# AUTOMATION FOR OYSTER HINGE BREAKING SYSTEM

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## ABSTRACT

A computer vision system was developed to automatically detect and locate the oyster hinge line, one step in shucking an oyster. The computer vision system consisted of a personal computer, a color frame grabber, a color CCD video camera with a zoom lens, two video monitor, a specially designed fixture to hold the oyster, a lighting system to illuminate the oyster and the system software. The software consisted of a combination of commercially available programs and custom designed programs developed using the Microsoft C™.

Test results showed that the image resolution was the most important variable influencing hinge detection efficiency. Whether or not the trimmed-off-flat-white surface area was dry or wet, the oyster size relative to the image size selected, and the image processing methods used all influenced the hinge locating efficiency. The best computer software and hardware combination used successfully located 97 % of the oyster hinge lines tested. This efficiency was achieved using camera field of view of 1.9 by 1.5 cm, a 180 by 170 pixel image window, and a dry trimmed-off oyster hinge end surface.

**Keywords.** Computer vision, oysters, oyster shucking.

## INTRODUCTION

Oyster shucking is generally not considered to be a highly desirable. Removing the oyster meat from the shell, shucking, is difficult, time consuming, potentially risky, and requires considerable skill to prevent mutilating the oyster meat. Commercially, oysters are opened by hand, using a knife, mallet, chisel, block, or combination of these tools.

Over the years, many inventors have labored long and hard, with considerable expenditure, to develop an automated oyster shucking system, but to date none have been proven to be commercially acceptable. Many of the problems associated with opening an oyster result from its unpredictable shape. The oysters grow on river and bay bottoms that are formed from a variety of substrates (e.g., sand silt, oyster shells, stones, clay and various animal life). Because oyster shape tends to be partially environmentally determined (Galtsoff, 1964), the variety of growth environments produces a variety of oyster shapes. This shape variation has made developing an automated oyster shucking system difficult. Developing a system that can insert a sharp object at the exact point needed to sever the two muscle attachments and the hinge, without mutilating the meat, has proven so difficult that no system developed has been accepted by the industry as a substitute for the skilled

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hand shucker.

One of the existing experimental automated oyster shucking systems, the Wheaton Shucking System (Wheaton, 1973), has been developed to the point where it can almost substitute for the skilled hand shucker. The So and Wheaton (1996) oyster hinge breaker, one part of the Wheaton Shucking System, uses a computer vision control system to automatically locate the oyster hinge line in a flat-white trimmed-off surface area on the hinge end of the oyster. The system then controls the hydraulically and mechanically driven hinge severing device which severs the oyster hinge. The computer vision control applied oyster hinge breaker, however, did not have a high hinge severing efficiency because of limitations in the image processing software (So and Wheaton, 1996). The image processing software had detection errors due to dark holes and spots in the oyster shell. This paper stress software development that improves the ability of the computer vision system to detect oyster hinges.

## MATERIALS AND METHODS

The equipment used in this research consists of the following three major units; 1) oyster hinge end trimming unit, 2) oyster image acquisition unit, and 3) image analysis unit.

### Hinge End Trimming Unit

The oyster hinge end trimming unit is a part of the Wheaton Oyster Shucking Machine (Wheaton, 1973; So and Wheaton, 1996) and was used in this research to trim the oyster hinge end. Trimming the oyster hinge end allowed access to the hinge exterior and provided an oyster with a flat-white surface on the hinge end that ideally produced images containing an upper and lower white object (i.e., the trimmed ends of both shell valves) with the dark hinge line separating the trimmed pieces of the two shell valves (Figure 1).

### Image Acquisition Unit

Figure 2 shows a schematic diagram of the image acquisition system used in this research. This system was designed to simulate the image acquisition unit of the Wheaton Oyster Shucking Machine (So and Wheaton, 1996). Imaging hardware used in this research consisted of a color CCD camera (PULNiX, Model TMC-74 (NTSC)) and associated RGB interconnect (PULNiX, Model SC-745), color frame grabber (Imaging Technology Inc., Model VP1300-KIT-512-U-AT), color video monitor (SONY, Model PVM-1342Q), and personal computer (DELL, Model OPTIPLEX 466/MX) with an integrated coprocessor. A commercially available library of subroutines (Image Technology Inc., Model VISIONplus-AT CFG) facilitated accessing image data. Algorithms were implemented in C (Microsoft Corp., C5.1).

The optics and front lighting system consisted of two, 75W incandescent lamps with individual reflectors, a black scene background, and an 11 - 110 mm motorized zoom lens (FUJINON, Model H10x11B-MD3) with its associated remote control box (FUJINON, Model CRD-2A). The camera was placed inside the environmental enclosure (PELCO, Model EH-5520) to protect the camera from dust, water, and mist. The enclosure was mounted onto an adjustable aluminum platform which was bolted to a vertical aluminum tube. The tube fit over a vertical shaft mounted to an aluminum base. The slide moved up and down on the shaft and was held in place vertically by a horizontal screw threaded through the side of the tube. Tightening the screw clamped the tube to the shaft and held it in place vertically. Loosening the screw allowed vertical adjustment of the camera. The camera height was adjusted to align the camera viewing axis in the same horizontal plane as the oyster. A frame to provide mounting for the lighting and to hold the oysters was constructed such that the camera saw exactly what it would using the real HSC conveyor (So and Wheaton, 1996). Additional details of the unit used are reported in So and Wheaton (1996).

**Image Analysis Unit**

An automated image processing software was written using the Microsoft C™ language with the ITEX CFG library of image processing functions for its associated color frame grabber (Model VP1300-KIT-512-U-AT). The software consisted of a data-training program for the oyster hinge line. Figure 3 shows the flow chart of the oyster hinge line detection image processing software. Additional details of the unit used are reported in So (1995).

A classification function for the hinge and non-hinge object was constructed using for feature measurements; circularity, rectangularity, aspect ratio, and Euclidian distance. These four variables were selected based on a preliminary study that determined the best hinge object classification rate in a sample (e.g., training sample) using different sets of variables. The best set of variables was determined by running Proc Stepdisc and Proc Discrim procedures in SAS (SAS Institutes Inc., 1988) using the training samples' feature data.

The classification function in the image processing software found the one and only one hinge object by calculating squared distances of the feature measurement vector $\mathbf{x}_0$ of each object to the hinge object feature measurement mean vector $\mathbf{x}_1$ obtained from the training sample, and then assigning the object with the minimum squared distance to the hinge object. Thus, the classification function, y, for oyster hinge line detection was (Johnson and Wichern, 1992)

$$y = \bar{x}_1 S^{-1} x_0 - \frac{1}{2} \bar{x}_1 S^{-1} \bar{x}_1 \qquad (1)$$

where S was a pooled covariance matrix and $S^{-1}$ was inverse of S.

**Oyster Samples**

A total of 500 oysters harvested from five different locations in the Chesapeake Bay (Wild Bar, Eastern Bay, Maryland; Choptank River, Cambridge, Maryland; Sea Side, Virginia; Little Choptank River, Fishing Creek, Maryland; and Crisfield, Eastern Shore, Maryland) were tested. The oyster samples were randomly hand-selected from each batch of oysters. Table 1 shows the oyster sizes used in this test. These averages were from 49 measured oysters that were randomly chosen from each batch of oysters. Measurements were taken after the hinge end was trimmed off.

**Oyster Sample Preparation**

Oysters were washed to eliminate dirt, mud, most fouling and other foreign materials using the Wheaton Oyster Washer (Wheaton, 1973). Approximately 6 mm was trimmed off the hinge end of each oyster to form the flat-white surface on the hinge end. The oyster hinge end trimming component of the Wheaton Oyster Hinge Breaker was used to trim the oysters (Wheaton, 1973; So and Wheaton, 1996). Each oyster sample was sprayed by water using a spray gun before the computer grabbed an image except as noted below. This simulated the "wetted" shell condition typical of oysters after they pass through the Wheaton Oyster Hinge Breaker (Wheaton, 1973; So and Wheaton, 1996).

**Experimental Procedures**

This study consisted of two tests to determine the effect of the image resolution on the computer vision system hinge line detection. The image resolution is related to the size of the image processing area and the field of view with respect to the image processing area (i.e., image window). The high resolution inside the image window with the small field of view dimensions was obtained by telescoping the camera lens closer to the oyster hinge end. Also, the effect of water on the trimmed-off surface was tested.

**Test 1**

The field of view dimensions of 2.8 x 2.2 cm were selected to be just large enough to allow the trimmed-off surface area at the oyster hinge end to be within the image window, no matter what sized oyster was viewed. The resolution selected in Test 1 was 2.013 x $10^{-2}$ $mm^2$/pixel with respect to the image window (180 x 170 pixel). The camera height, however, was adjusted if necessary for each oyster such that the trimmed-off surface area viewed within the image window during the test. Re-adjustment was occasionally necessary if a large portion of the trimmed-off surface area was found to lie above or below the rectangular image window boundary. The distance of the scene from the camera was approximately 113 cm.

**Test 2**

The field of view dimensions were reduced to 1.9 x 1.5 cm. However, the image window size was kept the same as in the previous test. In Test 2, the selected resolution was 9.314 x $10^{-3}$ $mm^2$/pixel. Oyster samples were placed on the HSC model conveyor such that they were located in front of the camera and positioned in the "best" possible orientation by observing the live image displayed on the color monitor. The "best" position was located by adjusting the view of a scene vertically until the trimmed-off surface area was in the middle of the image window.

The computer vision unit also was tested to determine if free water on the trimmed-off surface area affected hinge line detection efficiency. Wet samples were prepared by spraying water onto the shell. The dry samples were prepared by drying the same oyster sample using a hot air blow-dryer without moving the oyster and running the computer vision system again.

For Test 2, 100 validation sample oysters, from the Crisfield, Maryland, oyster bar were used. The classification criterion used in Test 2 was created using 60 training sample oysters. This training sample was formed from 15 oysters taken from each of the same four batches of oysters used in Test 1. A preliminary study showed that the two classification criterion used for the hinge line detection efficiency, those used in Test 1 and 2, were not significantly different when 400 oysters, 100 oysters from each of the four batches of oysters, were tested.

## RESULTS AND DISCUSSION

**Test 1**

Table 2 shows the oyster hinge line detection rate of the computer vision system when it was tested using 100 oysters from each location (i.e., a total of 400 oysters). Table 3 shows the detailed causes of the hinge line detection errors and the observed causes (e.g., hole or dot, black sea weed, and algorithm) of the misclassifications. An overall oyster hinge line detection rate was 91.5 % for the 400 oysters. The major causes of the hinge line detection error was an algorithm in the image processing software (e.g., edge-bounded hinge object and eliminated hinge object) except for the oysters from Sea Side. The second major cause was the error in the classification function. Below are detailed descriptions of the hinge detection error causes.

**Edge-bounded hinge object**

The segmentation process (i.e., background dilation followed by object dilation) segmented the hinge object from the background by connecting the background into one region. This was accomplished by filling a narrow gap or gaps between two major background regions. During the segmentation process, the segmented objects were distorted to some degree, but these small distortions were acceptable for hinge object detection by the computer vision system. The segmentation process, in most cases, isolated the objects from the single largest extracted background region and allowed the hinge object to be located without losing any objects. However, three edge-bounded hinge objets were observed in the 400 oysters (Table 2). The edge-bounded hinge object divided the image background into two major background regions. Because the image processing software was designed to segment objects that were fully surrounded by the background, the edge-bounded hinge objects were eliminated from images as hinge objects during image processing. The edge-bounded hinge objects were due to thick dark streak extending horizontally from the hinge object. The thick black streak was due to a dark line found between the upper and lower oyster beaks.

**Eliminated hinge object**

The algorithm sometimes eliminated a small hinge object during the binary image modification process. When the hinge line was small or the oyster hinge line was cut off by the saw during the hinge end trimming process, the hinge object was eliminated during the closing or background dilation process performed on the binary image. Small objects or noises (random dark pixels) were either eliminated or reduced in size. Thus, if the hinge object area was reduced to or the actual area was less than 100 pixels, the hinge object was eliminated from the image by the object area thresholding.

**Misclassification**

The misclassification was due to failure of the classification function to separate objects into hinge and non-hinge groups. In some cases, the classification error was caused by a small noise within the hinge object. This noise was usually caused by reflection from water droplets on the trimmed-off surface area near the hinge object boundary. During the closing process this small noise caused erosion of the hinge object and significant deformation of the object's shape. Consequently, the classification function located another "well-shaped" object as hinge. The holes in the trimmed-off surface area at the hinge end or black spots on the oysters shell sometimes caused misclassification. The black sea weed on the shell also caused misclassification.

**Test 2**

In Test 2, the hinge detection error causes observed in Test 1, such as edge-bounded objects and eliminated hinge objects, were corrected by reducing the field of view dimensions; field of view dimensions were 2.8 x 2.2 cm in Test 1 and 1.9 x 1.5 cm in Test 2 at the same image window size (180 x 170 pixel). None of the edge-bounded hinge objects and eliminated hinge objects were found in either the wet and the dry conditions in Test 2. By decreasing the field of view dimensions (i.e., a high resolution), the hinge detection efficiency was increased approximately 2.5 % under wet conditions in Test 2. The misclassification due to reflection from water droplets on the trimmed-off surface area was eliminated by drying the hinge end surfaces.

The classification error-rate on the wet and dry shell condition was 6 % and 3 % for the 100 oysters, respectively. Five samples that had misclassified hinge objects under wet conditions were correctly classified under dry conditions. One sample was misclassified under both the wet and dry condition. Two samples that had misclassified hinge objects under dry conditions were correctly classified when these same samples were wet.

## CONCLUSIONS

The computer vision system using a front lighting system and color video camera developed in this research efficiently detected oyster hinge lines. The following conclusions were drawn from this research.

1. The best hinge severing efficiency achieved in this research (i.e., 97 %) is sufficient to provide a commercially viable automated hinge severing system.
2. The object segmentation method employed, dilation of the background followed by dilation of the objects, was capable of segmenting the highly diverse hinge objects from other objects that were overlapped on or connected to edges of the image frame.
3. Selecting the field of view dimensions for the camera was an important factor in segmenting objects from the background and in detecting the oyster hinge line.

## REFERENCES

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**Table 2**. Statistical defining oyster dimensions in samples of 100 oysters from each location.

| Location | Range | | Average length (cm) |
|---|---|---|---|
| | Length (cm) | Thickness (cm) | |
| wild Bar* | 7.00 - 10.16 | 2.54 - 4.20 | 8.59 |
| Choptank River† | 7.00 - 9.84 | 2.54 - 4.32 | 8.10 |
| Sea Side‡ | 7.00 - 9.84 | 2.54 - 4.32 | 8.83 |
| Little Choptank River§ | 7.00 - 9.21 | 2.54 - 3.81 | 7.74 |
| Crisfield|| | 7.00 - 9.84 | 2.54 - 3.81 | 7.75 |

* Eastern Bay, Maryland
† Cambridge, Maryland
‡ Eastern Shore, Virginia
§ Fishing Creek, Maryland
|| Eastern Shore, Maryland

**Table 1**. The oyster hinge line detection rate of the computer vision system in Test 1.

| | Batch | | | |
|---|---|---|---|---|
| | WB* (%) | CTR† (%) | SS‡ (%) | LCTR§ (%) |
| Hinge line detection | 92 | 90 | 91 | 93 |
| Hinge detection error | | | | |
| Misclassification | 8 | 9 | 7 | 7 |
| Edge-bounded hinge object | 0 | 1 | 2 | 0 |
| Hinge detection error total | 8 | 10 | 9 | 7 |
| Total number of samples | 100 | 100 | 100 | 100 |

* Wild Bar
† Choptank River
‡ Sea Side
§ Little Choptank River

**Table 3**. The causes of the hinge line detection errors in Table 2.

| | Batch | | | |
|---|---|---|---|---|
| | WB* (ea) | CTR† (ea) | SS‡ (ea) | LCTR§ (ea) |
| Edge-bounded hinge object | 0 (00.0%)‖ | 1 (10.0%) | 2 (22.2%) | 0 (00.0%) |
| Eliminated hinge object | 5 (62.5%) | 6 (60.0%) | 1 (11.1%) | 4 (57.1%) |
| Misclassification# | 3 (37.5%) | 3 (30.0%) | 6 (66.7%) | 3 (42.8%) |
| Hole or dot | 1 | 0 | 0 | 3 |
| Black sea weed | 0 | 1 | 0 | 0 |
| Algorithm | 0 | 0 | 1 | 0 |
| Total detection error | 8 (100%) | 10 (100%) | 9 (100%) | 7 (100%) |

* Wild Bar.
† Choptank River.
‡ Sea Side.
§ Little Choptank River.
‖ Percent of errors.
# Observed causes of the misclassification are detailed under it as shown.

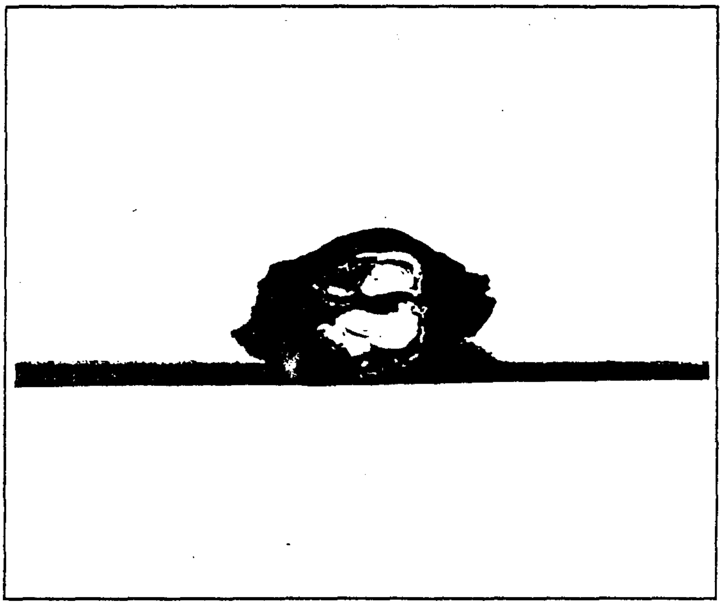

**Figure 1**. Front view of an oyster trimmed at the hinge end. The hinge line is located horizontally at the middle in a flat-white trimmed surface.

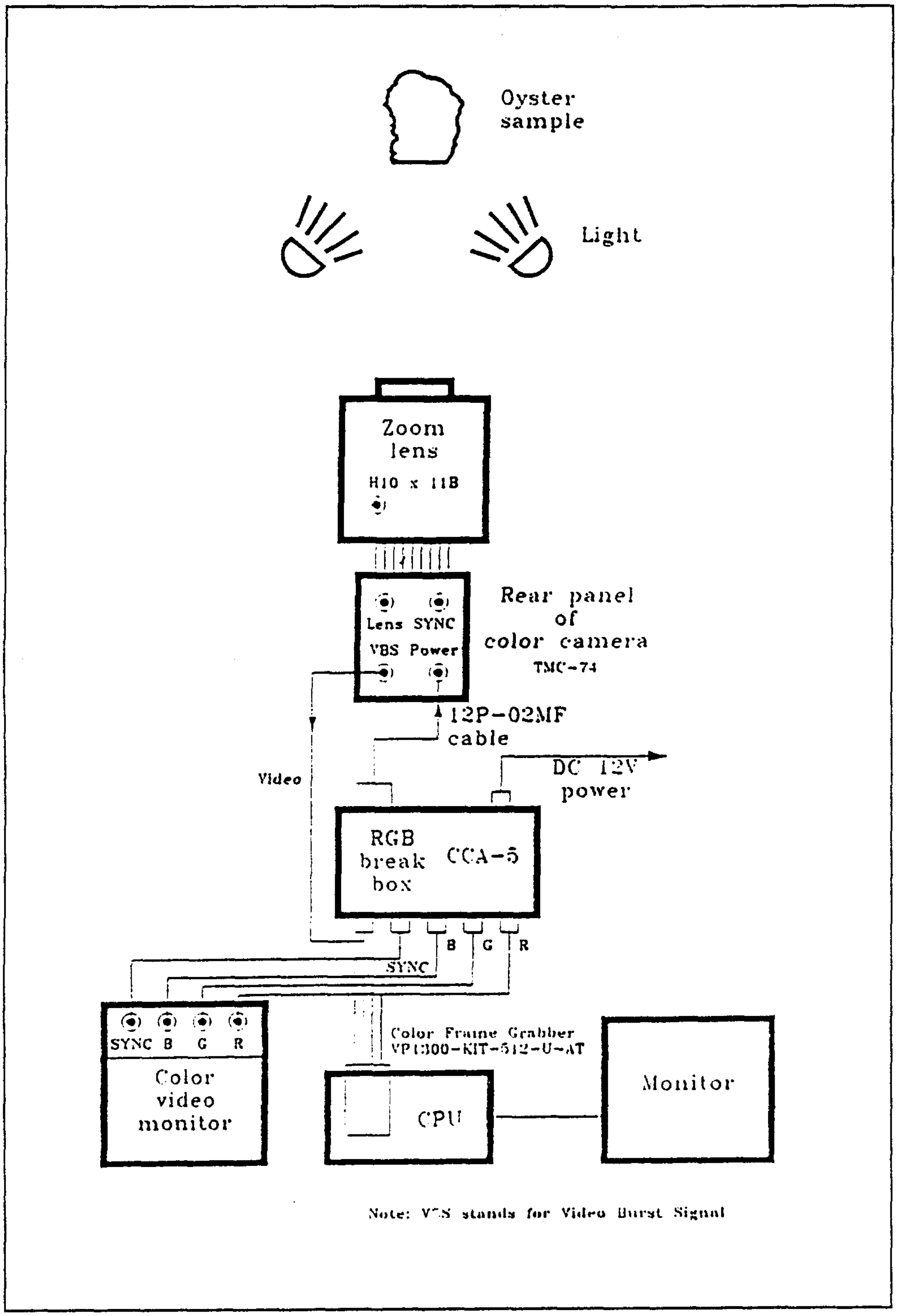


Figure 2. Overall image acquisition system schematic.

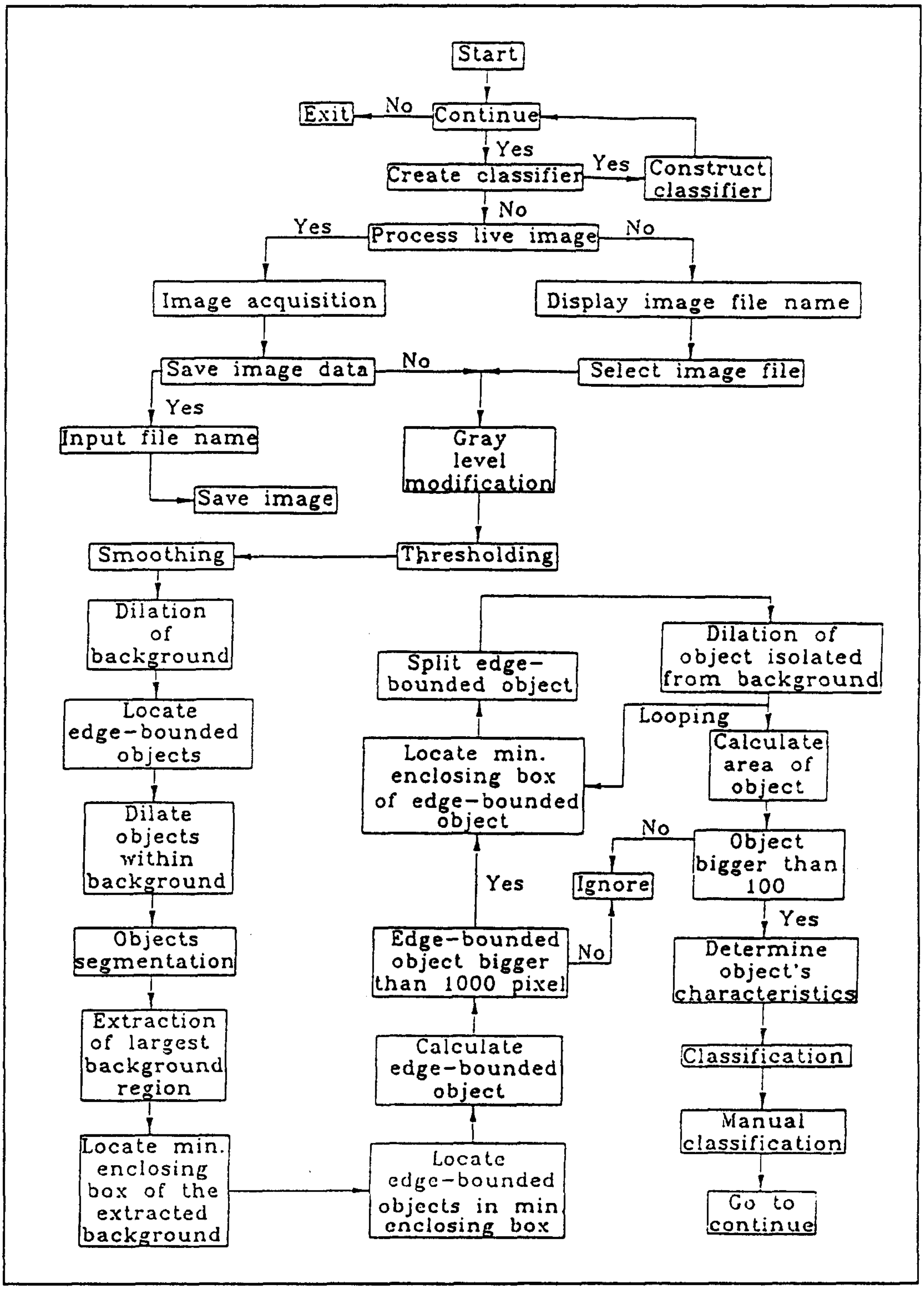


**Figure 3**. Flowchart of the image processing software for oyster hinge line detection.