Microcontroller Based Fuzzy Control System for Air Quality Controlling

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***Abstract*— Clean work environments and god air quality are essential for developing, manufacturing, constructing, maintaining products if the goal is that the employees work at high efficiency. Proper environmental parameters also can help a lot if the goal is to improve the effectiveness of the rest time. This paper is designed to control the parameters of enclosed airspace. By direct intervention in the measured parameters of the interior air and with the help of air exchange - if the parameters of the external atmosphere bring the parameters of the internal air space closer to the desired value - the internal airspace conditions can be optimized.**

Keywords — air quality, fuzzy control, fuzzy toolbox, s-function, embedded fuzzy controller, membership function, DS18B20, CO2 sensor, home automation, smart home

I. Introduction

Smart homes are all containing this feature, but smart homes are rear yet. Also nowadays a lot of houses and flats have got an air conditioning unit beside the controllable heating elements. Ventilation systems are less common, but it is easy to replace because of the low cost. Fig. 1. is showing a simple solution with a blower and an extractor ventilator. This cheap realization contains an easy to change air filter module. It is also possible to include a preheating element before the air filter, and a silencer element between the ventilators and the inner airspace.

The proposed solution primarily takes into account the temperature and humidity parameters of closed indoor airspace and the external airspace and measuring the carbon dioxide concentration of the internal airspace, which affects the control of the ventilation system.

II. System description

The measured parameter values are internal and external temperature, internal and external humidity, and internal carbon dioxide. The actuating elements are the heating element for increasing the temperature, the air-conditioning system for reducing the temperature - it also reduces the humidity. In addition to the above, the system also includes a humidifying element and an air exchange fan system.

A. *System design*

The system architecture can be seen in Fig. 2. The system has multiple inputs and multiple outputs (MIMO), the relationships between the parameters are non-linear, and there is an actuator whose activity also affects several input parameters, and the change of an input parameter also affects the output signals controlling several actuator elements. One way to solve these types of control tasks is to use Fuzzy controllers [1]. The controller was developed within the Matlab software package using the Fuzzy toolbox (Fig. 3).

Figure 1: Ventilation subsystem

B. *Defining membership functions*

The input membership functions were configured with trapezoidal functions, then formatted for type change(Fig. 4). This method is simple but appropriate because the proposed solution has got lot of simultaneously firing rules, and the control will be quite smooth. For the determination of the input membership functions, do not require a neural network.

Temperature limits were determined [2] based on the opinions of a small number of groups. For the determination of humidity, the optimal (for people) 40-60% range's boundaries were extended by ±10% due to the deviation of individual tolerance thresholds [3].

Values that were defining the membership functions of the internal temperature:

- • trapezoid – Cold: [-11 -11 5 20]
- • trapezoid – Ok: [10 20 25 30]
- • trapezoid – Hot: [23 40 51 51]
- • S gradual– Cold: [6.5 18.5]
- • Gauss – Ok: [6.158 22.25]
- • Z gradual– Hot: [24.7 38.3]

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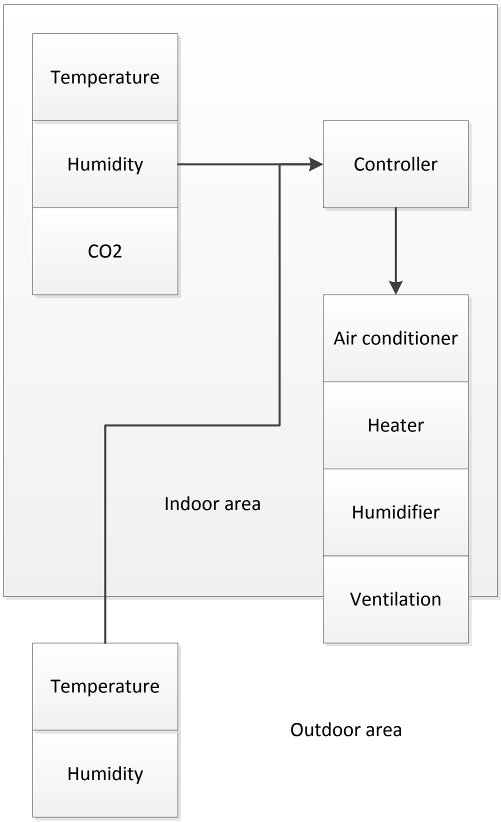

Figure 2: System architecure

The output membership functions are triangular [4], seen is Fig. 5. The output signals are generated at the fill factor of the actuator control PWM in the range from 0% to 100%.

C. *Creating rules*

It had been considered different groups when setting the rules [5] (see Fig. 6), as well as different weights had been given [6] for different rules:

- • It had been set the values of the heating and climate control output parameters based on the input internal temperature parameter (with lower weight)
- • It had been set the values of the climate and humidity control output parameters based on the input humidity parameter (with lower weight)
- • It had been set the values of the output parameters controlling the heating, climate, and ventilation based on the input external and internal temperature parameters
- • It had been set the values of humidity, climate, and ventilation control output parameters based on the input and internal humidity parameters
- • It had been set the values of humidity, climate, and heating control parameters based on the input temperature and humidity parameters

Based on the specified membership functions and rules [7], an illustration of the operation of the Fuzzy controller can be produced. Fig. 7 shows the output value for two input signals change, where the change within the allowed range (one output value can be displayed at one time). Also useful for checking the correctness of the regulation.

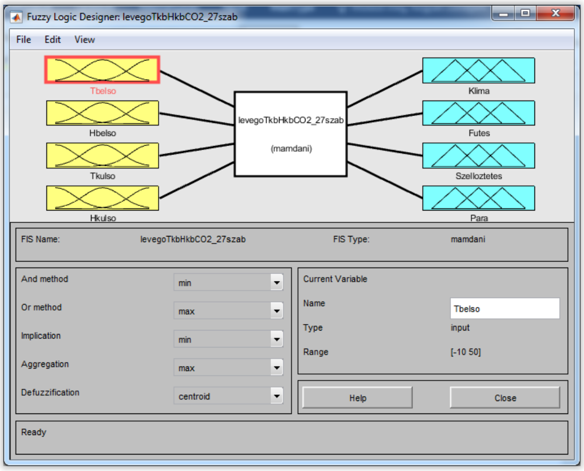

Figure 3: Fuzzy control toolbox

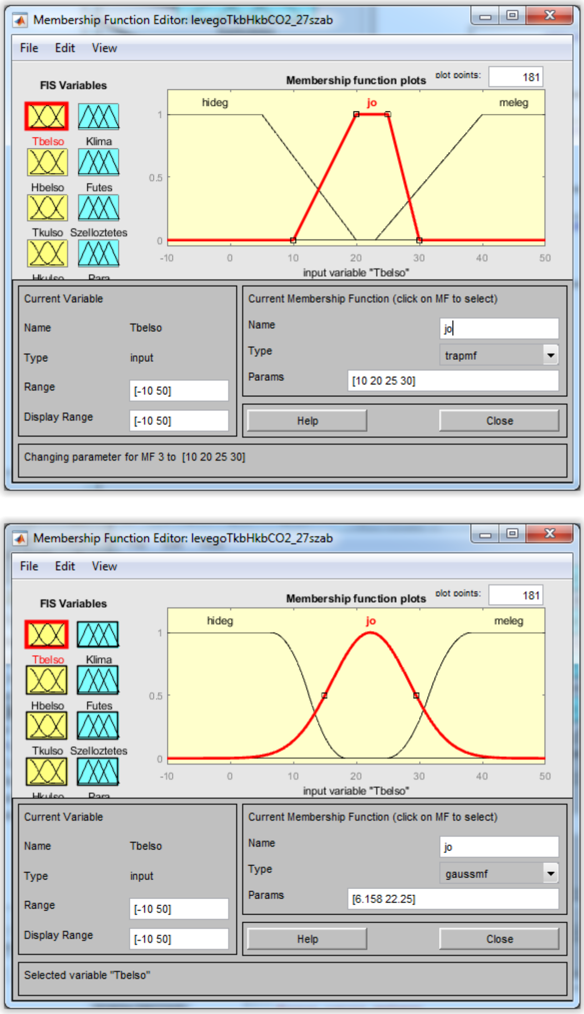

Figure 4: The internal temperature membership functions with trapezoidal and gradual transition

D. *Illustrating firing rules*

Based on the specified membership functions and rules, the operation of the Fuzzy controller can be emulated [8]. In the predefined range, firing rules can also be monitored for any level of inputs, and the output signals of their effect can be checked [9]. Fig. 8 show the output responses of the Fuzzy controller to various input parameters.

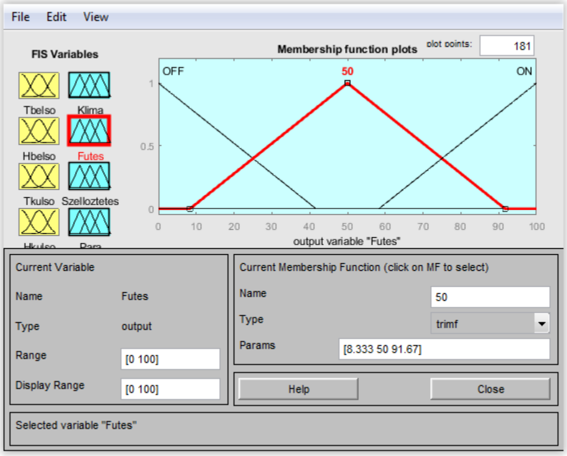

Figure 5: Example for the output membership function

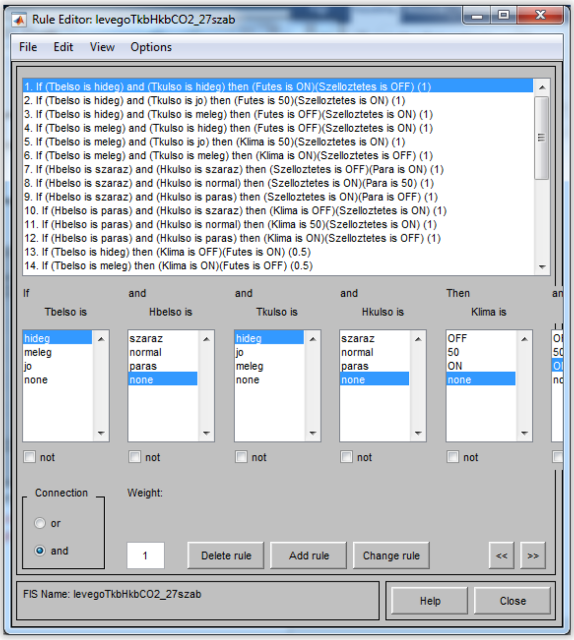

Figure 6: Illustration of the rules

III. Realisation

A. *Implementation in the development environment*

The system designed in Matlab Simulink is shown in Figure 9. In the left-hand side of the figure are the inputs; the inputs to the digital temperature sensors are on the upper part. Below are the pins used to measure analog humidity and CO2 concentration. The Fuzzy controller with multiplexed inputs and outputs is located in the center of the figure, and the PWM outputs used to control the actuators are on the right side of the figure.

The CO2 input influences the ventilation control's output through a feed-forward loop. Above a critical CO2 level, it activates the ventilation, and then deactivates it at a concentration below the critical level, creating hysteresis in the system.

B. *Realization with microcontroller*

Physical implementation was done using an AVR controller. Converting a Simulink-built model into a C / C ++ code was made using the Arduino toolbox that can be installed on the Matlab suite. The most critical parameters for translation and connection are the type of the development board / microcontroller and the communication channel parameters (see Figure 10). The applied controller must be memory sized appropriately to implement the generated code.

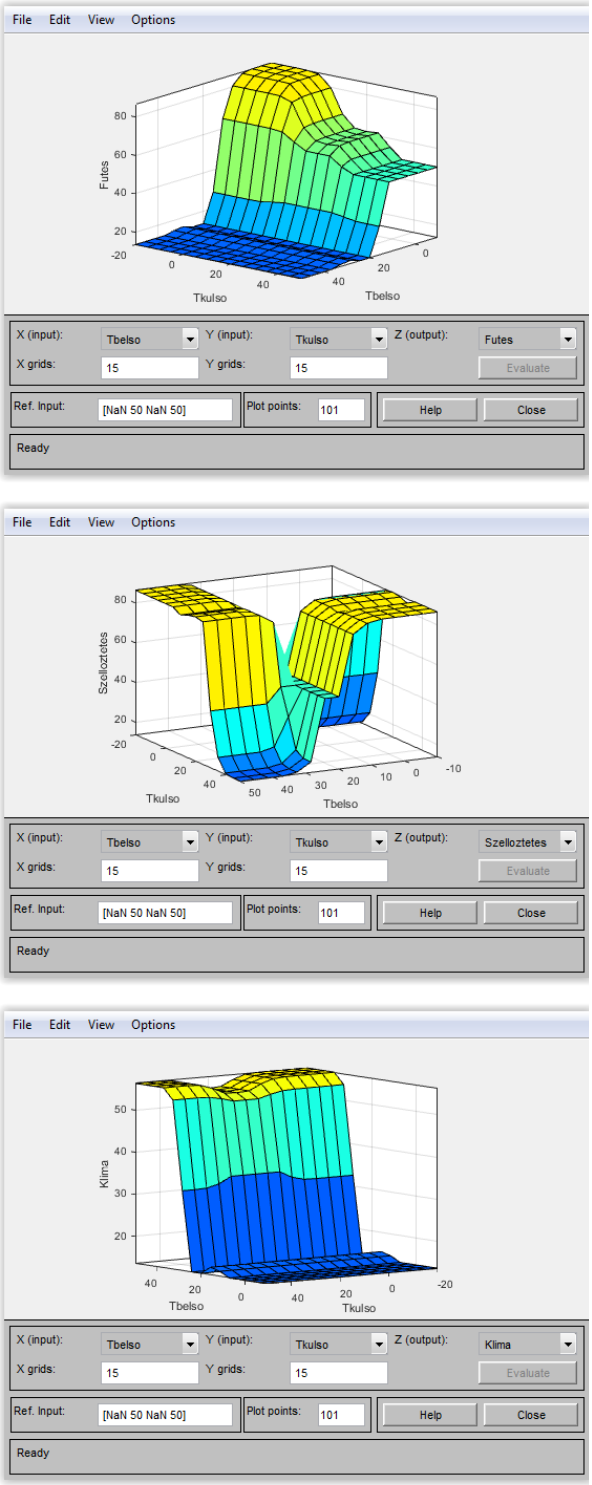

Figure 7: Changes in the values of Heating, Ventilation, and Climate Outputs as a function of internal and external temperatures

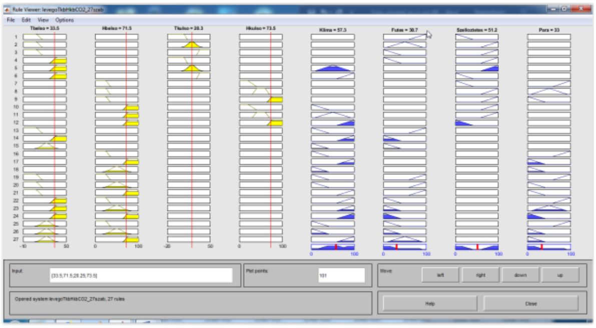

Figure 8: Illustration of firing rules and calculated outputs Beside high internal temperature and humidity under normal ambient temperatures, as well as higher internal than outer humidity

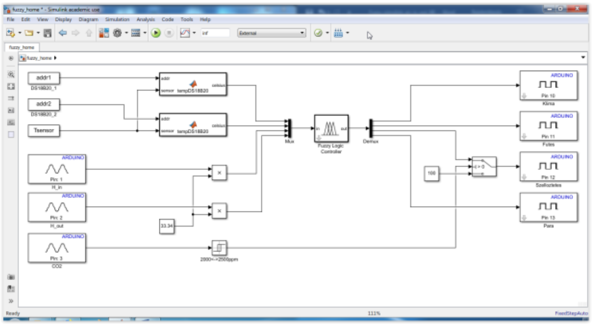

Figure 9: Realization in Simulink

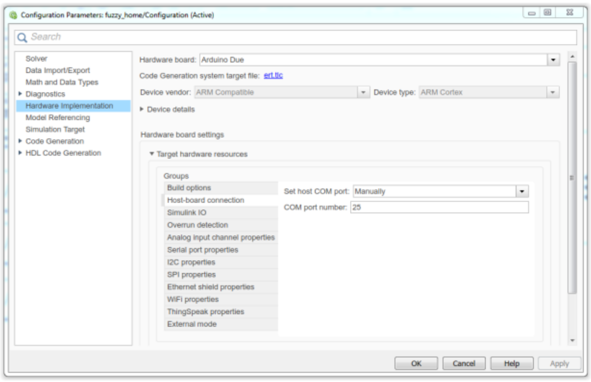

Figure 10: Realization in Simulink

IV. Sensors and Actuators

A. System-function

The protocol required to use the temperature sensor was implemented with the help of Matlab S-function. The value produced is in degrees of celsius, consistent with the input value range of the Fuzzy controller.

B. Temperature measurement

Measuring the temperature externally and indoors [10], a DS18B20 temperature meter integrated circuit was implemented. Block diagram is shown in Figure 11. The communication channel between the controller and the sensor is the 1-Wire Dallas bus, so the data cable must be connected to a digital leg. To ensure operation [11], the data bus must be equipped with a pull-up resistor. The measurement range is between -55 ° C and + 125 ° C, and the accuracy of the measurement is ± 0.5 ° C in the range of -10 ° C to + 85 ° C. Power supply voltage can be both of 3.3V and 5V voltage.

C. Humidity measurement

The humidity sensor [12] type AMT2001 (Fig. 13) has an analog output with a measurement range of 0% to 100%, with a range of output voltage between 0V and 3V. In the program - built in Simulink – the measured voltage is multiplied with a constant (33.34), to get the input range specified in the Fuzzy controller (0-100% RH). The accuracy of the measurement is ± 3%.

D. CO2 concentration measurement

The carbon dioxide sensor MG811 also has an analog output - see Fig. 14. The measurement range [13] is between 0ppm and 5000ppm, between 0V and 2V. Research shows that 3000ppm of CO2 concentration affects adversely mental and physical performance, so it must be ventilated above

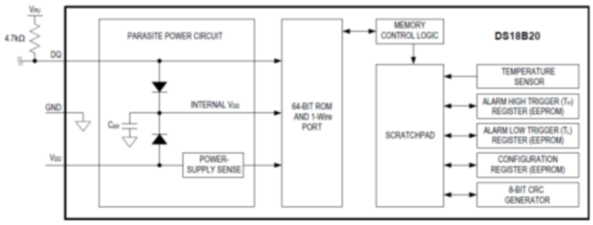

Figure 11: DS18B20 temperature sensor and internal block diagram

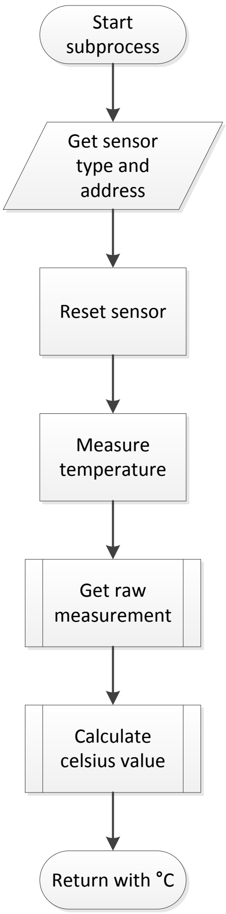

Figure 12: Matlab S-function flowchart

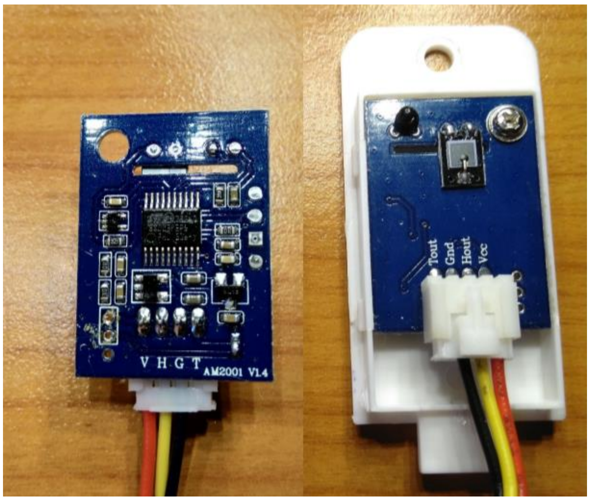

Figure 13: AMT2001 analog humidity sensor interior design

2500ppm. The corresponding analog voltage value is 1V. If the permissible reference level is exceeded [14], the output of the Fuzzy controller is shunted, and the ventilation is allowed at full speed. When the CO2 concentration is returned under 2000ppm, the control is given back to the fuzzy control system – to set a 500ppm hysteresis. [15] [16] [17] [18] [19] [20]

Conclusion

The controlling system made with relatively cheap electronic components and easy to implement software – if the user interface is well prepared –, therefore it is a cost-effective solution. It is a relatively low investment to expand the already existing actuators. The solution could also be useful if someone has a medical condition that requires them to keep the air clean in their homes. The proposed system architecture - as hoped by the author - could potentially be used for a variety of other applications.

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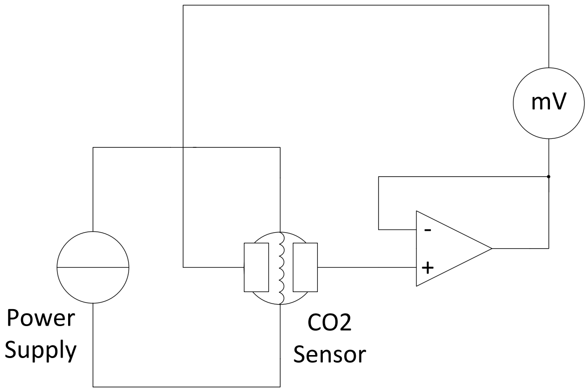

Figure 14: CO2 sensor and internal sensor structure

References

[1] Edit Tóth-Laufer, András Rövid, Márta Takács. Error Calculation of the HOSVD-based Rule Base Reduction in Hierarchical Fuzzy Systems. FUZZY SETS AND SYSTEMS 307C pp. 67-82. , 16 p. (2017)

[2] Márta Takács, Anikó Szakál, Igor Bagany. The Rule of the Aggregation Operators in Fuzzy Cognitive Maps. In: IEEE (szerk.) INES 2017, IEEE 21st International Conference on Intelligent Engineering Systems : Proceedings. Larnaca, Ciprus : IEEE, (2017) pp. 45-48. , 4 p.

[3] Neerendra, Kumar ; Márta, Takács ; Zoltán, Vámossy. Robot Navigation in Unknown Environment using Fuzzy Logic. In: Szakál, A (szerk.) SAMI 2017 : IEEE 15th International Symposium on Applied Machine Intelligence and Informatics. Budapest, Magyarország : IEEE, (2017) pp. 279-284. , 6 p.

[4] Judith, Pálfi ; Péter, Holcsik ; Márta, Takács ; Zsolt, Mitrik. Determination of the fault identification accuracy in LV networks using the Fuzzy method. In: Szakál, A (szerk.) 2016 IEEE International Conference on Systems, Man, and Cybernetics Conference Proceedings : SMC 2016. Budapest, Magyarország : IEEE, (2016)

[5] Khulan, Batbayar ; Márta, Takács ; Miklos, Kozlovszky. Medical device software risk assessment using FMEA and fuzzy linguistic approach: Case study. In: Szakál, Anikó (szerk.) Proceedings of the11th IEEE International Symposium on Applied Computational Intelligence and Informatics SACI 2016. Budapest, Magyarország : IEEE, (2016) pp. 197-202. , 6 p.

[6] J, Klespitz ; M, Takács ; I, Rudas ; L, Kovács. Performance of soft computing controllers in hemodialysis machines. INTERNATIONAL JOURNAL OF FUZZY SYSTEMS 17 : 3 pp. 414-422. , 9 p. (2015)

[7] Norbert, Sram ; Márta, Takács. A Type-2 Fuzzy- based Approach to the Minnesota Code. ACTA POLYTECHNICA HUNGARICA 13 : 7 pp. 103-121. , 19 p. (2016)

[8] B, Tusor ; A R, Várkonyi-Kóczy ; M, Takács ; J T, Tóth. A Fast Fuzzy Decision Tree for Color Filtering. In: IEEE (szerk.) IEEE International Symposium on Intelligent Signal Processing, WISP2015. Piscataway (NJ), Amerikai Egyesült Államok : Institute of Electrical and Electronics Engineers (IEEE), (2015) pp. 46-51. , 6 p.

[9] Gy. Györök. Programozható analóg áramkörök mikrovezérlő környezetben. Székesfehérvár. Óbudai Egyetem Alba Regia Egyetemi központ 2013. 165. p. ISBN:978-615-5018-97-8

[10] Edit, Tóth-Laufer ; Márta, Takács ; Imre, J Rudas. Fuzzy Logic-based Risk Assessment Framework to Evaluate Physiological Parameters. ACTA POLYTECHNICA HUNGARICA 12 : 2 pp. 159-178. , 20 p. (2015)

[11] FŐZŐ, Ladislav - ANDOGA, Rudolf - KOVÁCS, Radovan. Thermo-dynamic cycle computation of a micro turbojet engine / Ladislav Fozo, Rudolf Andoga, Radovan Kovacs - 2016.In: CINTI 2016. - Danvers : IEEE, 2016 P. 000075-000079. - ISBN 978-1-5090-3909-8

[12] KOMJÁTY, Maroš - FŐZŐ, Ladislav - ANDOGA, Rudolf. Experimental identification of a small turbojet engine with variable exhaust nozzle / Maroš Komjáty, Ladislav Főző, Rudolf Andoga - 2015. In: CINTI 2015. - Danvers : IEEE, 2015 P. 65-69. - ISBN 978-1-4673-8519-0

[13] ANDOGA, Rudolf - FŐZŐ, Ladislav - MADARÁSZ, Ladislav - KAROĽ, Tomáš. A Digital Diagnostic System for a Small Turbojet Engine / Rudolf Andoga ... [et al.] - 2013. In: Acta Polytechnica Hungarica. Vol. 10, no. 4 (2013), p. 45-58. - ISSN 1785-8860 Spôsob prístupu: http://www.uni-obuda.hu/journal/Andoga_Fozo_Madarasz_Karol_42.pdf

[14] ANDOGA, Rudolf - MADARÁSZ, Ladislav - FŐZŐ, Ladislav - LAZAR, Tobiáš - GAŠPAR, Vladimír. Innovative approaches in modeling, control and diagnostics of small turbojet engines / Rudolf Andoga ... [et al.] - 2013. In: Acta Polytechnica Hungarica. Vol. 10, no. 5 (2013), p. 81-99. - ISSN 1785-8860

[15] Monika Pogatsnik. Dual education: The win-win model of collaboration between universities and industry. INTERNATIONAL JOURNAL OF ENGINEERING PEDAGOGY 8 : 3 pp, (2018):145–152, 2018.

[16] Monika Pogatsnik. The impact of dual higher education on the development of non-cognitive skills. Gergely Kovats, Zoltan R´onay (szerk.) In search of excellence in higher education Budapest, Magyarorszag, (2019):179–190, 2019.

[17] GYÖRÖK, György, et al. Multiprocessor application in embedded control system. In: 2012 IEEE 10th Jubilee International Symposium on Intelligent Systems and Informatics. IEEE, 2012. p. 305-309.

[18] Gergely, G., Menyhard, M., Sulyok, A., Orosz, G. T., Lesiak, B., Jablonski, A., ... & Varga, D. (2004). Surface excitation of selected conducting polymers studied by elastic peak electron spectroscopy (EPES) and reflection electron energy loss spectroscopy (REELS). Surface and Interface Analysis: An International Journal devoted to the

development and application of techniques for the analysis of surfaces, interfaces and thin films, 36(8), 1056-1059.

[19] Gergely, G., Menyhard, M., Orosz, G. T., Lesiak, B., Kosinski, A., Jablonski, A., ... & Varga, D. (2006). Surface excitation correction of the inelastic mean free path in selected conducting polymers. Applied surface science, 252(14), 4982-4989.

[20] Orosz, G. T., Sulyok, A., Gergely, G., Gurbán, S., & Menyhard, M. (2003). Calculation of the surface excitation parameter for Si and Ge from measured electron backscattered spectra by means of a Monte-Carlo simulation. Microscopy and Microanalysis, 9(4), 343-348.