12th IMEKO TC4 International Symposium
Electrical Measurements and Instrumentation
September 25–27, 2002, Zagreb, Croatia

MULTIVARIABLE MEASUREMENTS AND OBSERVATIONS IN THE FRESHWATER FISH-FARMING INDUSTRY: AN INTERNET-BASED EXPERT SYSTEM

Krešimir Petrinec[1], Zdravko Petrinec[2], Zdenko Kovačić[1]

[1] University of Zagreb, Faculty of Electrical Engineering and Computing
Unska 3, 10000 Zagreb, CROATIA
[2]University of Zagreb, Veterinary Faculty, Department – Biology and Pathology of Fish and Bees
Heinzelova 55, 10000 Zagreb, CROATIA

E-mail: kresimir.petrinec@fer.hr, petrinec@vef.hr, zdenko.kovacic@fer.hr

Abstract – This paper deals with a description of a multivariable measurement system intended to be used in the freshwater fish-farming industry. The aim of the measurement system is to provide data about water temperature, water pH and oxygen dissolved in water necessary for operation of an expert system that supervises and controls the fish production process. The installed measurement equipment is connected with the expert system through a server-client type of communication via the Internet and an ability to handle multiple clients makes the whole system operable for an arbitrary number of fish farms. Access to the on-site measurement equipment via Internet enables better supervision, planning and better utilization of production resources, which results in turn with increased quality of fish, increased fish growth and bigger profits.

Keywords: measuring elements, expert systems, knowledge-based control, bio technical control.

1. INTRODUCTION

The ever increasing human population is facing the need for more food. The solution is in development of new food production technologies. While advanced agricultural methods have increased crop production almost to a point where it is impossible to produce more, there is still a lot of to be done in production of meat. In this sense, fish meat, as a reach source of proteins, represents a very interesting category for bio-technical treatment.

Parameters which have the largest impact on fish growth include the following: water temperature, water pH, oxygen dissolved in water, food quality and amount of food given to fish, as well as possible disease outbreaks in the fish population [1]. By taking insight into the current practice in the fresh-water fish-farming industry, it may be noticed that usually the whole process of fish production depends on the on-site personnel skills, experience and subjective decisions.

The multivariable measurement system described in this paper provides information about physical and chemical parameters of the fishpond water as well as parameters of biocenosis that are used by the accompanying expert system intended for supervision and control of fish production. The proposed measurement system is connected to Internet, thus allowing also establishment of the on-line expert system service via Internet issuing relevant recipes for the type of food and amount of food to be given to the fish population based on objective field measurements [2, 3]. The usage of Internet also elegantly overcomes a problem of simultaneous supervision and control of distant fish farms located far from each other. This also provides conditions for long-term scientific observations and investigations of the fishpond process behavior in a real-time by watching events as they are registered with the installed measurement equipment.

The paper is organized in the following way. First we describe the hardware part of the expert system focusing on the measuring instruments and their installation. Then we describe a server - multiclient application that serves for acquisition of measured data via network. Special attention has been paid to description of the experimental results obtained in the pilot system installation at Belje – Fish farm Mirkovac, Croatia. Final comments and directions for future research conclude the paper.

2. AN EXPERT SYSTEM – THE HARDWARE PART

The hardware part (Fig. 1.) of an expert system for freshwater fish-farming industry consists of the following:

1. one server PC
2. one or more client PCs
3. as many measuring instruments as there are clients.

Each client is connected to a measuring instrument which assesses the water quality parameters. The communication between the client and the measuring instrument is established via serial RS-232 protocol.

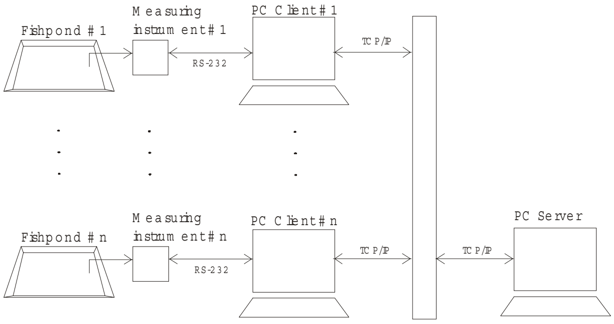

Fig. 1. The freshwater fish-farming expert system - hardware

2.1. The Measuring Instrument

As mentioned earlier, a measuring device is an important part of the expert system. There are a number of measuring instruments available on the market, but this particular process required a device which would be able to measure the following:

1. water temperature from 0ºC-30ºC
2. water pH levels from 2 to 11
3. dissolved oxygen levels from 0 mgO_2/l to 20 mgO_2/l

The measuring device Thermo Orion 1230 meter was found most appropriate for measuring all the above-mentioned parameters for fish-farming. This measuring instrument shown in Fig. 2 can simultaneously monitor water pH and dissolved oxygen levels, as well as show water temperature, display date and time, and is fully waterproof. Data logging and printing options offer needed data collection flexibility.

Fig. 2. The measuring intrument Thermo Orion 1230 that measures dissolved oxygen in water, water pH and water temperature.

Thermo Orion 1230 meter uses a probe to measure dissolved oxygen levels, but for proper operation it requires the sample flow of water to be at least 10 cm/s. A care must be taken with installation of the instrument in conditions of nonexistence of water flow such as in the experimental fishpond Belje – Mirkovac (Fig. 3).

Fig. 3. An experimental fishpond Belje – Mirkovac, Croatia.

The solution of the probe installation is shown in Figs. 4 and 5. A minimal sample flow was achieved by placing a low power rotary water pump inside the fishpond. The pump utilizes a pipeline or a hose to pump fishpond water and returns it to the pond. One end of the pipeline should be placed at least 0.5 meter deep under the fishpond surface.

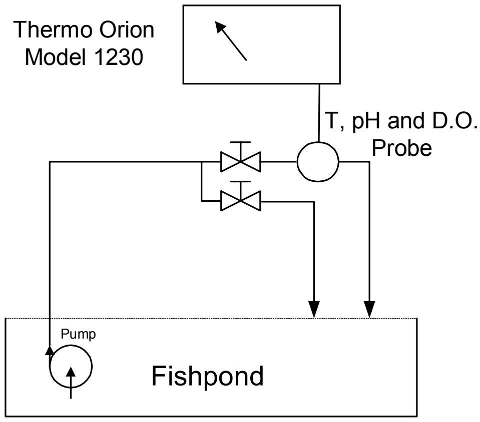

Fig. 4. Subsystem for generating minimal sample flow needed for measurement of dissolved oxygen.

Fig. 5. Closer look at the measurement system installation.

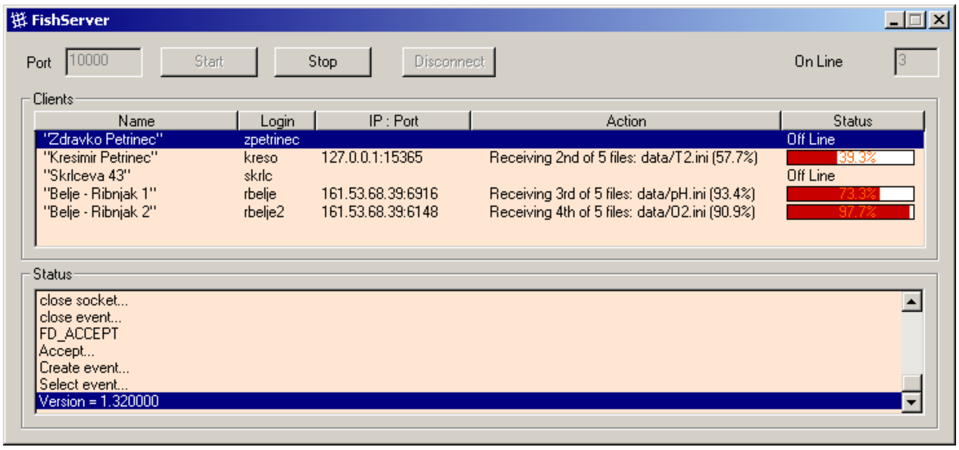

Fig. 6. Server application.

3. AN EXPERT SYSTEM – THE SOFTWARE PART

The software part of an expert system for freshwater fish-farming industry consists of the following: server application and client application. The server communicates with clients and vice versa via TCP/IP protocol while data is exchanged using Windows Socket 2.

3.1. The Server Application

The server application is intended to be under control of a fish-farming specialist. The server supports one or more clients and treats these clients independently (Fig. 6). The application receives data from a client who, for this purpose, needs to connect on-line. The application then stores the client's data in a database. Data can be displayed in a graph and a trend form, and can be used for debug or simulation purposes. An expert can create or modify forward reasoning expert system rules in his application editor, and use a debugger or a simulator to check correctness and the syntax of the rules. The debugger and the simulator are closely related to the interpreter which interprets and validates rules. Once an expert has modified the rules and decided to apply them, the modified rules are sent to the corresponding client.

3.2. The Client Application

The scheme of the client application shown in Fig. 7 encompasses the following:

1. reception and storage of measured data in a database
2. display of data in both a graph and a trend form
3. interpretation of expert system rules
4. interaction with the user
5. sending the data to the server and
6. reception of a new set of rules if there are any.

Every 60 seconds the client application (Fig. 8) receives measured data from the measuring instrument and stores them in the database. The main part of the application is an interpreter, which reads and interprets rules from the rule-base, and stores the results in a database [4]. Parameters, i.e. variables required by the rules, are read by the interpreter from the database. Once a day, the application sends the latest database data to the server and checks whether a new rule-base exists. If so, the client application downloads the new rule-base from the server and replaces the old one.

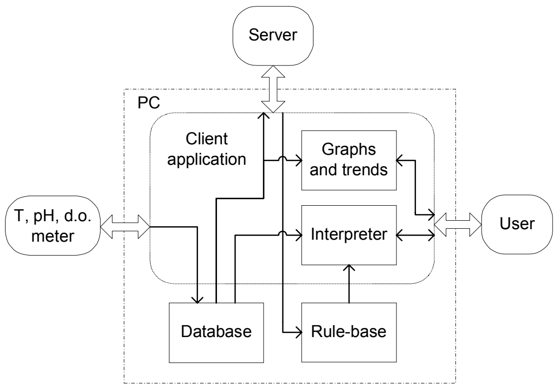

Fig. 7. A scheme of the client application.

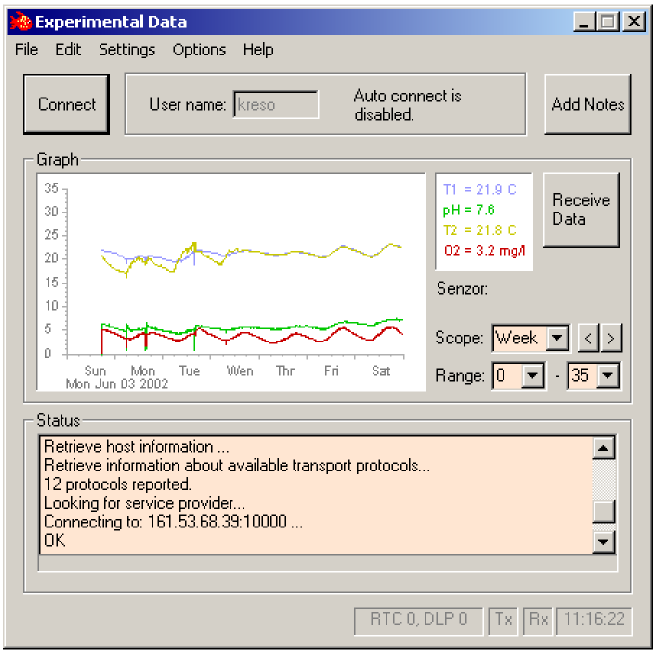

Fig. 8. Client application.

A rule-base is a text file that contains forward reasoning expert system rules that process states of multivariable inputs in order to generate optimal states of multivariable outputs (see Fig. 9.) according to the embedded expert knowledge.

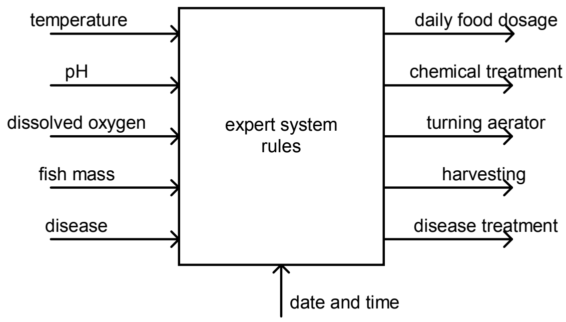

Fig. 9. Expert system input and output parameters.

There are five groups of rules. The first group of rules decides of the amount of food to be given to fish depending on the water temperature and current fish mass. The second group of rules monitors pH levels and in case of inappropriate levels suggests chemical treatment of the fishpond water. The third group of rules monitors dissolved oxygen levels and turns the aerator on or off. The fourth group of rules monitors time and fish mass, and decides whether harvesting is needed. In case the client detects a disease among the fish population, the last, fifth group of rules suggests ways of controlling and treating the disease.

The database consists of two different types of files. One type of file contains parameter names, parameter types and a file path. The other type of file, the storage-file, contains a list of specific parameter values as well as times when a specific parameter is stored.

4. FIELD RESULTS

The aforementioned measurement system that measures water temperature, water pH, and oxygen dissolved in water has been installed on the experimental fishpond at the fish farm Belje – Mirkovac, Croatia. The fish production cycle (of the common carp farming) is dominantly determined with atmospheric and environmental conditions and the season of the year. Feeding of fish normally begins when the water temperature reaches 10^{o}C. This normally occurs in the spring season. Figures 10-12 show the field results obtained in May 2002 when the process of fish production entered the second month of duration. It must be noted that in parallel to these measurements, other influential parameters like fish mass, food quality, disease outbreaks and amount of food given to fish have been checked and carefully recorded. These are parameters which affect fish growth the most. Figure 10 presents field results obtained under normal operating conditions. It may be noticed that the water temperature varies from 21 to 23,5^{o}C following the exchanges of day and night intervals. Water pH varied in the range from 5 to 7 because of the offset of –2 caused by the length of the communication cable (>100 m). This means that pH values prevail a little bit to the lime side (it may be explained with the vicinity of the river Danube whose underground waters fill the fishpond. Due to the presence of detergents and other lime chemicals, water pH tends to be below neutral pH=7. A dissolved oxygen varied in the range from 3 to 6 following the pattern of the temperature variations (due to larger production of oxygen by phytoplankton during the daylight and sunny periods).

Measurement results also indicate another event – a power utility blackout (Fig. 11). The power utility distribution system in the region of Belje fish farm is going through a capital reconstruction, and occasional blackouts stop the pump that provides a necessary water flow in the measurement system. By stopping the pump (i.e. water flow) measurement results become incorrect and therefore useless. On the other hand, registration of such event may help in preparation of the reserve power resources (UPS, batteries). Incorrect measurement results may be obtained also if the probes are not calibrated (Fig. 12).

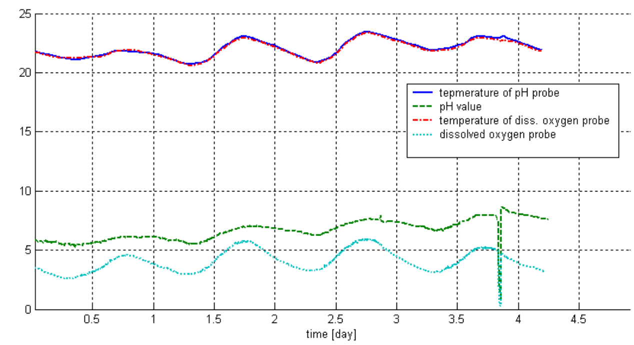

Fig. 10. Field results – normal operation.

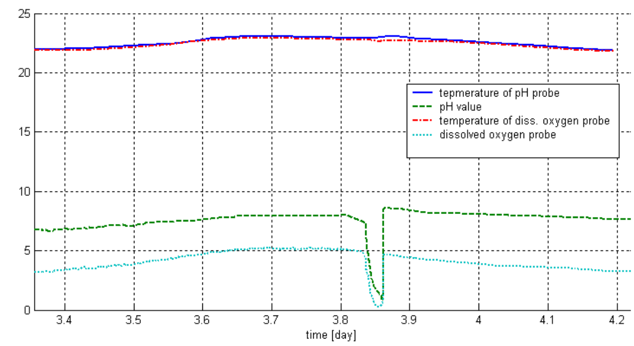

Fig. 11. Field results – power utility blackout.

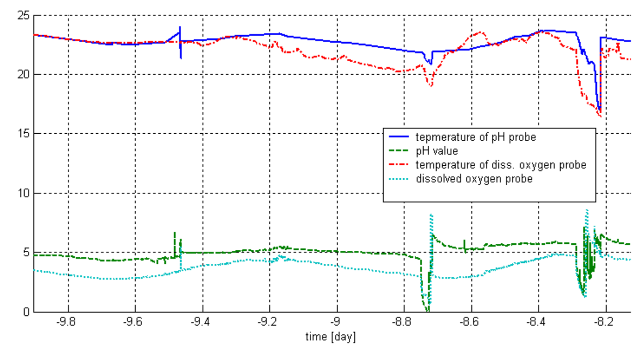

Fig. 12. Field results – calibration error.

5. CONCLUSIONS

This paper presents a concept and a technical description of a multivariable measurement system which is the part of an expert system for freshwater fish-farming industry. In most cases the efficiency of this industry depends on the staff working on the fish farms. Their interventions in the production process are mainly based on gained experience and on subjective field observations, which may be pretty far from interventions based on objective technical measurements and top expert knowledge. Additional problem represents dislocation and large areas of fish-ponds where production is going on. Then production planning and supervision of the production processes becomes very difficult.

By using new technologies that make it possible to – on a daily basis - measure and acquire data relevant for fish production, in combination with Internet-based technologies, a completely new method of supervision and control of fish-farming can be implemented.

By connecting measuring equipment to the Internet and by processing the acquired data with adequate software tools, fishpond staff as well as managers can follow fish growth and cost-effectiveness of the production while having the ability to influence the entire process of production.

The proposed expert system is configured as a server-multiclient type of application. The server application is intended to be under control of a fish-farming specialist. An expert can create or modify forward reasoning expert systems rules which become the prescribed rules for the clients. The server communicates with clients and vice versa via TCP/IP protocol while data is exchanged using Windows Socket 2. Internet-based network structure allows supervision and control of an arbitrary number of fish farms.

The expert system was built as an open architecture system which made it possible to take advantage of object-oriented programming techniques and the Internet's availability. This concept allows easy modifications of the expert rule-base so the version that has been developed for common carp farming can be adapted to suit other fish species (e.g. trout, catfish, pike, etc.).

Thanks to installation of the proposed measurement system and continuous monitoring of water temperature, water pH and dissolved oxygen in water, actions of the field personnel are more exact and more effective. The pilot system was installed in the experimental fishpond at the Belje – Mirkovac fish farm, Croatia.

Besides having insight into the parameters that have a significant impact on the fish growth, the results of measurements offer also a ground for environmental, climate and ecological studies.

Regarding future research activities, this would also provide conditions for long-term scientific observation and investigation of the fishpond process behavior in a real-time by watching events as they are registered with the installed measurement equipment. The developed expert system will be completely open to the expert giving him the opportunity to change or add new expert rules in accordance with newly acquired expert knowledge. This will provide possibility of immediate real-time intervention into the system and achievement of further improvements in production.

6. ACKNOWLEDGMENTS

We would like to thank the Croatian Ministry of Economy, the Croatian Agriculture, Food Industry and Forestry Department, Belje d.d. – Agriculture Mirkovac and IPK Osijek "Fish-farming" d.o.o. for giving support to the project "Expert System for Supervised Fish-farming via Internet". Particular thanks to Belje d.d. – Agriculture Mirkovac for providing an experimental fishpond and all necessary infrastructure.

REFERENCES

[1] Boyd, C.E. "Water Quality in Ponds for Aquaculture", *Shrimp Mart (Thai) Co. Ltd., Thailand,* 1996.

[2] Giarratano, J. and G. Riley, "Expert Systems Principles and Programming", Third Edition, *PWS Publishing Company*, 1998.

[3] Jackson, P., "Introduction to Expert Systems", Third edition, *Addison-Wesley*, 1999.

[4] Petrinec K.; Petrinec Z.; Kovačić Z. "An Expert System for Freshwater Fish-farming Industry", 15th World Congress IFAC, 2002, Barcelona, Spain (accepted for presentation).

Author(s): Krešimir Petrinec, B.S.E.E., University of Zagreb, Faculty of Electrical Engineering and Computing, Unska 3, 10000 Zagreb, Croatia, Zdravko Petrinec, prof.dr., University of Zagreb, Veterinary Faculty, Department – Biology and Pathology of Fish and Bees, Heinzelova 55, 10000 Zagreb, Croatia, Zdenko Kovačić, prof.dr. University of Zagreb, Faculty of Electrical Engineering and Computing, Unska 3, 10000 Zagreb, Croatia