



pws te /



IEEE



IEEE
POLAND SECTION

CADSM

2023 17th International Conference

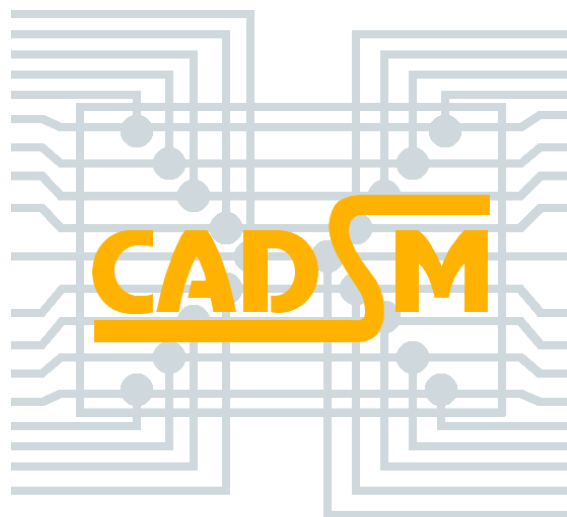
The Experience of Designing and
Application of CAD Systems
(CADSM'2023)

Proceedings

**Department of Computer-Aided Design of
Lviv Polytechnic National University, UKRAINE
Department of Microelectronics and Computer Science of
Lodz University of Technology, POLAND
AGH University of Science and Technology, POLAND
The State University of Technology and Economics in Jaroslaw,
POLAND
IEEE Poland Chapter of Electron Devices and Electronic Packaging**

**2023 IEEE 17th International Conference
on the Experience of Designing and Application
of CAD Systems (CADSM)**

CONFERENCE PROCEEDINGS



**Jaroslaw, Poland
22–25 February, 2023**

Organized by:



**Department of Computer-Aided Design
Institute of Computer Science and Information
Technologies,
Lviv Polytechnic National University**



**Department of Microelectronics and Computer
Science
Lodz University of Technology**



AGH University of Science and Technology



**The State University of Technology and Economics
in Jaroslaw**



**IEEE Poland Chapter of Electron Devices and
Electronic Packaging**

In technical co-sponsorship with



IEEE Poland Section



**IEEE Poland Chapter of Electron Devices and
Electronic Packaging**

**2023 IEEE 17th International Conference on the Experience of Designing
and Application of CAD Systems (CADSM)**

PROCEEDINGS

Part Number: CFP19508-USB
ISBN: 979-8-3503-1084-9

Copyright and Reprint Permission: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limit of U.S. copyright law for private use of patrons those articles in this volume that carry a code at the bottom of the first page, provided the per-copy fee indicated in the code is paid through Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA01923. For reprint or republication permission, email to IEEE Copyrights Manager at pubs-permissions@ieee.org.

All rights reserved. Copyright ©2023 by IEEE.

CADSM-2023 ORGANIZING COMMITTEE

- Conference Chairman:** **Prof. Mykhaylo Lobur,**
Head of CAD Department, Lviv Polytechnic National
University, Ukraine
- Conference Vice-chairmen:** **Prof. Andrzej Napieralski,**
Lodz University of Technology, Poland
- Prof. Marek Iwaniec**
AGH University of Science and Technology, Poland
- Technical Program
Committee Chair:** **Prof. Mykhaylo Andriychuk,**
**CAD Department of Lviv Polytechnic National
University, Ukraine**
- Conference Secretary:** **Dr. Nazariy Andrushchak,**
CAD Department of Lviv Polytechnic National
University, Ukraine
- Publication Chair:** **Dr. Oleksandr Belej,**
CAD Department of Lviv Polytechnic National
University, Ukraine

MEMBERS OF ORGANIZING COMMITTEE

- Prof. Serhiy Shcherbovskyh** The State University of Technology and
Economics in Jaroslaw, Poland
- Dr. Mykhaylo Melnyk** Lviv Polytechnic National University, Ukraine
- Dr. Uliana Marikutsa** Lviv Polytechnic National University, Ukraine
- Dr. Igor Farmaga** Lviv Polytechnic National University, Ukraine
- Dr. Tetyana Stefanovych** Lviv Polytechnic National University, Ukraine
- Dr. Wojciech Zabierowski** Lodz University of Technology, Poland
- Dr. Lukasz Starzak** Lodz University of Technology, Poland
- Dr. Przemyslaw Hawro** The State University of Technology and
Economics in Jaroslaw, Poland

INTERNATIONAL PROGRAM COMMITTEE

- Prof. Andriychuk M.** IEEE Ukraine Section (West) MTT/ED/AP/EP/SSC Societies
Joint Chapter (Vice-chairman)
- Prof. M. Banas** AGH-University of Science and Technology, POLAND
- Prof. T. Czachorski** Institute of Theoretical and Applied Informatics of the Polish
Academy of Sciences, POLAND
- Prof. Dziuban J.** Wroclaw University of Technology, POLAND
- Prof. K. Domino** Institute of Theoretical and Applied Informatics of the Polish
Academy of Sciences, POLAND
- Prof. Fedasyuk D.** Lviv Polytechnic National University, UKRAINE
- Dr. I. Grobelna** University of Zielona Gora, POLAND
- Prof. Georgiev G.** University of Veliko Turnovo, BULGARIA
- Prof. Hahanov V.** Kharkov National University of Radio Electronics, UKRAINE
- Prof. Janicki M.** Lodz University of Technology, POLAND
- Prof. Klymash M.** Lviv Polytechnic National University, UKRAINE
- Prof. Levin B.** Holon Institute of Technology, ISRAEL
- Prof. Lobur M.** Lviv Polytechnic National University, UKRAINE
(Conference Chairman)
- Prof. Matviyukiv O.** Lviv Polytechnic National University, UKRAINE
- Prof. Melnyk A.** Lviv Polytechnic National University, UKRAINE
- Prof. Napieralski A.** Lodz University of Technology, POLAND (Conference Vice-
Chairman)
- Prof. P. Sniatala** Poznan University of Technology, POLAND
- Prof. W. Sitek** Silesian University of Technology, POLAND
- Prof. M. Pawelczyk** Silesian University of Technology, POLAND
- Prof. Pleskacz W.** Warsaw University of Technology, POLAND
- Prof. K. Pytel** AGH-University of Science and Technology, POLAND
- Prof. Raida Z.** Brno University of Technology, CZECH REPUBLIC
- Prof. K. Rejman** The State University of Technology and Economics in
Jaroslaw, POLAND

Prof. Y. Romanyshyn Lviv Polytechnic National University, UKRAINE
Prof. Skryshevsky V. Kyiv National Taras Shevchenko University, UKRAINE
Prof. Tavzarashvili K. University of Georgia, GEORGIA
Prof. Teslyuk V. Lviv Polytechnic National University, UKRAINE
Prof. A. Timofiejczuk Silesian University of Technology, POLAND
Prof. Yanovsky F. National Aviation University, UKRAINE
Prof. Yashchyshyn Ye. Warsaw University of Technology, POLAND

A

Ahmed Md. Tanvir	2/76
Andriychuk Mykhaylo	3/18
Artyshechuk Iryna	3/23
Atamanyuk Volodymyr	5/11
Augustyniak Piotr	p/3
Aymen Mohammed Khodayer Al-Dulaimi	3/28
Averyanova Yuliya	2/28

B

Basystiuk Oleh	1/27
Belej Olexander	3/23
Beshley Mykola	1/5, 1/10, 1/22, 3/1
Beshley Halyna	1/5, 1/10, 1/22, 3/1
Bezkorovainyi Yurii	5/1
Bezkostyi Artur	5/15
Bruno Lorenzo	2/42

C

Chumachenko Svetlana	2/6
Chyzhovych Roman	5/11

D

Davitadze Zaza	2/6
Devadze David	2/6
Dyvak Mykola	2/60
Dyvak Taras	2/60

G

Gerasymenko Viacheslav	1/35
------------------------	------

Gharibi Wajeb	2/6
Grobelna Iwona	2/33

H

Hahanov Vladimir	2/6
Hahanov Ivan	2/6
Hacimahmud Abdullayev Vugar	2/6
Hirniak Yuriy	4/1
Hnativ Zoriana	5/11
Hordiichuk-Bublivska Olena	3/49
Holovatskyy Ruslan	1/18

I

Ivakhiv Orest	4/1
Ivanytskyi Maxim	2/28
Ivanochko Iryna	1/5
Ivanov Ivan	2/20
Ivashchuk Oleksandr	5/11

J

Jaworski Nazariy	5/15
Jowti Rowshan Ara	2/76

K

Kachur Oleksandr	5/6
Kaidan Mykola	1/14
Kahalo Ihor	1/2
Kamiska Maria	1/18
Karatkevich Andrei	2/33
Karkulovskyy Volodymyr	5/15
Klymash Mykhailo	1/10, 1/14, 3/49

Kochan Orest	1/5, 2/11, 2/55, 3/1
Kosobutskyy Petro	3/5
Kozyrskyi Volodymyr	1/35
Kovalenko Artem	5/1
Kovalov Oleksandr	1/35
Kopchak Bohdan	2/46
Korendiy Vitaliy	5/6
Kroshnyy Igor	1/30
Kruhlova Anastasiia	3/33
Kryvyy Rostyslav	5/11
Kushnir Andrii	2/46
Kutsenko Oleksandr	3/14

L

Lebedieva-Dychko Anastasiia	2/16
Levkiv Mariana	1/1, 2/64, 3/1
Liu Wei	2/64
Levkovych Mariana	1/39, 1/44
Litvinova Eugenia	2/6
Lobur Mykhaylo	1/18, 2/1

M

Maiborodina Nataliia	1/35
Maiduc Osiceanu Alexandra	3/28
Malanchuk Oksana	3/41
Manilov Anton	2/20
Manzhula Volodymyr	2/60
Manzhula V. Volodymyr	2/60
Marikutsa Uliana	2/1
Maryliv Oleksandr	3/10

Mazur Vitaliy	2/38
Medvetskyi Mykhailo	1/22
Melnyk Mykhaylo	3/18
Mersni Amal	3/33
Mohammed Khodayer Hassan Al-Dulaimi	3/28
Muliak Nazarii	2/1
Mysiuk Roman	2/68
Mysiuk Iryna	2/68
Mysyk Mykhailo	1/44

N

Nakonechnyi Markian	4/1
Nakonechnyi Yuriy	4/1
Nahid Md. Aynul Hasan	2/76
Nelin Evgeniy	2/51, 3/37
Nepochatykh Yuriy	2/51, 3/37

O

Oksentyuk Vira	2/46, 3/5
Omer Mohammed Khodayer Al-Dulaimi	3/28
Opotyak Yurii	4/6
Mariia Orynychak	3/18
Ostroumov Ivan	3/14

P

Pawelczyk Marek	p/1
Panchak Sofiia	2/38
Pawlowski Grzegorz	2/68
Ping Xu	1/22
Pisnenko Serhii	3/10

Politanskyi Ruslan	3/41
Predko Rostyslav	5/6
Pukas Andriy	2/60
Pyrih Yaroslav	1/14, 3/49
Pyrih Yuliia	1/14
Q	
Ouyang Yong	1/1
R	
Rabyk Vasyl	4/6
Rebot Dariya	3/45
Rubel Karina	3/10
Rybchak Zoriana	1/27
S	
Salyuk Oleksandr	5/1
Samotii Tetiana	1/30
Seliuchenko Nadiia	1/5, 1/10
Seliuchenko Marian	1/10
Shcherbovskykh Serhiy	3/45
Shilo Galina	2/16
Shkoropad Yuriy	1/5, 1/22
Shpur Olha	1/10
Skryshevsky Valeriy	2/20
Slonov Mykhailo	3/10
Sokolovskyy Yaroslav	1/30, 1/39, 1/44
Spas Nataliia	3/23
Solomko Mykhaylo	4/14
Stefanovych Tetyana	3/45

Stekh Yuriy	1/18
Strykhalyuk Bohdan	1/14
Sushchenko Olha	5/1

T

Tadeusiewicz Ryszard	p/2
Teslyuk Vasyl	4/6
Topilnytskyy Volodymyr	3/45
Trehubov Dmytro	3/10
Tsmots Ivan	4/6
Tyrkalo Yuriy	2/68

V

Vasylenko Vitaly	1/35
Viter Oleksandr	4/1
Vistak Maria	3/41

W

Wang Yuanlin	1/1
Wozny Janusz	2/42
Wu Dade	2/24

X

Xu Yuan	2/11
---------	------

Y

Yarkun Volodymyr	1/39
Yasynskyi Mykhailo	2/68
Yeremenko Sergei	3/33
Yevdokymenko Maryna	3/33
Yong OuYang	2/55

Yuzevych Volodymyr 2/68

Z

Zhao Zetong 2/64

Zhao Changxi 2/72

Zdobytskyi Andriy 2/1

Ze Wang 2/55

Znakovska Yevheniia 2/28

Zong Xinlu 2/11

TABLE OF CONTENT

PLENARY SESSION

Reduction of Noise Transmitted Through Structures – a Horizon Europe Project
Challenge Project Challenge
Marek Pawelczyk p/1

Hydrogen Storage and Generation in Nanocrystalline Silicon
Valeriy Skryshevsky p/2

CAD MODERN INFORMATION TECHNOLOGY

Academic Performance Prediction Model Based on Educational Similarity
Yuanlin Wang, Yong Ouyang, Mariana Levkiv 1/1

SDN-based Internet of Video Things Platform Enabling Real-Time Edge/Cloud
Video Analytics
*Orest Kochan, Mykola Beshley, Halyna Beshley, Yuriy Shkoropad,
Iryna Ivanochko and Nadiia Seliuchenko* 1/5

Software-Defined Multi-Access Edge/Cloud Computing for 5G/6G Time-Critical
Services
*Marian Seliuchenko, Nadiia Seliuchenko, Mykola Beshley, Mykhailo Klymash,
Olha Shpur and Halyna Beshley* 1/10

Method for Estimating the Topological Structure of Self-Organized Networks
*Mykhailo Klymash, Mykola Kaidan, Bohdan Strykhalyuk, Yaroslav Pyrih
and Yuliia Pyrih* 1/14

A New Hybrid Method for Predicting Recommendations for Collaborative
Recommender Systems
Yuriy Stekh, Mykhaylo Lobur, Ruslan Holovatsky, Maria Kamiska 1/18

QoS-Coordinated Adaptive Spectrum Management Method for Coexistence 5G-U
and Wi-Fi Networks with Short-Term Channel Failures
*Xu Ping, Mykola Beshley, Ihor Kahalo, Mykhailo Medvetskyi, Halyna Beshley
and Yuriy Shkoropad* 1/22

Exploring Multimodal Data Approach in Natural Language Processing Based
on Speech Recognition Algorithms
Oleh Basystiuk and Zoriana Rybchak 1/27

Physics-Informed Neural Network for Modeling the Process of Heat-and-Mass
Transfer Based on the Apparatus of Fractional Derivatives
Yaroslav Sokolovskyy, Tetiana Samotii and Igor Kroshnyy 1/30

Development of an Intelligent Forecasting Unit for the Protection Device Against
Leakage Currents in Electric Motors
*Viacheslav Gerasymenko, Vitaly Vasylenko, Volodymyr Kozyrskiy,
Nataliia Maiborodina and Oleksandr Kovalov* 1/35

Parallel Algorithm for Numerical Modeling of Anisotropic Heat and Mass Transfer in Fractal Media <i>Yaroslav Sokolovskyy, Volodymyr Yarkun and Mariana Levkovich</i>	1/39
Matrix Approach to Numerical Modeling of Heat- and-Moisture Transfer Processes in a Medium with a Fractal Structure <i>Yaroslav Sokolovskyy, Mariana Levkovich and Mykhailo Mysyk</i>	1/44
DESIGN OF SPECIALIZED SYSTEMS AND DEVICES	
Designing the Topology of Microelectromechanical Systems by Machine Learning Methods <i>Mykhaylo Lobur, Andriy Zdobytskyi, Uliana Marikutsa and Nazarii Muliak</i>	2/1
Deductive Matrix Synthesis for Fault Simulation <i>Wajeb Gharibi, Vladimir Hahanov, David Devadze, Abdullayev Vugar Hacimahmud, Svetlana Chumachenko, Zaza Davitadze, Eugenia Litvinova and Ivan Hahanov</i>	2/6
Pedestrian detection based on improved CSP network <i>Yuan Xu, Xinlu Zong and Orest Kochan</i>	2/11
Outdoor Positioning for Industrial Workplace <i>Anastasiia Lebedieva-Dychko and Galina Shilo</i>	2/16
Hydrogen Adsorption in Porous Silicon: Simulation and Control Method <i>Valeriy Skryshevsky, Anton Manilov and Ivan Ivanov</i>	2/20
Feature Selection and Parameter Optimization of Optimized Extreme Learning Machine for Motor Fault Detection <i>Dade Wu</i>	2/24
Meteorological Information Access and Decision-Making for UAS Flight Planning <i>Maxim Ivanytskyi, Yevheniia Znakovska and Yuliya Averyanova</i>	2/28
Deadlock Recovery for Flexible Manufacturing Systems with Exhaustive Exploration of the Reachability Graph <i>Iwona Grobelna and Andrei Karatkevich</i>	2/33
Control System of Mobile Platform Manipulator <i>Vitaliy Mazur and Sofiia Panchak</i>	2/38
Sentaurus TCAD Model for Thin Layer Sample Used in Van Der Pauw Hall Mobility Measurements <i>Janusz Wozny and Lorenzo Bruno</i>	2/42
Development of Heat Detector Based on Fuzzy Logic Using Arduino Board Microcontroller <i>Andrii Kushnir, Bohdan Kopchak and Vira Oksentyuk</i>	2/46

Formation of Bandpass Response by Orthogonal Resonators <i>Evgeniy Nelin and Yuriy Nepochatykh</i>	2/51
Bidirectional Linkage Robot Digital Twin System Based on ROS <i>Wang Ze, OuYang Yong and Orest Kochan</i>	2/55
Application of Global Optimization Toolbox for Identification of Parameters of Interval Nonlinear Models of Static Systems <i>Mykola Dyvak, Volodymyr Manzhula, Andriy Pukas, Taras Dyvak and Volodymyr V. Manzhula</i>	2/60
Automatic Diagnosis of Diabetic Retinopathy Based on EfficientNet <i>Wei Liu, Zetong Zhao, Mariana Levkiv</i>	2/64
Video-based Concrete Road Damage Assessment Using JetRacer Kit <i>Roman Mysiuk, Iryna Mysiuk, Grzegorz Pawlowski, Volodymyr Yuzevych, Mykhailo Yasynskyi and Yuriy Tyrkalo</i>	2/68
Traffic Flow Prediction Model Based on Temporal Convolutional Network <i>Changxi Zhao</i>	2/72
Multi-Class Alzheimer's Disease Stage Diagnosis using Deep Learning Techniques <i>Rowshan Ara Jowti, Md. Aynul Hasan Nahid and Md. Tanvir Ahmed</i>	2/76
MODELS AND METHODS FOR RADIOELECTRONIC DEVICES AND SYSTEMS	
The Technique of Modelling and Statistical Analysis of Energy Consumption in 5G Multi-Tier Radio Access Networks <i>Orest Kochan, Mykola Beshley, Mariana Levkiv and Halyna Beshley</i>	3/1
Models of Recurrent Distributions Statistical Averaging for Electronic Components with Fluctuations <i>Petro Kosobutskyy and Vira Oksentyuk</i>	3/5
A Method of Creating Virtual Pixels in Matrix <i>Mykhailo Slonov, Oleksandr Maryliv, Serhii Pisenko, Heorhii Samarets, Karina Rubel and Dmytro Trehubov</i>	3/10
Software-Defined Transmitter to Support Automatic Dependent Surveillance-Broadcast <i>Ivan Ostroumov and Oleksandr Kutsenko</i>	3/14
Investigation of Response from the Micro Objects of Complex Shape Irradiated by Acoustic Wave <i>Mykhaylo Andriychuk, Mykhaylo Melnyk and Mariia Orynychak</i>	3/18
Modeling of Wireless Sensor Network Based on Functioning Parameters of Unevenly Distributed Nodes <i>Olexander Belej, Natalia Nestor, Iryna Artyschuk and Nataliia Spas</i>	3/23

Cognitive Radio Spectrum Sensing for 5G Networks and Utilizing Soft Computing Techniques <i>Omer Mohammed Khodayer Al-Dulaimi, Mohammed Khodayer Hassan Al-Dulaimi, Maiduc Osiceanu Alexandra and Aymen Mohammed Khodayer Al-Dulaimi</i>	3/28
Analysis of Proactive Models of Fault-Tolerant Routing under Load Balancing and Border Routers Availability <i>Oleksandr Lemeshko, Oleksandra Yeremenko, Amal Mersni, Maryna Yevdokymenko, Mykhailo Persikov and Anastasiia Kruhlova</i>	3/33
Microstrip Resonator on Stub and Section <i>Evgeniy Nelin and Yuriy Nepochatykh</i>	3/37
Simulation of Slowwave Spiral Structures Based on Analytical Model <i>Ruslan Politanskyi, Oksana Malanchuk and Maria Vistak</i>	3/41
Vibration Oscillations Modeling for Printed Boards of Machine Control Units during Their Operation <i>Dariya Rebot, Volodymyr Topilnytskyi, Tetyana Stefanovych and Serhiy Shcherbovskykh</i>	3/45
Model of Large Sparse Datasets Processing Efficiency in IIOT <i>Mykhailo Klymash, Olena Hordiichuk-Bublivska, Maryan Kyryk, Taras Andrukhiv and Yaroslav Pyrih</i>	3/49
EMBEDDED SYSTEMS DESIGN AND IMPLEMENTATION	
Inverse-Dynamic Neural Controller Simulation <i>Markian Nakonechnyi, Orest Ivakhiv, Yuriy Hirniak, Yuriy Nakonechnyi and Oleksandr Viter</i>	4/1
Floating-Point Number Scalar Product Hardware Implementation for Embedded Systems <i>Ivan Tsmots, Vasyl Rabyk, Vasyl Teslyuk and Yurii Opotyak</i>	4/6
PRACTICAL APPLICATIONS OF CAD SYSTEMS	
Approach for Automated Designing Robust Systems for Stabilizing Data Measuring Sensors <i>Olha Sushchenko, Yurii Bezkorovainyi, Oleksandr Salyuk and Artem Kovalenko</i>	5/1
Development of a Remote-Control System for a Mobile Vibration-Driven Robot <i>Vitaliy Korendiy, Oleksandr Kachur and Rostyslav Predko</i>	5/6
The Computer Modeling of the Thermal Agent Hydrodynamics Through the Alcohol Distillery Stillage Stationary Layer <i>Roman Chyzhovych, Oleksandr Ivashchuk, Volodymyr Atamanyuk and Zoriana Hnativ</i>	5/11

A Software Complex for Researching Algorithms for Working with Graphs
*Volodymyr Karkulovskyy, Rostyslav Kryvyy, Nazariy Jaworski and
Artur Bezkostyi*

5/15

INDEX OF AUTHORS

i/1

Development of Heat Detector Based on Fuzzy Logic Using Arduino Board Microcontroller

Andrii Kushnir
SPAFA Department
Lviv State University of Life Safety
Lviv, Ukraine
andpetkushnir@gmail.com

Bohdan Kopchak
ECS Department
Lviv Polytechnic National University
Lviv, Ukraine
kopchakb@gmail.com

Vira Oksentyuk
CAD Department
Lviv Polytechnic National University
Lviv, Ukraine
vira.oksentyuk@gmail.com

Abstract — Heat detectors are the best ones for detecting flame fires. Unlike other types of fire detectors, heat detectors can be used in polluted and aggressive environments. They are resistant to various interferences. However, heat detectors have the highest operation inertia. You can reduce the fires detection time by heat detectors using fuzzy logic mathematical apparatus. The heat detector based on fuzzy logic was developed and investigated in this article. For this purpose, a microcontroller based on the Arduino hardware was used. Heat detector responds to both fixed temperature and the speed of temperature rise. A new model of heat detector based on fuzzy zero-order Sugeno logic with two inputs in the MATLAB/Simulink package was developed. Research of the accuracy and adequacy of the obtained mode was done. In the course of research, it showed 100% accuracy and adequacy in relation to the developed model in the Fuzzy Logic Toolbox. In the Arduino software package, using the C programming language and the Arduino Mega 2560 board, a hardware implementation of the Sugeno zero-order fuzzy logic heat detector was implemented. Experimental studies have been carried out. The error of the result calculated by the Arduino did not exceed 2.5%. Execution time of one complete cycle of fuzzy block is 0.004 sec.

Keywords — fire detection system, heat detector, intelligent fire detector, fuzzy logic

I. INTRODUCTION

To protect against fires, people have invented many ways and systems of fire protection. One of them is the fire detection system (FDS). According to the US National Fire Protection Association, the death rate per 1,000 fires in buildings is 55% lower with a working FDS than in buildings without a FDS or a non-operating FDS [1]. Therefore, it is very important that these systems are designed correctly and that the right equipment is chosen to save lives and property. Taking into account the significant damage from fires, time is a critical factor in detecting a fire. The ignition detection speed of FDS is influenced by various factors, for example: the selected type of fire detector (FD), the FD algorithm, the FD location, the type of fire, and so on. Fires can be smoldering or flaming. Smoldering fires are well detected by smoke detectors or gas detectors. Flame fires are well detected by heat or flame detectors.

Multi-sensor FD are considered to be the best. They detect both smoldering and flaming fires efficiently. However, the presence of smoke and/or infrared sensors makes it impossible to use them in polluted and aggressive environments, unlike heat detectors.

There are the following point heat detectors: rate of rise heat detector, fixed (statist) heat detector and for special applications detector [2]. The rate of rise heat detector is more efficient and sensitive than standard fixed heat detectors and detects fires at both slow and rapid

temperature rises. Also, they are much better used when the ambient temperature is low.

Heat detectors are the simplest, not expensive, simple and cheap to maintain, very reliable, have good resistance to various interferences. In general, heat detectors are more resistant to adverse environmental conditions compared to other types of FD. But they are considered the least sensitive and have the greatest inertia. However, there are a number of sites where flaming fires occur or where there is significant environmental pollution. For example, woodworking enterprises, elevators, mills, waste processing plants, etc. Then heat detectors are indispensable in use.

Disadvantages of FDs using information from only one sensitive element, including heat detectors, can be eliminated by developing algorithms based on fire detection methods by neural networks or fuzzy logic. Mathematical foundations of fuzzy logic are simpler than neural networks. They can be more easily implemented technically by means of microcontroller technology. These mathematical foundations make it possible to improve the technical characteristics of heat detectors: reduce their inertia, reduce the error of operation of the heat detectors from external interference and accurately detect fires.

Scientists are increasingly using hardware and computing platforms to study and debug the developed algorithms of heat detectors operation on the basis of fuzzy logic, for example, Arduino boards with Atmel ATmega328 or ATmega32U4 microcontrollers.

II. LITERATURE REVIEW

In the articles [3, 4] it is proposed to reduce the time of fires detection by heat detector due to the development of algorithms. Depending on temperature conditions of the environment, they change the value of static operating temperature and the speed of temperature increase at which the heat detector operates. However, the development of the FD algorithm is based on the use of clear logic. In this case, you cannot use expert judgment. Specific clear values are used. However, there may be cases when they may change.

In the articles [5, 6], the authors use an Arduino Uno board with different types of sensors to build a FDS. In the article [5], a smoke sensor is used to detect ignition. The system sends a fire or malfunction message via the GSM modem, turns on the fire pumps, gives alarms and turns off the power to the house. In the article [6], an IoT-based FDS using temperature and smoke sensors was proposed. After exceeding the threshold set values of controlled features, the microcontroller turns on the fan to remove smoke. At the same time, the Arduino sends information about the fire via the Wi-Fi module ESP8266. However, in the articles [5, 6]