Fuzzy control of temperature and humidity microclimate in closed areas for poultry breeding

M. Olejár, V. Cviklovič, D. Hrubý, L. Tóth

Department of Electrical Engineering, Automation and Informatics, Faculty of Engineering, Slovak University of Agriculture in Nitra, Nitra, Slovak Republic

Abstract

Olejár M., Cviklovič V., Hrubý D., Tóth L., 2014. **Fuzzy control of temperature and humidity microclimate in closed areas for poultry breeding**. Res. Agr. Eng., *60* (Special Issue): S31–36.

This contribution describes the ways of temperature and humidity microclimate control in breeding areas using a fuzzy controller. It is focused on poultry, whereby the most important parameters for optimal breeding are temperature and humidity. The main aim was to evaluate the control process according to control quality in the controller's steady state and the power consumption of the system. The used control algorithm was designed in the Matlab application, and it was practically verified in a closed thermodynamic system. Practical measurements have shown that with an increasing number of fuzzy controller's interference rules a better control quality in steady states and lower power consumption of the system is achieved.

Keywords: fuzzy algorithm; control quality; thermoregulation

With a classical insight into control and automation everything is based on the controller's dominance in a control circuit. The majority of analyses and criteria evaluating the results of control are subordinate to that. A number of methods used in practice have been existing for more than 50 years. However, there are a number of new methods that enrich the existing control theory. One of such methods is fuzzy control, the main advantage of which is a high-performance computing and possibility to control several physical variables at the same time. On the basis of described advantages, fuzzy control is applied to control systems where conventional methods of technological process control have been used to date.

One of applications is the maintenance of thermal and humidity microclimate in closed areas for poultry breeding. The role of control is to ensure conditions for a healthy and good organism growth, high utility with respect to basic needs of the species and category of poultry. One of other important conditions is to minimize the power consumption in order to achieve the lowest cost of breeding.

MATERIAL AND METHODS

The creation of optimal conditions for poultry is especially important in the first few days after hatching, when the chicken's body is not fully developed. Immediately after hatching and drying, a chicken can ingest the food, but is not able to compensate the temperature fluctuation because its thermoregulation is not fully developed. For this reason, it is necessary to ensure a relatively high temperature in the breeding area in the first weeks, as shown in Table 1. Temperature stabilization for adult hens occurs on approximately the fourteenth day of age. Thermoregulation is fully developed after the fourth week of age. Thermoregulation in halls is especially important in relation to the development of the chicken's body. Higher or lower

Table 1. Microclimate conditions for poultry breeding

Age (weeks)	Heating by local sources (°C)		Full-area heating (°C)	Relative humidity (%)
	in the hall	below the source		
1	24–25	33	33	70–75
2	21–22	28	28	
3	20	25	25	65
4	18	23	23	55–70

temperatures negatively affect the feed consumption, growth, activity of chickens and consequently the health. One of the indicators of a suitable microclimate in halls is also animal mortality during the laying breeding (Gálik 2004). At the same time, thermal and humidity regime is automatically regulated in halls. Relative humidity is considered always in relation to temperature. For higher temperatures, the relative humidity is lower, which causes drying of mucous membranes (and that supports infectious diseases), reduces the growth and increases the dust level. When the relative humidity falls below 30%, there is an increase in susceptibility to infections, which is related to the fact that microorganisms survive in dry air for a longer time. A high relative humidity, which is usually at lower temperatures, reduces the insulation ability of feathers, causes the wetting of bedding materials, which increases the production of ammonia and hydrogen sulphide (Skřivan et al. 2000). Therefore, a good development of chickens requires a higher relative humidity during the first weeks, and then it falls as shown in Table 1.

One of the ways to ensure suitable microclimatic conditions in poultry breeding is the use of fuzzy control. The advantage of this control in comparison with conventionally used controls is the ability

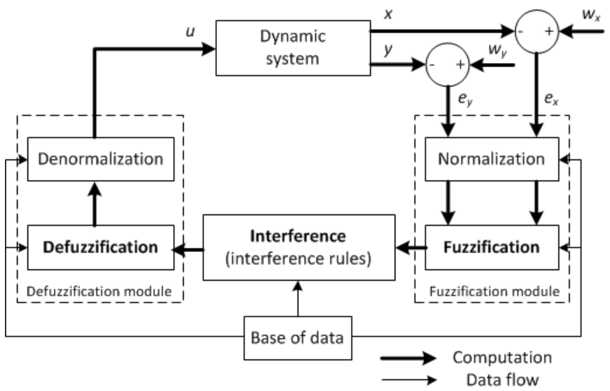

Fig. 1. Block diagram of the fuzzy controller
u – control variable; *y* – process variable 1; *x* – process variable 2; e_x – controller error variable *x*; e_y – controller error variable *y*; w_x – set point variable *x*; w_y – set point variable *y*

to control several independent physical quantities. A characteristic feature of fuzzy control is the possibility to use human's empirical knowledge about the controlled process, which is referred to as the base of data. The base of data is represented by information on steady states and intervals that include values of input and output variables, their limits, including the verbally defined control strategy by means of which it is possible to perform the control. The fuzzy controller's structure is shown in Fig. 1.

In the fuzzification block, there are converted data that are measured for fuzzy sets. Each fuzzy set is represented by membership function. These functions determine the degree by which the measured value is included in the fuzzy set. Values can range from 0 (measurement is not included in the fuzzy set) to 1 (measurement is included in the fuzzy set). Fuzzy sets are described by linguistic variables, which are expressions of a certain language such as, for example water is "cold", "warm" and "hot". Examples of three fuzzy sets, which are represented by linguistic variables *LP*1, *LP*2 and *LP*3, are shown in Fig. 2.

The fuzzification block can be preceded by a normalization block for conversion of physical values to normalized values. In the interference block, which forms the main part of the fuzzy controller, output fuzzy sets are obtained from input fuzzy sets on the base of interference rules. In our case, input variables are temperature and humidity *x*, *y* and one actuating variable *u*. These variables are described by several fuzzy sets represented by linguistic variables. The method of obtaining the output fuzzy sets from input fuzzy sets is as follows:

$$\alpha_1 = m_{LP1}(x) \wedge m_{LP1}(y) = \min\{m_{LP1}(x),\, m_{LP1}(y)\} \qquad (1)$$

$$\alpha_2 = m_{LP2}(x) \wedge m_{LP1}(y) = \min\{m_{LP2}(x),\, m_{LP1}(y)\} \qquad (2)$$

where

α_1 – degree of membership function $m_{LP1}(u)$ of linguistic variable *LP*1 of actuating variable *u*

α_2 – degree of membership function $m_{LP2}(u)$ of linguistic variable *LP*2 of actuating variable *u*

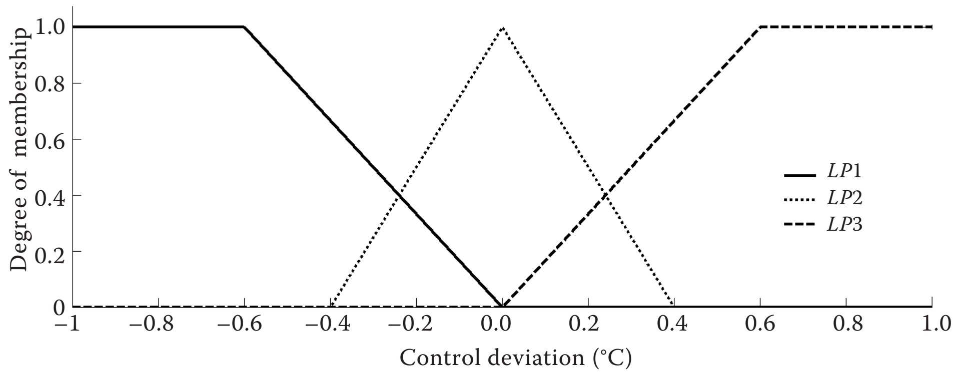

Fig. 2. Membership function for fuzzy sets of control deviation represented by the linguistic variables $LP1$, $LP2$ and $LP3$

$m_{LP1}(x)$ – membership function of linguistic variable *LP1* of input variable x

$m_{LP1}(y)$ – membership function of linguistic variable *LP1* of input variable y

$m_{LP2}(x)$ – membership function of linguistic variable *LP2* of input variable x

Fuzzy sets of the actuating variable u are determined as follows:

$$^{*}m_{LP1}(u) = \alpha_1 \wedge m_{LP1}(u) = \min\{\alpha_1, m_{LP1}(u)\} \quad (3)$$

$$^{*}m_{LP2}(u) = \alpha_2 \wedge m_{LP2}(u) = \min\{\alpha_2, m_{LP2}(u)\} \quad (4)$$

where:

$m_{LP1}(u)$ – membership function of linguistic variable $LP1$ of actuating variable u

$m_{LP2}(u)$ – membership function of linguistic variable $LP2$ of actuating variable u

$^{*}m_{LP1}(u)$ – fuzzy set of membership function $m_{LP1}(u)$

$^{*}m_{LP2}(u)$ – fuzzy set of membership function $m_{LP2}(u)$

The resulting fuzzy set is determined by unification of fuzzy sets $^{*}m_{LP1}(u)$ and $^{*}m_{LP2}(u)$:

$$^{*}m_{CEL}(u) = \max\{^{*}m_{LP1}(u), ^{*}m_{LP2}(u)\} \quad (5)$$

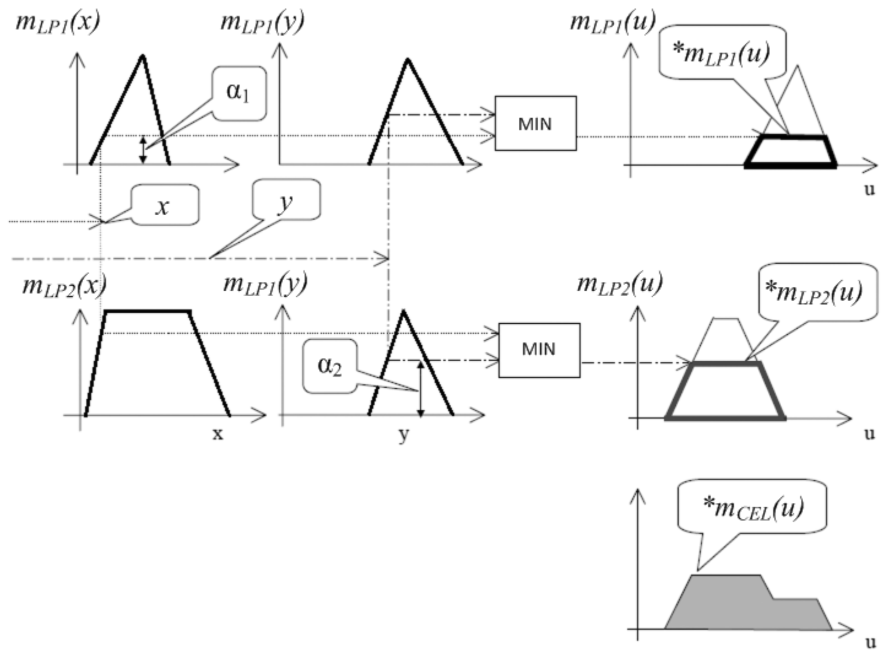

Fig. 3. Determination of output fuzzy sets for two output variables x, y (Modrlák 2004)

α_1 – degree of membership function $m_{LP1}(u)$ of linguistic variable $LP1$ of actuating variable u; α_2 – degree of membership function m_{LP2}(u) of linguistic variable $LP2$ of actuating variable u; $m_{LP1}(x)$ – is membership function of linguistic variable *LP1* of input variable x, $m_{LP1}(y)$ – membership function of linguistic variable $LP1$ of input variable; $m_{LP2}(x)$ – membership function of linguistic variable $LP2$ of input variable x; $m_{LP1}(u)$ – membership function of linguistic variable $LP1$ of actuating variable u; $m_{LP2}(u)$ – membership function of linguistic variable $LP2$ of actuating variable u; $^{*}m_{LP1}(u)$ – fuzzy set of membership function $m_{LP1}(u)$; $^{*}m_{LP2}(u)$ – fuzzy set of membership function $m_{LP2}(u)$; $^{*}m_{CEL}(u)$ – resulting fuzzy set is determined by unification of fuzzy sets $^{*}m_{LP1}(u)$ and $^{*}m_{LP2}(u)$

Graphical representation of determining the output fuzzy set is shown in Fig. 3. The relationship between input and output fuzzy sets that are represented by linguistic variables is determined by decision rules. Generally, it is a simple logical operation, the form of which for two input variables and one output variable is as follows:

IF (x belongs to $LP1$) **AND** (y belongs to $LP1$)
THEN (u belongs to $LP1$)

IF (x belongs to $LP2$) **AND** (y belongs to $LP2$)
THEN (u belongs to $LP2$)

The number of interference rules is determined by multiplying the number of input fuzzy sets. The last task of the fuzzy controller is to assign the actuating variable value to the output fuzzy set. This process of linking is named as defuzzification. There are many defuzzification methods which are based on the methods of determining the centre of gravity or methods for determining the maximum, as shown in Fig. 4. For the first method, the output value of action is determined as the coordinate of the resulting area of fuzzy set. The methods of determining the maximum are based on determining the most significant maximum of the resulting fuzzy set located on the left (LoM), on the right (RoM), or in the centre (MoM) (Modrlák 2004). After the defuzzification block, there can be a denormalization block where conversion of the output variable to the physical output variable is performed. We have used the centre of gravity method for defuzzification.

RESULTS AND DISCUSSION

In the control of microclimate temperature and humidity conditions in the breeding area, two physical variables are controlled. This type of control is demanding in terms of fuzzy controller selection and its setup. A standard PSD controller does not support a concurrent control of more variables due to their different behaviour. This is related to different setting of controller parameters for individual controlled variables. For such applications, it is therefore preferable to use a fuzzy controller that is independent of the number of input and output variables. A detailed mathematical description of the controlled system is not needed because the fuzzy controller uses human empirical knowledge on the controlled process. This feature simplifies the implementation of the fuzzy controller into real conditions of poultry breeding. The block diagram of the control algorithm is shown in Fig. 5.

Input variables of the fuzzy controller are temperature control deviation e_t and relative humidity control deviation e_h. The output variable is the actuating variable u that controls the heating and ventilation system. The closed breeding area represented an isolated thermodynamic system with dimensions 100 × 50 × 50 cm. A fuzzy controller with 9 and 49 interference rules was used for temperature and humidity control in order to assess the impact of the rules count on quality control. After defining all the fuzzy controller parameters, we have obtained the resulting control areas, which are shown in Fig. 6. These control areas determine the basic control strategy, the result of which is the waveform of temperature and humidity in the closed breeding space. Whereas the entire breeding is time-consuming, time was shortened to 18 h, which represents 3 weeks of breeding. This time is sufficient for evaluating the basic statistical parameters. As regards temperature control, we have focused on the required temperature values for full-area heating that are shown in Table 1.

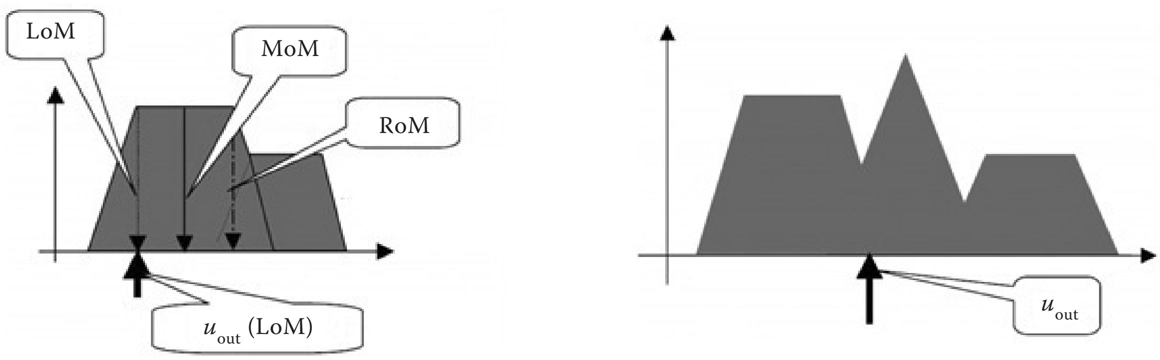

Fig. 4. Ways of defuzzification: (a) using the method of determining the most significantly located maximum on the left (LoM), on the right (RoM), or in the centre (MoM), (b) using the method of determining the centre of gravity (u_{out} – output actuating variable) (Modrlák 2004)

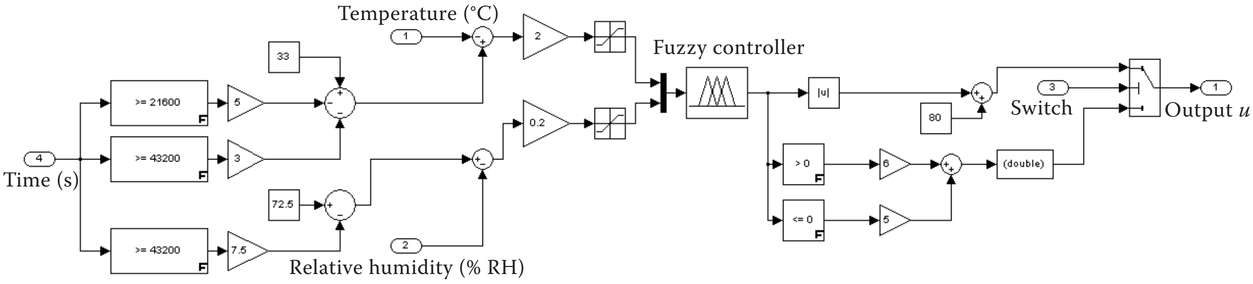

Fig. 5. Block diagram of control algorithm with the fuzzy controller

Fig. 7 describes the ability of the fuzzy controller to provide optimal temperature and humidity conditions for poultry breeding. In addition to stability, each control process must also meet the conditions of control quality in steady states. Selected indicators of descriptive statistics were used to evaluate the control quality in steady states. The data are shown in Table 2.

For internal temperature and humidity regulation, fuzzy control with 49 interference rules appears to be better. This is due to the fact that with increasing the number of interference rules (input fuzzy sets) of the fuzzy controller the control accuracy of physical parameters increases. When selecting the control algorithm, important is not only control quality but also energy consumption. The volt-ampere method was used for measuring the energy consumption during 10,000 s. Temperature was set to 28°C, and relative humidity was 72.5%. Fuzzy control with 49 interference rules is better not only for control quality but also for lower power consumption. Energy saving of the controller with 49 interference rules is 12.55% in comparison with the controller with 9 interference rules.

CONCLUSION

Using the fuzzy controller for microclimate control combines advantages of lower power consumption and higher control quality as compared to conventional controllers (PSD, PID, etc.). These parameters are improved with an increasing number of interference rules. The difference in energy consumption between the controller with 49 rules and with 9 rules is 12.55%. The accuracy of temperature and humidity regulation is higher by a decade. Another advantage is the possibility to implement the fuzzy controller into an existing system without modification and with a minimal investment.

The disadvantage is in increasing complexity and time consumption of setting the controller. Therefore, it is necessary to consider the cost-effectiveness of its setting with respect to saved funds from lower energy consumption. For large objects such as poultry breeding areas the investment return is short.

Fuzzy control provides a wide application in agricultural production where multiple variables are needed to be controlled simultaneously. Such applications are, for example microclimate control in

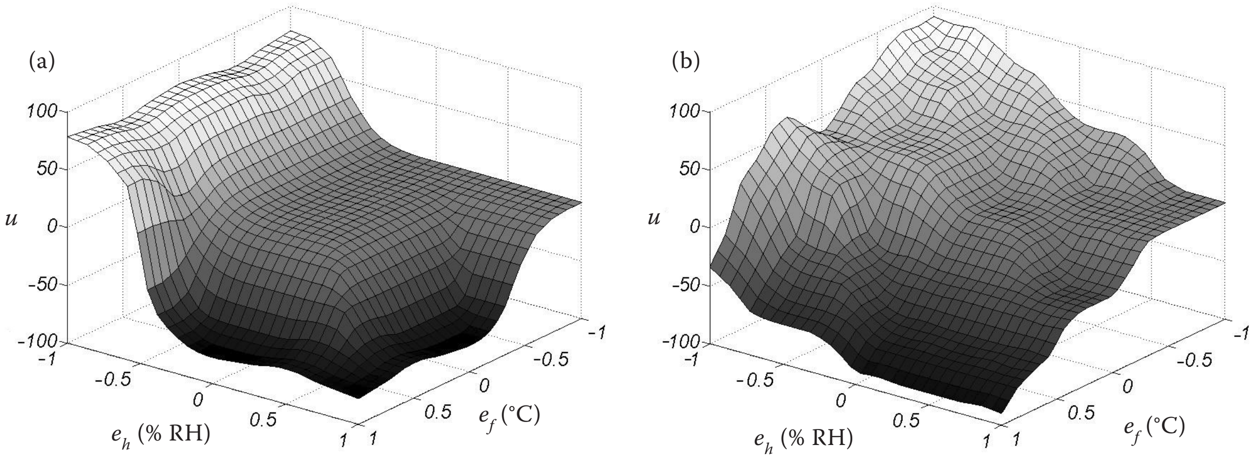

Fig. 6. Regulation area of the fuzzy controller of temperature and humidity: (a) with 9 interference rules, (b) with 49 interference rules

e_h – humidity control deviation; u – actuating variable; e_f – temperature control deviation

Table 2. Statistical indicators of control criteria in steady states for fuzzy control of internal temperature and relative humidity with 9 and 49 interference rules

Statistical indicator	Internal temperature		Internal relative humidity	
	9 rules	49 rules	9 rules	49 rules
Variance	0.046°C	0.0039°C	3.45% RH	1.82% RH
Standard deviation	0.216°C	0.062°C	1.858% RH	1.348% RH
Coefficient of variation	0.774%	0.225%	2.543%	1.86%
Average deviation	0.175°C	0.051°C	1.57% RH	1.069% RH

RH – relative humidity

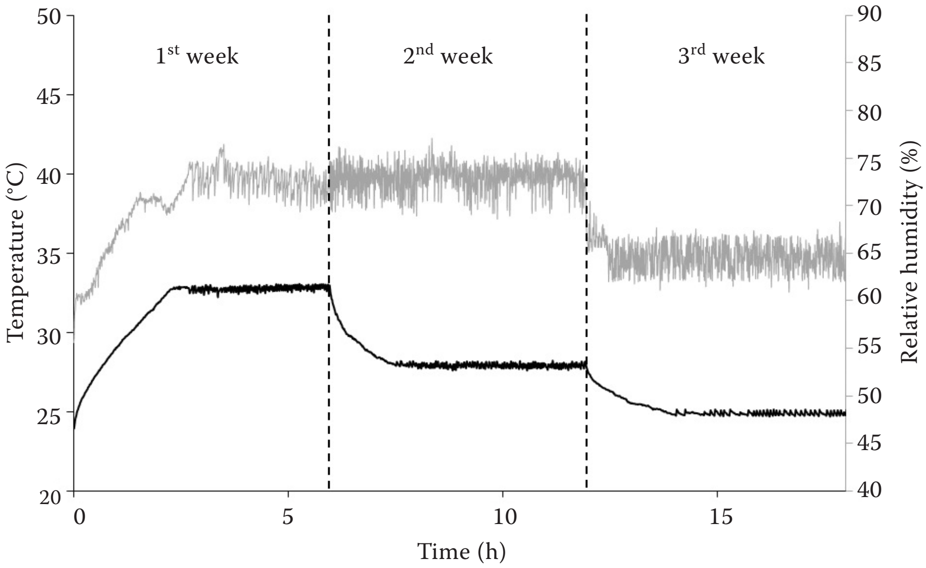

Fig. 7. Time waveform of temperature and humidity regulated by the fuzzy controller in closed breeding areas with 49 interference rules

greenhouses, drying of agricultural products and farm machinery steering.

References

Gálik R., 2004. Analýza mikroklimatických podmienok v hale na rozmnožovací chov nosníc. [Analysis of microclimatic conditions in a hall for production breeding of laying hens.] Acta Technologica Agriculturae, *3*: 60–64.

Modrlák O., 2004. Fuzzy řízení a regulace. [Fuzzy control and regulation.] Available at http://www.kirp.chtf.stuba.sk/~bakosova/wwwRTP/tar2fuz.pdf (accessed January 15, 2013)

Skřivan M., Tůmová E.; Vondrka K., Dousek J., Lancová B., Ouředník J., Oplt J., 2000. Drúbežníctví. [Poultry Science.] Prague, Agrospoj, 2000.

Received for publication April 15, 2013

Accepted after corrections July 29, 2013

Corresponding author:

Ing. Martin Olejár, PhD., Slovak University of Agriculture in Nitra, Faculty of Engineering,
Department of Electrical Engineering, Automation and Informatics, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic
phone: +421 376 415 783, e-mail: martin.olejar@uniag.sk