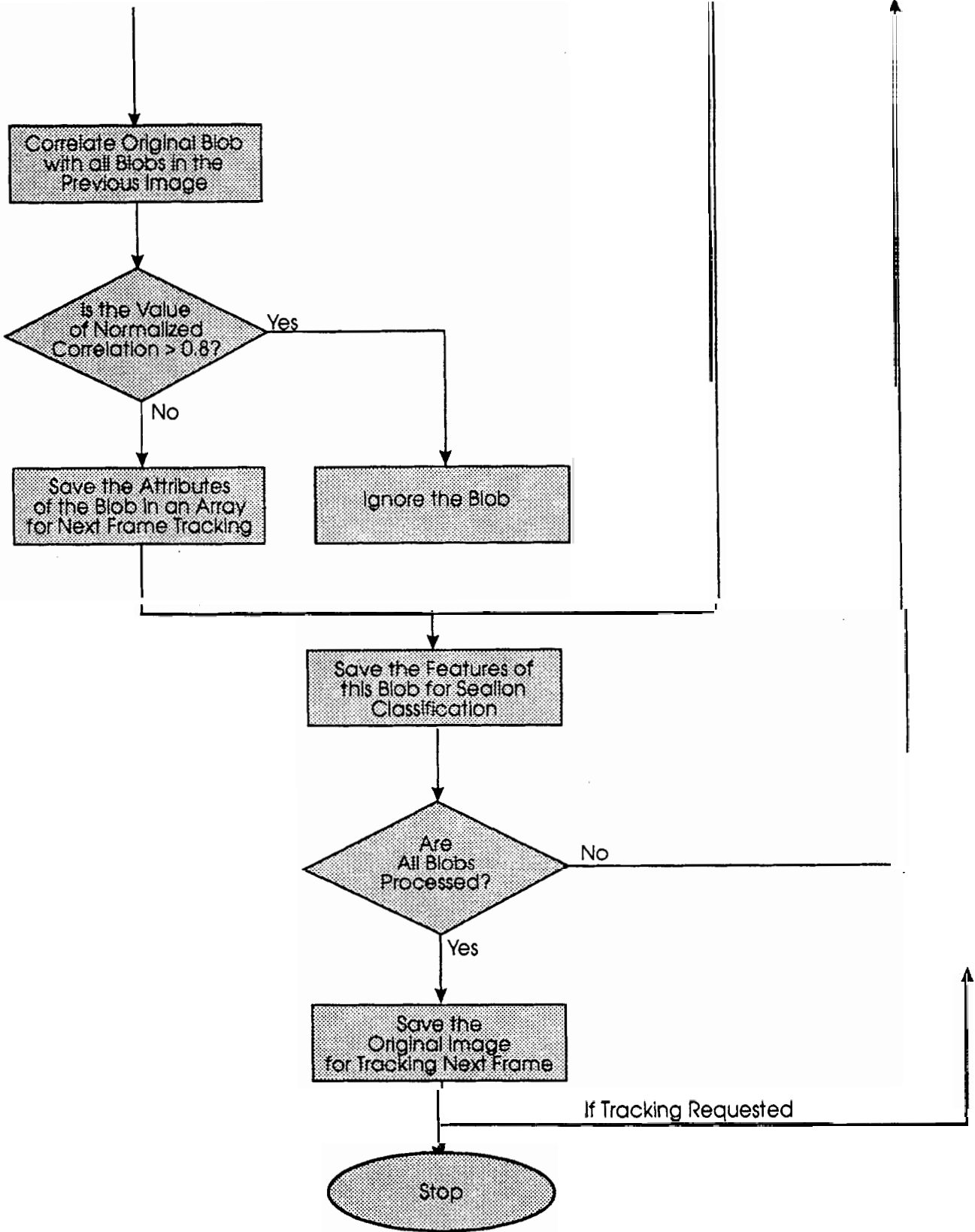
# OVERVIEW OF THE SYSTEM



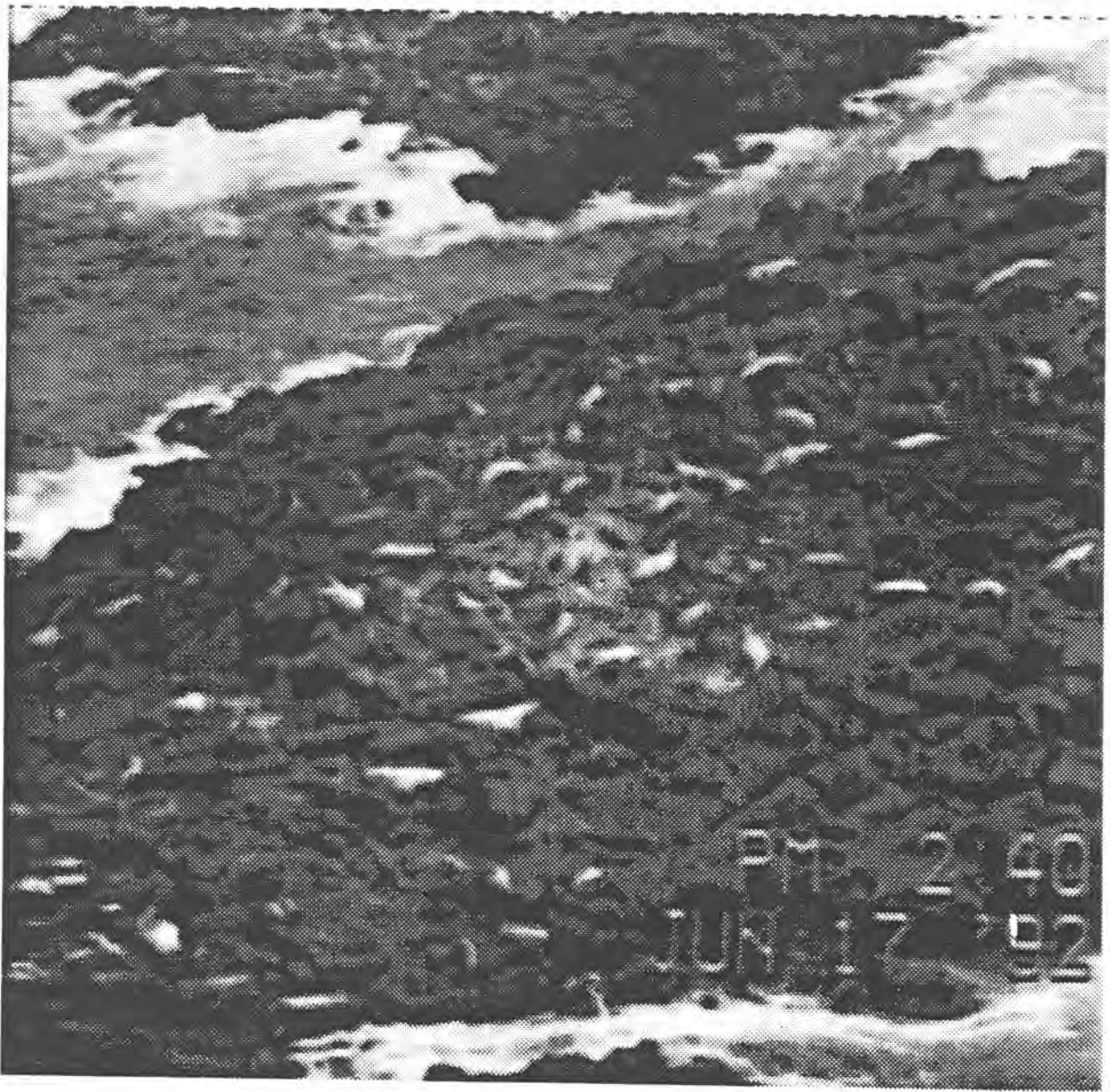
## **APPENDIX B - SOFTWARE FLOWCHART**



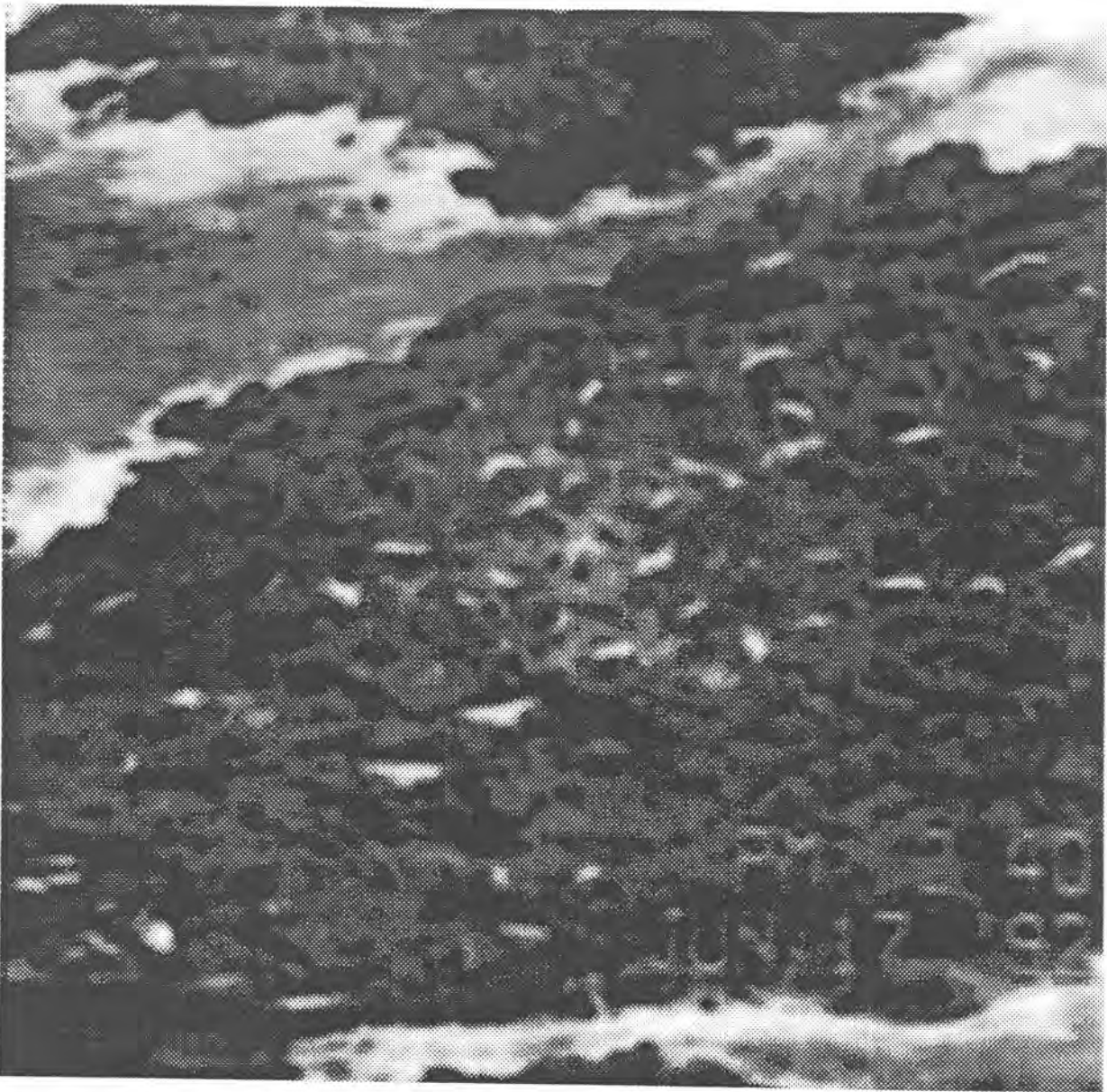




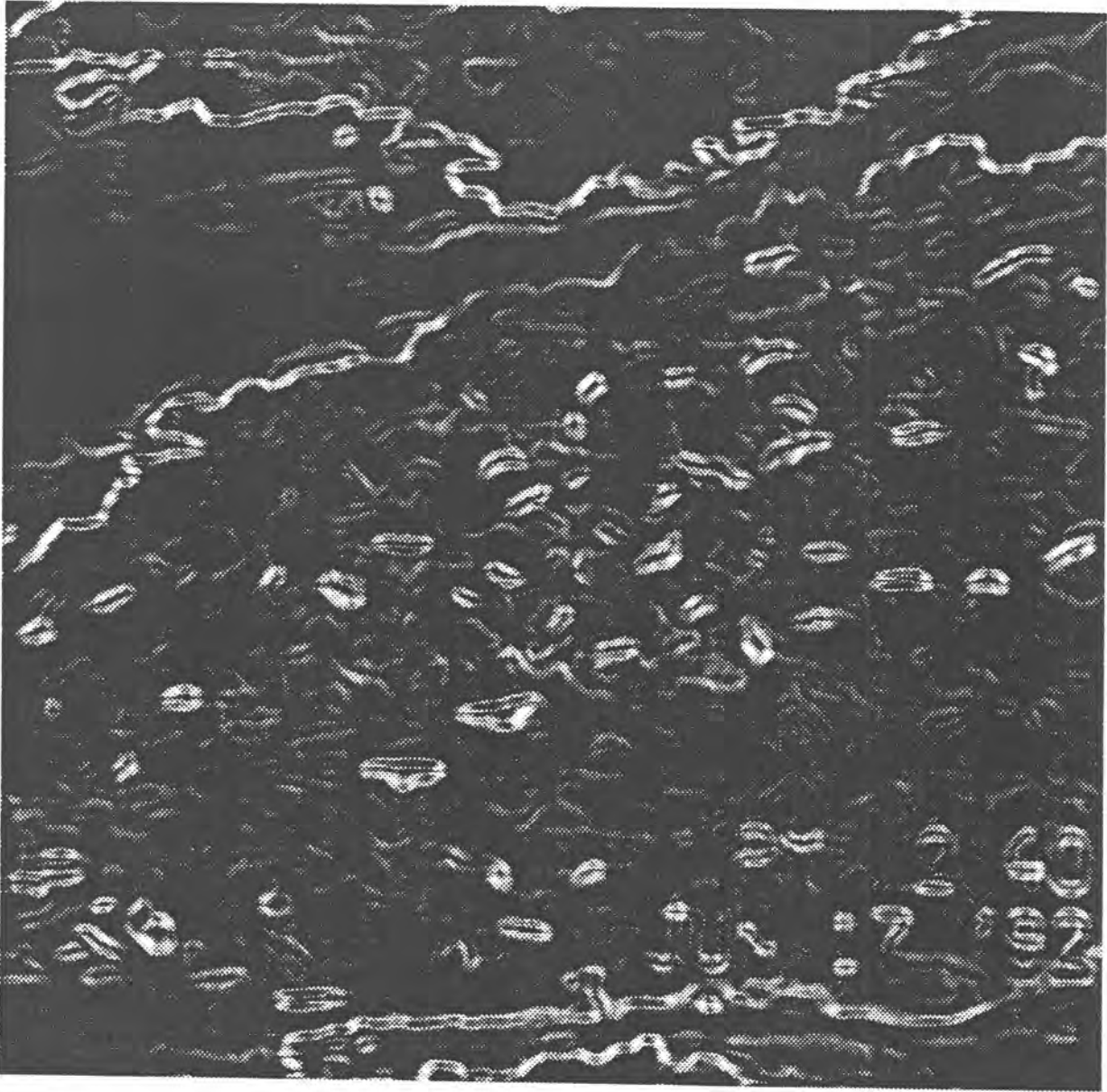
**APPENDIX C - INTERMEDIATE IMAGES**



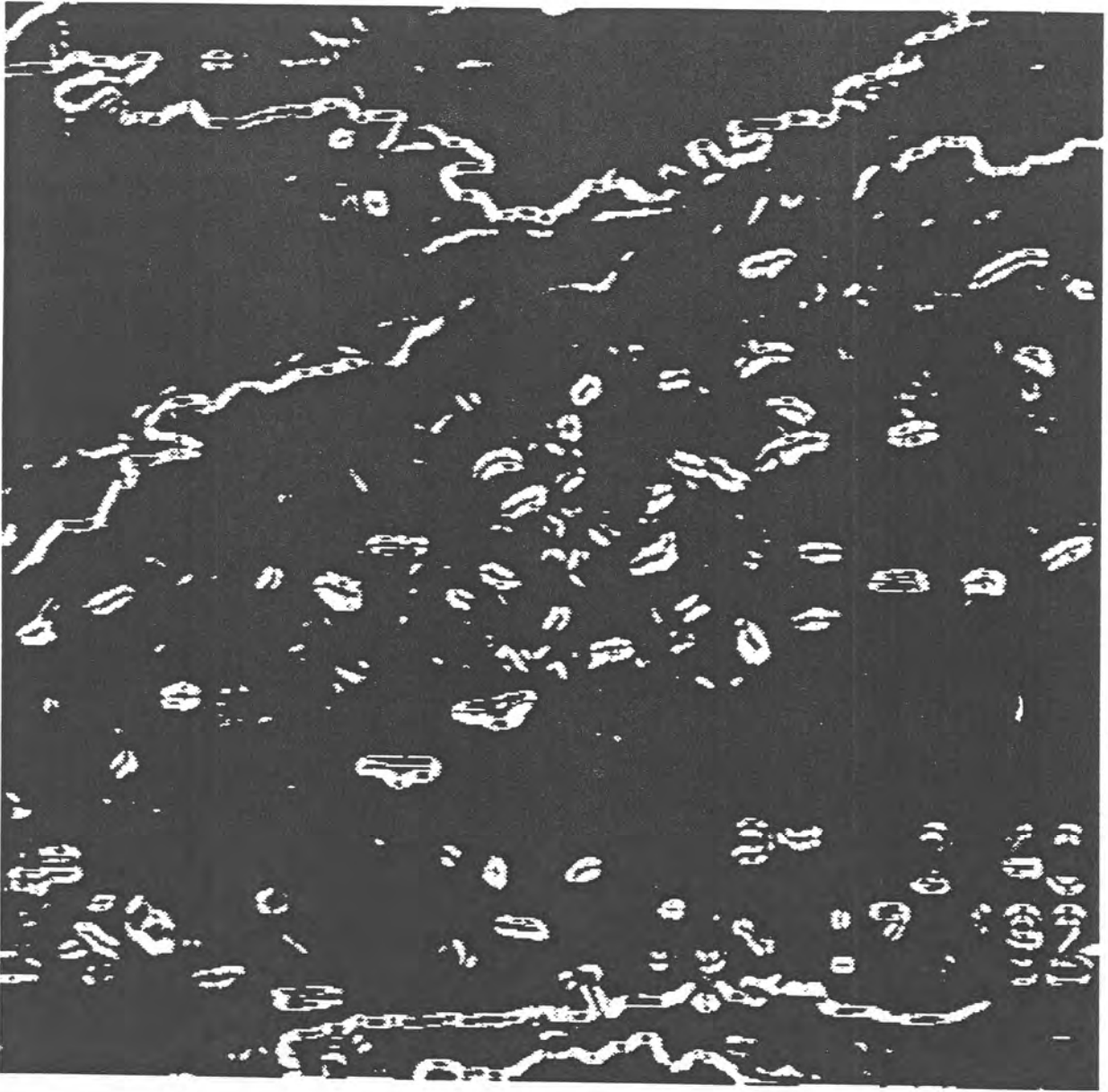
Original Image Captured by the Vision Station from the Video Tape



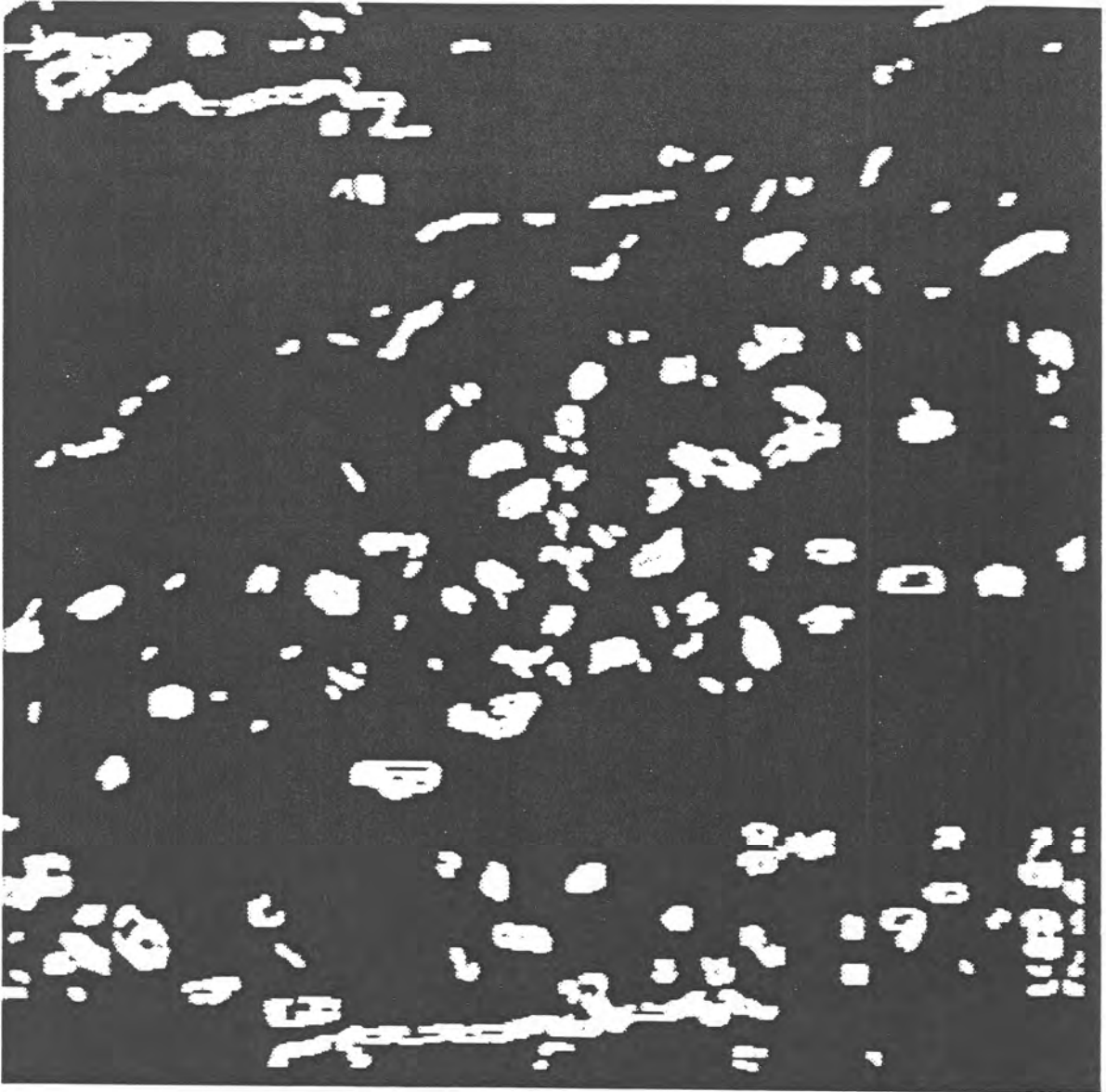
Smoothed Image ( $5 \times 5$  Low Pass Filtered)



Edge Enhanced Image (Sobel Edge Operator)



Thresholded Edge Enhanced Image (Binarized)



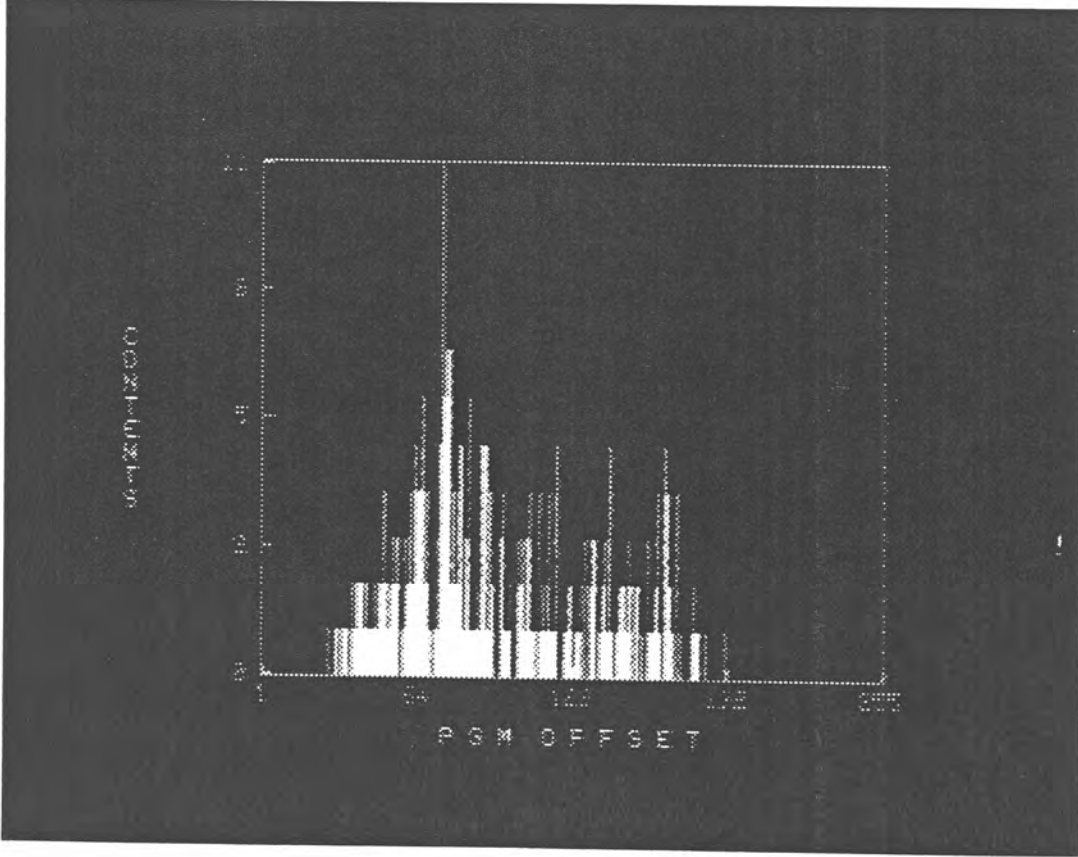
Dilated Image  
(After Removing Unwanted Structures from the Thresholded Image)



Gradient Map of the Blob



Original Blob



Histogram of Pixel Brightness Values within the Original Blob

## APPENDIX D - RESULTS

## RESULTS FOR HI-8I VIDEO

Ugamak -----	Count
Computer	47
Manual	43

Pinnacle Rocks -----	Count
Computer	59
Manual	54

Cape Morgan -----	Count
Computer	43
Manual	42

Vsevidof -----	Count
Computer	28
Manual	27

Kagalaska -----	Count
Computer	28
Manual	28

Cape Yakak -----	Count
Computer	32
Manual	34

## RESULTS FOR CD-ROM IMAGES

Location	Count	Overlap	Total
Ugamak -----			
Computer	74	3	77
Manual	70	20	90
Pinnacle Rocks -----			
Computer	49	0	49
Manual	48	20	68
Cape Morgan -----			
Computer	29	17	46
Manual	28	37	65
Vsevidof -----			
Computer	18	0	18
Manual	17	1	18
Kagalaska -----			
Computer	33	0	33
Manual	32	11	43
Cape Yakak -----			
Computer	15	6	21
Manual	18	16	34