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COMPUTERBASED DETECTION OF SCHOOLS FOR COUNTING, QUANTIFICATION
OF SIZE AND SWIMMING BEHAVIOR BY THE SIMRAD SA950 SONAR

by

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Abstract

As a help in stock assessment of pelagic, schooling fish a software for detection of schools and quantification of their size and swimming behaviour by a high resolution sonar has been developed. The system reads the echo telegrams that forms the display of the SIMRAD SA950 sonar, and organize an echo table for the colour code value of each pixel for each of the 32 beams and 512 range rings of the sonar for each ping. The settings of the sonar is written to a separate table. Detection of schools is based on identification of echo lines which are defined as a minimum number of succeeding pixels with colour code value above a predetermined threshold. The position in the beam sector and horizontal extent for each echo line detected is written to a separate echo line table. A procedure then search through this table for identification of echo blocks which are defined as adjacent echo lines that extend above a certain width. The horizontal extent, depth, and geographic position of echo blocks are written to an echo block table together with information on time and vessel navigation. If an echo block is detected in a minimum number of succeeding pings, it is assigned a school

number. It is possible to store both the echo table, the echo line table, and the echo block table on disk or take printouts directly.

A colour printer echogram for use with the SIMRAD SA 950 has also been developed. For this purpose the sonar is interpreted as a sounder with a 45° beam, and the maximum colour code value for each range ring in the echo table is identified and printed. The printed echogram is divided by range lines and log marks, and there are indicators for tilt angle and train of the sonar beam.

The developed software can be used as a basis for automatic counting of schools, school size estimation, and quantification of swimming behavior.

Introduction

Horizontal guided sonar is an efficient tool for recording of pelagic, schooling fish swimming close to surface, and is a basic instrument for detection of fish and monitoring of the capture situation in many purse seine fisheries. Such equipment may also be used in scientific investigations of fish populations for mapping of geographic distribution and counting of schools (MacLennan and Simmonds, 1991). With the intention of making the use of horizontal guided sonar a rational method for acoustic abundance estimation, Hewitt et al., (1976) developed a computerized system for automatic detection, counting and sizing of fish schools. However, it has been difficult to establish conversion factors from the parameters measured by the sonar (number of schools, school area or school target strength) to fish biomass. Misund et al., (1992) found consistent relationships between the geometric dimensions (area or volume) and biomass of fish schools. Such relationships may be used to convert sonar measurements of school dimensions to school biomass.

To develop a method for direct measurement of fish schools close to surface, R/V "G.O.Sars" has been equipped with a 95 kHz, narrow beamed, high resolution naval sonar designed for detection of submerged mines, the SIMRAD SA950. The sonar construction make use of modern computer technology enabling connection to the internal network that handle the sonar data that makes up the sonar display.

Here we describe software developed to read and organize the sonar data for real time search of possible echoes from schools. The identification and numeration of schools is done by a separate algorithm working on data files of echoes recorded by the sonar. To have a visual interpretation of the sonar recording, a software that produce a sonar echogram on a colour printer has also been developed.

Reading and organization of sonar data

The SA950 sonar consists of a control and display unit (CDU) and a signal processor unit (SPU). The CDU is used to control all sonar settings and to display the sonar picture, while the SPU transmits, receives and processes the sonar signals. Communication between the two units is achieved by sending telegrams over an ethernet connection. For each ping the CDU will send a telegram with all sonar settings to the SPU. Based on these settings the SPU will transmit one ping and return telegrams with color code values for each beam and range ring to the CDU. These telegrams were originally only intended to be used as internal communication in the sonar. SIMRAD has made some minor modifications to the ethernet protocol to conform to standards and enable a computer to listen to the communication between the two units. This allows the ethernet cable of the sonar to be connected to the network interface of a UNIX workstation and enabling it to read the sonar data.

We have connected an HP9000/720 computer to the SA950 ethernet cable. From the GPS (via a SIMRAD EK500 echosounder) the vessel position goes to the computer on a serial line. A program read telegrams from the sonar and organize the data in two separate tables that is updated for each transmission. The first table contains data for the sonar settings. The other is an echo table of 32 columns (one for each beam) and 512 rows (one for each distance ring). Each element in the echo table thereby represents a particular pixel in the display of the beam sector, and the element gives the color code value for that particular pixel (Fig. 1). Vessel position is read and decoded by another program and added to the sonar data. Further processing is left to a third program. This handles school detection, data storage and printout of a colour echogram and works as the user interface. Various configuration settings can be altered online during logging by a separate configuration program.

Detection of possible school echoes

The principle for detection of echoes from possible schools is to search through the echo table for each ping and identify succeeding elements with colour code values over a certain predetermined threshold. The unit searched for is called an echo line and is defined as more than a minimum number of succeeding elements in a column with colour code values above a threshold. Small gaps below the threshold is allowed. To delimit such groups of elements there must be a minimum number of elements with colour code values below the threshold before and after. On the sonar display an echo line thereby corresponds to a minimum number of succeeding pixels with colour code values above the threshold that is delimited by a minimum number of pixels with colour code values below threshold within one single beam. For each echo line detected the start and stop range, the average range, and the horizontally projected area covered is calculated and read into a separate echo line table (Fig. 1).

A procedure then search through the echo line table for each ping to identify groups of echo lines that may represent possible recordings of schools. The unit searched for is called an echo block and is defined as adjacent echo lines that is delimited by a predetermined distance to each side. First, the procedure creates a thirty-third column into which the maximum colour code value for each range ring is read. Then the procedure search through this "maximum echo column" and search for "maximum echo lines" according to the same principles as for ordinary echo lines as outlined above. If such a maximum echo line is detected the procedure then identify echo blocks as adjacent, delimited echo lines within the range interval of the maximum echo line. For each echo block detected the area is calculated by summing up the area of each contributing echo line. Similarly, the range and bearing is calculated as the average of the range and bearing to each contributing echo line. The data on area, range and bearing is written to an echo block table together with information on ping number, vessel log, date, time of day, geographic position, vessel heading, vessel speed, tilt and train angle of sonar, and actual detection threshold.

User interface

The work station is set up with X-windows software and UNIX operation system. The start of the logging and detection software is implemented on a popup menu on the workstation. Activating the sonar logging gives two options; start logging of sonar data and detection of echo blocks or configuration of the detection procedures. If the start logging option is chosen, the colour printer will start running and produce one line for each transmission of the sonar, and three windows will appear on the workstation display. One window gives the option to stop the logging program, while the "status" window contains the table that updates the sonar settings (Fig. 2). For each ping the sector width, range, transmission power, pulseform, amplification gain, display gain, automatic gain control, ping-to-ping filter, normalization, vessel speed, course, heading, train, tilt, TVG, absorption, sound speed and zoom status are updated. Information on date, time, vessel position and number of dropped pings are also given. In the "logging" window the echo block data is presented as they appear ping by ping.

If the configuration option of the program menu is chosen, a configuration menu appear in a separate window. In an echo block detection configuration group it is possible to set the maximum and minimum range for echo block detection, the minimum range extent of echo blocks, the minimum width of echo blocks, the minimum gap between neighbouring echo blocks, and the colour code detection threshold. A printer configuration enable start/stop and speed regulation of the printer. The output configuration give options for which tables to be printed; the echo table, the echo line table and the echo block table. It is also possible to print the echo block limits, the echo line definition and to turn colour usage when printing the echo table on/off. A status command gives a quick overview of the current configuration.

Identification and numeration of schools

The principle for identification of a school is that the corresponding echo block must appear within the beam sector in a minimum number of pings, and follow an acceptable coordinate trace as it is passed by the vessel. All echo blocks, including those corresponding to a school recording, are given a running echo number even if they appear in just one ping. The coordinates used to calculate the position in the beam sector are cartesian and defined as:

$$x = \sin(\text{bearing}) * \text{range}$$

$$y = ((\cos(\text{bearing}) * \text{range} / 1852) + \text{vessel log})$$

The unit for the x-coordinate is meter, while the y-coordinate is in nautical miles. A school candidate must move through the beam sector within a predetermined window. Since the increment in the y-direction will be negative if the vessel moves forward at a greater speed than the school, the principle of expected position is introduced in addition to the window limits a and b :

$$X_n = x_{n-1} \pm a$$

$$Y_n = (y_{n-1} - \Delta y) \pm b$$

$$\Delta y = (\text{vessel speed}) * \Delta t$$

$$\Delta t = \text{time}_n - \text{time}_{n-1}$$

For each new echo block that appears, the identification procedure compares the position of the new one with the expected position of echo blocks detected in previous pings that can possibly still be within the beam sector. If the coordinates of the new echo block is within the expected ones of a previous echo block, the new echo block is assigned the same echo number as the previous one. If the new echo block does not match expected coordinates of former echo blocks, the new echo block is assigned a new echo number. If an echo block appear in more than a certain number of pings, it is assigned a school number.

Colour echogram printout

The recordings by the multibeam sonar is displayed in a two dimensional sector of 45° which is updated for each successive transmission. Such a presentation gives an instantaneous overview of the underwater situation that is favorable for detection of rapid changes in the recordings. In scientific work there is a need for visual documentation of what is recorded. One alternative is to store the sonar picture on video tape by connecting a VHS video recorder directly to the video output of the sonar. For regular survey work this method is not

convenient as it would fill up an amount of video tape that would be very time consuming to look through. Continuous recordings on paper is much easier to work with. A proper technique to reproduce a two dimensional, coloured sonar picture on paper with time (distance) as one axis, is difficult to implement.

A simple, but useful solution is to interpret the sonar as a single beam sounder, and present a two dimensional echogram with range as one axis and sailed distance as the other. Such a presentation is implemented in the sonar display to give a short history of the preceding recordings. For the single beam presentation on an echogram, a procedure search through the echo table and find the maximum colour code value for each distance ring. The colour corresponding to this peak colour code value is then printed for each distance ring. The distance coordinate to the recordings will thereby be present, but the direction information within the beam sector of the sonar will be neglected.

The echogram is presented with 10 equidistant range intervals that is automatically scaled according to the current sonar range (Fig. 3). There is a vertical mark for each nautical mile sailed, and date, time of day, position and tilt angle operating is written after each fifth mile sailed. In the upper part of the echogram there are continuous colour indicators for tilt angle and train. The tilt angle is indicated by a blue line with thickness proportional to the value of the angle. The train is indicated by a line that is red when the sonar is directed port and green when directed starboard, and the thickness of this line is proportional to the train angle.

Postprocessing and statistical analysis

The files with school data, including school number, are well suited for further processing by analysis tools. It is a simple task to use e.g. SAS software (SAS 1989) to produce a report on the total number of schools per square nautical mile, with information on average and total school size. Another possible use is for studies on fish behavior like vessel avoidance and migration.

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References

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Figure 2. Screendump from workstation showing logger program windows.

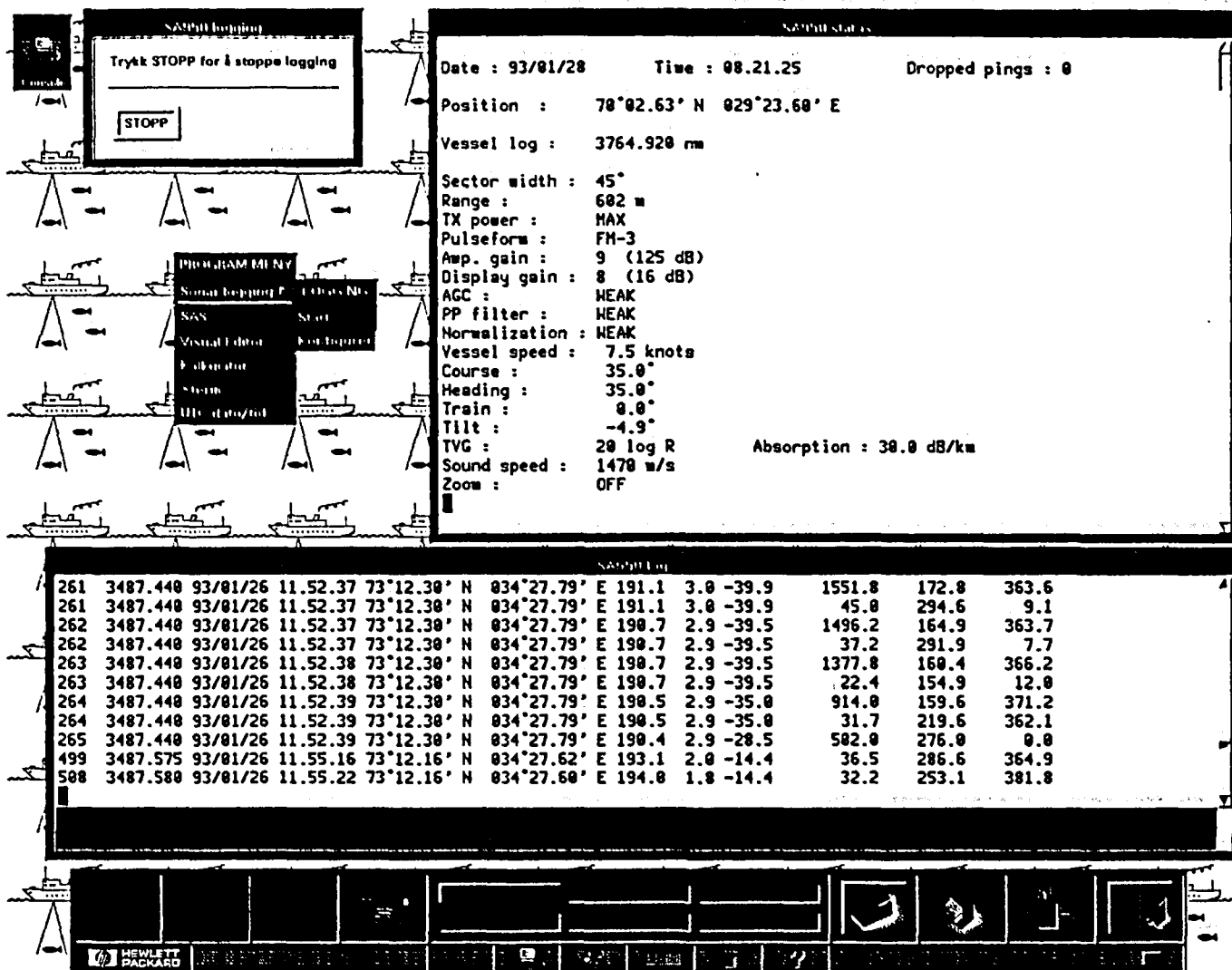


Figure 3. Example of echogram output.

