**Ministry of Education and Science of Ukraine**

# *Odessa National Academy of Food Technologies*


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# BLACK SEA SCIENCE 2020

## Information Technology, Automation and Robotics

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The introduction of such a control system will allow to effective usage of power resources, easy maintenance of PowerGrid nodes and gives complete control over all devices in system.

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## HEAT LOSS MONITORING OF MULTI-STORY BUILDINGS USING MULTI-AGENT APPROACH

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***Abstract.*** *In this paper, the problem of developing a multi-agent method for detecting the places of heat energy leaks on the multi-story buildings using machine learning is solved. Efficient data processing of scanning areas for the heat energy leak monitoring was achieved using the multi-agent monitoring system (MAMS) that can perform calculations in the cloud conditionally. Features of the monitoring system with the integration of an analytical model for presenting a heat loss map with an account of multiple autonomous separated UAV's for temperature measurements were contained. The MAMS reliability of the synchronization model between simultaneous localization and mapping method and generated heat loss map based on temperature measurements was confirmed. It has been experimentally proven that theoretical assumptions and accuracy for experimental usage during the multi-story building leaks analysis are sufficient.The recognition time of markers of the front of the building is in the range from 0 to 27 s. In this case, with the proposed model CNN, the CPU load during the execution of tasks did not exceed 26%.*

***Keywords:*** *heat loss mapping, heat leak detection, machine learning, multi-agent system, GPS, pyrometer, UAV, MAMS.*

# 1 Introduction

Energy-saving experts provide heat loss calculations for different scenarios. It may be to ascertain the heat loss of a structure through the floor, walls, and roof, via the building fabric and by ventilation losses, it may be used to calculate heating loads, or it may be to demonstrate compliance with the building regulations. Building regulations required different methodologies depending on if the building is to be extended, renovated, or changing use. Different parts of the multi-story building must have effective thermal separation from the rest of the building. All parts of the multi-story building need to meet minimum requirements for the thermal elements, windows, doors, and building services.

There are several ways to demonstrate the above. To show heat loss management from the specification and drawings that the building's part meets the minimum requirements, with particular attention to the area of glazing. Experts provide area-weighted heat loss value calculations to show that the extension as planned is no greater than one that meets the regulations. Change of use by real estate developers shows compliance is to provide a report detailing the specification of the building, showing the heat loss values supported by area-weighted heat loss value calculations and this is a problem.

Again heat loss monitoring software should have report formats accepted for submission. Renovation of thermal elements of the building is usually linked to an extension or a change of use, but not always. Therefore the means to demonstrate compliance is the same as for those two, however, there are minimum requirements for upgrading thermal elements that are different to those for new elements. The area of the element to be upgraded is important to establish, likewise if by doing so it would have less than a 15-year payback. The main goal of the heat loss monitoring software is to calculate all of this for tenants and present in a written report for renovation's submission. So, if we have had an advanced methodology in gaining compliance with heat loss monitoring results by presenting the facts and calculations in a clear and consistent format that makes it easy for heat loss management to check the building's compliance criteria.

Not too long ago, UAVs were not much more than an ambitious, futuristic concept for data collection and aerial imagery. Now that the technology is relatively established, researchers and manufacturers are already looking for ways to build upon that foundation. Some avenues are more obvious than others. A natural progression is to shift from a single pilot controlling a drone to a single pilot controlling multiple drones. Or, eventually, multiple drones operating independently but cooperatively with a common purpose.

However, flying in formation to a preprogrammed sequence is one thing. Adapting on the fly to perform more complex tasks as a group is quite another. The latter implies communication within the group, as well as goals that are more dynamic than simple synchronized flight. Drone swarms could cut down the time needed to complete mapping missions for the heat loss monitoring of multi-story building to reduce costs for maintenance. AI and computer vision can be used to help drones determine their next move and perform tasks without crashing into the first obstacle they come across.

# 2 Analysis of the heat loss management systems

The general situation in the field of heating systems is that the main purpose of heat supply to consumers is dominated by the need for an efficient system. About 90% of all

Ukrainian high-rise buildings require measures to improve the functioning of the heat supply systems. Of these, 60-70% of the houses were built in the years of industrial construction in typical series who are currently faced with the problem of heat loss[1]. Heat loss at home is the amount of heat generated by a house on the street per unit of time. They are measured in watts (watts). Heat loss is affected by temperature differences inside and outside the house. This dependence is directly proportional - the larger the temperature difference, the higher the heat loss[2]. Also, heat loss depends on the design of the house. How strongly the external walls or windows impede the generation of heat characterizes the resistance to heat transfer. Between the resistance to heat transfer of building envelopes and heat losses there is an inversely proportional relationship - with increasing thermal resistance, heat losses decrease [3].

The Quick U-Building (QUB) method is a dynamic method developed to estimate the heat loss coefficient of a building in one night without occupancy[4]. Feasibility measurements and comparisons with various references have been done in earlier studies whatever numerically, experimentally in an ideal case, or experimentally in real cases [5,6]. This article presents a review of various perturbation methods developed to assess building thermal performance, details of theoretical understanding of the QUB method, and gathers experimental results obtained in many different configurations[7]. The heat loss coefficients estimated with the QUB method are in good agreement with experimental references and are reproducible. This demonstrates that the QUB method has a real potential to estimate the heat loss coefficient of a building in a short duration and with a reasonable accuracy [8].

The thermal imager is a modern device that analyzes the air circulation in the room, helps to identify structural defects and provide the customer with visual inspection results [9].

The device emits infrared light and picks up the electromagnetic reaction of the surfaces of the studied object. By measuring the intensity of such radiation, the thermal imager can calculate the maximum temperature of a surface and determine the place of heat leakage[10].

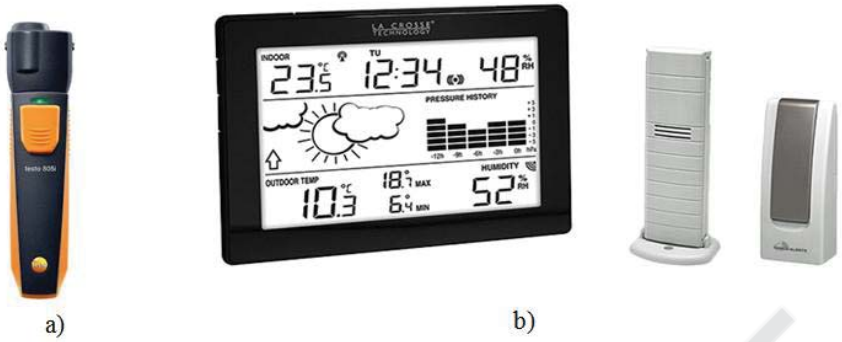
The device is able to analyze the input data and display a graph of temperature differences, as well as calculate the optimal performance for the object [11]. The thermal imager on its screen creates a thermogram - this is a spectrozonal picture of the circulation of warm and cold air in a room. The color scheme in the picture varies from saturated red to blue or blue.

The main problem in measuring heat loss is about a thermal imager is used for measurement, this is a high price for the device, data transfer complexity, averaging of readings along the edges of the measurement zones. In turn, the need for a high density of measurement points for the accuracy of the result is added to the pyrometer. Also a common problem will be low mobility, which is completely dependent on human capabilities. After processing the data, there is a problem with an error when averaging data during the collection, and then when calculating the heat loss of the region and reducing it to a heat map [12].

## 3 Heat loss measurement hardware

To implement idea for automated heat loss measurements list of equipment was analyzed. The testo 805i (see Fig. 1, a), for example, is a professional measuring infrared

(IR) thermometer from the Testo Smart Probes series, for use with smartphones/tablets with either Android or Apple operating systems. It is, however, worth drawing attention that you need to download and install free Testo Smart Probes App on your device before using the Testo 805i Infrared Thermometer.




a) b)

**Fig. 1.** Testo 805i Infrared Thermometer (a) and Crosse MA10006-BLA Wireless Weather Station with Gateway (b)

A La Crosse MA10006-BLA smart weather station with Mobile Alerts Weather Gateway MA10000 and Wireless Wifi Thermo-Hygro Transmitter TX29DTH-IT+ options can also be used as an instrument for detecting the heat leakage areas in multi-storey buildings and industrial facilities. And furthermore, the data obtained with the help of the weather station can be used to develop the Heat Leakage Detecting app.

Besides build-in weather stations features, such as 12-hour forecast, outdoor/indoor temperature and humidity sensors) the La Crosse MA10006-BLA is able to share weather data (indoor/outdoor humidity and temperature, wind speed, etc) via the Internet, as well. The weather data will further be available on any smartphone with necessary app installed.

a) b)

**Fig. 2.** Quadrocopter DJI Matrice 210 with thermal Zenmuse XT and video camera on board (a) and quadrocopter DJI Phantom 4 with TX29DTH-IT on board (b)

Moreover, it should be mentioned that up to 50 Mobile-Alerts sensors at the same time can be connected to the weather station due to the build-in Gateway MA10000 functionality (see Fig. 1, b). Thus, with the help of any drone being equipped with heat sensors it would be possible not only collecting walls temperature data necessary for heat mapping, but also receiving inside and outside temperature data for further comparison and subsequently more accurate detection of the heat leak rate.

The DJI with thermal imaging (see Fig. 2, a) or with the previously mentioned temperature sensor (see Fig. 2, b) can be used as transport means for the heat measuring equipment. An external sensor transmits the information to the weather station with the help of an IT+ technology (Instant Transmission technology) at 868 megahertz. IT+ technology advantages:

1. High Level System Security ;

2. The transmission distance is increased to 100 meters;
3. More economical (Cost-effective);
4. High-quality sensors;

Functional scheme, allow transmission distance is increased to 100m take sensors data on IT + on station, across cloud service Mobile-Alerts via ethernet – on mobile. So device must include a smartphone, with OS Android above 3.2. functional diagram system we can see on Fig. 3.

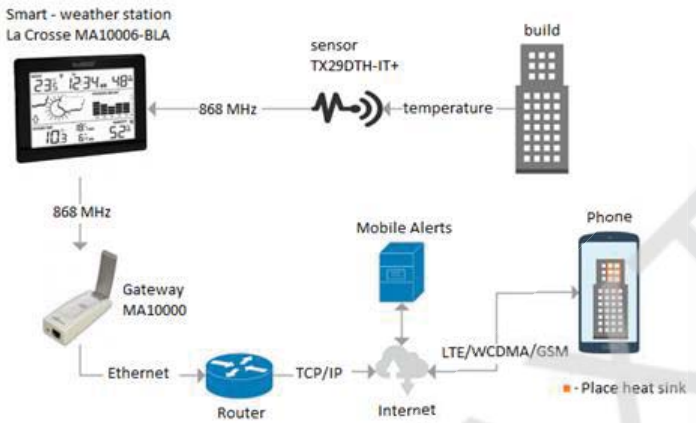



**Fig. 3.** Functional diagram for the heat loss measurement unit of MAMS.

At the current, the weather station can be upgraded to analyse the data to prevent the fungus formation. In order to protect the walls of houses from damaging, such as mold, fungus, fluctuations in temperature, the comprehensive approach is required, to be outlined in the next report. This upgrade can also help to prevent an occurrence of microcracks between floor panels and in the seams between walls.

## 4 Multi-agent monitoring system

To solve technical problems, a multi-agent monitoring system for the efficient control of the trajectories of many UAVs was proposed. The functional diagram of MAMS for scanning heat losses was presented (See Fig. 4). The $DS^{HLS}$ set describes an array of UAVs that perform *HLS* heat loss scanning. Each $HLS_j$ scanning path includes an *HLA* scanning area. Processing of the scan area by each $DS_i^{HLS}$ UAV is implemented and based on a neural network, which is capable of detecting markers of the scanning area of building windows using the Deep CNN architecture. Positioning accuracy is ensured according to the SLAM algorithm.

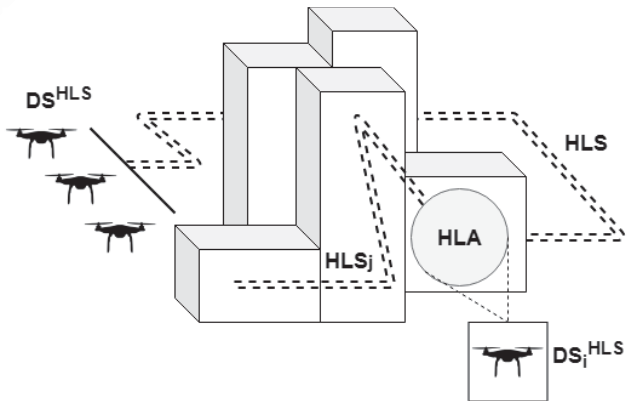



**Fig. 4.** The heat loss scanning process using MAMS.

The $SLAM^{TR}_{A_{MAMS}(i)}$ is a path mapping system for the $A_{MAMS}(i)$ agent and given as a set of *HLS* trajectories. A section of the trajectory $TR_j$ is considered correct if, in the implementation of the SLAM algorithm, the region of the surrounding space $RG(TR_j)$ was defined. Displayed equations are described the model of the MAMS logic to control the UAVs set:

$$\begin{cases} SLAM^{TR}_{A_{MAMS}(i)} = \sum_{j=0}^{P} TR_j \left| DTC(RG(TR_j)) \in HLS; \right. \\ DCNN^{HLA}_{A_{MAMS}(i)} = \sum_{k=0}^{W} MD_{ACC}(HLA) \left| MD_L(HLA) < V_{THRБ}; \right. \\ ITP_{A_{MAMS}(i)} = T_{SNS} + T^{FLC}_{UAV} \cdot C^{ST}_{TR} \cdot C^{M}_{TR} + T_{WS} + T_{ETH} \cdot VL_{DT}; \\ HLS_{A_{MAMS}(i)} = K_e \cdot VIS^{HLS}(W_x^{DCNN}, W_y^{DCNN}, TMP^{ITP}(x, y, c), t). \end{cases} \quad (1)$$

The next condition for the correct operation of the model is adequate recognition of markers within the *HLA*. The $A_{MAMS}(i)$ agent entity that operating based on one or several UAVs must ensure the recognition of all *W* markers in the *HLA* scanning area with floating $MD_{ACC}$ recognition accuracy at the $MD_L$ recognition threshold. The total data processing time $ITP_{A_{MAMS}(i)}$ depends on the data transmission time from the temperature sensor, the processing time of the sensor signals by the system, the computing resources of which are occupied by the $C^{ST}_{TR}$ stabilization commands and the recognition of window markers by the $C^{M}_{TR}$ neural network. The dynamic dependence of the $HLS_{A_{MAMS}(i)}$ visualization map of the heat loss map taking into account the noise $K_e$ has been determined.

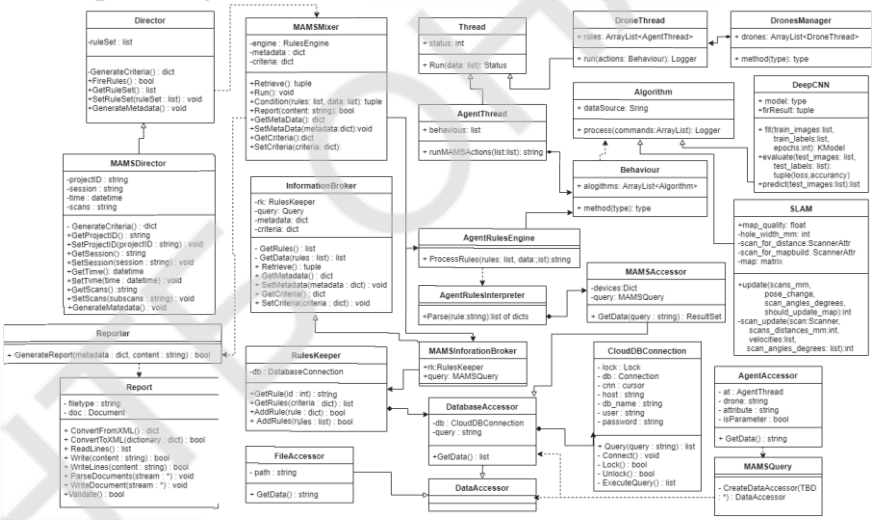



**Fig. 5.** Software architecture for MAMS included algorithms for scanning optimization.

The architecture of the MAMS software implementation with a multithreaded object-oriented model of managing functional agents was presented in Fig. 5. Abstractions of algorithms that optimize UAV positioning during scanning of the heat loss region were determined. This provides the flexibility to control processing in the MAMS-Mixer object based on the interpretation of the MAMSRulesInterpreter rules.

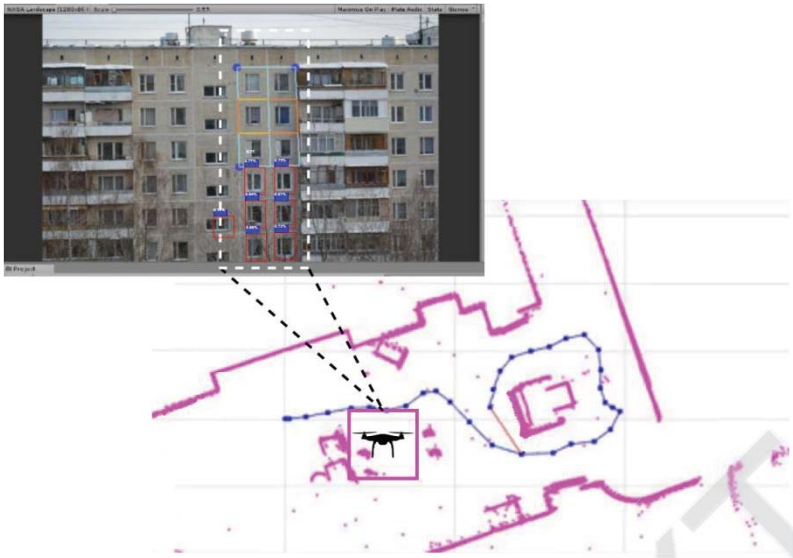


**Fig. 6.** The result of combination DCNN and SLAM algorithms inside MAMS for heat loss mapping.

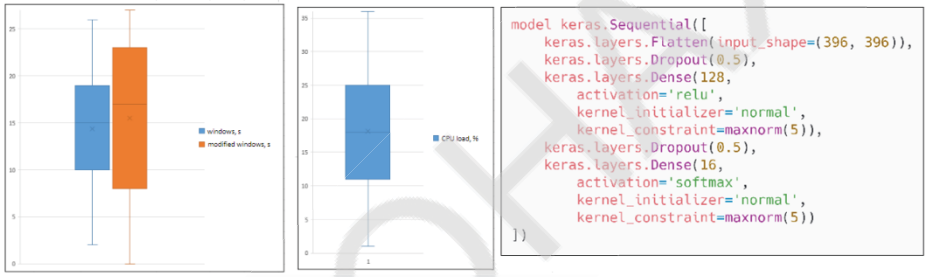



**Fig. 7.** Plot boxes diagrams of markers recognition time (a), CPU load percentage (b) and description for the proposed CNN model (c).

The software for determining the places of heat leakage of structural elements of buildings was developed. As can be seen in Fig. 7. the recognition time of markers of the front of the building is in the range from 0 to 27 s. In this case, with the proposed model CNN, the CPU load during the execution of tasks did not exceed 26%.

## 5 Video Streaming Service

The video system is responsible for getting video from the broadcaster agent $A_b$ to our viewers. This includes the following core components: Video ingest is RTSP video in, and then transport it to the transcode system. Transcode system – we take the incoming RTSP stream from the broadcaster, and transcode it into multiple HLS streams. VOD – we take all of our incoming video systems and archive them for our VOD system.

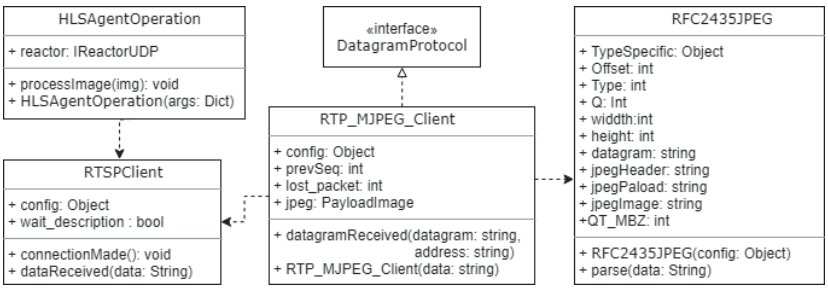



**Fig. 8.** Architecture of MAMS module for thermal elements quality detection via video stream .

The HLSAgent bevaviour's module in Fig. 8 consists of several files, main.py contains a callback function that processes the received images, it also starts the network transferring mechanisms and stores the parameters for connecting to the camera. Communication between the VLC layer and UAV camera was implemented and requests from the VLC to port 554 of the camera start with "RTSP / 1.0". If we want to receive only video, then from the audio data we ignore everything except the name of the track. We need it to configure the stream, but no one forces us to accept this stream, however, the camera refuses to work if you completely ignore the audio (if SETUP done only for the video track).

Different cameras will react if we neglect the port number for the audio stream (7878), because we specify it with the SETUP command. Next are two SETUP requests, indicating the ports on which we would like to receive video and audio streams. The first is the port for RTP, the second is for RTCP. The camera response contains information about the ports, you can consult them to make sure that everything is configured correctly. Session identifier to indicate it in all subsequent calls is need to be remembered. After the PLAY command, video will begin to be transferred to port 41760 and audio to port 7878 and by TEARDOWN broadcast will stop, the connection will be disconnected.

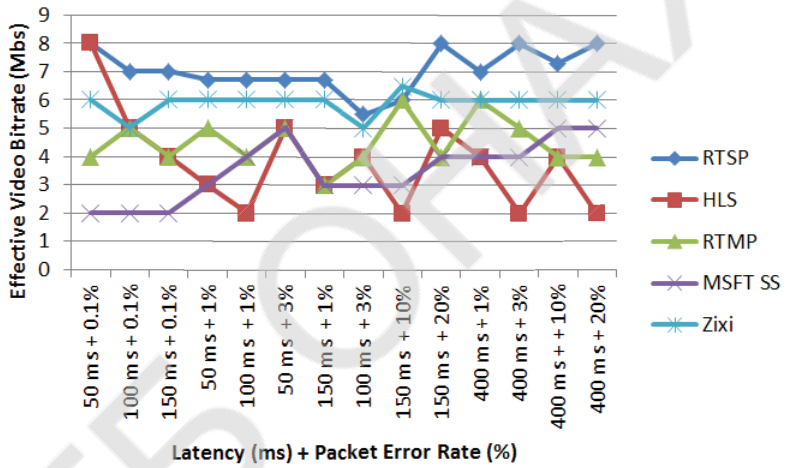



**Fig. 9.** RTSP performance compared with many of the popular streaming protocols.

Transferred one level of encapsulation above. Conversion the received video data into a full-fledged JPEG image is important. In the case of MJPEG over HTTP, everything is simple - we cut out a piece of the stream and work with it immediately as with a JPEG image. In the case of RTP, the image is not completely transmitted. The JPEG header is omitted to save traffic and must be restored independently from the attached data. The RTSP Payload for MJPEG specification is described in RFC2435.

RTSP video MAMS agent transfers video data via receiving module, but did not convert them to playable data. This problem is handled at the VLC layer so UAV's manager can perform a multi-story building monitoring to find the visual defects that affects the heat losses. It is only necessary to organize parsing similar to rfc2435jpeg. Audio data is easier because it is not fragmented. Each package carries enough data to reproduce. SS and RR types carry information about sent / received packets and about time delays. A graph of the performance of the RTSP transport protocol measured against others shown in Fig. 9 taking into account latency and packet error rate.

## 6 Conclusion

The functional scheme of the mobile system for detecting heat leakage through the elements of construction of a residential building is developed.

The developed mobile system connects up to 50 wireless sensors up to 100 meters away via the Mobile Alerts cloud server. External wireless sensors transmit information to the Smart Weather Station using IT + (Instant Transmission Technology) at 868 MHz.

The device includes a smartphone with Android OS version not lower than 3.2. System testing was performed using a mobile phone Xiaomi Mi A2 6/128GB. It is suggested to use a quadcopter to lift the sensors to the specified height UAV DJI Phantom 4. Performance comparison of the popular streaming protocols was analysed. RTSP protocol is more efficient than other and provides 7–8 Mbs bitrate in the latency range of 100–400 ms with average packet error rate 8.25%.

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## STATUS AND PROSPECTS FOR THE USE OF INFORMATION AND COMMUNICATION TECHNOLOGY IN GERMANY

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***Abstract.*** *This research reveals the topic of the use of information and communication technology in Germany. The degree of involvement in country life and the main modern trends in application of this technology in different industries and community governing are reviewed. Germany is the country which has shifted its focus on digitalization as the main direction in its economic and social advancement. The government engages specialized institutions, leading universities, legislative and expert groups in developing policies, strategies and measures aimed at improving this area. The research provides a general overview and analyses of German large-scale IT projects which impact business and society. Extensive use of information and communication technology has some drawbacks, one of which is lack of security. The wider IT intrusion in life is, the more opportunities for cybercrime arise. This issue and other problems connected with the field under investigation are mentioned in our work.*

***Key words****: information and communication technology, digitalization, innovation technologies, digital Germany, Industry 4.0.*

## I. Introduction

Nowadays the dramatic rise and convergence of emerging new information technology causes rapidly and radically transforming in all spheres of society's life. The Internet has become increasingly important to users in their everyday lives. It creates new ways for citizens to congregate, store, transmit and retrieve the data and to communicate and share information with others. Ability to work with different computer programs is the skills that are increasingly important for everyone living in the digital age. New mobile and Internet technologies lead to the digitization of the economy and the emergence of new jobs based on the use of technologies such as artificial intelligence, virtual and augmented reality, biotechnology, Internet of things, cloud computing. Therefore, further development of information technology is inevitable.

## II. Literature Review

The issue of country digitalization is one of the most vital in modern society. On the one hand, it needs to be studied in order to manifest the outcome of this process implementation, statistic reports, as well as follow the development and progress. On the other hand, exploration of this sphere is necessary to prepare a clear vision of prospects, follow trends, predict changes which might happen in future due to the use of information and communication technologies (ICT) in various fields. Use of ICT in business, science,