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Automatic species recognition, length measurement and weight determination, using the CatchMeter computer vision system.

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Abstract

The collection of biological data on species composition and individual length and weight of specimen has always been an important part of fisheries research. Traditionally, the collected information has been recorded on paper prior to being entered into a computer for analysis. Electronic measuring boards that record length measurements, such as the FishMeter (Øvredal and Totland, 2000), have made the data collection process more efficient and reliable. In this contribution we describe a vision-based catch registration system called the CatchMeter that makes it possible to automatically recognise fish species and measure the length and weight of fish. A camera and light unit is located above a conveyer belt moving at a maximum speed of 1.5 m/s. One ore more images of the fish are taken as it passes the camera and are then analysed by the computer. Both roundfish and flatfish from 5 cm to over 1 m can be recognised and the system can easily be trained to recognise new species of fish. So far the prototype system has been trained to identify 10 different species with a recognition rate of 98.6 %. In a test where the length of the same fish was measured repeatedly, the standard deviation of the length measurement was 3 mm on a 265mm

long haddock. Weight measurement has not yet been implemented but we plan to do this by using electronic grader, laser triangulation and/or using length-weight relationships. Provisions for connecting an automatic sorting unit to the CatchMeter will be included to enable sorting of selected individual fish for registration of extended biological parameters. A computer controls all the processes and sorting criteria may be selected from the user interface. With the CatchMeter the sampling process is automated and the capacity for biological sampling will be increased with a reduced need for manpower for measurements and sorting. The new system is initially intended for use on research vessels but it will also be of interest to commercial fishing vessels and at landing sites of fish processing plants. The prototype has been successfully tested on the Norwegian research vessel “G.O. Sars”.

Introduction

Recommendations for quota and regulation of the fishery are based on stock assessment. The stock assessment is calculated by combining data from scientific cruises and fishery dependant data gathered from commercial vessels, coastguard and landing sites. On research vessels information on length, weight and age distribution from trawl catches is used in combination with acoustical recordings to give an estimate of the fish abundance. Data collection in commercial fisheries is a manual and labour intensive process today giving a limited sampling volume. Sampling procedures, capacity and accuracy in data collection may vary significantly among sources giving imprecise input to the estimate of fish stocks.

The new system for automatic species recognition, length and weight measurement, CatchMeter, will result in an increased capacity for biological sampling when used on research vessels, fishing vessels and fishing ports. The system will give a small and predictable statistical variation in length and weight measurements. In combination with age registration this may give a considerable improvement in the catch statistics and stock assessment. Using CatchMeter with a sorting unit on fishing vessels will give an instant overview of catch composition and give valuable information to the skipper and fishing company in the operation of their vessels. A fully automated process may also reduce the need for manpower.

Materials and Methods

Mechanically the CatchMeter consists of a conveyer belt and light box (Fig. 1) (White *et al*, 2006a*)*. In brief, fish move along an opaque conveyor belt under a video camera. The video camera and lights are housed within the light box, the purpose of which is to offer uniform and diffuse lighting. To compensate for any drift caused by the camera or lights, colour is measured and corrected for in real time. This ensures that any data captured by a particular CatchMeter is not machine specific. The conveyor system is designed to present fish to the vision system in a controlled fashion, although the system can analyse fish presented with any position or rotation. The mechanical systems are controlled by a programmable logic controller (PLC) interfaced to the main computer and software via an Ethernet link. This offers the possibility of operating the CatchMeter from a remote terminal in a different location to the machine itself. The analysis software can run on a desktop personal computer (PC). The system can process roundfish, flatfish and gutted fish with a theoretical maximum throughput of 3600 one meter fish/h or 30 000 10cm fish/h.

The CatchMeter utilises a 1392x1024 pixel resolution, digital Universal Serial Bus (USB) video camera and a high resolution fixed focal length lens. Tungsten Halogen bulbs supply diffuse front lighting.

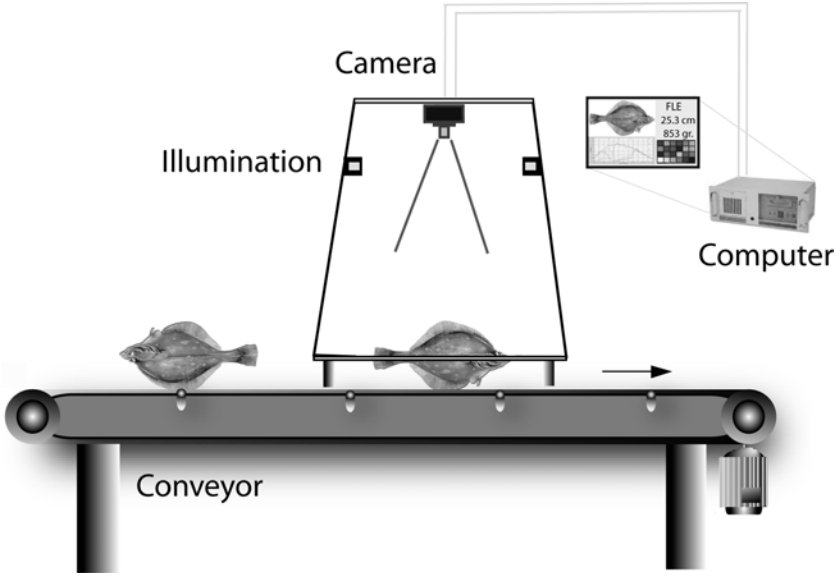
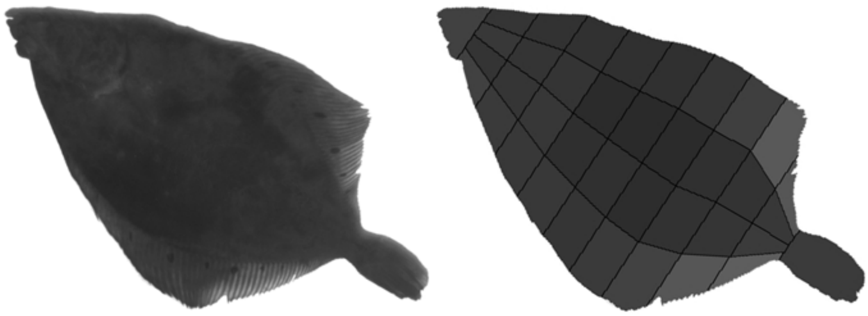


Fig. 1 - Schematic diagram of the CatchMeter system.

The mechanical systems of the CatchMeter are controlled from the PC through a PLC. In this way the user has control of the conveyor belt speed, water flow and conveyor belt cleaning systems, the camera, lights and actuators to position the colour chart for colour calibrations. The maximum speed of the conveyor system is 1.5 m/s.

There are two main modes of image capture, single image capture and video mode. Single image capture mode is used to capture and store only images of any fish that pass under the camera. Video mode is used to capture and store a continuous sequence of images so that everything that passes under the camera can be stored. The colour in all images is calibrated and corrected (Strachan *et al*., 1990). Regions of interest such as fish are separated from the background by the software (White *et al*., 2006b). The method is robust enough to perform correctly even against a background heavily soiled with blood, water, mud and other debris. Fish that are greater than 300mm in length do not fit into one single image in this system; so several images may need to be joined together (White *et al*., 2006b). Briefly, this involves joining images based initially on timing information from the camera and from the PLC, which monitors the conveyor belt speed. The join is then optimised based on a cross-correlation technique (Lewis, 1995).

Fish passing through the computer vision system are analysed in terms of their colour and shape (White *et a*l., 2006a). The method includes functionality to analyse the colour distribution of each fish (Fig. 2a) including spatial information regarding the colour, by means of a size and shape invariant grid drawn over each fish (Fig. 2b). The overall shape of the fish can be analysed and described by an n-sided polygon, which facilitates the collection of other shape information as required. The colour and shape data collected for each fish is used to identify the species in real-time (White et al., 2006a). In order to recognise the species of fish the CatchMeter must first be presented with a training set of fish for each species to be identified. There is no upper limit to the number of species that can be trained.



a b

Fig. 2 - Shape grid with average colours calculated for each grid element.

Automatic length measurements of fish are performed by the CatchMeter (White *et al.*, 2006b). The length is calculated regardless of how the fish is orientated as it passes through the system and the presence of fins and belly flaps (if the fish is gutted) do not affect the measurements (Fig. 3). The software will return fork and total length of the fish. All data captured by the CatchMeter can be synchronised with the manual measuring board, FishMeter, giving a flexible system for data collection (Øvredal and Totland, 2000).

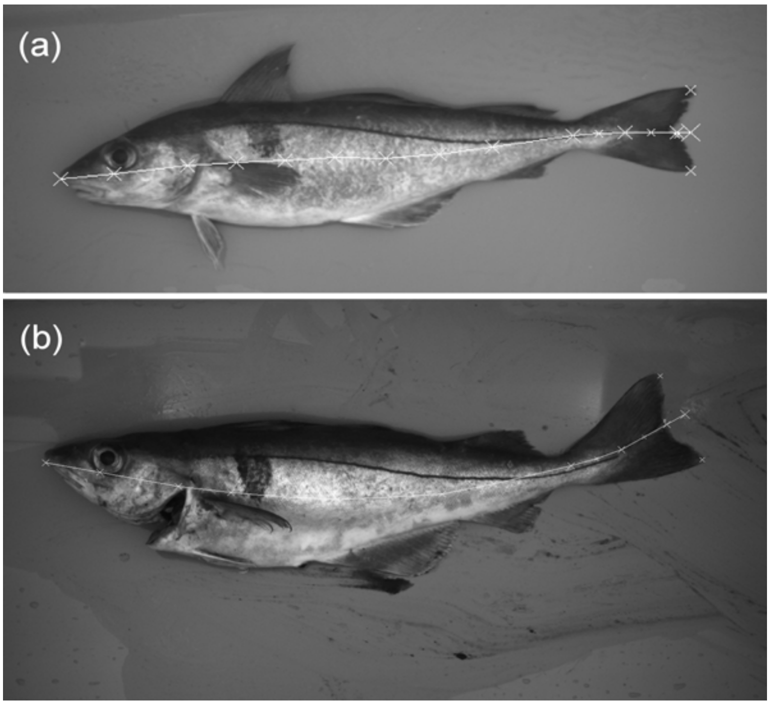


Fig. 3 - (a) Fish length calculation of fork and total length, is not affected by fins and other protuberances; (b) Fish length calculation is not affected by gutting or soiled background.

During testing the CatchMeter was been installed on research vessel “G.O. Sars”. Data was collected during two periods when the vessel was used for regular fish sampling. The fish used to test the CatchMeter were caught in the Barents Sea in August 2005 and February of 2006. In total ten species were caught in large enough numbers to be used for testing.

The following species were used in these initial tests: blue whiting (*Micromesistius poutassou*), capelin (Mallotus villosus), cod (*Arctogadus glacialis*), deepwater redfish (*Sebastes mentella*), golden redfish (*Sebastes marinus*), haddock (Melanogrammus aeglefinus), herring (*Clupea Harengus*), long rough dab (Hippoglossoides platessoides), Norway pout (*Trisopterus esmarkii*) and saithe (*Pollachius virens*).

Results

When analysing the fish that were used to train the system all 100 fish for each of the 10 species were correctly classified. When analysing the test sets the sorting reliability was between 95.3% and 100.0% for all species. The fish that could not be identified were labelled as unknown. See Table 1 for a full breakdown of the combined results from the August 2005 and February 2006 test cruises.

Table 1. Results for the species sorting of fish in the Barents Sea in August 2005[1] and February 2006[2].

Species	No. of calibration fish sorted correctly	Sorting reliability (%)	No. of test fish sorted correctly	Sorting reliability (%)
B. Whiting[2]	100/100	100.0	450/451	99.8
Capelin[2]	100/100	100.0	292/298	98.0
Cod[2]	100/100	100.0	1275/1294	98.5
D. Redfish[1]	100/100	100.0	445/467	95.3
G. Redfish[1]	100/100	100.0	118/118	100.0
Haddock[2]	100/100	100.0	892/927	96.2
Herring[1]	100/100	100.0	212/214	99.1
L. R. Dab[2]	100/100	100.0	627/638	98.3
N. Pout[2]	100/100	100.0	100/100	100.00
Saithe[1]	100/100	100.0	127/129	98.4
Total	1000/1000	100.0	4538/4636	97.9

To test the length measurement algorithms, two tests were performed. First a haddock was manually measured to be 265mm. When measured 100 times by the CatchMeter the minimum measurement was 261mm, the maximum was 274mm and the mean was 266mm (Fig. 4a). These values correspond to an error of ±1.8% based on the 95% confidence level for the CatchMeter measurements. Another haddock was manually measured to be 380mm. The results of measuring the fish 100 times in the CatchMeter show a minimum measurement of 379mm, a maximum of 396mm and a mean of 384mm (Fig. 4b). These values correspond to an error of ±1.2% based on the 95% confidence level for the CatchMeter measurements.

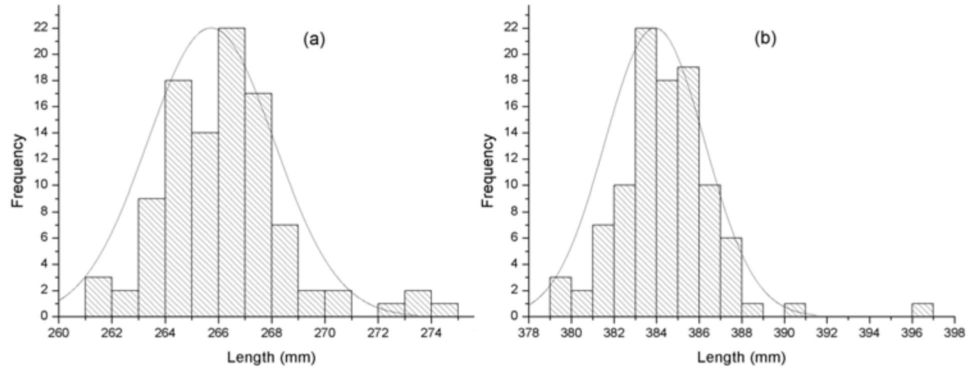


Fig. 4. (a) Results for a single haddock measured 100 times by the CatchMeter. The fish measured as 265mm on a FishMeter by a fisheries research scientist; (b) Results for a single haddock measured 100 times by the CatchMeter. The fish measured as 380mm on a FishMeter by a fisheries research scientist.

Discussion

The main focus so far has been on the primary task of species recognition and length measurement. The prototype has been revised and modified to improve and simplify the system. Both species recognition and length measurement have been greatly improved compared to the original version. Originally background light was used under the conveyor belt to improve contrast in captured images. To make it easier to incorporate CatchMeter in an existing fish processing line, an effort was made to remove the need for background light and still keep the reliable image recognition. The physical size of the system may be reduced due to stitching of images to form a complete image of each fish.

The system needs to be trained to recognize a particular species but so far only a limited number of species has been available for training and there is still need for more species in the recognition database to be able to see how CatchMeter will perform in a realistic setting. All tests have been done on the research vessel “G.O. Sars”, but there are plans for installing an improved CatchMeter on a commercial trawler.

Now that the basic capabilities of the system are working, a number of issues have to be addressed. The next step will be to incorporate weight measurements by adding a scale and do volume calculations based on laser triangulation of the fish. A complete system will also include a single fish feeder and a fish-sorting unit (grader) controlled by stratification software.

By introducing the CatchMeter in fisheries research a number of benefits will be obtained. Due to its efficiency, the system will enable a larger sampling volume with good quality and a representative sample of the catches. Additional information, such as volume and extended shape and length data, will be available and further information like fish quality and condition may be introduced. CatchMeter is being designed to be able to talk to the manual measuring board, FishMeter, letting the two systems work as an integrated data recording platform.

On commercial vessels this system will provide an automated sorting and measurement process giving the skipper and fishing company an instant overview of catch composition with a reduced need for manpower. This will make it easier to decide the best fishing grounds and help planning sale of the catch. Catch information may be linked to the electronic catch report improving management of the fishery. CatchMeter will give data on total fish length instead of length of gutted and headless fish, which is usually the case today. The catch statistics used in stock assessment will be much more reliable if this system is introduced on a large number of fishing vessels and processing plants. Public fisheries management authorities would also have a tool that could be used to provide instant and more accurate information on catches.

A new cruise is planned for August 2006 with extensive tests of the CatchMeter and hopefully collection of a larger number of fish and species.

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