Biblid: 1821-4487 (2012) 16; 3; p. 116-1119.
UDK: 664.951

Original Scientific Paper
Originalni naučni rad

IMPLEMENTATION OF EXPERT SYSTEM FOR PROCESS CONTROL OF FISH PROCESSING

REALIZACIJA EKSPERTSKOG SISTEMA ZA UPRAVLJANJE PROCESOM OBRADE RIBE

Dragan MATIĆ, Andrea HRABOVSKI, Vladimir BUGARSKI
Faculty of Technical Science, University Novi Sad; Trg Dositeja Obradovića 6; 21000 Novi Sad
e-mail: dmatic@uns.ac.rs

ABSTRACT

This paper presents the development and implementation of expert systems for process control of fish processing. The plant is intended for primary fish processing, freezing and packaging. In order to improve the pace of production, an expert system based on fuzzy logic is designed and developed. Inputs in the fuzzy expert system are the speed of conveyors in the plant, the temperature of frozen fish and desired processed fish quantity. The expert system estimates amount of processed fish from each subsystem and the total quantity of processed fish. Expert system for management in such a facility sets the trends that benefit everyone from top level management to plant operators. The system could have more applications; the prediction of fish to be processed and to point out the problems in the sub-systems and failure of the machines.

Key words: *expert system, fish plant, fuzzy logic.*

REZIME

U radu je prikazan razvoj i realizacija ekspertskog sistema za upravljanje procesom obrade ribe. Postrojenje je namenjeno za primarnu obradu ribe, zamrzavanje i pakovanje. Izvedeno je kao celina podeljena u međusobno zavisne podsisteme za lakšu kontrolu i upravljanje. U cilju unapređenja tempa proizvodnje uvodi se ekspertski sistem baziran na fuzzy logici. Za razvoj fuzzy ekspertskog sistema potrebno je definisati lingvističke promenljive, fuzzy skupove kao i fuzzy pravila. Ulaze u fuzzy ekspertski sistem predstavljaju brzine pokretnih traka u postrojenju, temperatura zamrznute ribe i željena količina obrađene ribe. Ekspertski sistem na osnovu ulaznih parametara procenjuje količinu obrađene ribe iz svakog podsistema kao i ukupnu količinu obrađene ribe. Fazzy ekspertski sistem obezbeđuje veću fleksibilnost modela proizvodnje u postrojenju za primarnu obradu ribe sticanjem ekspertskog znanja u proizvodnji ribe. Koristeći ekspertsko znanje iz postrojenja za obradu ribe, četiri fuzzi kontrolera su razvijena za podsistem obrade ribe, slaganje, frižider i pakovanje. Fuzzy kontroleri objašnjavaju njihovu međusobnu zavisnost i odnose. Ekspertski sistem za upravljanje u jednom ovakvom postrojenju postavlja trendove koji su od koristi svima, od najvišeg nivoa menadžmenta do operatera u postrojenju. Sistem može imati više primena od predviđanja količine ribe koja će se obraditi do ukazivanja na probleme u podsistemima ili kvarove na mašinama. Realizacija predloženog ekspertskog sistema će olakšati praćenje i upravljanje dinamikom procesa prrade ribe, a takođe će olakšati i planiranje proizvodnje.

Ključne reči: *ekspertski sistemi, fabrika za preradu ribe, fuzzy logika.*

INTRODUCTION

Fish processing, a multi-billion dollar industry inNorth America alone, vastly uses outdated technology. Wastage of useful fish meat during processing, which reaches an average of about 5%, is increasingly becoming a matter of concern for reasons such asdwindlingfish stocks and increasing production costs. Due to the seasonal nature of the industry, it is not cost-effective to maintain a highly skilled labor force to carry out fish processing tasks and to operate and service the processing machinery. Due to the rising cost of fish products, and also the diverse tastes and needs of the consumer, the issues of product quality and products-on-demand are gaining prominence. To address these needs and concerns, the technology offish processing should be upgraded so that the required tasks could be carried out in a more efficient and flexible manner *(De Silva and Wickramarachchi, 1998)*.Mamdani fuzzy logic expert system has been applied in the area of production optimization and control in the food processing industries as well as other industries *(Lilly Amelia at al.,2009)*.

In order to improve the pace of production an expert system based on fuzzy logic is designed and developed. Inputs in the fuzzy expert system are the speed of conveyors in the plant, the temperature of frozen fish and desired processed fish quantity. The expert system estimates amount of processed fish from each subsystem and the total quantity of processed fish.

MATERIAL AND METHOD

Silver Bay Seafoods Craig is a seasonal plantthat process salmonfrom June to September, that is, during the fishing season. The final product of the plant is the H & G COLLAR OFF frozen fish block, which means that it is without the head and guts, processed into frozen blocks from 22.68 kg and packed in special paper bags. The finished product is placed in the transport vans (1074 bags of each) that are certified for overseas transportation.

The first subsystem is receiving. Fish is received from tender vessels (a special type of ship that is responsible for the purchase and transportation of raw fish and plants for processing, Figure 1) on the dock, where the fish ispumped out from the boat. The receiving dock can anchor up to two vessels. The fish is pumped using one or two pumps that are placed on the dock depending on quantity and desired speed of offload.The protected room at the dock storespump's motors and control panel that operates pumps, lights and hydraulic pumps.

Fig. 1. Receiving of the fish

The fish is transported to the plantusing pressurized pipes, to the following sub-systems for fish sorting. The fish is pumped into receiving tanks, so the vertical conveyor is raising fish to the level of sorting. This plant is processing four types of salmon: sockeye, coho, keta and pink.

There are two lines for fish sorting, north and south, which are positioned above the six tanks, (Figure 2). Each tender boat brings documentation that provides managementwith initial input of the allocation of storing tanks. Production workers sort the fish from the conveyor belts based on species and place it in slots for weighing. Before it falls into the designated storage tank, fish is positioned on the scales. When it reaches the predetermined weight, it opens and fish gets into storage tank.

Fig. 2. Fish sorting

The following sub-system consists of three Iron Butchers (The machinery used for fish processing almost since the industry created, Figure 3.).

Fig. 3. Iron Butcher machines

Operators are placingfish one by one in the machinethat cuts off the head of fish and squeezes guts out. In this case, a modern, slightly modified machine is used. Machine ON/OFF control and speed (the speed of chain conveyers, knives and brushes on the machine)is controlled from thetouch panel that is designed for this subsystem. This machine is controlled only by well trained production supervisor. Fish isthen transported and raised, using incline conveyors, to the next sub-system for panning and measuring fish (Figure 4.). Workers are placing empty pans (fish block molds) onto the scaling conveyor and fish fill them up. Department supervisor usually adjusts the speed of the conveyors with intention to get the pans loaded with about 22.68 kg of fish. Pans with fish reach scales where workers check the weight and adjust it to 22.68 kg with margin of error of +/- 0.11kg. Fish in scaled pans is aligned for better handling on the second part of the scaling conveyor.

Fig. 4. Panning and weighing sub-system

Final transport conveyer takes pans to freezer loading. Pans are loaded in special racks that carry 33 pans each (748 kg of processed product). Racks are equipped with heavy-duty wheels that allow it to move trough the freezer. Worker loads the pans and using the joystick to initiate the sequence that lowers the rack by one position. When the final pan is loaded, system takes the rack to bottom position, initiate opening of the freezer doors, activated powerful hydraulic system that pushes the whole rack inside. When the last shelf on rack is full, lift automatically lowers rack in the freezer.

Fig. 5. Operator puts pan into the rack

The next part of the production belongs to the freezing subsystem. It is a cyclone freezer with a capacity of 113,400kg. It is divided into two tunnels, north and south, each with three lanes. When the freezer is full with racks and fish gets frozen at -20 ° C, the workers begin to pull out racks on the other side of the freezer.Both freezer loading and freezer offloading are heavily automated but due to the speed and complexity of the process it requires well-trained and experienced operators as well as confident and educated management.

The next subsystem is the fish packing. In this subsystem frozen fish blocks are removed from the pans (that are transported back to panning deck and instantly used in production again). Frozen fish blocks travel trough double dip glazer that puts a coating of ice around the fish block; “the glaze” increases product shelf life. Glazed fish blocks are transported to the packing machine; these machines are engineered, developed and constructed by Silver Bay Seafoods. Packing machines as consisted of 2 short conveyers, heat sealing section and self-labeling and stamping section. Machine is communicating with information system and every bag with label is closely monitored prior to being loaded in transport container. The label contains species of the fish, class, method of processing, and the country of origin and lot number.

Fig. 6. Packing machine

The bag with frozen product is stored in the transport vans (1074 bags in the each) that are certified for overseas transportation Figure 7. The temperature in the van is maintained at -20 ° C.

Fig. 7. Loading van with the bags

There are several major tasks that will typically perform when developing a fuzzy logic expert system *(Durkin,1994)*:

Define the Problem

In order to determine the problem, we must obtain a source of knowledge. Usually the source is an expert on the problem, person assigned to run the whole production process. In the fish processing plant, problem is to control the pace of production. Each delivery is different due to changes in quantity of fish that goes through the system. Each subsystem depends on the previous and to get more consistent pace of production andit is necessary to eliminate unnecessary delays in each of the subsystems. The expert system will help support decision making for managers, in order to achieve better profits and improve the quality of the final product.

Define Linguistic Variables

Definition of linguistic variables begins by interviewingthe expert and clarifying how problems are being solved. Expert should allow us to find out how to solve the problem. Conclusion from this interview should provide us with generic knowledge of the process. Example: "When the speed of conveyor is slow, than the quantity of processed fish is small."

For similar discussions with experts we come to the linguistic variables and their intervals. In table 1.are listed fuzzy variables used in the system and their intervals.

Define Fuzzy Sets

The next step involves defining the fuzzy sets on each universe. To accomplish this, we consult with an expert. For example if the hourly amount of received fish is from 0 to 50,000 kg, how to describe a situation when you have 15.000 kg? Is it smaller, small or medium?

Table 1. Linguistic variable with ranges

Linguistic variable	Range
Iron Butchers speed	0 to 40 Hz
Specified quantity of fish	0 to 36,000 kg
Processed fish	0 to 23,000 kg
Conveyor speed	0 to 70 Hz
Number of input Racks	0 to 30 racks/h
Temperature	5 to -30°C
Number of output Racks	0 to 30 racks/h
Packing machines speed	0 to 20 bags/min
Number of packed bags	0 to 1000 bags/h

Define Fuzzy Rules

The next step is to define the fuzzy rules. Consultation with an expert is needed for this step also. Expert, using the previously defined fuzzy adjectives, describes the solution to the problem. Rule:

IF iron butcher speed IS slow THEN amount of processed fish IS low

The number of different algorithm combinations measures the complexity of the model. Although the rules define the behavior of the model, large number of rules can be very difficult to handle. For these reasons, we have two objectives, reducing the number of rules and simplifying the structure of rules*(Arias-Aranda et al.,2010).*

Build System

Now that we have a set of fuzzy rules, the next step is to build the system. This step involves the coding of the fuzzy sets, and rules and procedures for performing fuzzy logic functions such as fuzzy inference. To accomplish this task there are two ways: build the system from scratch using a basic programming language, or rely on a fuzzy logic development shell. Expert system in this plant was developed using Matlab/Simulink shell.

Model is composed of four Mamdanifuzzy controllers that control the input and output of each subsystem.Every of four fuzzy controllers have combination withone triangular and two trapezoidal fuzzy membership functions. Centroid method is used for the defuzzyfication.

These fuzzy controllers give a proposed numerical value to the operators and managers in order to reach better results. Shows an ideal case in relation to the input variables and provide guidance, as they should be compared to the previous and the current state of subsystems. If the ideal case of processing is 453,592 kg of fish in the 24-hour production, it calculates the production rate in subsystems for each hour in order to achieve the desired production.Figure 8.shows the system model in Simulink.

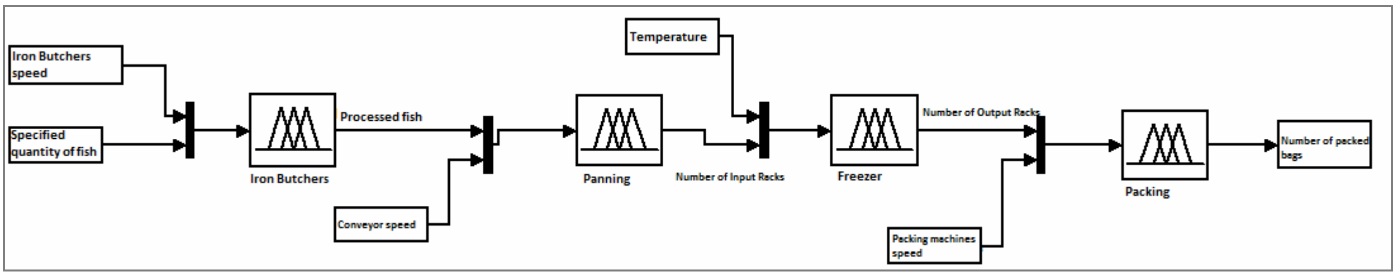

Fig. 8. Simulink model of an expert system

RESULTS AND DISCUSSION

Fuzzy expert system is designed as a preliminary concept with the use of scenarios. Each scenario is based on the possible alternatives of each fuzzy expert system as an example of the fuzzy membership functions, rule base and reasoning mechanism. All scenarios were tested in the original model, using real data from the production, which were obtained from interviews in order to choose the best fuzzy expert model. Fuzzy reasoning mechanism is a process of mapping input to output using an appropriate theory of fuzzy sets. Mamdani method is used, considering that it is widely accepted in the development of the fuzzy expert systems *(Idrus et al.,2011).*

Five scenarios have been tested, which represent the real situation in the plant. They are shown in Table 2.

Table 2. Scenarios for expert system testing

Name	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Iron Butchers speed	30	30	30	25	40
Specified quantity of fish	18.144	18.144	18.144	18.144	27.215
Conveyor speed	35	35	25	35	45
Temperature	-15	0	-15	-15	-15
Packing machines speed	10	5	7	5	20
Outputs from fuzzy controllers					
Processed fish	11.285	11.285	11.285	4474	18.288
Number of Input Racks	17	17	11.93	6.25	25.48
Number of Output Racks	17	6.26	8.21	6.25	26.18
Number of packed bags	572	223.4	228.06	223.4	858.77

First scenario

The plant daily goal is to process 453,592 kg of fish in 24 hours, and pack 308,442 kg. The difference represents losses due to freezing of fish and percentage of waste on their heads and guts. If the Iron butcher machines are set up to cut at 30 Hz that gives18,143 kg of fish and 11,285 kg of processed fish as output on the processing machines. In the freezer 17 racks per hourare inserted. If the temperature is appropriate, as in this scenario is, than same amount is taken out (17 racks per hour) from the freezer. This represents an ideal case, the projected daily goal, and if 10 bags are packed per minute, we get 572 bags packed.

Second scenario

If we set all parameters as in the first scenario, we have a situation in which the temperature of the fish is at the border of acceptable range and the speed of packing bags is reduced to five bags per minute, thus slowing down the pace. Finally we get the reduced number of bags packed, which is to be expected if the temperature is not in the acceptable range.

Third scenario

In the third scenario, we slowed down conveyor speeds. On the conveyor speed of 25 Hz we only have 11 racks that being inserted into the freezer and 8 racks as the output, which will help us slow down packing machines at 7 per minute and at the end we will have 228 bags packed. For this scenario conclusion is that one subsystem slowing leads to the overall decline of production pace in all subsystems, which reflects poorly on the overall quantity of fish processed in this hour, or throughout the day.

Fourth scenario

The fourth scenario represents the case when Iron butchers machines are slowed down. That is a common situation if the problem occurs on one of three machines. We will have to process much smaller amount of fish, and fewer will enter into the freezer racks. Finally we will not get the expected number of packed bags of finished product.

Fifth scenario

The fifth scenario should demonstrate that the system will work well even if there is a desire to increase the daily goal. In the peak of the season when a great quantity of fish is available, it is necessary to increase the daily goal. The freezer is able to freeze up to 25 racks per hour, and if the fish is in appropriate range of the temperature 26 racks comeout and eventually it gets 858 packed bags.

The system performed well in various scenarios, so it should help managers to estimate how much fish will be processed. Also, it is agreat help to the operators to adjust the conveyer speed across the plant.

CONCLUSION

Expert system for management in such a facility sets the trends that benefit everyone from top level management to plant operators. The system can have more applications from the prediction of quantity of processed fish to pointing out the problems in subsystems ormalfunction of the machines.

Fuzzy expert system provides greater flexibility in the plant model for the primary processing of fish acquiring expert knowledge in the fish production. Using expert knowledge of fish processing plants, four Mamdani fuzzy controllers were developed for fish processing subsystem: receiving, processing, freezer and packing. Controllers are explaining their interdependence and relationships.

Management carried out by the expert system is moderate and management decisions are consistent with the decisions made by human experts. Expert system is an excellent approach to problem solving management. Considering the complexity of the process, the rule base of fuzzy logic is a suitable choice.

Models based on fuzzy logic are promising areas of decision support and prediction. The expert system provides a way for understanding how plantlike this one functions in correlation knowledge bases, reasoning mechanism and user interface. Operators and managers attach their knowledge and use heuristic rules (IF-THEN) to make decisions. They must know how to react in every situation in the future as well as situations that have previously occurred.

Development of fuzzy expert systems is still in the research stage. In the future this system should better address the problems of input variables, optimization rules and membership functions. Better methodologies and reliable results should convince managers to implement the fuzzy expert models in practice.

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Received: 05.11.2012. Accepted: 15.11.2012.