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Mechatronics Applications to Fish Sorting Part 1: Fish Size Identification

M. Yousef Ibrahim
Gippsland Regional Automation Centre
School of Applied Sciences and Engineering
Monash University, Churchill
Vic. 3842, Australia
Yousef.Ibrahim@eng.monash.edu.au

J. Wang
Gippsland Regional Automation Centre
School of Applied Sciences and Engineering
Monash University, Churchill
Vic. 3842, Australia
Jack.Wang@sci.monash.edu.au

***Abstract*—This paper describes research conducted on the design of a new automatic fish sorting system at Monash University, Australia. A concurrent mechatronics approach was implement to achieve the project's goals. Also, a technique based on digital imaging was developed for the task of identification of fish sizes. The system is being implemented in the local fish export industry, providing a low cost operation with improved productivity and reliability in the fish sorting process.**

A computer-based vision system is used for analysis of the fish. A new algorithm is developed to directly determine the length of fish with fast on-line real-time processing. The measurement technique is also applicable to various species. The design specifications of the vision system and the camera capture devices are also presented in this paper.

I. Introduction

The aim of this research is to design an automatic fish sorting system to replace the current manual sorting system for Lakes Entrance Fishermen's Co-operative Limited (LEFCOL). LEFCOL is a major Australian fish exporter of school whiting, processing 17 to 20 tonnes per day. Fish is manually sorted by size using 25 to 30 labourers in an eight hour shift. Commercial fish sorting is a labour-intensive task. The use of Mechatronic technology will reduce the production cost and increase the accuracy of fish sorting.

Automation of fish sorting by size is a challenging and complex research issue [1]. There have been various techniques developed for automation of fish sorting in the past 30 years [2]. The optical-based sensory system method, using light-emitting diodes (LED), is attempted to measure the length of the fish [3]. A light beam is cut off at the time the fish travels. The length of the fish can be measured given the speed of conveyor. The fish is required to be positioned with specific orientation. However, this is not practical due to the flexible nature of fish.

Also attempted was the use of the roller grader method to measure the thickness of the fish and hence estimate the length and the mass [4]. However, the proportion of the length to the thickness of the fish is different for different species and may not be applicable in some species. Moreover, there is a high risk of physical damage of the fish.

The use of computer-based vision system became popular in agricultural industry. In fact, there have been a few attempts on machine vision applications in the fish industry in early days, such as parasite detection [5] and bone detection [6]. Tayama et al successfully developed a vision system to capture fish (binary image) in 1982 [7]. More research on the automation of the fish industry, with the aid of computer vision, has been carried on in the past 20 years. Examples of those automation tasks are the weight estimation [8], fish species sorting for flatfish and round fish [9] and fish categorization and identification for Atlantic salmon [10]. Arnarson et al [11] investigated a computer-vision based fish sorting system in 1991. It was claimed that an accuracy of 98% with a throughput of 75 fish per minute could be achieved. A further application involved a computer vision system for the measurement of live fish in 3-D coordinates [12], [13], which could be used as the monitoring system studying fish growth.

There also have been many attempts on automated fish soerting using the computer vision technique with acceptable accuracy. However, some methods may work well on one species but not on others. Foe example, the area measurement technique works best on flatfish but produces 30% error on roundfish [14]. A different measurement technique [15] achieved accuracy of +/-3% for randomly oriented fish. However, this technique achieved this result only for fish having having a length of 27 cm or more.

The past achievements show that computer vision system can provide a low cost output with improved

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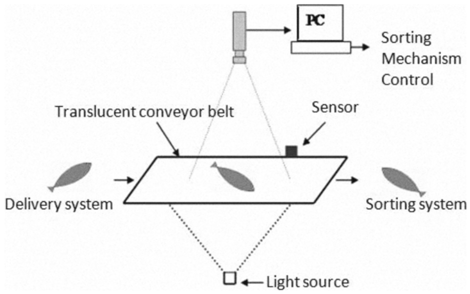

Fig. 1. Fish size identification concept.

productivity and accuracy. However, there are limitations using the attempted techniques due to the shape of the fish and the size range issues. In this research, a computer vision system is used to analyse the fish. A new measuring algorithm is developed to overcome the above issues. The objective of our design is to fully automate the process of fresh fish grading by length for various fish species. In this context the search is for a fast, reliable and non-destructive size identification system.

II. Image Capture System

The concept of the fish size identification technique is schematically illustrated in Fig. 1. The vision system consists of a camera mounted over a translucent conveyor belt, a sensor, a light source, and a computer with an image capture system.

The presence of the fish is detected by a proximity sensor. As the fish approaches the desired position on the translucent conveyor belt the sensor triggers the camera to capture the fish image. The computer system stores it as an image frame. The image frame is converted into an 8-bit grey scale image matrix which is able to be recognized by the computer system. However, image processing work was needed to be carried out on the image frame before further analysis. The computer vision system then calculates the length of the fish; compares it with user input and send the results to the process control system. The flow chart of this process is shown in Fig 2.

III. Identification System Hardware

The speed of the conveyor belt is set at 0.9 m/s in order to achieve the desired production rate set by industry. In order to meet the design specification, a camera with a fast shutter speed was used to capture the fast moving object. A 0.5% error during image capture is considered acceptable. The desired minimum distance between two fish from head to head is 30 cm.

Therefore, the allowable distance error is

$$0.5\% \times 30cm = 0.15cm$$

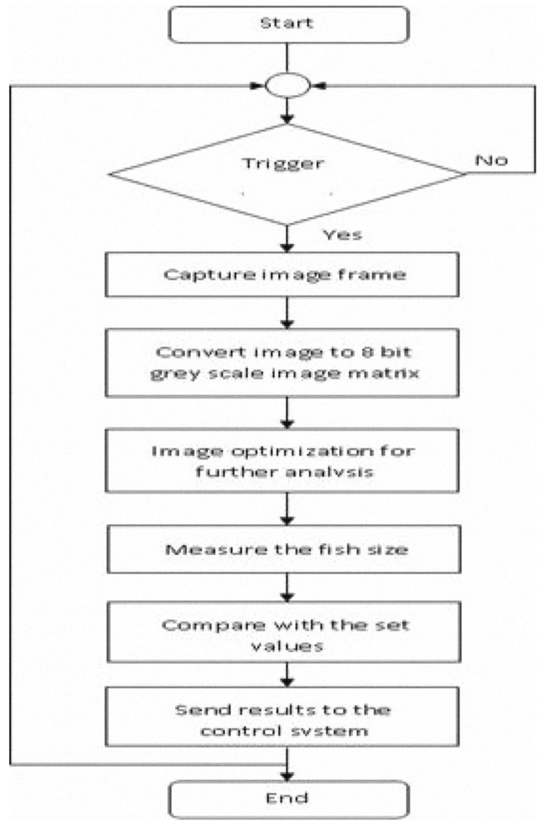

Fig. 2. Flowchart of the Vision System.

TABLE I
Camera specifications

Brand	PLUNiX
Shutter Speed	1/3000 Sec(max)
Video standard	PAL (635 lines/frame)

Hence, The time to travel this distance at 0.9m/Sec is

$$0.15cm/0.9m/Sec = 1/600Sec$$

The frame grabber captures the image once it is triggered by an external signal from an optical sensor. The frame grabber does not start to capture the image immediately after it receives the signal. It waits until the detection of the start point of a new frame. The maximum delay associated with this process is equal to one period of the shutter speed. This problem can be rectified by doubling the shutter speed. Hence, the designed shutter speed should be 1/1200 second. The specifications of the camera selected for this project are shown in Table I.

Once the fish comes into the camera's field of view, the camera will be triggered to capture the image. An optical proximity sensor is used to detect the presence of fish. The optical proximity sensor must be selected considering the following criteria:

TABLE II
OMRON E3F2-R2C4 SPECIFICATION

Type	Retro reflective
Packaging	Moulded plastic
Light source	Infrared
Max Measuring distance	2m
Ambient illumination	3000lx(max)
Ambient temperature	-25o C to 55 o (operating)
Supply voltage	10 to 30 VDC
Response time	2.5ms
Current consumption	25ma (max)

1) Must withstand wet conditions.
2) Should not use visible light as the sensing medium because of the dirty nature of the work environment.
3) Must have a narrow beam so that detection is triggered at the same place across the belt section with high repeatability.
4) Must be able to perform failsafe detection in high ambient light conditions because of its location above the light box.

Based on the above criteria an Omron E3F2-R2C4, optical proximity sensor, was selected. The specification of the sensor is shown in Table II.

IV. SOFTWARE AND SYSTEM DEVELOPMENT

The application software is developed using LabView realtime. The software performed the tasks of image capture, image analysis, human machine interface and communication between the control system and the vision system. The image analysis is developed with LabView IMAQ module. Figure 4 shows the block diagram of LabView.

The Labview IMAQ (an additional graphic module) is able to optimise the image frame in the following steps:

1) Convert the grey scale image into a two-colour scheme;
2) Remove the noise in the background;
3) Fill up the unwanted holes in the objects' image.

The optimization of the image will be discussed in more detail in the following section. Further analysis of the image can be executed after these steps. Two approaches were used for determining the size of the fish. Both approaches are discussed in a later section.

V. IMAGE PROCESSING

When an image is captured, it always returns arrays of image elements (pixels). The captured images were 8-bit grey scale. Every pixel is assigned a value that indicates its brightness, which is 8-bit data, ranges from 0 to 255. Higher value indicates brighter pixel and lower value indicates darker pixel. Since a back-lit method is used to capture the image, the object's image will contain much lower pixel values than the background. Therefore, threshold pixel identification can isolate the fish image from the background. Fig. 3 shows the threshold process achieved by the LabView IMAQ module.

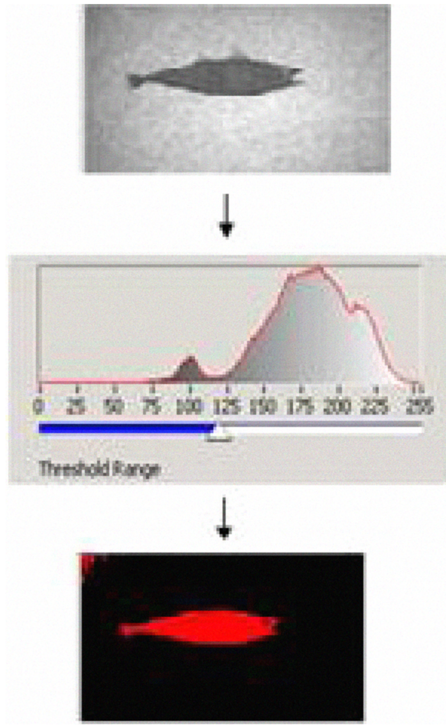

Fig. 3. Fish image Threshold.

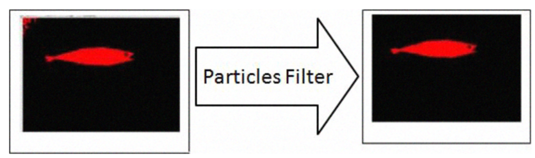

Fig. 5. Particles Filter Process.

Although threshold process removes most of the background noise from the image, there would be still some noise in the background. These particles are due to non-uniform lighting distribution or existence of dirt on the conveyor belt. A special purpose algorithm based on particle size was used to remove the unwanted particles from the image. Any particle containing less than 5000 pixels is removed from the image. This is accomplished using IMAQ Particle Filter. Figure 5 shows the image before and after the filtering process.

It is possible that some of the image noise would be removed during the background removal process by applying the threshold methodology. A solid image would be desirable for further analysis. These holes can be eliminated using the LabView *Hole Filling* tool as

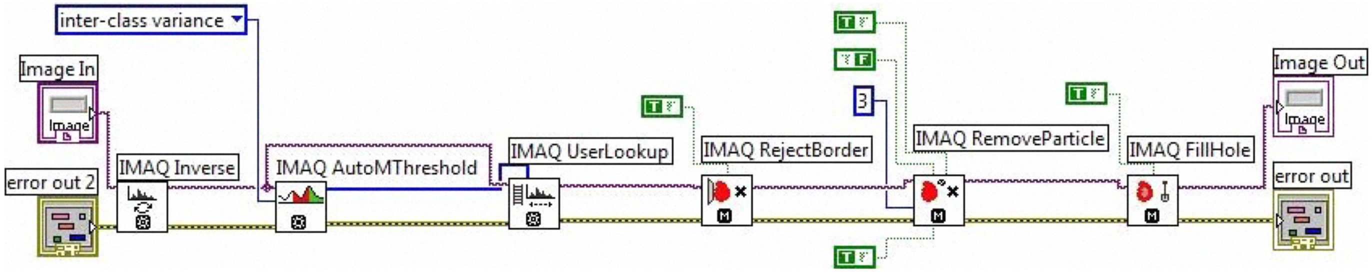

Fig. 4. LabView Block Diagram.

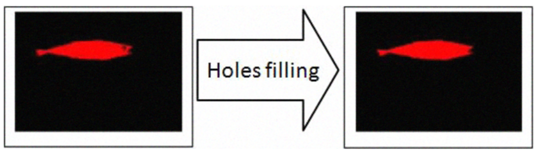

Fig. 6. Holes Filling Process.

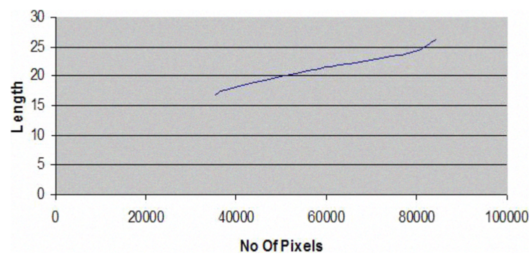

Fig. 7. Relationship between fish length and number of pixels (School Whiting).

shown in Fig. 6. The image processing produces a well presented image such that further analysis can be made to measure the length of the fish.

VI. Measuring Algorithm

Several tests were conducted on the fish species regarding the relationship between the fish length and its image area. A quasi-linear relation was found between the two fish parameters, i.e. the number of the fish image pixels is directly proportional to the length of the fish. This relationship is shown in Fig. 7. Therefore, the length of the fish can be deduced by counting the image pixels. This was also achieved using LabView IMAQ function, Fig. 8.

The fish length is estimated as a function of the image area. However, similarly to the other attempted approaches, this method cannot reliably sort the fish by length. Different orientations of the fish give different results of the fish image area as shown in Fig. 9. In practice, the control of the fish orientation is difficult to achieve. Moreover, it is only applicable to limited fish

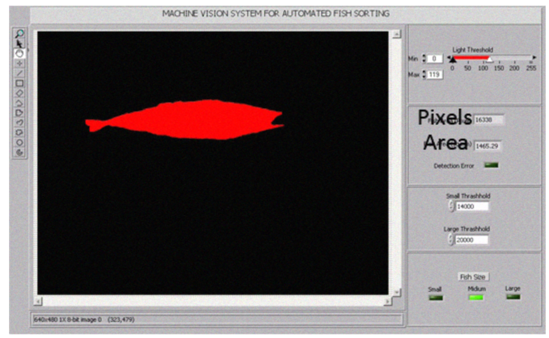

Fig. 8. Counting the pixels.

Fig. 9. Different orientations of fish produce different image areas.

species. The correlation between the area and the length of other fish species is not known.

Due to the above uncertainty, a new algorithm was implemented to calculate the length of the fish. The basic idea is shown in Fig 10. A centre line is constructed along the main bone of the fish, and hence the length can be estimated.

This process involves scanning the whole image both

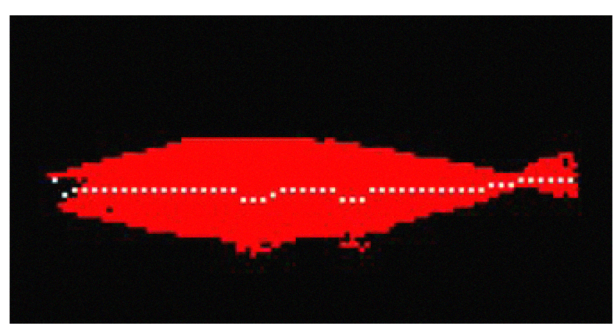

Fig. 10. Construction of the centreline.

horizontally and vertically with small intervals (4 pixels in our case). The centre point of the portion on the scanning line intercepting the fish is determined during every scan. All centre points are then connected and the length of each segments (between two successive centre points) is calculated after a complete scan of the whole image in both horizontal and vertical directions. This process produces two different lengths measurements. One measurement is from the vertical scanning and the other from horizontal scanning. Two examples of this technique are illustrated in Fig. 11 and Fig. 12.

Each example produces a pair of lengths, one from the horizontal scan and one from the vertical scan. The maximum value from the horizontal and vertical scanning is taken as the length of the fish. In Fig 11, the centre lines constructed from the horizontal scan and the vertical scan are very similar. However, in the second example shown in Fig 12, the two different scans produce different values.

The algorithms can be summarized in the following steps and equations:

1) Scan horizontally and plot the middle point of the shaded area in a small interval;
2) Construct the centreline by connecting adjacent points;
3) Calculate the total length of n intervals in Cartesian Coordinates by the following equation,

$$L_{horizontal} = C \sum_{i=1}^{n_h} \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}$$

4) Repeat the above steps but scan the image frame vertically and apply the similar equation,

$$L_{Vertical} = C \sum_{i=1}^{n_v} \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}$$

where,

$n_h \stackrel{\text{def}}{=}$ Intersection points representing the centreline in horizontal scanning

$n_v \stackrel{\text{def}}{=}$ Intersection points representing the centreline in vertical scanning

$C \stackrel{\text{def}}{=}$ scaling factor since the fish image is scaled during image capturing

5) Find the maximum value of the horizontal and vertical scanning as the true length.

$$L = \max\left[L_{Horizontal}, L_{Vertical}\right]$$

The length returned by the L is then passed to the sorting module and the corresponding flap is activated to separate fish into different flap stations. This new algorithm can calculate fish length on the belt in any orientation, any amount of rotation along its axis (on spinal cord) or even up to 90 degree of bend.

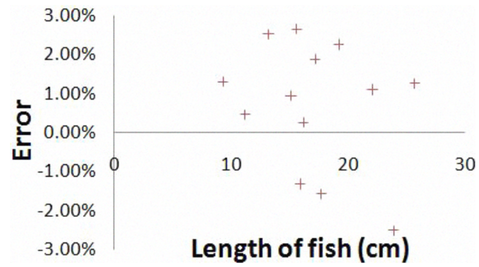

Fig. 13. Measuring error Vs length of fish.

VII. Conclusions

The design of the automatic fish sorting system involves the new length measuring algorithm. The technique is able to overcome the orientation problem of the fish. It also works reliably on small fish size and on various species. The theory of the technique also provides for measurement accuracy as it estimates the length of the fish directly from the image. The quality of the image capture becomes a critical issue in the vision system. Reliability tests were conducted on the new system. As shown in Fig. 13 the errors were random with no relation between the errors percentage in sorting and the fish size. However, the results show that the maximum error exhibited by this new Mechatronic system was +/-3%. Real fresh fish were used in the investigation. A patent application has been filed for this new fish sorting system (Australian Patent Application No. 2008905325).

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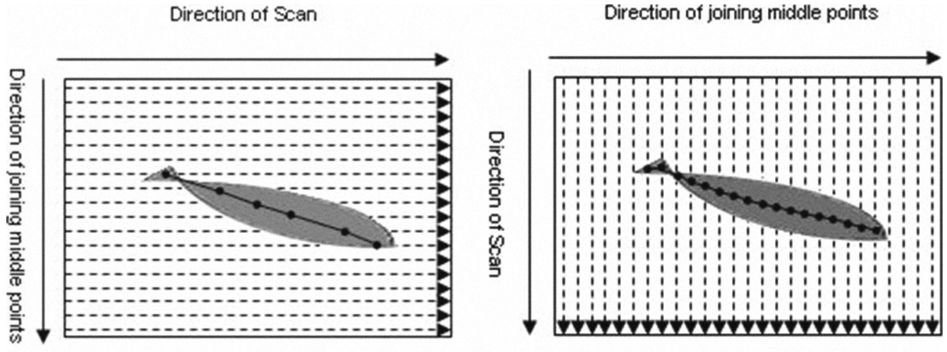
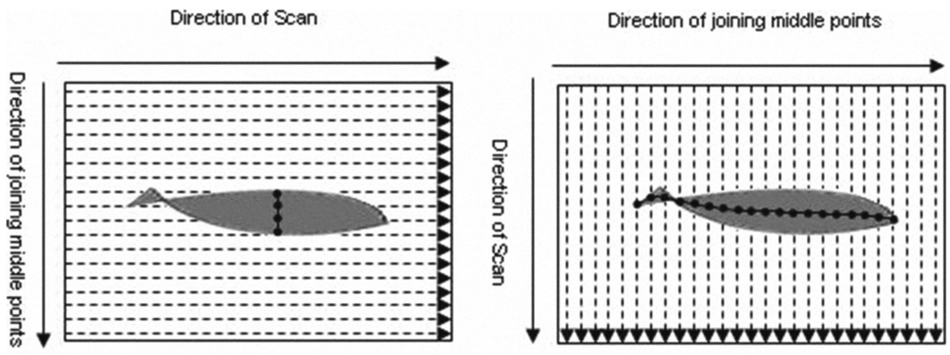


(a) Horizontal Scan (b) Vertical Scan

Fig. 11. Centreline construction example 1



(a) Horizontal Scan (b) Vertical Scan

Fig. 12. Centreline construction example 2

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