

# Evaluation a Process using Fuzzy Principles and Tools of Matlab

Stella Hrehova, Jana Mizakova

Department of mathematics, informatics and cybernetics

Faculty of manufacturing technologies Technical university of Kosice with seat in Presov

Presov, Slovak Republic

stella.hrehova@tuke.sk, jana.mizakova@tuke.sk

*Abstract*— Expert systems are currently used in several areas. Their advantage is that they can simulate the decision-making process of an expert in a particular application area. In conjunction with the principles of fuzzy logic, which can be converted numerical value into verbal expressing are expanding their area of application. The paper deals with design of simple expert system to evaluate the achieved quality of the production process using tools of Matlab. There are data which are gained through process and which are written to a file. They are subsequently evaluated using fuzzy toolbox of Matlab system. The rules designed for individual decision-making processes reflect the experience of experts in the field. These tools allow easy application of fuzzy rule by Fuzzy Toolbox and the connection with Simulink and its tools allow display the results.

*Keywords*— fuzzy; capability indices, Matlab

## I. INTRODUCTION

Expert systems incorporate human expertise in computer programs to allow these programs to perform tasks normally requiring a human expert [1]. They are designed to make available some of the skills of an expert to nonexperts. Fig. 1 describes the parts of expert system. It consists of these parts [2].

- Knowledge network is the data structures which the system uses.
- Inference engine is the main processing element of the expert system. It is the generic control mechanism that applies the axiomatic knowledge to the task-specific data to arrive at some conclusion.
- Knowledge acquisition is a process of gathering and transferring problem solving expertise from all sources of knowledge in a computer program.

User interface is a way how can the user communicate with expert system. It enables the user the query the system, input information and receive the advice.

Explanation facility acts to help user understand how an expert system reaches a certain decision or conclusion of the problem.

Most expert systems work based on user input issues whose evaluation leads to the solution of problem.

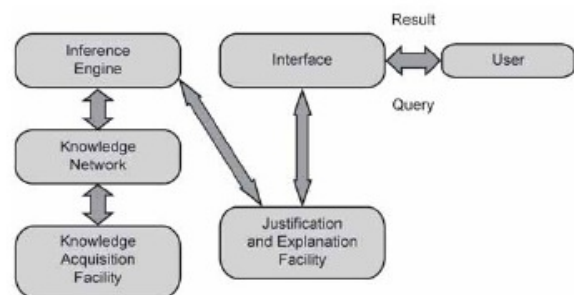


Fig. 1 Parts of expert system

## II. USING A STATISTICAL APPROACHES FOR EVALUATION OF PROCESS

The evaluation of the individual processes through the use of statistical methods is an effective tool for optimizing these processes [3]. The most applied tools of statistical evaluation of processes are the tools of statistical process control (SPC), which play an important role in practice.

The ability to produce products of required quality is a priority for each production company. Great competitive pressure is forcing these companies to use techniques that analyze the production process for compliance to quality. Operating a company's ability to respect the required criteria of quality of production has thus become critical potential for success in the market.

The power system for evaluating the quality of manufacturing process is statistical process control. It is a set of tools to maintain process stability and to improve its capability by reducing process variability. The theory of statistical process control is based on the existence of variation parameter in the production process which is influenced by a number of effects which make it impossible to produce completely two identical products. The aim of SPC should be to maximize the number of real faults detected, minimize the time taken to detect real faults. This requirement can be expressed in terms of a cost function to be minimized [4].

To ensure effective using gained information it is necessary to express it in an acceptable form for managers who need it. Acceptable form how we can represent expert knowledge is to express the obtained numerical values in the form of verbal evaluation. In this context, the ideal solution is using the tools of fuzzy logic.

In this paper is analyzed a production process in terms of evaluation the achieved level of quality using the principles of statistical process control and fuzzy logic. For the aim of creating inference network evaluation were achieved quality levels divided into part of evaluation of production process and evaluation loss of process. There are the individual coefficients describing the achieved quality and losses that may arise from non-compliance with quality requirements. There is considered a loss function and estimation of non-conforming products.

**A. Evaluation of production process- QP**

$C_p$  index (the process capability index) compares the required tolerance limits with natural tolerance limits of a process. It is assumed the normal distribution [4].

$$C_p = (USL-LSL)/6\sigma \tag{1}$$

where  $\sigma$  is standard deviation of process

$USL$  - Upper Specification Limit

$LSL$  - Lower Specification Limit

$C_{pk}$  index is an indicator of current capability of the process. It responds to the deviation of the mean volume of the process from the centre of the tolerance interval, eventually from the target value of the reference indicator of quality. The disadvantage of  $C_{pk}$  index is that if the desired target value is not equal to the centre of the tolerance limits, the process does not capture the deviation from target values.

$$C_{pk} = \min\{(USL - \mu)/3\sigma ; (\mu - LSL)/3\sigma \} \tag{2}$$

where  $\mu$  is the arithmetic mean of the measured values.

The index  $K$  indicates that if the required target process is not identical with the centre of the tolerance range than it captures the mean deviation from the desired value  $T$ , which is very important information.

$$K = (|T - \mu|)/((USL - LSL)/2) \tag{3}$$

$T$  - required value

In this case we assume required value  $T$  such as centre of tolerance limits.

It may occur

$K = 0$  - the mean value of the process is identical to the desired target value

$0 < K < 1$  - mean the process is within tolerance limits

$K > 1$  - the mean value of the process is out of the tolerance limits.

Detailed description of these indices in terms of applications of fuzzy approach is presented in [5].

Another input to evaluation of the production process can be a percentage of the values -  $P$  that are over the upper, respectively, lower control limit.

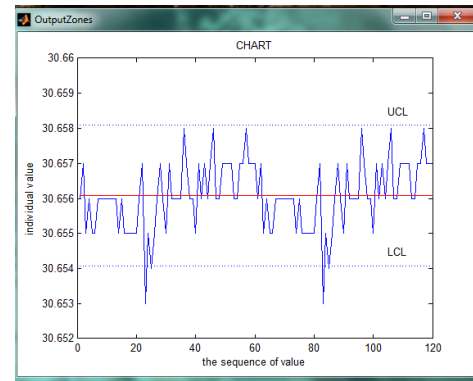


Fig.2 Graph of evaluation values

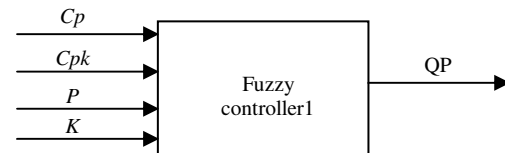


Fig.3 Block diagram of the production process control using a Fuzzy controller1

Fig.2 represents an evaluation production process. Chart consists of three guidelines, centre line, a lower control limit (LCL) and an upper control limit (UCL). The center line is the average number of occurrences-per-unit and the two control limits are set at plus and minus three standard deviation. If the process is in the statistical control, virtually all subgroup occurrences-per-unit should be between the control limits and they should fluctuate at random about the center line [6].

These values do not constitute the defective products, but may indicate possible errors in the process. To assess the quality of evaluation production process will evaluate these values as a percentage.

Fig.3 represents the designed block scheme for the evaluation of the actual production process.

**B. Loss of process- LP**

Loss function is a mathematical function that reflects a financial loss. This loss is caused by the variability of the true value of quality characteristics of the desired (target) value. The value of the loss function is determined by the financial constants to be determined in each case separately.

Taguchi recognized that in an industrial process it is vital to produce a product on target, and the variation around the mean caused poor manufactured quality leading to economic losses and they can be quantified using the following equation [7].

$$L = k(X-T)^2 \tag{4}$$

where

$L$  - is the loss in money

$k$  - is a constant that depends on the magnitude of the characteristic and the monetary unit involved

$T$  - target value,

X - quality features of selected product

The constant  $k$  is solved according (5):

$$k=A/\Delta^2 \tag{5}$$

where  $A$  - costs for repair,

$\Delta$  - deviation of specification from target value

By Taguchi losses grow quadratically with the deviation characteristics of the product from its nominal value  $T$ . Minimizing losses is possible only by reducing the variance of these values around the nominal value. Achieve nominal value and steadily reduce the variance is the task for the continuous improvement of quality.

Estimate the probability  $p$  that the value of a random variable  $X$  with a normal distribution lie outside the desired tolerance interval ( $LSL, USL$ ) is:

$$p = \Phi\left(\frac{LSL - \mu}{\sigma}\right) + \left[1 - \Phi\left(\frac{USL - \mu}{\sigma}\right)\right] = 1 - \left[\Phi\left(\frac{USL - \mu}{\sigma}\right) - \Phi\left(\frac{LSL - \mu}{\sigma}\right)\right] \tag{5}$$

where  $\Phi(u)$  is the distribution function for a standard normal distribution  $N(0,1)$ . The probability  $p$  that the values of the monitored quality indicator  $X$  which have a normal distribution, lie outside the desired tolerance range, if the process is centered is 0.0027. This means that if the index  $Cp = 1$ , 0.27% of the products lie outside of the desired tolerance range. Given that the index  $Cp$  not captured position the average of process to the middle of the tolerance range, the values are considered only a minimum estimate of the proportion of non-conforming products. From the interpretation can be confirmed that the process is the best one that produces only products placed inside the tolerance interval [8].

The loss function and non-conforming products are inputs for evaluating the achievement level of quality in terms of possible economic losses. The block diagram is shown in fig. 4.

The total evaluation of achieved quality of the production process represents the block diagram shown in fig. 5.

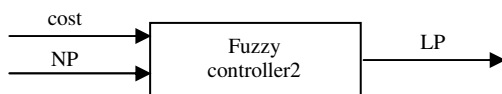


Fig.4 Block diagram of the production process control using a Fuzzy controller2

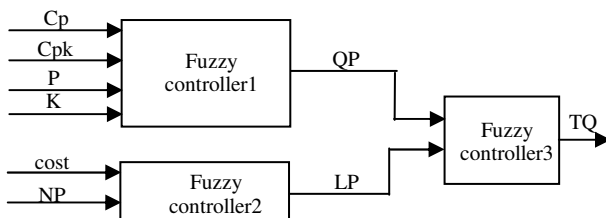


Fig.5 Block diagram of the total quality

### III. BRIEFLY DESCRIPTION OF USED FUZZY PRINCIPLES

The Fuzzy Logic tool was introduced in 1965 by Lotfi Zadeh. It is a mathematical tool for dealing with uncertainty. It offers to a software computing system the important concept of computing with words. It grants a technique to deal with vagueness and information granularity. Fuzzy systems are capable to emulate the imprecision and incertitude that are characteristic to human behavior. Also, this can intervene in most of real world applications, using for this a number of if-then rules. The fuzzy systems depend largely on the acquisition process from the human expert and have serious problems of adaptation [9].

#### A. Identification of linguistic variable

An important term in this area is linguistic variable. Linguistic variables represent crisp information in a form and precision appropriate for the problem. It is a type of variables, whose values are the words of natural language. The linguistic variable is determined by arranged foursome  $(X, T(X), U, M)$  where  $X$  is the name of linguistic variable,  $T(X) = \{A, B, \dots\}$  is set of verbal linguistic variable values,  $U$  is universe of linguistic variable, where each linguistic variable  $A \in T(X)$  is expressed by fuzzy set  $A = \{(x, \mu_A(x)); x \in U\}$  a collection of these fuzzy sets is a set of  $M$  [10].

In this paper are three variables interpreted by the verbal as: **Insufficient**, **Sufficient** and **Very Good** for production system and for loss of process there are **NoLoss**, **Sufficient** and **Insufficient**

#### B. Membership function

To quantify a linguistic term is used a membership function. Membership functions allow us to graphically represent a fuzzy set. The  $x$  axis represents the universe of discourse, whereas the  $y$  axis represents the degrees of membership in the  $[0,1]$  interval [11]. In this case was chosen a Gamma function-

### IV. USING THE TOOLS OF MATLAB

To simulate the proposed evaluation model of the production process in terms of achieved quality were used tool of Matlab - Simulink, Fuzzy toolbox and program tools.

Simulink is an interactive tool for modeling, simulating, and analyzing dynamic systems. It enables you to build graphical block diagrams, simulate dynamic systems, evaluate system performance, and refine your designs. Simulink integrates seamlessly with MATLAB, providing you with immediate access to an extensive range of analysis and design tools.

The Fuzzy Logic Toolbox is a collection of functions built on the MATLAB numeric computing environment. It is a tool for solving problems with fuzzy logic. The construction of fuzzy models can be accomplished in three ways: the first being through commands, the second through a graphical interface, and the third through block diagrams. The graphical interface provided is very intuitive, encouraging learning. The system allows export source code in C for embedded software projects. The tool also allows performing simulations of features which may be accompanied by visual form. The designer can configure the system so that the values corresponding to the inputs of fuzzy controller are obtained

through an external interface. A strong point of the system is the simplicity in the construction of fuzzy systems [12].

There is considered a most common type of fuzzy system, which consists of a single rule base, whereby the associated fuzzy model is described as a 'grey box' [13]. A single rule based system deals with all process inputs simultaneously while not taking into account the interactions and the structure of the system.

A. Simulation of process

The main script retrieves data from MS Excel, and individual necessary variables should be stored in the workplace of Matlab. Given the fact that the proposal was also applicable to other data, it is necessary require of user input basic value of Upper and Lower specification limit and the estimated cost of repairing the loss assessment process. After entering the required inputs the process is visualized in parts. On the basis of the achieved level of visualization process we can assume a level of achieved quality of process. Visualization recourse was described in more detail in [14].

Within the individual subsystems in a simulation scheme are used the user functions which calculate the necessary values. These values are input to the fuzzy block, which they subsequently processed by established rules. For the quality of the process and the loss of process there are designed two fuzzy control blocks according to fig. 6. This proposal is based on the requirements in order to assess the quality reached in terms of process and in view of the possible economic losses. To better assess the actual process values are key indicators Cp and K shown separately.

Fig. 7, 8, 9, and 10 sequentially show the concept of some rules for each fuzzy block and their surfaces.

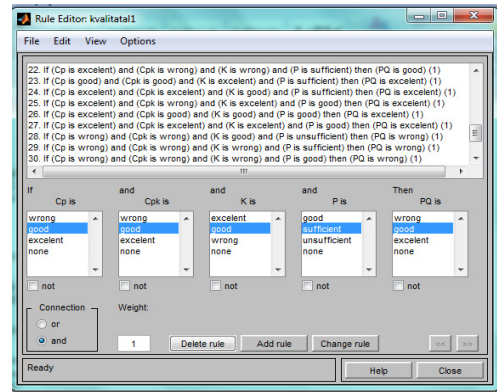


Fig. 7 Rule for evaluating a process

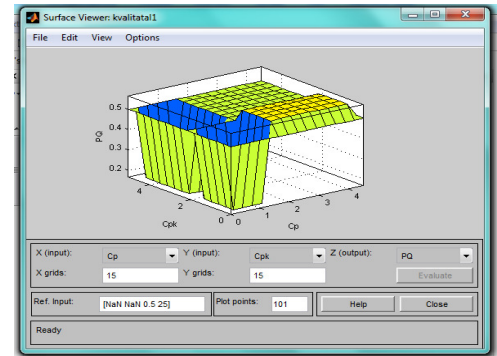


Fig. 8 Surface viewer for evaluating a process

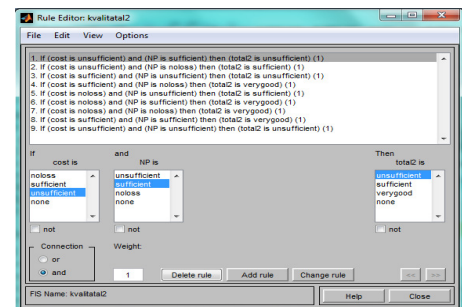


Fig. 9 Rules for loss of process

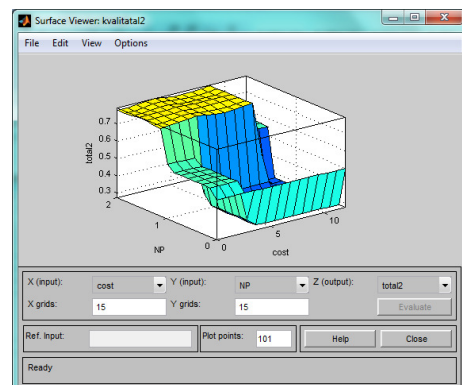


Fig. 10 Surface viewer for a loss of process

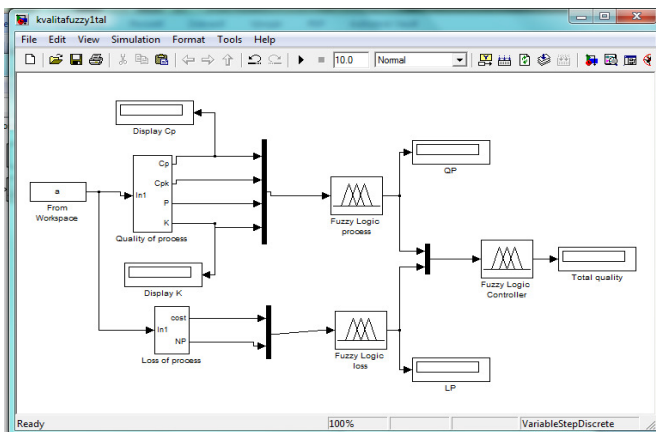


Fig. 6 Simulation scheme for evaluating of quality of process

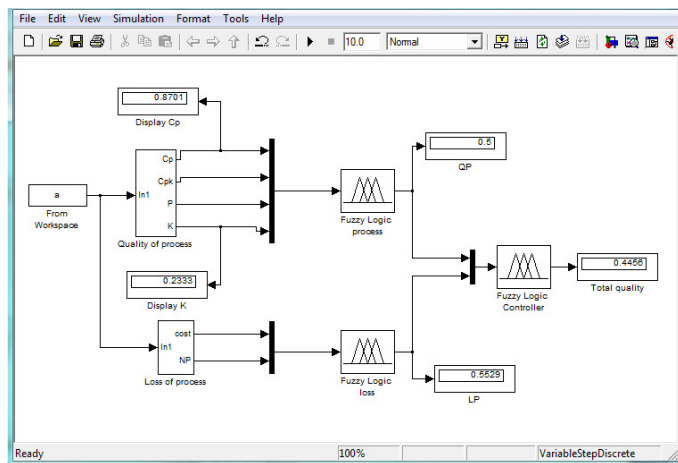


Fig. 11 Simulation scheme of selected process

After running the main script, the individual display units in the diagram show the numeric values that represent the level of quality of evaluation process.

ACKNOWLEDGMENT

The research work is supported by the Project of the Structural Funds of the EU. Title of the project: „Research and development of intelligent nonconventional actuators based on artificial muscles”, ITMS code: 26220220103

V. SUMMARY AND CONCLUSION

In this presented paper was proposed a simulation scheme, which serves as a graphical representation of the simple system of evaluation of production process quality. There is assumed that the user enters through an appropriate user interface to the basic values - lower and upper specification limits - they are know through technical documentation and coefficient A. It is an assumption to evaluate any process data.

The proposed simulation scheme and using the tools of Matlab allows evaluation of the selected process in terms of the process itself and in terms of potential financial losses. Evaluation of these two directions together determines the total quality.

After simulation, the output of each block shows the numerical values. To evaluate the total quality was proposed distribution in Table I.

TABLE I. RANGE OF TOTAL QUALITY

Total quality	
Range	Quality
0–0,5	Insufficient
0,5–0,75	Sufficient
0,75–1	Very Good

On the basis of this division the value of the total quality achieved after simulation is evaluated as insufficient. This fact may indicate it also displayed value of the index Cp, which is below the minimum required value of 1.33.

REFERENCES

- [1] R. M. O’Keefe and D. E. O’Leary. "Expert system verification and validation: a survey and tutorial". Artificial Intelligence Review 7, 3-42, KluwerAcademic Publishers. Printed in the Netherlands ISSN: 0269-2821,1993  
<https://msbfile03.usc.edu/digitalmeasures/oleary/intellcont/ES-Verification-validation-2.pdf>
- [2] "Topic 8- Expert systems" <http://www.slideshare.net/norelianamdsharif/topic-8-expert-system>
- [3] A. Vagaska. "Statistical quality optimization of milled surface". In. Process Control Pardubice, pp.C154a-1-C154a-5, 2008 ISBN 9788073950774
- [4] M. Terek and L. Hrnčiarová. "Statistical process control" EKONOMIA Bratislava, 2004, ISBN 80-89047-7-1
- [5] S. Hrehova and A. Vagaska. "Application of fuzzy principles in evaluating quality of manufacturing process". WSEAS Transaction on Power Systems. Volume 7, Issue 2, pages 50-59, 2012 ISSN 17905060
- [6] G.Vijaya and S.Arumugam. "Monitoring the Stability of the Processes in Defined Level Software". WSEAS Transactions on information science and applications, Issue 9, Volume 7, p. 1200-1209, 2010, ISSN: 1790-0832
- [7] M. Benkova, L. Florekova and G. Bogdanovska. "The variability of quality parameters and loss function". In Acta Montanistica Slovaca, 2005 Volume 10, No 1, p. 57-61, ISSN 1335-1788
- [8] M. Terek and L. Hrnčiarová. "Process capability indices and percentage non-conforming products". Quality innovation prosperity, Vol. IV, No 1. 2000 ISSN 1335-1745
- [9] A.M. Spiridonica, M. Pislaru and R.C. Ciobanu. "A Fuzzy Approach Regarding the Optimization of Statistical process Control through Shewhart Control Charts". In. 10th International Conference on DEVELOPMENT AND APPLICATION SYSTEMS, 2010, Suceava, Romania, May 27-29.  
<http://www.dasconference.ro/cd2010/data/papers/A51.pdf>
- [10] V. Kvasnicka. "Nonclassical logics III. Fuzzy logics, logical connectives and Mandami regulator"  
<http://www2.fiit.stuba.sk/~kvasnicka/Logika/Lecture09/9.kapitola.pdf>
- [11] eMathTeacher: "Mamdani’s Fuzzy Inference Method."  
[http://www.dma.fi.upm.es/java/fuzzy/fuzzyinf/funpert\\_en.htm](http://www.dma.fi.upm.es/java/fuzzy/fuzzyinf/funpert_en.htm)
- [12] L.F.R.E. Silva, R. Frozza and R.F. Molz. "Qualitative Study of Software for Fuzzy Systems Simulation and Development". Proceedings of the 11th WSEAS international conference on nural networks and 11th WSEAS international conference on evolutionary computing and 11th WSEAS international conference on Fuzzy systems, pp. 285-292,World Scientific and Engineering Academy and Society (WSEAS), 2010 ISBN: 978-960-474-195-3
- [13] A. Gegov, N. Petrov., B. Vatchova and D. Sanders. "Advanced Modelling of Complex Processes by Fuzzy Networks". WSEAS Transactions an circuits and systems, Issue 10, Volume 10, October 2011, pp.319-330, ISSN: 1109-2734
- [14] S. Hrehova "Visualisation of input data using tools of Matlab".Automatization and control in theory and practise ARTEP 2013, 2013, Stara Lesna,Slovak republic, ISBN 978-80-553-1330-6