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AN EXPERT SYSTEM FOR FRESHWATER FISH-FARMING INDUSTRY

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Abstract: This paper deals with a technical description of an expert system for the freshwater fish-farming industry. The expert system is connected with on-site measurement equipment and by means of expert control rules supervises and controls the fish production process. Additional features such as server-clients communication via the Internet and an ability to extend a rule-base with new expert knowledge makes development of expert systems for any number of fish farms possible. Access 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. *Copyright © 2002 IFAC*

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1. INTRODUCTION

Constant growth of the human population imposes the need for more food and consequently, more food production. Genetics and biotechnologies have particularly important roles in achieving this goal. 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 biotechnical treatment.

This paper is concerned with development of an expert system for freshwater fish-farming industry. This expert system can be also viewed as a multivariable input – multivariable output control system having maximal fish growth as its goal. Although the proposed expert system could be easily modified to suit other freshwater species grown on fish farms (e.g. trout, catfish, pike, etc.), it has been developed for the specifics of carp farming. Namely, in most countries of Europe and Asia, and in some areas of Central America, the common carp is the most important cultured fish (Horváth, *et al*., 1992). Common carp (Fig. 1.) are good at utilizing artificially fed cereals and natural food, which results in rapid growth. This makes carp one of the most popular species to be grown in freshwater fish farms.

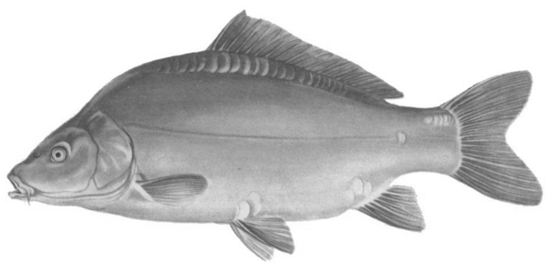

Fig. 1. Common Carp (lat. Cyprinus carpio)

Experience has shown that using ‘extensive’ methods in carp farming, about 500 kg/ha can be achieved, while the application of the most advanced technologies can produce about 2,000-3,000 kg/ha - even in temperate climates. Under ideal conditions, as much as 5,500 kg/ha have been grown (Petrinec, *et al., 1983)*. However, these so-called “intensive” methods increase the possibility of occurrence of various diseases such as parasitic and bacterial infections and therefore require a greater control of production and growth processes.

Benefits of using an expert system to control carp farming become clearer when one considers the complexity of the fish-farming process. Parameters which affect 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 (Boyd, 1996).

To begin with, carp must not be fed unless the water temperature is over 10ºC (Antalfi and Tölg, 1971; Horváth, *et al*., 1992; Fijan, 1975; Steffens, 1985; Tölg, 1981; Treer, *et al.*, 1995). Feeding must begin with minimal amounts of carbohydrate pellets. When the carp adjusts to the food, the amount is increased as the water temperature increases, but not more than 5% of the individual fish mass. When the temperature rises over 16ºC, the carp is fed another type of food, known as “complete” which must include at least 38% of protein. Daily food dosage varies depending on the water temperature as well as the changing mass of carp (i.e. as the carp grows, it is fed greater amounts of food, up to 10% of individual fish mass).

Besides a great need to control food intake precisely, it is extremely important to control dissolved oxygen levels and water pH levels. In case of a sudden change of water temperature or water pH levels, the daily food intake for carp needs to be decreased or, in some cases, feeding must be stopped altogether. In case of a sudden change or a drop of dissolved oxygen levels under 5 mgO_2/l, aerators must be turned on. If the aerators are not able to prevent the drop of oxygen levels, similarly to a change in water temperature, daily food intake needs to be decreased, or the feeding must be stopped altogether.

These control demands are only a tip of the iceberg of this exceptionally complicated process. Therefore, an Internet-based expert system which would serve in the capacity of specialist guidance for the fish farm workers would be extremely beneficial for the industry, and is very likely to reduce costs of expert consultancies, especially in far-away fish farms.

The paper is organized in the following way. First we describe a software part of the expert system implemented as a server-client(s) application connected via network with on-site measurement equipment. Then we describe the hardware part of the expert system focusing on the measuring instruments. Special attention has been paid to describing the rule base as the core of the expert system (Giarratano and Riley, 1998; Jackson, 1999). Final comments and directions for future research conclude the paper.

2. AN EXPERT SYSTEM – THE SOFTWARE PART

The software part of an expert system for freshwater fish-farming industry consists of the following:

- server application
- client application

The server communicates with clients and vice versa via TCP/IP protocol while data is exchanged using SOAP protocol (XML data).

2.1 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 (see Figure 2). 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 graph and trend form, and can be used in debug or simulation-purposes. An expert can create or modify forward reasoning expert systems 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.

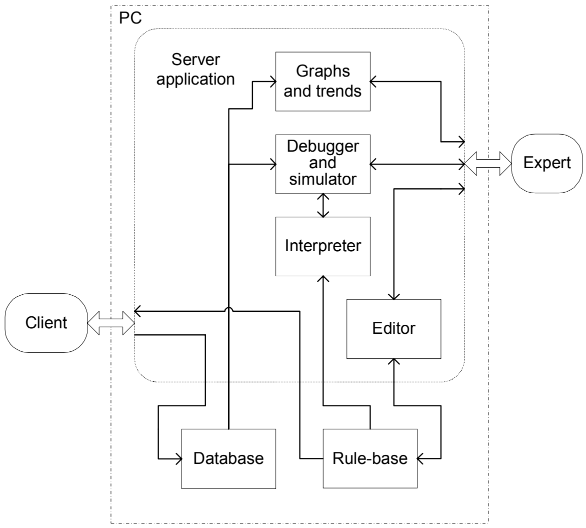

Fig. 2. Server application.

2.2 The Client Application

The scheme of the client application in Fig. 3. shows the following:

1. recepetion of measured data
2. storage of data in a database
3. display of data in both graph and trend form
4. interpretation of expert system rules

5. interaction with the user
6. sending the data to the server and
7. reception of a new set of rules if there are any.

Every 60 seconds a measuring instrument sends data measured in the fishpond to the client. The client application receives data 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. 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 this is so, the client application downloads the new rule-base from the server and replaces the old one.

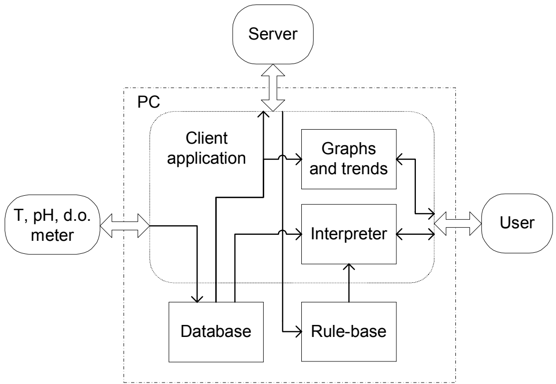

Fig. 3. Client application.

Special care was taken to design an interpreter that offers a good interaction with a user. For example, if one of rule-base rules is:

```
if (diss_oxy_conc < 5)
    textout ("Turn on the aerator");
```

the interpreter reads the value of the variable diss_oxy_conc from the database, and if the value is less than five, the following message will appear on the PC screen:

Turn on the aerator.

A similar rule could, for example, start the PLC which would then turn the aerator on.

The interpreter recognizes different keywords (int, long, float, character, bool, etc.), statements (if, else, do-while, for, etc.), expressions (<, >, <=, >=, ==, &, etc.), functions (print, alarm, quest, get, etc.), and properly declared variables.

2.3 The Database

The database consists of two different types of files. One type of file contains parameter names, parameter types and a file path (see Fig. 4). 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. Figure 4. illustrates how the variables are stored and reached.

File start.ini contains a list of parameters. The parameters shown here are water temperature, water pH and aerator condition (i.e. on or off). The temperature and pH are floats and the aerator is boolean type. File temperature.ini is an archive file. Therefore, it shows the date, the time and the value of the last and previously saved temperatures.

```
; Filename: start.ini
; Author:  Kresimir Petrinec
; Created: 03/04/2001
;
; var_name       var_type     storage_filename
temperature      Float        data\temperature.ini
pH               Float        data\pH.ini
aerator          bool         data\aerator.ini
```

```
; Filename: aerator.ini
;
; date&time                   value
; [yyyy mmddhhmmss]           [bool]
2001 0304160201               F
2001 0304160203               T
2001 0304160333               F
2001 0504160352               F
2001 0504160411               T
2001 0504160525               T
2001 0504160549               F
2001 0504160617               T
2001 0504160711               F
```

```
; Filename: pH.ini
;
; date&time                   value
; [yyyy mmddhhmmss]           [float]
2001 0304160302               5.2
2001 0304160303               5.3
2001 0304160306               5.4
2001 0504160549               6.1
2001 0504160617               7.8
2001 0504160715               6.2
2001 0504160711               6.3
```

```
; Filename: temperature.ini
;
; date&time                   value
; [yyyy mmddhhmmss]           [float]
2001 0304160301               21
2001 0304160303               22
2001 0304160304               23
2001 0304160410               22.1
2001 0304160514               21.7
2001 0304161333               22.3
2001 0304162335               23.4
2001 0304162343               23.6
2001 0304162410               24.1
```

Fig. 4. Example of the database.

3. AN EXPERT SYSTEM – THE HARDWARE PART

The hardware part (Fig. 5.) 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.

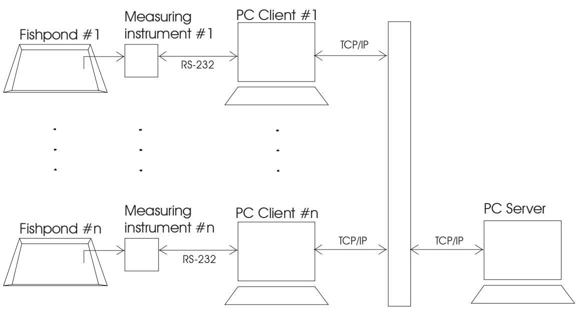

Fig. 5. The freshwater fish-farming expert system.

3.1 The Measuring Instrument

As we mentioned earlier, a measuring device is an important part of the expert system. There are several 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

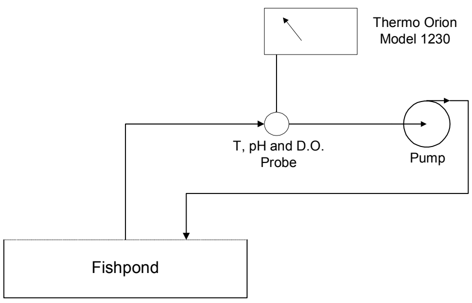

Fig. 6. Subsystem for generating minimal sample flow needed for measurement of dissolved oxygen.

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

Thermo Orion 1230 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. This presents a problem if there is no water flow in a fishpond. A solution of the problem is a subsystem shown in figure 6. A minimal sample flow was achieved by placing a low power rotary water pump outside the fishpond. The pump utilizes a pipeline or a hose to pump fishpond water and returns it to the pond. In order to avoid erroneous measurements of increased dissolved oxygen concentration caused by cavitations in the water pump measuring probes should be attached to the pipeline which pumps the water out, and not to that which returns the water. Both ends of the pipeline should be placed 0.5 meter deep under the fishpond surface.

4. AN EXPERT SYSTEM – THE RULE-BASE

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. 7.) according to the embedded expert knowledge.

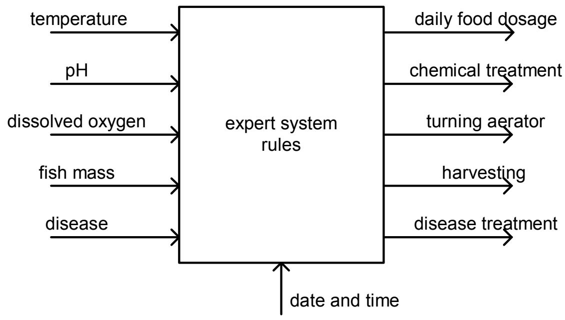

Fig. 7. Expert system input and output parameters.

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 number of rules depends on the amount of knowledge transferred into the rule-base. A sample of a pseudocode of the expert system illustrates common expert rules forms:

```
if (temperature>=10 && temperature<16) {
   food_type = carbohydrate;
   food_coefficient = 0,005;
   expected_increase = 4;
}
if (temperature>=16 && temperature<20) {
   food_type = complete;
   food_ coefficient = 0.03;  // 0.03-0.05
   expected_increase = 1.5;
}
if (temperature>=20 && temperature<26) {
   food_type = complete;
   food_ coefficient = 0.05;  // 0.05-0.10
   expected_increase = 1.5;
}
if (temperature>=26 && temperature<28) {
   food_type = complete;
   food_ coefficient = 0.05;  // 0.03-0.05
   expected_increase = 1.5;
}
if (temperature<10 || temperature>=28) {
   food_type = no_feeding;
   food_ coefficient = 0.0;
   expected_increase = 1.5;
}

if (food_type != no_feeding) {
   food_amount = fish_mass*food_coefficient;
}
if (newdate != olddate) {
   if (food_type == carbohydrate) {
      printout("feed fish with carbohydrate
         pellets");
      printout("amount of food = %f kg",
         food_amount);
   }
   if (food_type == carbohydrate) {
      printout("feed fish with complete
         food");
      printout("amount of food = %f kg",
         food_amount);
   }

   olddate = newdate;
   feedingday++;
}
if (pH < 6.5) {
   chemical_type = lime;
   chemical_amount = water_amount * 0.015;
   printout("add lime in fishpond");
   printout("amount of lime to add = %f",
       chemical_amount);
}
if (pH >= 9 && exchange_water==false) {
   exchange_water = true;
   printout("begin with water exchange");
}
if (pH < 9 && exchange_water==true) {
   exchange_water = false;
   printout("stop water exchange");
}
if (feedingday%10 == 10) {
   do_harvesting = true;
   printout("harvest 100 fish and
      measure weight");
}
if (do_harvesting == true) {
   printout("fish weight?");
   get(new_fish_mass);
   calculated_increase =
      (new_fish_mass-fish_mass)/
         food_amount;
   if (abs(calculated_increase -
      expected_increase) > 0.1) {
      //recalculate food_ coefficient
   }
   fish_mass = new_fish_mass;
   do_harvesting = false;
}
```

In terms of the client application the rule base is implemented as a read-only file. The rules syntax is similar to that of C programming language.

5. CONCLUSIONS

This paper presents a concept and a technical description 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.

We have shown that the aforementioned technologies can be combined with an advanced expert system created by top professionals in the field to get an on-line system capable of guiding the fish production so that increased quality of fish, greater fish growth and bigger profits could be achieved.

The proposed expert system is configured as a server-client 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 SOAP protocol (XML data). Internet-based network structure allows supervision and control any 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.).

Future work will focus on development of more complex expert systems which would contain rules associated with fish pathology. It would be necessary to add statistical tools for short-term and long-term statistical analysis which would help in correction and improvement of the embedded expert knowledge. Our goal is to integrate self-learning mechanisms into the rule base, which would then adapt expert rules automatically.

6. ACKNOWLEDGMENTS

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