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DESIGN OF "SMART HOMES" UNDER OPEN-SOURCE SYSTEM OPENHAB

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The dissertation is structured in an introduction, 3 chapters, conclusion, contributions, directions for future research, list of publications, list of noticed citations, declaration of originality of results and bibliography. The dissertation has a total volume of 123 pages, 30 figures and 16 tables, 126 cited literary sources.

The defense of the dissertation will take place on ……..2023. from …… hours in hall ……. on block 2 of IIKT-BAS at an open meeting of a scientific jury composed of:

Scientific jury
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2. Prof. Dr. Georgi Petrov Dimitrov - UniBIT
3. Assoc. Dr. Alexander Ivanov Shikalanov - UniBIT
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Author: Viktor Kanchev Danev
Title: Designing "Smart Houses" under OpenHAB open system

INTRODUCTION

The rapid development of ICT (information and communication technologies) is a prerequisite for the introduction of new technologies. ICT and IoT (Internet of Things) are closely related and complementary fields. Some of the aspects of the relationship between ICT and IoT are Integration: ICT provides the infrastructure that allows devices in the IoT to connect and communicate with each other and with other systems. Data processing: ICT provides the platforms to process, analyze and store large volumes of data generated by IoT devices. Security: ICT provides the security solutions that protect data and communications in IoT networks. IoT refers to an interconnected network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, and connectivity that enable these entities to collect and exchange data. IoT is a rapidly developing technology that is transforming the way we live, we work and interact with the world. They exist however and significant challenges and risks, which must be addressed to ensure that IoT everything accepts and uses by responsible and sustainable way.

The smart ones houses are species environment for living which includes the technology Internet on the things (IoT) to automate various aspects of the home, such as lighting, heating, security and fun . A smart house is a connected network of devices that work together to provide a seamless, intuitive and comfortable living experience. Smart houses can also be energy efficient as they can automatically to regulate lighting, heating and cooling and other appliances. Not only that saves energy and decreases the expenses but too so helps for reduction on the carbon one imprint and Protection on the environment environment. The design on smart houses (" smart homes ") imposes the integration on different technologies and systems, for Yes everything created comfortable, efficient and automated habitat.

This dissertation analyzes methods and tools for designing smart homes. The focus of the research is on multi-criteria decision-making in the selection of open-source home automation platforms, IoT-based smart home automation architecture, and the software solution for this automation, including a model for determining a team to implement IoT projects.

STRUCTURE OF THE DISSERTATION

Chapter **1** provides an overview of IoT technologies, standards, and applications. The various aspects of the smart home as part of the IoT paradigm are discussed . The advantages and disadvantages of commercial software and open source software platforms for use in home automation are analyzed. Methods of multi-criteria decision-making in selecting appropriate alternatives for dealing with conflicting criteria accompanying the decision-making of complex problems are reviewed .

Chapter **2** describes the proposed models for evaluation and ranking of the possible alternatives in decision-making for a smart home project with MCDM techniques that enable informed decision-making, prioritization of alternatives and optimization of different aspects in the context of smart homes. A decision model for choosing an open source software platform for IoT home automation design is presented. For this purpose, the main characteristics of the platforms were defined, which were used as evaluation criteria. Also described is the proposed model that has for aim to determine the necessary competences for the implementation of projects in the field of IoT and in particular for home automation. The proposed multi-criteria mathematical model takes into account not only IoT knowledge, but also takes into account characteristics of teamwork specialists.

In **Chapter 3** the conducted numerical experiments of the proposed models for the implementation of a smart home are presented. The implemented smart heating project, which uses open source home automation software OpenHAB, is described. The automation architecture of IoT-based smart home heating is presented, as well as the software solution for this automation. The numerical results of the testing of the proposed mathematical multi-criteria model for the assessment and ranking of necessary competences for the implementation of projects in the field of IoT using two groups of key indicators are described.

In the conclusion, the obtained results are summarized and some directions for future research related to various aspects of creating smart homes are indicated.

CHAPTER 1. ANALYSIS OF CHALLENGES IN THE FIELD OF THE INTERNET OF THINGS AND TECHNIQUES APPLICABLE IN DESIGNING SYSTEMS USING THE INTERNET OF THINGS

1.1 Definitions, characteristics, architecture on IoT

The concept for Internet is used for first way through 1999 Mr. from Kevin Ashton (Atlam,Walters & Wills, 2018). From Ashton's point of view, the Internet of Things has the potential to change the world in various ways such as the use of the Internet. Traditionally the technology can Yes everything examines and like next step in the job on Internet. On practice IoT can Yes provided connection with almost all objects in the real one world (Sharabov & Tsochev, 2020), including communication and collaboration via the Internet (Borisova, Dimitrova, Dimitrov, 2020).

Description on IoT

The Internet of Things (IoT) refers to everyday physical devices that are connected to the Internet for the purpose of data collection, transmission and processing relating to various applications and services (Hamza et al., 2021).

Research directions

In general, two research directions can be defined , namely: Standardization and Security and privacy

Applications on IoT

The applications on IoT they promise Yes bring huge value in life thank you onthe newer ones wireless networks, the modern ones sensors and the modern ones computational opportunities. Among the application areas of IoT are: Healthcare; Monitoring on the environment environment; Smart agriculture; Connected industry; Autonomous cars; Smart cities and smart homes; Intelligent energy saving and intelligent electrical networks; Wearables devices; and others.

Challenges

IoT challenges are related to: Big data; Network provision; Heterogeneity; Interoperability; Scalability; Security and Privacy; Support.

Intelligent home

The varieties on the applications for intelligent home are illustrated on Fig. 1.5.

Figure 1.5. Applications for intelligent home

1.2 Analysis on techniques and funds, applicable at design onsystems, using IoT

Software for management on IoT the hardware ones devices

The choice between the commercial one software and the software with open code must Yes everything based on the following factors:

- **Functionality:** Research and compare the functionality of the two types software, for confidence, that respond on the specific ones needs and requirements.
- **Devices and integration:** Viewing compatibility on the software with the devices that integrate into the system for home automation. Checking whether the software supports the necessary ones protocols and standards.
- **Flexibility and Customization:** If you want great flexibility and the ability to customization of your system, open source software can be more suitable. If everything looking for ready decisions and easy setting, the commercial one software may be preferred.
- **Budget:** Budget can also play a role in the decision. The commercial one software usually requires payment for licenses or subscriptions, while the software with open code is free for use. Although that at the software with open source additional hardware costs must be considered and technical support, if is

necessary.

These are just some of the factors to consider when choosing software for homemade automation. Important is Yes everything conducted in detail research and Yes everything do comparison for Yes everything found the most suitable answer.

Open source home automation platforms

Open source home automation platforms such as Home Assistant and OpenHAB serve as the foundation for creating smart homes. These platforms offer a centralized hub that integrates and controls various devices, including lighting, thermostats, security and entertainment systems. In addition, open source platforms support different communication protocols, which ensures compatibility with multiple devices from different manufacturers.

Systems for homemade automation with open code

They exist a few systems for homemade automation with open code, who offer flexibility and opportunities for personalization.

Platform	Basic characteristics	Flexibility and personalization	Integration and compatibility	Community and support
Home Assistant	Broad supporton devices and protocols	A large number supplements and integrations	Integration with popular smart devices and services	Active community and forums for support
OpenHAB	Flexible and expandablesoftware framework	An opportunity for doing of complex automations	Wide compatibility withdevices and protocols	Active community and support
Domoticz	Easy installation and setting	Easy creationon rules and scenarios	Integration with standard protocols such as Z-wave, Zigbee	Forums and maintenance from the community
Mozilla WebThings	Focus on the personal privacy and security	Opportunity for adding your own modules	Integration with voices assistants and standardprotocols	Development and support fromMozilla Foundation
ioB roker	Support of a wide range ofdevices and protocols	An opportunity for creation of complex systems	Integration with popular devices and services	Active community and forums for support

1.3 Collection on decisions by multitude criteria (MCDM)

Multi-criteria taking on decisions (Multi-Criteria Decision-Making – MCDM) is approach which everything deals with with structuring and solving on problems involving multiple criteria. It is designed to support decision makers and planning, faced with complex problems. The term "solving" in this one context can Yes matches on the choice on "the best" an alternative from set from available alternatives or even choice on small set

from good ones alternatives.

The solution on issue with MCDM requires turn on on information for preferences, as there is no single optimal solution. As such, the taker solutions often have to replace certain criteria with others. That can everything achieve with the help on different approaches and methods.

The role of MCDM in handling conflicting criteria at decision making

Multi-criteria decision making (MCDM) methods play a crucial role at coping with contradictory criteria at the taking on decisions. Controversialcriteria arise when different criteria or aims no they can Yes be optimized at the same time and must Yes everything do compromises.

By considering and managing conflicting criteria, MCDM techniques enable decision makers to navigate the complexities of makingon decisions and Yes achieved balance between the competing ones everything aims. They provide systematic approach for evaluation on the alternatives quantitatively determination on efficiency, setting weights and making informed decisions that optimize the compromises and everything bring in compliance with preferences and the priorities on those interested countries.

The concept for not dominated decisions in MCDM

The non-dominated decisions represent set from alternatives, who no are dominated from another an alternative byattitude on multiple criteria

Techniques on the multicriteria analysis at taking on decisions

Techniques of multicriteria analysis in decision making provide a framework and tools, who they help Yes everything compare and appreciate different alternatives based on a number of criteria that are optimized simultaneously in a given set of acceptable alternatives. In general there is no alternative, which Yes is optimal for all criteria, but can Yes everything composed multitude from alternatives. Ones from the most famous techniques on the multicriteria analysis are *The method on Analytical hierarchical process* and *Method on the weighted one sum .*

1.4 Conclusions

As a result of the overview analysis of technological solutions, mathematical methods and software tools applicable in the field of smart home design using IoT and open source home automation platforms, they can Yes everything do the following conclusions:

- the key benefits of IoT are in automating various processes in the homes as and

in gathering and analysis on large quantities data;

- mental challenges need to be taken into account homes in terms of cost to install and maintain, compatibility,and confidentiality and security.
- certain factors should be considered when choosing software for homemade automation, important is systematic and objective analysis onthe alternatives at the taking on decisions. MCDM the techniques allow informed taking on solutions, prioritization on the alternatives and optimization on different aspects in the context on the intelligent ones homes.

1.5 Purpose and tasks of the dissertation work

From the analysis of the existing technologies, software approaches and challenges in designing the smart home, the following goal of the dissertation is formulated: to propose a project for building a smart home using an open source software platform . In order to achieve this goal, it is necessary to complete the following tasks:

1. Yes everything do analysis on the challenges in the area on IoT and the techniquesapplicable at design on systems, using IoT,
2. Yes everything suggested multi-criteria model for taking on decisions for choice on platform with open code for design on clever home;
3. Yes everything suggested model for determination on competencies on specialists by IoTfor the design and realization on clever home;
4. Yes everything suggested approach for construction on intelligent homemade environment withuse on software systems with open code.
5. Yes everything held the numerical ones experiments for validation on the proposed onesmodels and approaches.

CHAPTER 2. MODELING And DESIGN ON SMART HOUSES THROUGH APPROACH FORTAKING OF PLURAL DECISIONS CRITERIA

This chapter describes the proposed decision-making models for the selection of alternatives at design on the intelligent one automation with use on open source software platforms, as well as for assessing member competencies from the team for application on technologies, connected with IoT.

2.1. Multi-criteria approach at design on clever home

The design and implementation on smart homes is complex task which requires

complex processes on taking on decisions. These decisions they can Yes cover wide spectrum from factors, like energetic efficiency, profitability, automation, comfort, security and aesthetics. The complexity of these decisions is multiplied when examines the multitude available technologies and opportunities for design. This is the place of the Multiple-Criteria decision-making concept Decision-Making (MCDM). MCDM includes structuring on complicated problems and expressly consideration on multitude criteria, which can Yes brought to more informed and better ones decisions.

2.2. A decision model for software platform selection with open code for design on homemade automation with IoT

Smart home automation relies on the latest technologies that give many practical advantages such as remote control of home functions; improved device functionality; manage all home devices from one central point; improved home security; increasing energy efficiency, etc. All this allows home functions to be controlled remotely (Lin et al., 2020). Home security and energy efficiency are the two important factors supporting the smart home concept. The use of surveillance cameras and the ability to receive security alerts on a mobile device allows activities to be monitored in real time (Arif et al., 2020). The Internet of Things makes possible the optimization of energy efficiency in the design of buildings, related to the reduction of energy costs for heating, cooling and lighting, including in the smart home (Guliashki & Marinova, 2021; Filho et al., 2019; Terroso-Saenz et al., 2019). This is due on precise control on the heating ones and the coolers devices with a programmable smart thermostat that plans the temperature and offers the mostthe good one energetic efficiency. The automated ones shades too they can Yes be programmed in evening mode, when the sun is setting even the lights they can Yesturn on and off automatically.

Using wireless technology doesn't have to be an end in itself to do your smart home, but you must carefully approach the selection and management of every device. This is imperative as like some recent publications warn for possible psychologically and physically impacts from the excessive use of smart technologies (Borissova et al., 2020; Markov, 2019). Because the use of many smart devices can not be prevented, the solution must be properly managed. It has to be chosen the right one software product for management on these intelligent devices. There is two opportunities for choice on such software, which can Yes manages intelligent home: : commercial or open source systems.

2.2.1. Multi-criteria model for evaluation and ranking on platforms forhome automation open source

Open source platforms are used for ranking basic parameters, considered for criteria for assessment,like is used the following function for utility:

$$A^*_{WPM} = max \prod_{j=1}^{N} \left(e_{ij}\right)^{w_j},\ i = 1,2,\dots,M \quad (2.1)$$

$$\sum_j^N w_j = 1 \quad (2.2)$$

where the grades on the criteria *(e ij)* would they could Yes accept values and the bigger one value matches on the better performance on the alternative by attitude of the specific criterion. The set of alternatives is expressed by an index *i* , *i={1,2,…M},* while the set from criteria for evaluation everything expresses through index *i j={1,2,…N},* . The weighed ones coefficients *w j* and grades *(e ij)* follows Yes share one and the same rock.

The best alternative will be the one with a high value for the overall performance of the alternative expressed through multiplication on the grades on the criteria on the alternative by the degree of the weighted coefficient of performance for the relevant criterion, as is expressed from (2.1).

For Yes everything do ranking on the platforms for homemade automation with open code formanagement on IoT, it was used the opinion on competent expert (Decision Maker - DM), which will implement the selected platform. The evaluation of the selected platforms by attitude on the specified criteria everything performs by rock from 0 to 100 (100 matches on the best presentation and 0 on the worst) followed from normalization in the range between 0 and 1, as is shown in Table 2.1.

Selected are the following criteria: Installation; Flexibility and UI; The community on the users; Pace on development; Integration; Protocols; Language for programming

The alternatives at taking on answer for choice are the following platforms: Open HAB; Home Assistant; Domoticz; Callaos; OpenMotics; HomeGenie; PiDome; Pytomation; OpenRemote

Table 2.1. Evaluation results for selected platforms versus certaincriteria

	Installation	**Flexibility and custom interface**	**The community of the users**	**Pace on development**	**Integration**	**Protocols**	**Programmatic language**
Open HAB	1	1	1	0.9	0.9	0.9	0.7
Home Assistant	0.9	0.89	0.78	0.88	0.8	0.9	0.85

Domoticz	0.86	0.87	0.85	0.86	0.87	0.83	0.9
Calaos	0.75	1	0.68	0.7	0.82	0.87	0.9
OpenMotics	0.55	0.6	0.6	0.6	0.6	0.6	0.85
HomeGenie	0.8	1	0.5	0.62	0.6	0.6	0.8
PiDome	0.5	0.5	0.46	0.58	0.62	0.6	0.8
Pytomation	0.53	0.52	0.42	0.53	0.6	0.66	0.85
OpenRemot e	0.5	0.8	0.57	0.57	0.6	0.62	0.7

All these grades are strongly subjective, especially by attitude on the languages for programming. To implement the ranking using the model (2.1) – (2.2) along with the scores from Table 2.1, it is necessary to determine the weighted ones coefficients for the importance on the criteria. IN this one connection the expert assessed the platforms for homemade automation with open code for IoT, expresses preferences you are for four different the case like uses different weights for the importance on the criteria as is shown in Table 2.2.

Table 2.2. Odds for significance on the criteria for evaluation

	Installation	**Flexibility and custom interface**	**The community ofthe users**	**Pace of develop ment**	**Integration**	**Protocols**	**Programmatic language**
	w_1	w_2	w_3	w_4	w_5	w_6	w_7
Case-1	0.166	0.167	0.167	0.166	0.167	0.167	0
Case-2	0.10	0.25	0.12	0.12	0.24	0.17	0
Case-3	0.14	0.14	0.14	0.14	0.15	0.14	0.15
Case-4	0.05	0.22	0.10	0.10	0.18	0.15	0.20

Case-1 and Case-2 do not consider the "programming language" parameter, while Case-3 does examines all criteria with same importance a in Case-4 the criteria are taken with different meaning.

2.2.2. Analysis on the results

The results obtained for the ranking of home automation platforms with open source IoT management are based on the inputs given by Table 2.1, Table 2.2 with the help on the model (2.1) – (2.2). Ranked platforms according to Case -1 and Case-2, who no report the parameter language for programming, are displayed on Fig. 2.1.

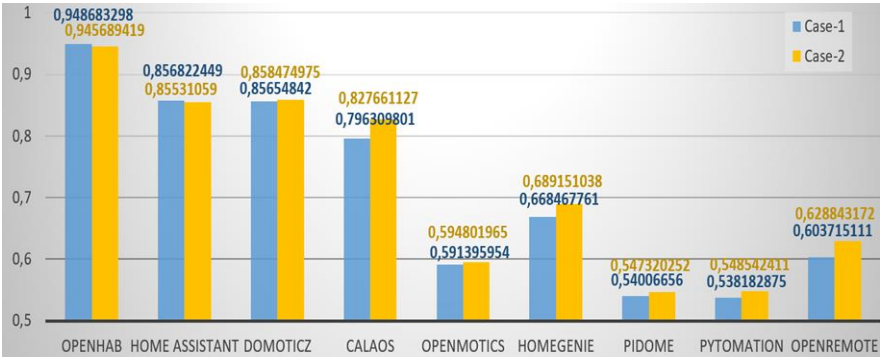

Figure 2.1. Comparison between ranked platforms according to Case-1 & Case-2

The designated ones results for the parameters on OpenHAB lead to morethe good his ranking among the rest platforms. Although the little ones differences in ranking, deserves Yes everything point out the influence on the ones used coefficients on the importance of the criteria. For example, only OpenHAB, Home Assistant and Domoticz have better ones results, if all criteria everything consider with same importance with exception on the language for programming (Case-1) in comparison with Case-2, where preferences for evaluation criteria have a different distribution. There are two additional situations that consider all evaluation criteria simultaneously (Case-3 and Case-4). Ranked platforms according to the preferences expressed from Case-3and Case-4, who report the parameter language for programming, are displayed on Fig. 2.2.

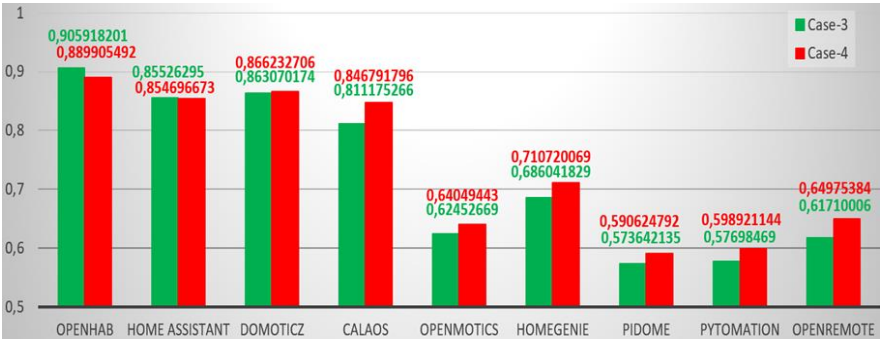

Figure 2.2. Comparison between ranked platforms according to Case-3 and Case-4

This comparison of criteria importance preferences showed little ranking

difference. For example, the results in Case-3, where all criteria are considered equally important, show that only OpenHAB and Home perform better, than in Case-4, where the meaning on the criteria accepts different values. The general comparison between all of them 4 the case is illustrated on Fig. 2.3.

Regardless of which platform will be chosen for home automation, it should is compatible with already installed smart devices in home. This everything relates in particular to protocol compatibility, ensuring the collection and transmission of data.

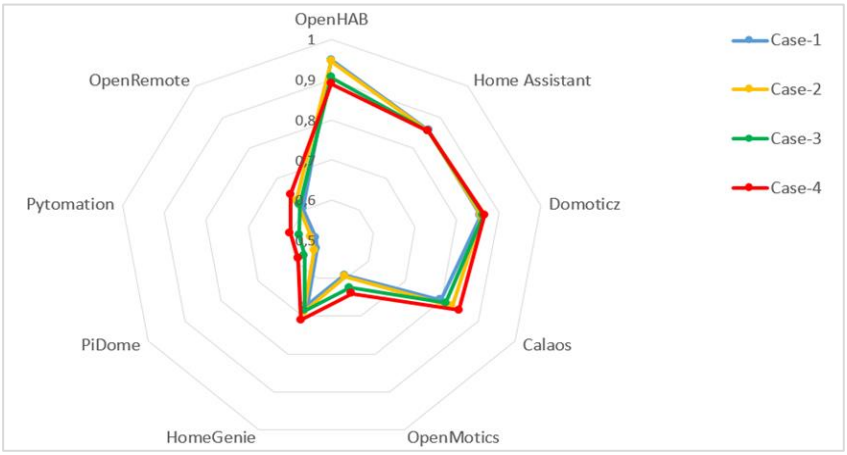

Figure 2.3. Comparison between the different ones rankings

2.3. Model for determination on competencies by IoT

The application of IoT can be found in every field of our real life and like such complex issue is hard Yes everything indicate all difficult skills, who the preferred one candidate must Yes meet One good IoT a specialist must Yes has knowledge in the field of sensors that measure and ensure the conversion of the data for the environment environment in mechanically readable data. From especially meaning are the knowledge in area of the technologies for transmission data, inclusive wireless networks and correct protocols (Hofer-Schmitz & Stojanovic, 2020). These protocols must Yes be secure enough and less power consumption to ensure continuous real-time connection of transmitted data (Bahashwan et al., 2021). They are necessary additional knowledge to understand data mining (Naka & Guliashki, 2021), some artificial intelligence techniques (Jafari et al., 2020) and the models for taking solutions _ (Borissova, 2021), who are prerequisite for the

right one functioning on IoT.No on last place understanding on the specific application is an advantage forcoping with some challenges. All them determine the meaning on IoT the technology in the area on the education for improvement on efficiency on the teaching and learning (Ramlowat & Pattanayak, 2019).

The meaning on the hard ones and the soft ones skills determines the necessity from establishment on appropriate approach to evaluate the most suitable candidate for the specific positioncharacteristic.

2.3.1. Key indicators for measurement

For Yes be successful good the educated IoT specialist, he must Yes owns diverse technologies, connected with sensors and processing on signals, software(programming languages), communication protocols, data extraction and retrieval on decisions. The proposed one concept for the necessary competence on IoT the specialist is illustrated on Fig. 2.4.

Figure 2.4. Solid skills and knowledge for successful IoT a specialist

the skills connected with the sensors, include and competencies like processing on signals, data analysis, big data processing, data visualization. The software ones skills imply the ability to program one or more languages for programming sensors or for visualizing and analyzing data from processing on signals.

Along with these must-have hard skills, the preferred specialist in the field of IoT must also have the additional skills such as good communication, teamwork, leadership, entrepreneurship, ability for management on conflicts and stress, motivation, management on the weather construction on trust, taking on decisions and etc. The basis is the frame shown in Fig. 2.4, and considering the aforementioned skills, the following hard and soft skills they can Yes be certain as follows:

1. *Solid skills:* sensors, processing on signals, retrieval on data, statistics, data analysis, data visualization, big data, machine learning, language for programming.
2. *Soft skills* : communication, work in team, leadership, entrepreneurship, conflict

management, stress management, motivation, management of the weather construction on trust, taking on solutions, solving on problems cooperation, adaptability and etc.

The hard ones skills are a lot easier for identification, asas they can be measured while soft skills are highly subjective. These two the species skills they can Yes everything consider like criteria for evaluation for measurement on progress on the specialists by IoT and the ability them for work in team.

2.3.2 Multi-criteria mathematical model for the assessment of knowledge of the specialists in the area on IoT and the ability for work in team

In order to assess the knowledge of specialists and their ability to adapt to teamwork, it is necessary to consider two separate parts related to hard and soft skills. This can be realized through the proposed mathematical model for evaluating the achievements of specialists (2.3)-(2.6), formulated as follows:

$$S_i^{performance} = \max\{\alpha \sum_{h=1}^{H} w_h e_{ih} + \beta \sum_{s=1}^{T} w_s e_{is}\}, \forall i = 1, \dots, N \quad (2.3)$$

$$\alpha + \beta = 1 \quad (1)$$

$$\sum_{h=1}^{H} w_h = 1 \quad (2.5)$$

$$\sum_{s=1}^{S} w_s = 1 \quad (2.6)$$

where *i={1,2,…N}* represents the assigned specialists, the coefficient α expresses the importance of hard skills, while the coefficient β expresses the ability to work in a team (soft skills), the coefficients w_h and w_s express the relative importance between the criteria related with the hard and soft skills, e_{ih} and e_{is} represent the scores of *the i* -th specialist around *the h* -th criterion related to hard skills and the corresponding *i* -th specialist around *the s* -th criterion related to soft skills. This range for the estimates should match the range of other variables of the proposed model (2.3)–(2.6). The acceptable range for these results is to be between e_{ih} and e_{is} to have a comparable scale. Expression (2.4) makes it possible to combine the separate two parts of the assessment in terms of hard skills (acquired knowledge) and soft skills (ability to work in a team) in the final summary assessment. As can be seen from the formula (2.3), the ranking of specialists is realized taking into account hard and soft skills, and these two types of components can be considered with different importance. This feature allows the model to be made more flexible to consider hard and soft skills in different proportions when determining the final complex ranking of specialists. The proposed mathematical model (2.3) – (2.6) can be simplified by using a value equal to zero for the coefficient β (β =0). In this case, the model (2.3) – (2.6) will rely

only on the hard skills (acquired knowledge) of the specialists.

CHAPTER 3. NUMERICAL TESTING OF THE PROPOSED MODELS PROPOSED FOR THE REALIZATION OF A SMART HOME

3.1. Construction on intelligent homemade environment

The problem under consideration is focused on combining the advantages of IoT for effectively management on the intelligent heating on home through use on the OpenHAB software platform. In order to implement such an approach, it is necessary to everything uses suitable hardware and software.

The main ones challenges at the construction on intelligent homemade environment depend from the following factors:

- the complexity on home,
- user preferences, what number of home functions to consider,
- possibility of future development/upgrade of the system,
- what type of smart devices to choose and how to combine them,
- what type of management Yes everything choose

One from the possible ones hardware decisions is Raspberry Pi, which is single board, cheap and high performance computational technique. Avg the software ones platforms with openIoT-based home automation code, OpenHAB could be the perfect fit choice, as is shown in section 2.2 on this one dissertation labor.

A hardware solution for effective IoT-based management intelligent heating at home

The hardware components, used for implementation on IoT, they can Yes vary from circuit boardslow-power or single-board processors such as the Arduino Uno (Ahmed et al., 2021). Lately the most popular platform for IoT is Raspberry Pi, because this is a very small computer that can include an entire web server (Raju et al., 2021; Danev, and et al., 2021).

Systemic architecture on the heating on clever home

To enable energy efficiency management in a smart home needs to be able to control the temperature. Possible answer for management on energy efficiency in clever home with the help on similar sensors is shown in Fig. 3.2.

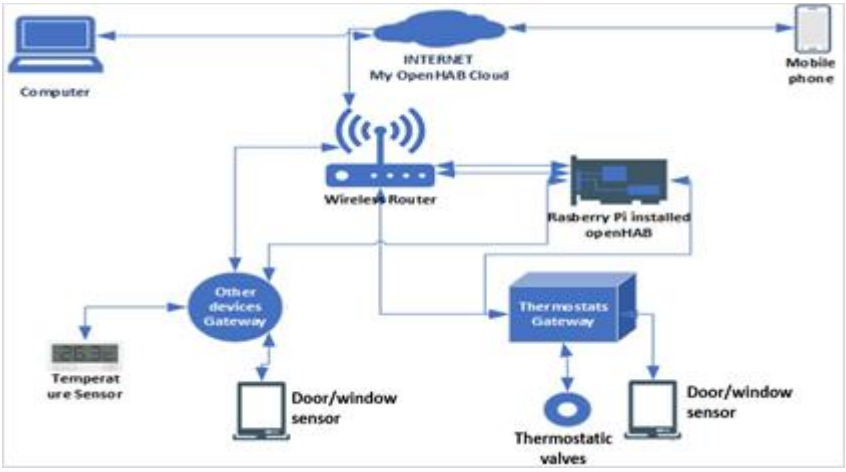

Figure 3.2 Intelligent homemade architecture for automation on the heating

The OpenHAB platform is selected in Section 2.2 according to the applied MCDM techniques. The physical ones devices and controllers (IoT) on the intelligent one homemade environment everythingchooses mostly from Xiaomi and MAX!.

Software answer for automation on the heating on clever home

For Yes everything realized the automation on the heating in clever home, must Yes everything install intelligent thermostatic valves for radiators. These valves they can Yes be connected to appropriate software platform like OpenHAB. One from the advantages isthat without meaning how everything increases the temperature (from direct sunny light from the window electric heater and etc.), the thermostatic one valve everything closes automatically when the set temperature is reached. The heating control is only part from the overall digital transformation on home, which includes management on the lighting, security, fireproof and Protection from floods and etc.

Rules for configuration on the software for the heating on clever home

АКО времето = <определено време> **ТОГАВА** <valves_name
_setpoint_temperature> = <предпочитана температура >

It is possible to set different time zones for morning 6:30 - 8:00, day 8:00 - 18:00,

evening 18:00 – 21:00, night 21:00 – 6:00.

CLOSED_OPEN

АКО <sensor_status_open_window> променени от ЗАТВОРЕН на ОПЕН,

ТОГАВА променлива = <valves_name_setpoint_temperature> &
<valves_name_setpoint_temperature> = MIN

OPEN_CLOSED

АКО <sensor_status_open_window> променен от OPEN на CLOSED

ТОГАВА <valves_name_setpoint_temperature> = променлива

3.2 Numerical simulating on suggestions project on intelligently heating through software for homemade automation with open code OpenHAB

This section describes the numerical testing of the proposed model for taking the platform selection decision when designing home IoT automation with open code, Described in section 2.2 on Head 2.

Entrance data

Applicability on descriptions approach is tested for apartment with rooms, whose distribution and used sensors are displayed on Fig. 3.5.

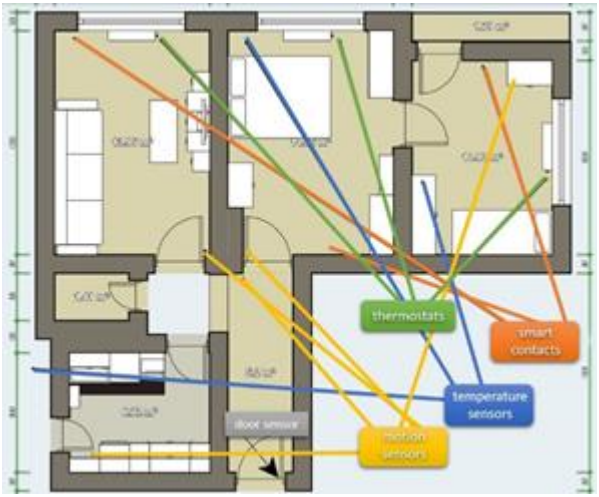

Figure 3.5 Distribution of rooms and sensors

A complete 3D model is created with the adjacent interior spaces (Fig. 3.6) and complete interior and exterior specifications on the model are set like for example:

- Set swarms for location and introduction on data for climate,
- Building data – glazing, external walls, pitched/flat roof, external under to air/ground and etc. Locally shading, if there is and so on
- Introduction on internal data – natural ventilation, temperature set points for heating/cooling, internal loads, infiltration,
- Setup hand or automated (via set points/sensors , three-level control and etc.).

The digital one a twin on the apartment everything uses for simulating on the effect on the digital oneinfrastructure on the heating ones loads.

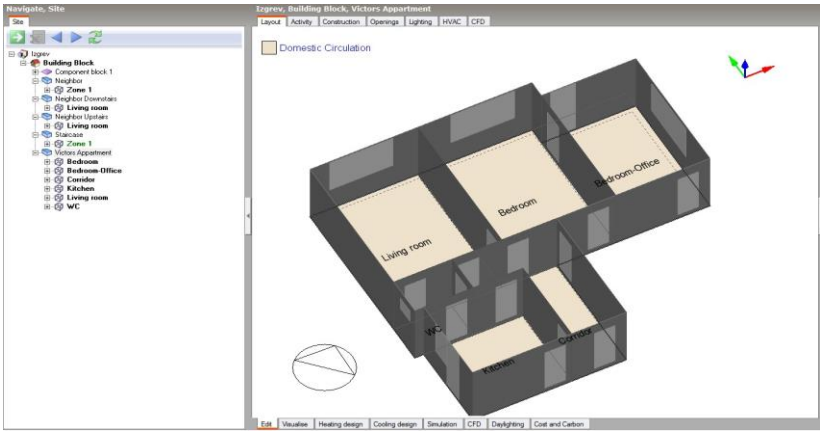

Figure 3.6. Digital twin model of the studied single apartment

Results and analysis

The heating load before the implementation of IoT for digital home transformation in smart home is shown in Fig. 3.7, while Fig. 3.68 illustrates the heat load after application on IoT.

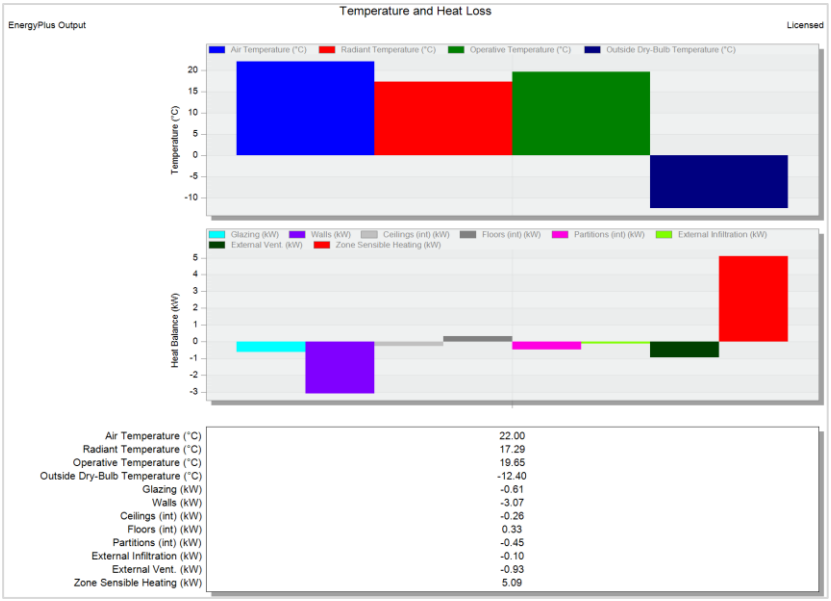

Figure 3.7. Heating load before applying digital transformation

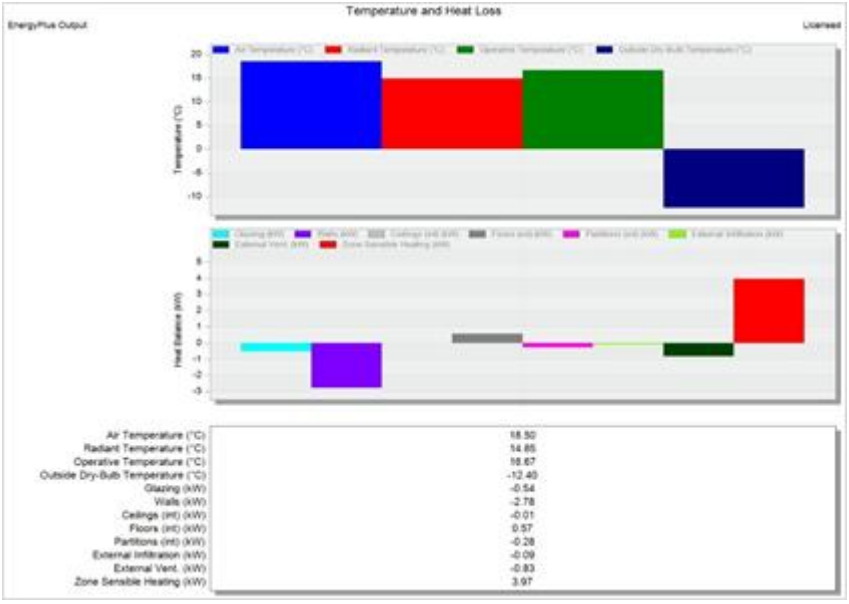

Figure 3.8. Heating load after applying digital transformation

The expense on energy and in both the case for one year old period is shown on Fig. 3.9.

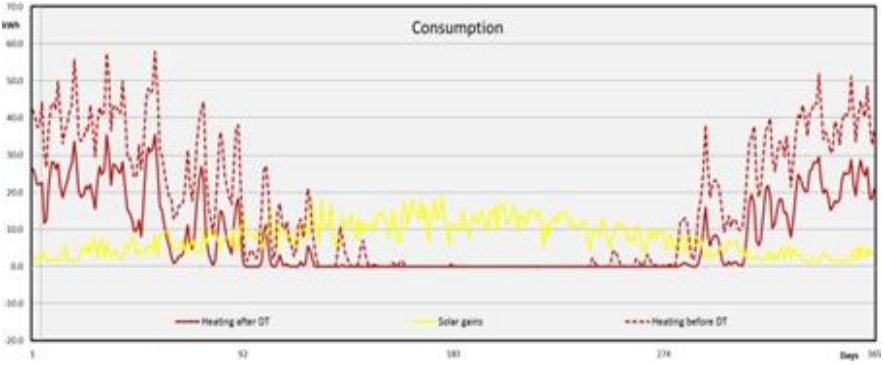

Figure 3.9. Daily consumption of thermal energy for heating before and after implementation of digital transformation (for 365 days)

As observed in the graph, peaks and troughs keep similar patterns for statistically averaged climatic year, but the curve for digitally transformations home shows clear lower living rooms levels on consumption. Except that, external and internal air temperatures, including surface radiant temperatures, are displayed on Fig. 3.10.

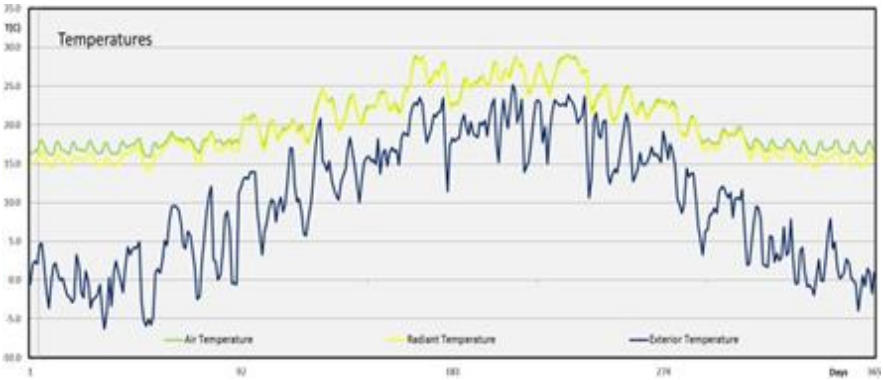

Figure 3.10. Average daily air temperatures, radiant and outside temperature

All simulations are done using EnergyPlus models. It should be noted, that EnergyPlus models are based on basic principles of heat balance and rely on on function for transmission on conductivity. One important consideration on the digital one

transformation on the apartment is that the reduction on the set temperatures on heating leads to increase on incoming thermal stream from the neighbors apartments. If the set temperature on heating everything lower and controls from the home one automation, the apartment begins Yes "fetch" heat from the neighbors you are and "the savings" are significant (cf. Table 3.1) in comparison with the previous one condition on the apartment.

Table 3.1. Comparison between total and surface consumption ofheating before and after digitization with the help on IoT *1*

	Heating ago (tkWh)	**Heating after (tkWh)**	**difference, %**
Total	5925.49	2818.64	47.56
kWh/ m^2	95.57	45.46	

The main ones characteristics on the proposed one system they can Yes be summarized as:

- comprehensiveness – the system covers a wide range of functionalities; universality – the system allows easy connection and setup of different smart devices developed by different manufacturers;
- flexibility – easy to upgrade and improve.

3.3 Numerical testing on suggestions model for determination competencies by IoT based on groups from key indicators

In order to verify the applicability of the proposed mathematical model (2.3) – (2.5), described in section 2.3 of Chapter 2 of this dissertation, to assess knowledge ofspecialists in order to identify the most educated candidates with the opportunity to teamwork, an experiment was conducted with a group of 25 specialists. The ranking ofthese specialists everything performs with the help on The 5 hard skills, a namely: sensors and processing on signals (H-1); software: language for programming (H-2); communication protocols (H-3); retrieval on data (H-4); 5) making decisions and compiling algorithms (H-5);and 3 soft skills regarding; work in team (s-1); motivation (s-2); management on the weather (s-3).

The skills on these specialists everything consider for criteria for evaluation in the ranking. The corresponding scores for hard knowledge (*e ih)* and soft skills (*e is*), expressed by grades by attitude on these skills, are displayed in Table 3.2.

Table 3.2. Assessment on specialists is to their skills

#	**Solid skills**					**Soft skills**		
	H-1	**H-2**	**H-3**	**H-4**	**H-5**	**C-1**	**C-2**	**C-3**
1	0.94	0.78	0.81	0.94	0.86	0.78	0.98	0.91
2	0.95	0.91	0.79	0.87	0.88	0.92	0.75	0.81

3	0.88	0.96	0.79	0.83	0.89	0.95	0.77	0.92
4	0.87	0.93	0.8	0.82	0.89	0.9	0.85	0.81
5	0.91	0.87	0.79	0.86	0.81	0.82	0.92	0.79
6	0.89	0.93	0.78	0.86	0.79	0.89	0.85	0.77
7	0.90	0.93	0.72	0.81	0.79	0.88	0.94	0.86
8	0.80	0.97	0.82	0.78	0.9	0.82	0.9	0.79
9	0.86	0.94	0.86	0.86	0.8	0.79	0.85	0.82
10	0.88	0.87	0.86	0.88	0.76	0.88	0.83	0.8
11	0.89	0.85	0.81	0.89	0.72	0.95	0.86	0.85
12	0.90	0.82	0.78	0.81	0.87	0.88	0.92	0.9
13	0.81	0.86	0.8	0.79	0.88	0.85	0.81	0.92
14	0.79	0.86	0.77	0.83	0.84	0.84	0.88	0.91
15	0.79	0.91	0.87	0.85	0.86	0.93	0.79	0.8
16	0.80	0.78	0.91	0.77	0.86	0.9	0.84	0.86
17	0.87	0.85	0.87	0.84	0.81	0.88	0.91	0.77
18	0.78	0.77	0.95	0.79	0.88	0.81	0.88	0.92
19	0.76	0.80	0.89	0.83	0.86	0.93	0.98	0.86
20	0.79	0.86	0.9	0.8	0.86	0.87	0.91	0.79
21	0.86	0.97	0.8	0.86	0.81	0.88	0.89	0.93
22	0.88	0.92	0.86	0.86	0.78	0.95	0.9	0.82
23	0.89	0.96	0.88	0.81	0.80	0.92	0.81	0.9
24	0.89	0.92	0.89	0.78	0.80	0.91	0.72	0.87
25	0.90	0.87	0.86	0.83	0.77	0.81	0.92	0.88

Okay with the grades for hard knowledge (*hey)* and soft skills (*eis*), is necessary Yes everything determine and the importance between them through the coefficients (α) and (β), as and the value for the coefficients *wh* and *ws* . Three different the case are identified and displayed in Table 3.3.

Table 3.3. Coefficients for hard and soft skills and their distribution among criteria

	Case-1	**Case-2**	**Case-3**
Solid skills	$\boldsymbol{\alpha = 0.5}$	$\boldsymbol{\alpha = 0.65}$	$\boldsymbol{\alpha = 0.65}$
H-1	0.2	0.2	0.22
H-2	0.2	0.2	0.2
H-3	0.2	0.2	0.22
H-4	0.2	0.2	0.18
H-5	0.2	0.2	0.18
Soft skills	$\boldsymbol{\beta = 0.5}$	$\boldsymbol{\beta = 0.35}$	$\boldsymbol{\beta = 0.35}$
C-1	0.33	0.33	0.38
C-2	0.33	0.33	0.20
C-3	0.34	0.34	0.42

Received results for ranked specialists up basis on the data from Case-1 are visualized on Fig. 3.11.

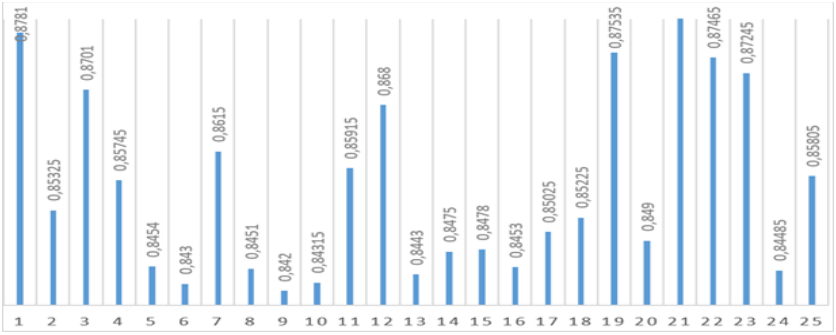

Figure 3.11. Ranking on the specialists by importance on the criteria from Case-1

If the strategy is changed and the preferences presented in Case-2, then the ranking of the specialists takes a different look as it is shown in Fig. 3.12.

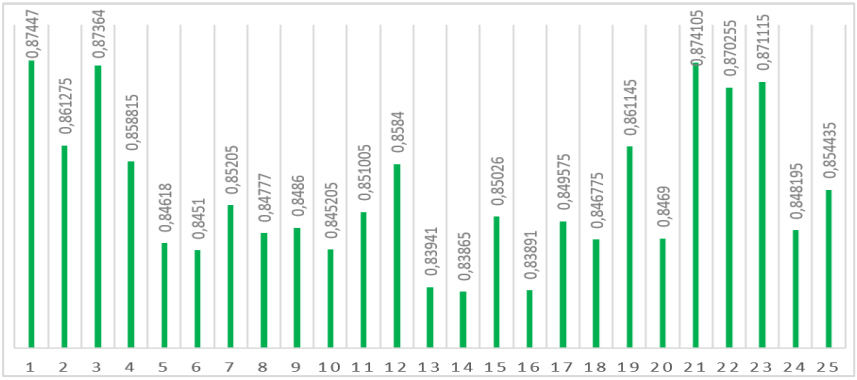

Figure 3.12. Ranking on the specialists by importance on the criteria from Case-2

When using the preferences expressed through the scenario of case 3, the following ranking of the students is obtained, as shown in Fig. 3.13. In this ranking, the top 3 ranked students are as follows: student #3 with a score of 0.88034, followed by student #23 with a score of 0.87764, and student #21 with a score of 0.87492.

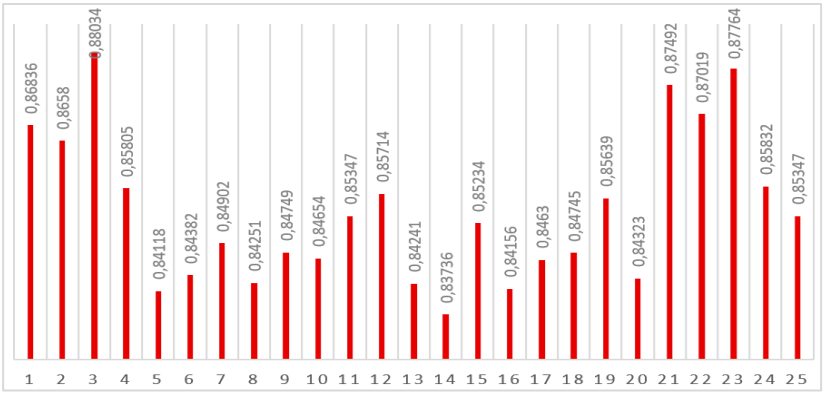

Figure 3.13. Ranking on the specialists by importance on the criteria from Case-3.

The comparison between the rankings on these specialists is shown on Fig. 3.14.

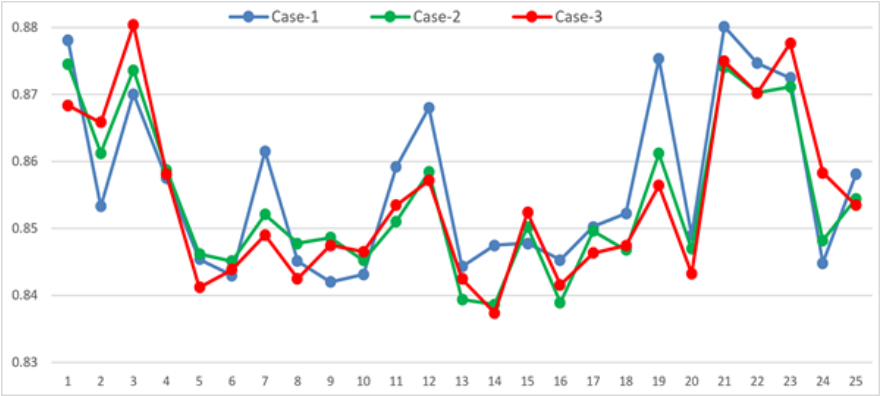

Figure 3.14.Comparison on the ranking on the specialists

Depending on the purpose of the ranking, it is possible to make a suitable list for specialists with more abilities for hard skills, suitable list for the specialists with soft skills or some combination of hard and soft skills. Theselists can be used to recommend specific specialists yes find a suitable job, according to their level of knowledge and adaptation to work in team. Given the issues of IoT, there are some activities without a requirement for teamwork like programming sensors or other smart devices like whole.

3.4 Conclusions

IN this one head are described the results from conducted numeric experiments with suggestions model for ranking on software platforms for homemade automationopen source and cluster-based IoT competency model key indicators, as and results from conducted simulations and real experiments from the designed intelligently heating in clever house, systematized as:

- Numerical simulation of the proposed smart heating project using open source home automation software OpenHAB,
- numerical testing of the proposed model for determining IoT competences based on groups of key indicators.

The described approach implements an open source software platform such as OpenHAB with low-cost and high-performance computing hardware such as the Raspberry Pi. Received results show a significant reduction in total and surface consumption on heating after digitization with use on IoT, which amounts to on 47%.

Through identified key indicators for measurement on the performance on the specialists in IoT and theirs ability for work in team in formulations integrated model for measurement on the performance on the specialists is shown the practical applicability of the proposed model for ranking specialists. An advantage of the proposed modeling approach is the possibility to considerhard and soft skills with different meaning.

Basic stages at the construction on clever home

As a result of the conducted research described in this dissertation they can Yes everything formulate four basic stage/tasks, at realization on IoT applications, as is shown on Fig. 3.15.

Figure 3.15. Basic tasks connected with realization on IoT applications

1) Selecting a software platform – this is the first major task is determining a specific software platform to be used for the respective automated system. This is an important stage, as the choice will also determine the specific functionalities and the appropriate hardware for implementation.

2) Digital twin model. At this stage, it needs to be built on a digital twin model to be used to simulate the desired home automation. Based on the conducted simulations, it can be determined whether the simulated home automation system would

have the desired efficiency or not. In the case of a positive opinion, it is necessary to implement the corresponding software and hardware solutions.

3) Identification of suitable specialists. In this third stage, it is necessary to determine the necessary specialists with the appropriate skills capable of implementing the simulated home automation system.

4) Practical implementation. At this stage, everything has already been determined and it is only necessary to realize the relevant project by the determined team .

CONCLUSION – SUMMARY ON RECEIVED RESULTS

Internet on the things everything founded on the use on different sensors, multi-layered architecture and set from communication protocols, who vary in dependency from the specifics on the system.The smart home is one of the most typical possibilities for realizing the concept of Internet on the things. This is quickly developing direction, which creates prerequisites for increased comfort, convenience, security and entertainment. They exist however and challenges, connected with the intelligent ones homes, like price, compatibility and privacy that must be addressed to ensure thatthat the smart ones homes everything accept and they use by responsible and sustainable way.

The digitization of technology is becoming increasingly critical to economic progress. This imposes Yes everything update a lot from the university ones disciplines, for Yes respond to the needs of such professionals capable of developing and maintaining devices on IoT. Because of that in the current one dissertation labor are proposed basic decisions in the field of IoT related to 1) choosing a home automation platform; 2) digital twin model for the purpose of simulating the proposed software and hardware solutions, as well as 3) a model for determining suitable specialists, for realization of projects in the area on IoT.

The choice on platform for homemade automation is from decisively meaning as like fromit depends on what functionalities will be possible from a software point of view implemented. This choice also depends on what hardware will be needed for realization of the specific home automation and in particular automation of the heating. Like evidence for efficiency on the software the system and adjacent hardware for homemade automation is realization on digital twin, which with a good enough approximation simulates the real situation. Thus and in the current dissertation, as a next step after the

selection of software platform is realized digital a twin for conducting on the research. Reportingthe necessary knowledge and skills for realization on homemade automation, based on use on IoT and in private automation on the heating on clever home, a model is proposed for the assessment of key indicators for measuring knowledge and the skills for work in team. Vaz basis on the proposed ones key indicators is it is possible to determine the appropriate specialists for the realization of the specific ones tasks for realization on specific project, connected with IoT.

Conducted numeric experiments on the proposed ones models and algorithms, inclusive and suggestions model on digital a twin are implemented like areused real data, which proves their practical applicability. Received results, described in dissertation labor are reflected in total 5 scientificpublications, like 4 from them are in editions, referenced and indexed in World famousbases data with scientific information – Web of Science and Scopus.

OF JUICES FOR FUTURE RESEARCH

Reporting achieved results in the current one dissertation labor they can Yes everything indicate and some guidelines for future research and improvements, connected with the followingdirections:

- Integration on mechanically training and artificial intellect
- Taking on decisions in real time
- Taking on solutions, tailored with the context
- Multi-criteria optimization
- Improved visualization and assistance on the taking on decisions
- Viewing on social and the environmental ones impacts
- Personalization, oriented to the user

LIST ON THE PUBLICATIONS PO THE DISSERTATION LABOR

1. **D Danev** , V., Kirilov, L., Nikolov, R. Creating Smart Home Environment Based on Open Source Home Automation Software. CompSysTech'21: International Conference on Computer Systems and Technologies,'21, June 2021, pp. 81-86, https://doi.org/10.1145/3472410.3472444 (**Scopus)**

2. **Danev, V.** : The Internet of Things: Description, Applications, Development, Challenges. Problem of Engineering Cybernetics and Robotics, vol. 76, pp. 3-24, 2021, ISSN:2738-7356, https://doi.org/10.7546/PECR.76.21.01

3. Borissova, D., **Danev, V.** , Garvanov, M., Yoshinov, R., Garvanov, I.: Identification of the Important Parameters for Ranking of Open-Source Home Automation Platforms for IoT Management. In: Borzemski, L., Selvaraj, H., Świątek, J. (eds) Advances in Systems Engineering. ICSEng 2021. Lecture Notes in Networks and Systems, vol 364, pp. 310–319, 2022, Springer, Cham. https://doi.org/10.1007/978-3-030-92604-5_28 (**SJR=0.15**)

4. Borissova, D., **Danev, V** ., Garvanova, M., Garvanov, I., Yoshinov, R.: Key Indicators to Measure Student Performance in IoT and Their Teamwork Ability. In: Auer, ME, Tsiatsos, T. (eds) New Realities, Mobile Systems and Applications. IMCL 2021. Lecture Notes in Networks and Systems, vol 411, pp 711–720, 2022, Springer, Cham. https://doi.org/10.1007/978-3-030-96296-8_64 (**SJR=0.15**)

5. Borissova, D., **Danev, V.** , Rashevski, M., Garvanov, I., Yoshinov, R., Garvanova, M.: Using IoT for Automated Heating of a Smart Home by Means of OpenHAB Software Platform, IFAC-PapersOnLine, Volume 55, Issue 11, 2022, Pages 90-95, ISSN 2405-8963, https://doi.org/10.1016/j.ifacol.2022.08.054 . (**SJR=0.324**)

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