AUTOMATION IN FISHERIES AND AQUACULTURE TECHNOLOGY

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Contents

Summary

Fish and other aquatic animals constitute one of the most important sources of food in the world, and the industries associated with the production and marketing of these goods have high priority in modern society. The paper analyzes the three most important ways of producing fish as a raw material for the consumer market, namely harvesting the natural yield of the oceans, aquaculture and ocean ranching. The paper deals with the application of automation technology in these sectors for the purpose of improving productivity in terms of the use of resources, improving the quality of products and reducing the environmental impact.

Automation in the fisheries and aquaculture technology is mainly characterized by a high degree of manual control and supervision, but in mechanization and instrumentation there is a strong trend in the direction of automated technological solutions.

The most important harvesting methods are discussed and the present automation technologies are reviewed with illustrations of specific types of equipment. The trend towards increased focus on aquaculture is analyzed, and some indications are given about what directions this development may take.

1. Introduction

A majority of the world's nations are located near the oceans and have easy access to exploiting their great resources. One sector of resources is the natural production of a large number of species of fish and other living beings ranging from phytoplankton and zooplankton to various kinds of shrimps and large ocean mammals. Over the centuries, these nations have developed special technologies that are adapted to their local conditions for harvesting the natural production of the oceans**.**

Because there is a limit to how much of the natural production can be harvested by man without disturbing the ecological balance, the fishing nations have established national and international organizations which monitor fishing activities and set up quotas for each nation in different regions of the oceans. This problem leads to a field of research and development activity often referred to as Model Based resource Estimation and Management (MBEM**),** since numerical models of the resource dynamics are used to make quantitative estimates.

In contrast to just harvesting what the natural ocean system produces there is aquaculture which dates back to the time people in the Far East recognized its potential. In aquaculture, artificially bred juveniles of the particular species of fish or crustaceans are placed in properly sized enclosures such as tanks, cages (pens) made of netting or earth dams and are fed at regular intervals with diets yielding optimal growth. During the last 20-30 years there has been a dramatic expansion on a worldwide basis in the aquaculture business. The driving forces in this expansion have been both the high quality and low price of aquaculture products and the overexploitation of the natural production of the oceans. All studies indicate that there will be great demands for both basic and applied research, as well as industrial developments in the field of aquaculture to meet rapidly expanding markets.

A third line of development with relation to fisheries and aquaculture is ocean ranching, which is also an old idea, but has experienced renewed interest both in research and the fishing industry. New developments in many countries prove that it is possible to achieve good economic results by releasing artificially bred juveniles of particular species of fish and crustaceans directly to the ocean in selected locations for feeding on the natural supply of biological production and relying on the homing instinct of the species to return the adult animals to the release point for harvesting. This concept has been known to be effective for many subspecies of salmonids for a long time and is put into commercial use in Japan and the USA. Ocean ranching has also been shown to be promising for more stationary species such as the clawed lobster (*Homarus gammarus / Homarus americanus).*

The total production of fish on a worldwide basis from harvesting and aquaculture is reported in FAO statistics as:

Total world harvesting in all oceans in 1990-2000 was about 70 million metric tons per year (mt/y). During the same period, the production of fish by aquaculture has been15-20 million mt/y. The total industrial activity associated with the harvesting operations, product processing (offshoreand onshore), and the aquaculture-based fish farming/ product processing are subject to strict demands upon productivity of processes in terms of the resources used (manpower, capital, energy and feed) to produce the products, quality of products set up by the international competition, and impact upon the environment**.** The best available technology must be employed to meet these demands. Among the key technologies that can offer progress in both productivity and quality are mechanization, instrumentation, computer-based sequential control and automatic feedback control. All these technologies will for convenience be referred to as Automation.

Fisheries and Aquaculture Technology have a relation to Automation in much the same way as the processing and manufacturing industry and the transportation industry, since standard automation equipment is being used in this sector. However, many of the problems encountered in Fisheries and Aquaculture Technology are unique to this field and demand special solutions. As in most other technological fields the development work starts with the basic process (i.e. fishing gear, fishing vessel, fish processing machine, aquaculture hatching process, aquaculture cage- and feeding system, etc.) that is operated under manual control based on visual observations by the operator. This could be termed the mechanization and manual control phase. Later, some basic instrumentation is added to aid the operator to make more accurate accounts of the state of the process (the instrumentation phase). Furthermore, pre-programmed sequential controls (often implemented as computer programs) are added to relieve the operator for routine functions (the open loop control phase). Finally, when all the problems in these early phases have been resolved the time has come for implementing closed loop feedback control based on data from the instrumentation system, acting on the mechanized process. In Fisheries and Aquaculture Technology, the majority of processes and operations are still under manual or open loop control, but the rate of changes is high and new achievements are constantly being announced by system vendors and by research organizations.

The following sections will review some of the most relevant developments.

2. Traditional harvesting technology. Relations to instrumentation, Mechanization, control and automation

The traditional harvesting technology is extremely diverse and ranges from the most primitive fishing tools to the most sophisticated large-scale modern fishing systems. This survey will deal mostly with modern technological systems. It will be limited to the systems used in ocean fisheries.

2.1 Modern harvesting gear

The harvesting gear itself (not considering any control systems) can be grouped in many ways according its basic method of operation. One group (A) of gears is based on placing passive devices in certain pre-determined locations in the ocean that intercept a periodic migration (daily or yearly) of the fish for feeding or spawning. Gill nets (ground set or drifting) and weirs belong to this category. Another group (B) is based on searching with acoustic echo location equipment to find shoals of fish to be harvested by means of a variety of nets that are hauled and positioned by means of velocity and position control of the fishing vessel. Bottom and pelagic trawling and purse seining belong to this category.

Figure 1 illustrates bottom and pelagic trawling. The trawl consists of a large conical sack made of net that is hauled by a vessel via two wires (warps) either along the bottom or in mid water (pelagic). The warps are kept apart by two otter- boards in order to keep the trawl net open. A number of sensing systems have been developed to assist the skipper in controlling the vessel velocity and heading in order to improve the catch in the shoal of fish with the trawl. The system includes otter- board spread sensor, depth sensor, trawl opening sensor, catch sensor etc.

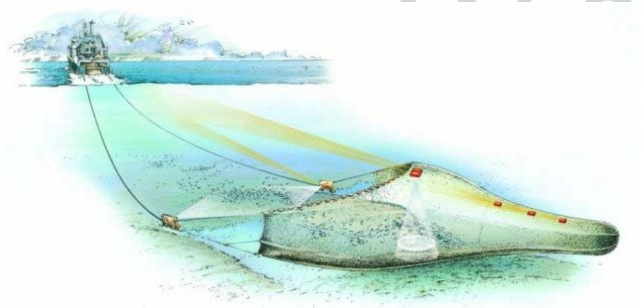

Figure 1. Bottom and pelagic trawling with instrumentation (courtesy SIMRAD).

Figure 2 shows the situation encountered when *shooting and hauling a purse seine*, which is equipped with sensors for depth and temperature to aid the skipper in controlling the vessel motion.

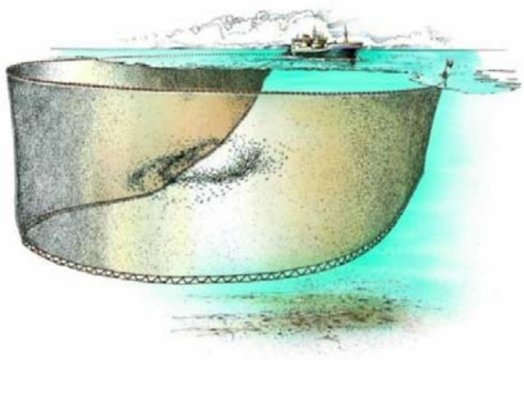

Figure 2. Purse seining with instrumentation (courtesy SIMRAD).

A third group (C) is based on attracting shoals of fish (which are known to be present in a general area due to daily or yearly migration) by means of attractive olfactory stimuli (smell) or visual stimuli (lures). The source of an olfactory stimulus can be either a natural or an artificial bait or a container releasing an attractant. *"Longline*" (Figure 3*), "Jigging"* and *"Fish traps"* belong to this category.

A highly automated system for longline fishing is shown in Figure 3 (in a small vessel version). A typical longline system consists of a multifilament mainline (a number of kilometers long) and a large number (up to 30000) of snoods (mono- or multifilament) with hooks with 1-3 m spacing. The bait on the hooks may be natural (different kinds of fish, shrimp, squid etc) or artificial. The system in Figure 3 has automatic baiting, setting at a speed of 2-4 m s^{-1} at depths of 100-1000 m, fishing for 1-24 hours, hauling (normally over the starboard side) at a speed 1-3 m s^{-1}, automatic de-hooking and hook cleaning.

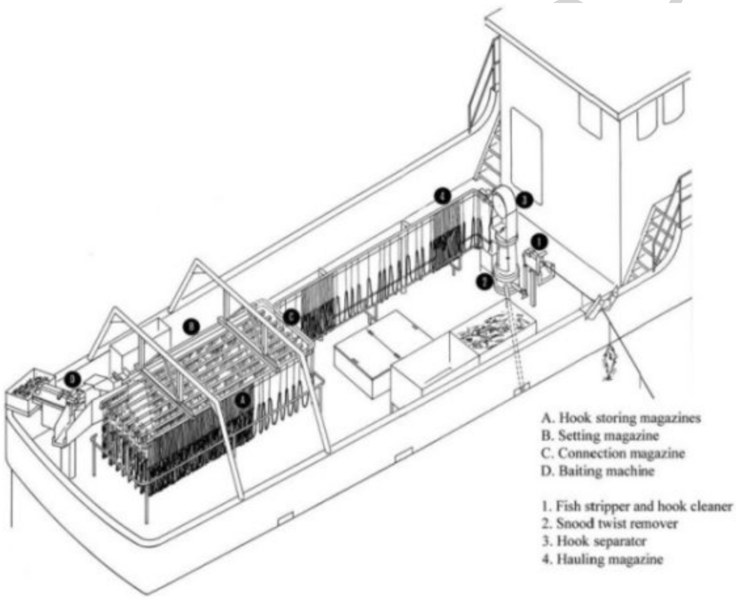

Figure 3. A modern automatic longline fishing system (courtesy MUSTAD Autoline)

Finally, a fourth group (D) has its basis in the application of artificial stimuli that are either attractive or repulsive, to guide the fish towards a harvesting device. The stimuli can be low frequency sound signals, light patterns, electric pulses etc.

In one of the techniques for electric fishing illustrated in Figure 4, the fact that fish are attracted to the positive electrode in a field of an electric current is utilized. So far, electric fishing has not become important commercially.

Among these different types of fishing gear, categories B, C and D have the highest potential in terms of being part of an automated fishing system.

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Biographical Sketch

Jens G. Balchen is Professor Emeritus at the Department of Engineering Cybernetics (DEC) of the Norwegian University of Science and Technology, Trondheim, Norway. He has been active as an educator and researcher in the field of control theory and engineering for 50 years and led the foundation of DEC in 1954. He was one of the "founding fathers" of IFAC in 1956 and has served on a number of boards and committees of IFAC. Balchen has initiated and managed a large number of development programs in the electrometallurgical, paper and pulp and off-shore oil industries and has pioneered new concepts related to automation in fisheries and aquaculture technology.