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імені ВОЛОДИМИРА ДАЛЯ



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Сєвєродонецьк 2019

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НАЦІОНАЛЬНОГО УНІВЕРСИТЕТУ
ІМЕНІ ВОЛОДИМИРА ДАЛЯ

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IMPLEMENTATION AND PERFORMANCE ANALYSIS OF PROPOSED SECURITY FRAMEWORK FOR UIDAI

Arpana Chaturvedi

РЕАЛІЗАЦІЯ ТА АНАЛІЗ ПРОДУКТИВНОСТІ ЗАПРОПОНОВАНИХ ОСНОВ БЕЗПЕКИ ДЛЯ UIDAI

Арпана Чатурведі

The development of new technologies like Hadoop, Map Reduce, used to store, manage, analyze vast amount of data, when associated with WSN (Wireless Sensor Network), the risk factor for information security increases. When it is applied in various applications of government like Aadhaar, DigiLocker etc., chances of hidden security issues increased. In this paper AESXTS encryption mechanism and digital signature technology is used with AODV (Ad hoc On-Demand Distance Vector) routing protocol to get rid of various issues like DoS (Denial of Service), eavesdropping, imitation, coaxing etc. The theoretical analysis is shown using NS2 simulator and implementation assures to provide better data security, reliability, transmission and energy efficiency. This implementation shows that SAODV(Secure-AODV) routing protocol when used in routing layer in these applications and system, it increases its own self defensive ability to fight against various challenging hidden security issues.

Keywords: AODV, SAODV, WSN, AES-XTS, UIDAI, DoS

Introduction

The UIDAI (Unique Identification Authority of India) data, both at rest or on move, stored at CIDR (Central Identities Data Repository) is at high risk. Due to the advent of new Hacking technologies and advanced tools, the risk factor has increased. The government is enforcing citizen of India to link Aadhaar number with different citizen centric services so that right citizen can avail the benefits. There is need to safeguard the data stored in different data centers which might be secured through a strict encryption technique applied on application process in parallel mode. In this chapter, an encryption process to be performed in parallel mode is discussed. The proposed approach is AES in XTS Mode in Map Reduce paradigm which supports parallel programming in the distributed environment. The findings after reviews of results show that it provides better security against external attacks and overcomes the shortcomings of Kerberos. Encryption followed by compression on vari-

ous datasets provides better result and protection from vulnerabilities and threats. With the development of wide application of WSN (Wireless Sensor Network) and advanced technologies, the risk to the information security in various government and private sector has increased. Here we integrate the AES encryption standard in XTS mode and digital signature technology to improve classic AODV (Ad hoc On-Demand Distance Vector) routing protocol. The resultant SAODV (Secure Ad hoc On-Demand Distance Vector) routing protocol provides better information security and achieves energy efficiency as well. In this chapter, we reviewed different observations and it is concluded that the algorithm is an appropriate choice.

The chapter is divided into five sections. Section 1 explains the requirement of strict encryption algorithm in current scenario. The concept is suggested with respect to the requirement of security approaches for the UIDAI System. Section 2 describes the importance and benefits of AES -MR technique highlighting the XTS encryption Mode. Section 3 shows the experimental results are explained using implemented simulation environments. It highlights the benefits of using this approach to secure sensitive information. The chapter is finally concluded in Section 4.

1. Requirement of Strict Encryption of Data

Since ages data collection has increased enormously with high velocity. 80% of the total data is collected just during the last two years. This extraordinary growth in data generated is due to miscellaneous activities performed by common man. The advent of technologies like cloud computing, active use of social media, mobile computing, internet of things, sensor-based network etc. requires large and efficient storage with security. This advancement in technology increases the generation of data exponentially and need strict security strategies to be implemented in the system. The sensitive data are stored in various datacenters. The government initiated the concept of Digital India and enforces end us-

ers to link their Aadhaar number with various services. UIDAI system and related infrastructure have already implemented strong security authentication and compliances. With the pace, speed, and momentum the citizens are enforced to link their Aadhaar number with various services to a vail benefits, their concern about the breach of privacy of their data has increased. Citizens of India have submitted their demographic and biometric details to the UIDAI system. To avail benefits, their personal data need to be shared among different agencies. They need assurance that the data will not be misused. Many issues in past were raised regarding misuse of private information, leakage of private information and theft of data. IBM estimates that 90% of the world's data was generated in the last few years alone which has increased the reliability and security challenges to keep safe and secure the enormous data. Major challenges are related to reliable storage, efficient processing, data integrity, and recovery. It is necessary to modify the existing security compliances, legal provisions, and auditing policies.

There are so many technologies and algorithms available which might be appropriate to handle security issues. The study concludes that the implementation of AES XTX with map reduce parallel programming will be a cost-effective solution to process such a large user-generated vital and sensitive data.

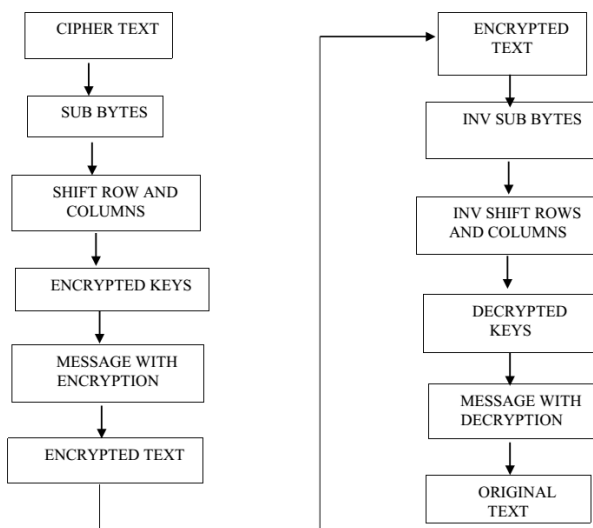


Fig. 1. Encryption and Decryption Process

2. AES-MR

The combination of Advanced Encryption Standards (AES) and Map Reduce (MR) is termed as AES-MR. It is the proposed algorithm for this research work which is related to the case study done for UIDAI to provide better data security. This encryption algorithm is proposed to provide Data level security. Map Reduce is a parallel programming language and AES is the encryption algorithm suitable for longer messages. It is suggested that the best features of both techniques should be used together to provide much stricter security features in the introduced security layer.

Map Reduce with AES-XTS has the capability to compose applications that generates endless data during runtime. It has the ability to adapt non-critical failures and can perform better planning, testing of information. The failed jobs if encountered in the clusters of machines, it re-executes them.

2.1. Proposed encryption algorithm- AES (XTS)-MR

In this proposed technique AES is used with XTS mode which is supported by IEEE 1619-2007 standards [5]. The XTS modes contain XEX-TCB-CTS (XTS) mode where XTS stands the XEX Tweakable Block Cipher with Cipher Text Stealing. The XTS mode performs parallel executions and allows pipelining in respective executions. Data Encryption Standards which were used earlier is vulnerable to Brute Force attacks. It was due to the small size of the key (53 to 2054 bits) DES uses for encryption. US Government Agency NIST (National Institute of Standards and Technology) selected Rijndael's Algorithm as Advanced Encryption Standard. It is being a better security standard now becoming an Industry Standard.

AES is designed to accept 128, 192, 256 bits' size of keys. These various sizes of keys are capable of encrypting different types and variety of information in bulk. The performance of AES algorithms varies on different 32 bit and 64-bit CPU's based on key sizes. This technique will provide better security (Fig.2) in case of the UIDAI system where the large data sets are generated for storing sensitive information of residents and generating UID numbers of a citizen of India.

The block contents can perform parallel processing in various modes of operations. These operations can handle fixed block as well as variable block encryption with the help of single key or different keys.

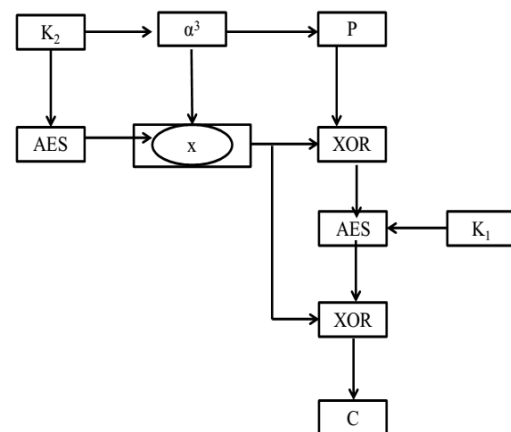


Fig. 2. Operation of AES-XTS Mode with two different keys

2.2. XTS encryption mode

The Electronic Cook Book (ECB) and XTX are used with AES to increase the efficiency of an algorithm and can be improved by the use of it. [5] The XTX supports parallel encryption mode with Symmetric Block Cipher encryption mode. It was designed to protect data lying at rest on storage devices. It uses a fixed

size of data units to perform cryptographic protection of data at rest. The operation of AES -XTX Mode with two different keys is shown in Fig. 2 [12] [5]. The XTS-AES mode is an enhanced concept of Rogaway’s XEX (XOR Encrypt XOR) Tweakable Block Cipher, improved with a method called "Cipher Text Stealing". It expands the range of possible different types of data inputs. XEX can only encrypt sequences of complete blocks of any data type. This input data should be an integer and necessarily be a multiple of 128 bits. In XTS-AES, the data string consists of one or more complete blocks which are followed by a single, non-empty partial block ().

The working of AES-XTS is shown in Fig. 3. The XTS-AES is composed of two keys, first one is an encryption key and second one is tweak key. It incorporates the logical position of the data block into the encryption [11]. The output produced by XTS is independent which leads to parallelization. XTS, an instantiation of the tweakable Block Cipher class. It is capable to implement ciphers in parallel and pipeline modes. It enables the encryption of the last incomplete block also.

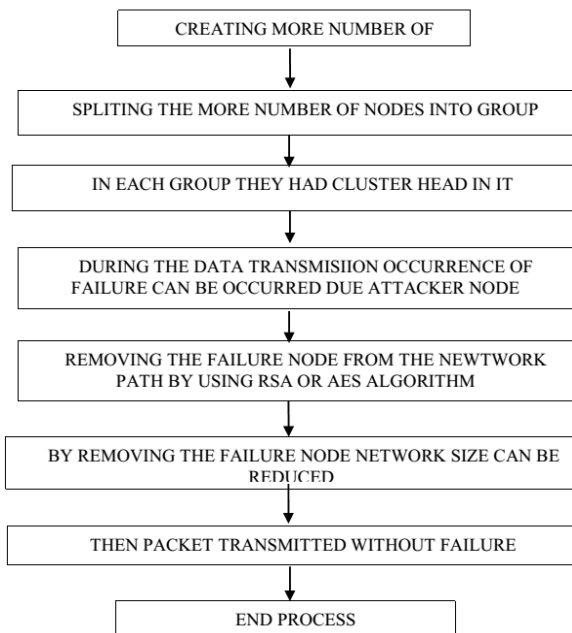


Fig. 3. Flow Chart to show steps used in Implementation Work

3. Experimental result and analysis

The experimented results are drawn are done using various randomly created sizes of datasets. This work integrates the international popular AES-XTS encryption standard to improve existing AODV routing protocol, and uses improved, energy efficient SAODV routing protocol to provide better information security. The details of the simulation environment used to show the proposed implementation work is shown in Table 1.

The theoretical analysis and simulation shows the better performance of SAODV by adding proposed se-

curity mechanism to AODV in the routing layer. The steps of implementation work are shown in Fig. 3.

Table 1

Details of Simulation Environment

CPU type	Intel® Core™ i5 4210U
Clock speed	CPU @2.40 GHz
Ram size	16 GB RAM x-64- based processor
Operating System	Ubuntu Server Basic, 64 Bit Windows 7 Home
Framework	Hadoop Framework
Simulation Tool	NS2
Tools	Ms. Office, MS Excel
Language	Java, , JDK1.8,

3.1. Description of Routing Protocol and its Assigned Protocol: The routing protocol used in this simulation environment to show implementation and other details are shown below in the Table 2 as:

Table 2

Description of Routing Protocol and assigned protocol

Routing Protocols	Remarks
Number of nodes used	31
Node act as source node	Node 2
Node act as destination node	Node 21, 15, 19
Node act as cluster head	Node 4, 9, 16, 26
Mobility speed	10mps
Simulation time	25ms
Transmission range	300m
Mobility movement	Random path
Transmission range	2packets/sec
Number of connection	5 connections
Buffer size	128 packets
Number of graphs	6

3.2. Using AES algorithm

In the below shown screenshot (Fig. 4), it clearly gives the explanation of the process of encryption and decryption by using AES method has been explained. Thus in this first we used plain text after encryption process can be occurred and convert the message into cipher text.

At final receiver want to receive the original message thus the decryption had been occurred and convert cipher text message to original message.

```

ubuntu@ubuntu-vm:~$ cd Desktop
ubuntu@ubuntu-vm:~/Desktop$ cd Arpana
ubuntu@ubuntu-vm:~/Desktop/Arpana$ g++ -g3 -ggdb -D0 -Wall -Wextra -Wno-unused -o AesOutput aesexample2.cpp -lcryptopp
aesexample2.cpp: In function 'int main(int, char**)':
aesexample2.cpp:43:23: warning: comparison between signed and unsigned integer expressions [-Wsign-compare]
     for (int i = 0; i < ciphertext.size(); i++) {
                       ^
ubuntu@ubuntu-vm:~/Desktop/Arpana$ ./AesOutput
Plain Text (71 bytes)
AES Advanced Encryption Standard with both Encryption and Decryption...

Cipher Text (88 bytes)
0xbc 0x19 0xec 0xb2 0xd5 0x5a 0xbe 0x5a 0xd0 0xd0 0xa9 0x28 0x40 0xad 0xfe 0xb7 0x40 0xc4 0x8d 0x43 0x42
0xa8 0x5e 0xd 0xd3 0x12 0xad 0xa1 0x39 0x76 0x2a 0x6a 0xe5 0x48 0x0b 0xac 0x14 0x3d 0xaf 0x79 0x21 0xca 0
x73 0x16 0xc6 0x42 0x5a 0x34 0xa 0x0 0x4d 0xcc 0xf7 0x85 0xfe 0xb8 0x95 0x5 0xae 0x74 0x79 0xd9 0xfc 0x1e
0x94 0x9b 0xf5 0xdc 0x76 0xb8 0xf8 0x33 0x29 0xcd 0x1f 0x83 0xc 0x26 0x66 0xf1

Decrypted Text:
AES Advanced Encryption Standard with both Encryption and Decryption...
    
```

Fig. 4. Screenshot of command used to execute the implementation work

3.3. Output of implementation work

The various output of the implementation work is shown below in the sequence of implementation of work performed.

i) Node formation

The formation of nodes is shown here. In this the total number of nodes used are 31. Among these 31 nodes, four nodes are used as a cluster node. These are node 4,9,16 and 26. The node which acts as a source node is 2. The nodes which acts as a destination nodes are 21,15 and 19. The mobility speed 10 mpbs. The simulation time is 25ms and the transmission range is 300m. The total number of connections used in the implementation are 5 with random mobility movement. The transmission range is 2 packets per second with buffer size of 128 packets. The four channels ch1 as node 4, ch2 as node 9, ch3 as node 16 and ch4 as node 26 are used with Key exchange node as node 7. The total number of graphs shown here are 6.

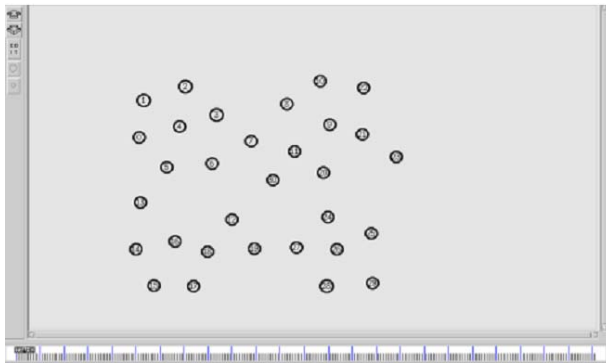


Fig. 5. Screenshot which show Node creation

In the above screenshot (Fig. 5) node creation has been occurred. In this network number of node created is 30.

ii) Allocation of sender and receiver for various nodes

In the below (Fig. 6) screenshot for the formation of group of nodes it had been assign the cluster head with source and destination.

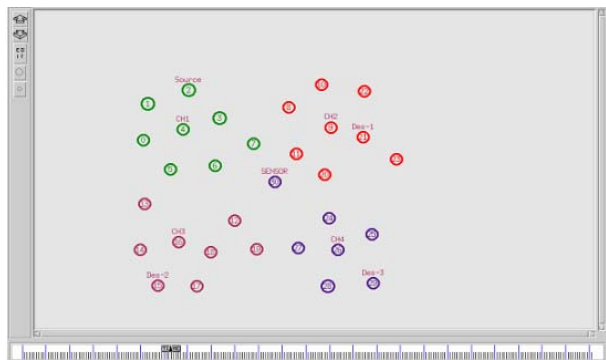


Fig. 6. Assign the cluster head with source and destination

iii) Data transmission

In this graph (Fig. 7) it has shown that how TCP/IP protocol is selected among various channels. The total

channels used here are 4. These are as Ch1, Ch2, Ch3 and Ch4 as node 4, node 9, node 16 and node 26 respectively.

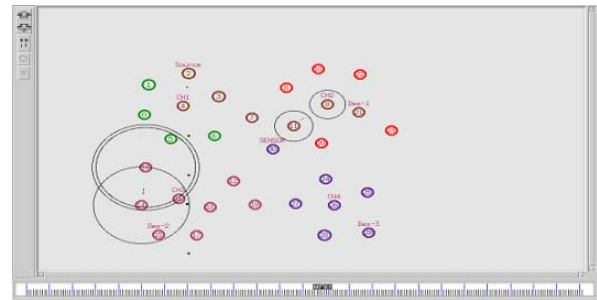


Fig. 7. Selection of Channel by TCP/IP Protocol

In the above after the assigning of cluster head, source and destination the process of transmission had been occurred. While transmitting the data loss may be occurred due to this security of the network had been occurred problem.

iv) Transmission with key exchange

In this graph (Fig. 8) the key exchange node is identified as node 7. It is responsible for exchange of keys while transmission of packets from single source to multiple destinations. It performs encryption and is known to sender and receivers only. As during transmission only, the key exchange node is identified, it is very difficult for hackers to identify it. In this way it provides better security implementation.

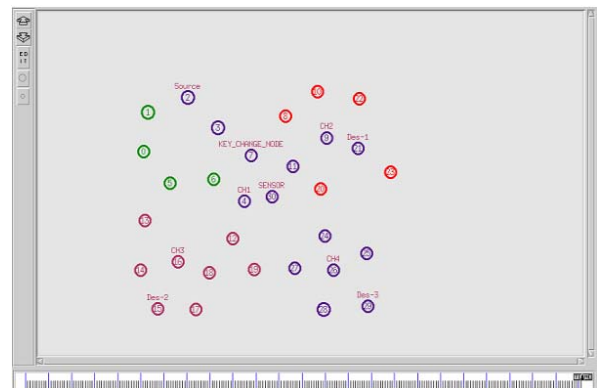


Fig. 8. Transmission of Information with Key Exchange

In the above screenshot due to the occurrence of loss we want to reduce that loss and improve the security of network. We can use the AES algorithm in which while transmitting the data, key had been used to improve the security without any loss in the network.

3.4. Graph Representation

The various output obtained after implementation of proposed technique is shown below in the form of graph as:

i) Drop in data

In this graph (Fig. 9) the packet drop has been showed between both existing and proposed method. Packet drop has been calculated by number packets drop in network while transmitting the data between the different nodes.

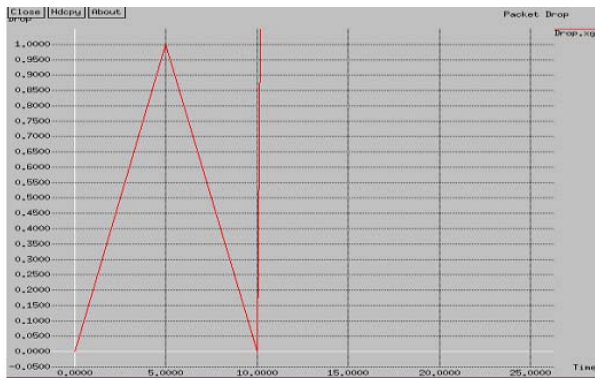


Fig. 9. Packet drop between the Existing and Proposed Method

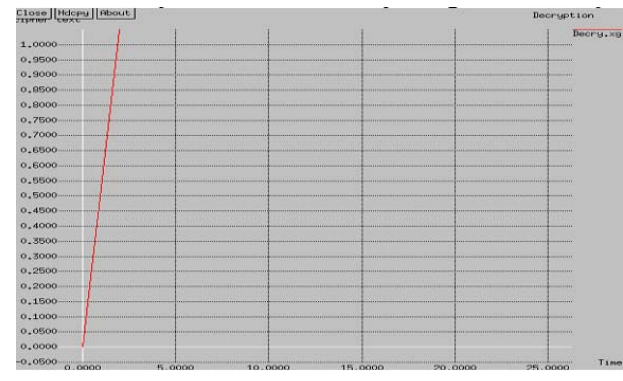


Fig. 11. Data Decryption while Transmission of Information

ii) Data transmission in encryption

In this graph (Fig. 10) the filtering of nodes and packets are shown. It checks the packets which are manipulated while transmission by some intruders, hacker's or by eavesdropping. It does not allow the corrupted packets as removes them and passes rest of the filtered packets. It also checks the nodes. If some nodes through which packets are transmitted are not authorized and registered, it removes it from the channel.

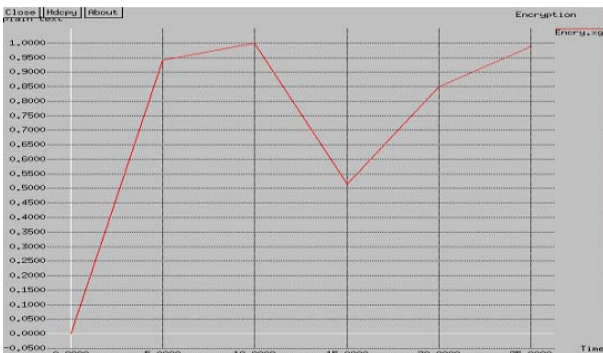


Fig. 10. Filtering of Nodes and Packets

In this graph the data encryption has been showed while transmitting the data. When the sender sends the original data by using encryption process data can be converted to cipher text. During the process encryption of the data in the network has been calculated.

iii) Data decryption while data transmission

In this method, data is decrypted while transmission of data to provide better security using AES technique.

In this graph (Fig. 11.) the data decryption has been showed while transmitting the data. Thus after the process, of encryption data want to decrypt to plain text for the receiver view. Thus data transmission has been calculated in decryption.

iv) Comparison of losses in packets in existing vs. proposed

The loss of data has been showed while transmitting the data. It is identified by particular amount of data loss and filtering of nodes.

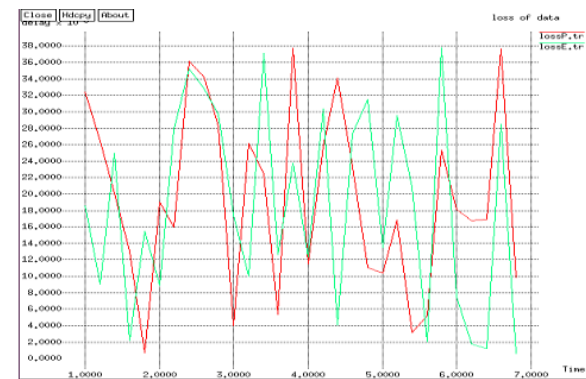


Fig. 12. Loss of Data while Transmission of Information

In this graph, the loss of data has been shown while transmitting the data. When the data transmitted from sender to receiver, the particular amount loss in data has been occurred. Thus it has been calculated and shown in the graph in the relation of existing and proposed method

v) Data packet transmission in various nodes

The data transmission has been showed while transmitting the data in various nodes. Sender sends the data packets in various nodes and it is clear through graph (Fig. 13) that more packets are transmitted in case of proposed methodology in comparison to the existing one. It has shown a 95% of difference in number of data packets transmitted in various nodes and increases the speed of transmission also.

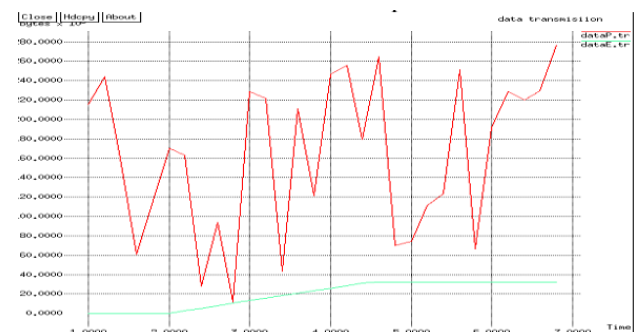


Fig. 13. Increased speed when Data Packets transmitted through Various Nodes

In this graph the data transmission has been showed while transmitting the data from sender to receiver.

vi) Passing of data with individual key values

In this graph (Fig. 14) it's clearly shown that when data passed or transmitted through different channels in the form of packets, using AES -XTS encryption methodology and using key exchange according to this encryption technique, provides better transmission in comparison to existing encryption techniques. The comparison shows 95% of betterment and difference in transmission with individual key values. This proposed encryption technique results in better security implementation in comparison to existing mechanisms

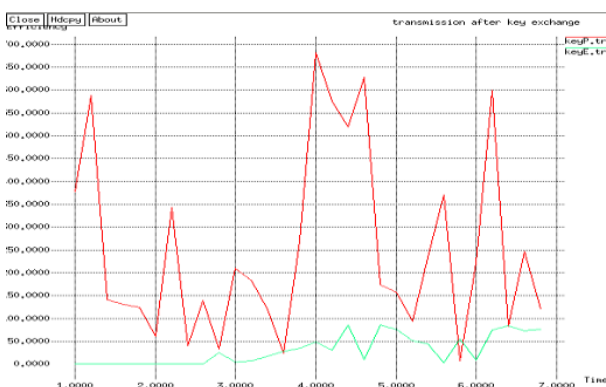


Fig. 14. Comparison of Security implementation in Existing and Proposed Mechanism

In this graph, the data transmission has been shown while transmitting the data from sender to receiver in the presence of the key.

5. Conclusion

In this work we suggested AES-MR encryption technique to be implemented to solve the issue of data security at the storage level i.e. on HDFS (Hadoop Distributed File System). It is done by encrypting the data using AES-MR(XTX) along with compression at Mapper and Reducer phase. AES-MR(XTX) will not only enhance the security of important data at HDFS level but with the help of parallel processing, we can do it with a faster manner as well.

With the help of simulation using NS2 simulator, it is concluded that as the security is key anxiety of the wireless network which transfers data from nodes towards others. In the existing work, the performance of MANET is considered by using different parameters such as Network Overhead, Delay and Throughput. There are a few nodes which increase the system transparency, Delay and reduce Network throughput they are famous as malicious nodes. In proposed work, we used the AES algorithm in WSN and then encryption to expand the demand or of the network. In the future this approach can also be used to get better security in other networks like VANET, SPANs, etc. it has been concluded that AES encryption standard, when used in XTS mode, will give better results in terms of security, Speed of transmission, better filtration of packets and Nodes.

This technology can be used in various services provided by the government nowadays where it became mandatory to use Aadhaar card to link with the services to avail benefits. The block size used in AES is comparatively larger and varied, depending upon the requirement. The encryption process of XTS mode in AES is also complex that hackers cannot easily hack the transmitted crucial information. We can conclude that as AES-MR (XTS) helps to attain all the levels of security that too at a faster speed, it is a good approach.

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Арпана Чатурведі. Реалізація та аналіз продуктивності запропонованих основ безпеки для UIDAI

Розвиток нових технологій, таких як Hadoop, Map Reduce, використовуваних для зберігання, управління і аналізу величезної кількості даних, пов'язаних з WSN (Wireless Sensor Network), збільшує фактор ризику для інформаційної безпеки. При застосуванні їх в різних додатках для уряду, таких як Aadhaar, DigiLocker і т. П., Ймовірність прихованих проблем безпеки збільшується. У цій статті механізм шифрування AESXTS і технологія цифрового підпису використовуються з протоколом маршрутизації AODV (Ad hoc On-Demand Distance Vector), для усунення різних проблем, таких як DoS (відмова в обслуговуванні), прослуховування, імітація, коаксіалізація і т. Д. Теоретичний аналіз проведено з використанням симулятора NS2, а реалізація забезпечує кращу безпеку даних, надійність, передачу та енергоефективність. Представлена реалізація показує, що протокол маршрутизації SAODV (Secure-AODV) при використанні на рівні маршрутизації в цих додатках і системі підвищує його власну

здатність до самооборони для боротьби з різними складними прихованими проблемами безпеки.

Ключові слова: AODV, SAODV, WSN, AES-XTS, UIDAI, DoS.

Арпана Чатурведі. Реализация и анализ производительности предложенных основ безопасности для UIDAI

Развитие новых технологий, таких как Hadoop, Map Reduce, используемых для хранения, управления и анализа огромного количества данных, связанных с WSN (Wireless Sensor Network), увеличивает фактор риска для информационной безопасности. При применении их в различных приложениях для правительства, таких как Aadhaar, DigiLocker и т. п., вероятность скрытых проблем безопасности увеличивается. В этой статье механизм шифрования AESXTS и технология цифровой подписи используются с протоколом маршрутизации AODV (Ad hoc On-Demand Distance Vector), для устранения различных проблем, таких как DoS (отказ в обслуживании), прослушивание, имитация, коаксиализация и т. д. Теоретический анализ проведен с использованием симулятора NS2, а реализация обеспечивает лучшую безопасность данных, надежность, передачу и энергоэффективность. Представленная реализация показывает, что протокол маршрутизации SAODV (Secure-AODV) при использовании на уровне маршрутизации в этих приложениях и системе повышает его собственную способность к самообороне для борьбы с различными сложными скрытыми проблемами безопасности.

Ключевые слова: AODV, SAODV, WSN, AES-XTS, UIDAI, DoS.

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ANALYSIS AND MODELING OF DYNAMIC ROUTING NETWORK PROTOCOLS

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АНАЛІЗ І МОДЕЛЮВАННЯ ДИНАМІЧНОЇ МАРШРУТИЗАЦІЇ МЕРЕЖЕВИХ ПРОТОКОЛІВ

Барбарук Л.В., Михайлова А.О., Бакитько Д.Е.

This article analyzes the work of the OSPF routing protocol. Considered and justified the need for its use, identified the advantages and disadvantages. Analyzed the main features. A comparative analysis of the protocols OSPF and RIP. Based on the work done, conclusions formulated.

Keywords: OSPF, RIP, metrics, interface cost, routing table, packet hops, Cisco Packet Tracer.

Introduction. Network configuration is a complex and often multi-level process, the consequences of which have a huge impact on the future operation of the network. One of the main tasks that need to be addressed when setting up a network is the choice of a routing protocol. A routing protocol is a network protocol used by routers to decide possible routes for results to flow through a composite computer network.

Dynamic routing is a type of routing in which the routing table is programmatically edited.

Dynamic routing protocols are usually divided by the type of algorithms used in them into:

- distance-vector;
- link-state;
- mixed type.

In fact, the protocols, taking into account the state of the channels, have replaced the distance vector protocols. The reasons for this transition were:

- The growth of channel capacity, accounting for which was absent in the distance-vector algorithm.
- The slowness of the distance-vector, which caused by so-called «count to infinity».

The following dynamic routing protocols exist RIP, OSPF, EIGRP, BGP, IS-IS.

Formulation of the problem. Many enterprises, firms, educational and government institutions have their own network in their structure. The properly chosen protocol can help to eliminate loops in the network, quickly identify and bypass its inaccessible areas and minimize the bandwidth used for routing.

The purpose of the article. The main goal of the work is to compare the routing protocols to identify their features and areas of use.

Theoretical information about the protocols.

A. OSPF protocol

One of the most commonly used communication protocols is OSPF.

OSPF (Open Shortest Path First) is a link-state technology routing protocol that has an open specification. To find the shortest path, this protocol uses Dijkstra's algorithm [1].

Among the advantages of OSPF could be distinguished [2]:

- Support VLSM (variable length subnet mask).
- High convergence time.
- Optimum bandwidth time.
- Fault tolerance, which provided by switching the exchange of information to another route for when of failure of one the routers.
- Reduced downtime risks.

B. RIP protocol

RIP (Routing Information Protocol) is an internal remote vector-type routing protocol. It is one of the easiest routing protocols. Based on its limitations, it is mainly used in small networks. Allows routers to update their routing information dynamically by getting it from their neighbor routers [3].

Comparative analysis of OSPF and RIP protocols by main criteria. Comparison of protocols carried out on the basis of key indicators, including security, load balancing, type of algorithm, and some others. The protocol metrics and the routing table configuration were considered in most detail. In addition, the issue was considered the issue of convergence.

Speaking about the comparison of the OSPF and RIP protocols, primarily, note that the OSPF protocol is intended for use in large and complex networks, while RIP is more often used for small networks. A more detailed analysis conducted in Table.

Table

Table of comparison

Indicator	OSPF	RIP
Security	Open password or key authentication MD5	Open password or key authentication MD5
Load balancing	Same metrics	-
Algorithm Type	Link-state	Distance vector
Combining routes	+	-
Variable-length subnet masks	+	+
Maximum number of routers in the network	65534	15
Accounting in the metric of various characteristics of the path	One main and three additional	One main
Update routing information	Only changes	Whole table
Availability of implementation	Open	Open
IPv6 support	+	-

A. Convergence

Network convergence is a necessary characteristic, without which the network is not fully operational. Convergence refers to the process of agreement between all routers on the best routes. Routing algorithms with poor convergence lead to creating routing loops or network failure.

This characteristic implies not only the joint but also the independent operation of devices. Despite fact is that routers communicate with each other, they need to independently find the impact of changes in topology on their own routes.

The following properties of convergence distinguished: the speed of propagation of routing data and calculate optimal paths. The propagation speed correlates with the time needed to send routing information from routers within a network.

Routing protocols are often evaluated by the convergence rate, which means that the faster the convergence performed, the more efficient the protocol is. OSPF, as a relatively new protocol, provides the fastest convergence, which makes it one of the most preferred.

One of the main principles of OSPF operation is that each router inside a zone stores the full topology of its zone. The time of bringing the network into this state is called convergence [4].

B. Protocol metrics

The metrics used by the routing protocols have a direct impact on creating the best route with the least number of hops. OSPF and RIP use different metrics, which described in more detail below.

In OSPF, when choosing the best route, a metric called cost used. It said that each link has a cost, respectively, if the route passes through several links, then their cost summed up. But the best route is the one whose cost is the lowest. The cost of an interface is inversely proportional to its bandwidth [2].

Cisco provides the following costing options:

- Cost calculated as the inverse of the link speed value.
- The cost for each link set by the user manually, based on personal ideas about the quality of this link.

The cost calculated by the formula (1):

$$p = a/b, \tag{1}$$

where p is the cost, a is the specified bandwidth, and b is the bandwidth of interface.

RIP as a metric used packet jump - this is the number of routers through which a packet can pass along a given route. Each hop in the path from the source to the destination assigned a value of the number of hops, which is usually 1. When the router receives an update of the routing information that has a new or modified destination record, the router adds 1 to the metric value specified in the update and writes the network to routing table the sender's IP address is used as the next hop. A directly connected network to the router has a metric of zero; the inaccessible network has a metric 16 [4].

C. Configuring Routing

To configure dynamic routing, the following commands used: router and network. The router command that starts the routing process has the form:

```
Router(config)# router protocol [keyword]
```

where protocol is one of the routing protocols and keyword is an optional parameter.

The network command has the form:

```
Router (config-router)# network network-number [keyword]
```

where network-number is the identifier of the connected network and keyword is an optional parameter [5].

When using the OSPF protocol, when the router configured to work with the protocol, it begins to explore the environment through the following initialization stages [6]:

Use hello to find.

- The phase of first exchange between route bases.
- Sending route information with later confirmation.
- Compiling the routing table.
- Transition to full status.

When using the RIP protocol, the routing process connects the interfaces with the addresses that correspond to them and begins processing packets in specified networks.

Simulation and comparison. Conducting an experiment.

A. Cisco Packet Tracer Features

This simulator was developed by Cisco and recommended for use in the process of studying telecommunication networks and network equipment. But the

Cisco Packet Tracer features are suitable not only for training but also for setting up any network at the planning stage.

It includes the following features:

- Workspace, which used to create a network.
- Simulation, both in simulation mode and real-time.
- A graphical interface that used to interact with the user during the configuration process.
- Image of network equipment with the ability to move, add and remove components.

The software product allows you to design your own networks, create and send data packets. An important feature of the program is the ability to explore and use switches, routers, and workstations. Two simulation modes allow not only to see the result of packet transmission, but also to see their movement in the simulation model.

With the help of commands that entered into the command line of devices, you can display a variety of information about the network, including the routing table [7].

B. Network modeling

For a more detailed analysis of operating the OSPF protocol, a network modeled. Simulations performed using the Cisco Packet Tracer simulator. The network was configured in two ways: using OSPF and RIP. The network depicted in Fig. 1.

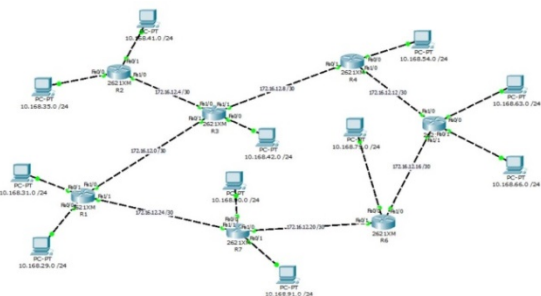


Fig. 1. Simulated network

Both of the resulting networks tested for performance by sending packets. An example of packet transmission shown in Fig. 2

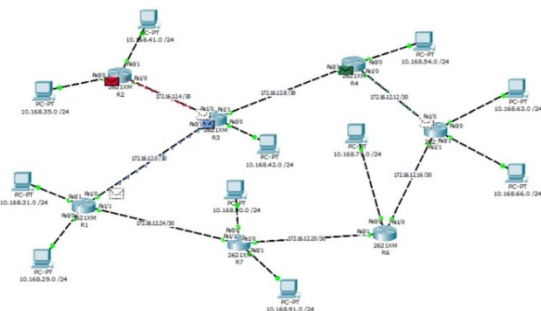


Fig. 2. Packet transmission

C. Routing Configuration Comparison

Configuring network routing using OSPF (3) and RIP (4) presented below. For example, the router R1 taken. Setup made in the command line.

```
R1>ena
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#router ospf 1
R1(config-router)#network 10.168.29.0 0.0.0.255 area 0
R1(config-router)#network 10.168.31.0 0.0.0.255 area 0
R1(config-router)#network 172.16.12.1 0.0.0.3 area 0
R1(config-router)#network 172.16.12.26 0.0.0.3 area 0
```

Fig. 3. Network configuration setup (OSPF)

```
R1>ena
R1#conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#router rip
R1(config-router)#network 10.168.29.0
R1(config-router)#network 10.168.31.0
R1(config-router)#network 172.16.12.1
R1(config-router)#network 172.16.12.25
```

Fig. 4. Network configuration setup (RIP)

The difference in configuration setting is only in the advanced parameters — the inverse subnet mask and indication of the zone used in the OSPF protocol.

Further on Fig. 5-6 shows the routing tables of two networks:

```
10.0.0.0/24 is subnetted, 11 subnets
C 10.168.29.0 is directly connected, FastEthernet0/0
C 10.168.31.0 is directly connected, FastEthernet0/1
O 10.168.35.0 [110/3] via 172.16.12.2, 00:57:06, FastEthernet1/0
O 10.168.41.0 [110/3] via 172.16.12.2, 00:57:06, FastEthernet1/0
O 10.168.42.0 [110/3] via 172.16.12.2, 00:57:06, FastEthernet1/0
O 10.168.54.0 [110/3] via 172.16.12.2, 00:57:06, FastEthernet1/0
O 10.168.63.0 [110/4] via 172.16.12.2, 00:57:06, FastEthernet1/0
O 10.168.66.0 [110/4] via 172.16.12.25, 00:57:06, FastEthernet1/1
O 10.168.66.0 [110/4] via 172.16.12.2, 00:57:06, FastEthernet1/0
O 10.168.79.0 [110/3] via 172.16.12.25, 00:57:06, FastEthernet1/1
O 10.168.90.0 [110/2] via 172.16.12.25, 00:57:06, FastEthernet1/1
O 10.168.91.0 [110/2] via 172.16.12.25, 00:57:06, FastEthernet1/1
172.16.0.0/30 is subnetted, 7 subnets
C 172.16.12.0 is directly connected, FastEthernet1/0
O 172.16.12.4 [110/2] via 172.16.12.2, 00:57:06, FastEthernet1/0
O 172.16.12.8 [110/2] via 172.16.12.2, 00:57:06, FastEthernet1/0
O 172.16.12.12 [110/3] via 172.16.12.2, 00:57:06, FastEthernet1/0
O 172.16.12.16 [110/3] via 172.16.12.25, 00:57:06, FastEthernet1/1
O 172.16.12.20 [110/2] via 172.16.12.25, 00:57:06, FastEthernet1/1
C 172.16.12.24 is directly connected, FastEthernet1/1
```

Fig. 5. Routing Table (OSPF)

```
172.16.0.0/30 is subnetted, 7 subnets
C 172.16.12.0 is directly connected, FastEthernet1/0
R 172.16.12.4 [120/1] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 172.16.12.8 [120/1] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 172.16.12.12 [120/2] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 172.16.12.16 [120/2] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 172.16.12.20 [120/1] via 172.16.12.25, 00:00:00, FastEthernet1/1
C 172.16.12.24 is directly connected, FastEthernet1/1
C 10.168.29.0/24 is directly connected, FastEthernet0/0
C 10.168.31.0/24 is directly connected, FastEthernet0/1
R 10.168.35.0/24 [120/2] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.41.0/24 [120/2] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.42.0/24 [120/1] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.54.0/24 [120/2] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.63.0/24 [120/3] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 10.168.66.0/24 [120/3] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.66.0/24 [120/3] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 10.168.79.0/24 [120/2] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 10.168.90.0/24 [120/1] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 10.168.91.0/24 [120/1] via 172.16.12.25, 00:00:00, FastEthernet1/1
```

Fig. 6. Routing Table (RIP)

Both routing tables show directly connected devices and the paths along which devices that at distance from the router are connected, as well as the ports used for this.

In addition, we can see the difference in the administrative distance, which is 110 for OSPF and 120 for RIP.

The designation O is the address formation by the OSPF protocol, and R is the address formation by the RIP protocol, respectively.

D. Comparing Metrics

An important difference between OSPF and RIP could be observed in the metrics that they use. These data could be viewed, and in some cases even changed, when you configure the network in Cisco Packet Tracer. In Fig. 7 marked packet hop for RIP:

```

172.16.0.0/30 is subnetted, 7 subnets
C 172.16.12.0 is directly connected, FastEthernet1/0
R 172.16.12.4 [120/1] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 172.16.12.8 [120/1] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 172.16.12.12 [120/2] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 172.16.12.16 [120/2] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 172.16.12.20 [120/1] via 172.16.12.25, 00:00:00, FastEthernet1/1
C 172.16.12.24 is directly connected, FastEthernet1/1
C 10.168.29.0/24 is directly connected, FastEthernet0/0
C 10.168.31.0/24 is directly connected, FastEthernet0/1
R 10.168.35.0/24 [120/2] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.41.0/24 [120/2] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.42.0/24 [120/1] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.54.0/24 [120/2] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.63.0/24 [120/3] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 10.168.66.0/24 [120/3] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.66.0/24 [120/3] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 10.168.66.0/24 [120/3] via 172.16.12.1, 00:00:06, FastEthernet1/0
R 10.168.75.0/24 [120/2] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 10.168.90.0/24 [120/1] via 172.16.12.25, 00:00:00, FastEthernet1/1
R 10.168.91.0/24 [120/1] via 172.16.12.25, 00:00:00, FastEthernet1/1
    
```

Fig. 7. Hop records (RIP)

For greater clarity, one route considered for both networks using the traceroute command. The results presented in Fig. 8-9:

```

R1#traceroute 10.168.54.0
Type escape sequence to abort.
Tracing the route to 10.168.54.0

 0 172.16.12.0 30 msec 30 msec 30 msec
 1 172.16.12.2 47 msec 31 msec 32 msec
 2 172.16.12.10 23 msec 62 msec 46 msec
    
```

Fig. 8. Traceroute (OSPF)

```

R1#traceroute 10.168.54.0
Type escape sequence to abort.
Tracing the route to 10.168.54.0

 0 172.16.12.0 30 msec 30 msec 30 msec
 1 172.16.12.1 32 msec 31 msec 31 msec
 2 172.16.12.10 47 msec 62 msec 62 msec
    
```

Fig. 9. Traceroute (RIP)

We can notice that there is no difference in the number of packet hops, but there are small differences in time in favor of the OSPF protocol.

In addition, on the network using OSPF it is possible to find out and change the cost of interface, as one of the main protocol metrics. To do this, use the command:

```
R1#show ip ospf interface
```

The results shown in Fig. 10:

```

R1#show ip ospf interface
FastEthernet0/0 is up, line protocol is up
Internet address is 10.168.29.1/24, Area 0
Process ID 1, Router ID 172.16.12.26, Network Type BROADCAST, Cost: 1
Transmit Delay is 1 sec, State DR, Priority 1
Designated Router (ID) 172.16.12.26, Interface address 10.168.29.1
No backup designated router on this network
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
No Hellos (Passive interface)
Index 1/1, flood queue length 0
Next 0x0(0)/0x0(0)
Last flood scan length is 1, maximum is 1
Last flood scan time is 0 msec, maximum is 0 msec
Neighbor Count is 0, Adjacent neighbor count is 0
Suppress hello for 0 neighbor(s)
    
```

Fig. 10. Interface Cost (OSPF)

Changes in cost will make adjustments to the formation of routes.

The Cisco Packet Tracer simulator does not provide for such commands for the RIP protocol since the protocol has a completely different principle of route generation. Accordingly, introduction of changes by the user is also not provided.

At the same time, the software product allows you to consider most of the features of the protocols, which reflected in the work.

Conclusions. According to the results of the study, we can conclude that the OSPF protocol is one of the most popular in the modern world, but this, for the most part, concerns networks with a large number of nodes. Many factors contribute to this, in particular, the high time of network convergence. Best of all, the difference between the OSPF protocol and others can be seen in the example of comparison with other dynamic protocols, like the RIP protocol used in the work. It can be concluded that the results of the two protocols may be about the same, provided that the network being studied is small. In addition, the OSPF protocol has more functionality than the older RIP protocol. The analysis and comparison carried out in this paper allow us to draw conclusions about feasibility of using the OSPF protocol in certain conditions.

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Барбарук Л.В., Михайлова А.О., Бакитько Д.Е.
Аналіз і моделювання динамічних протоколів мережі маршрутизації

У цій статті аналізується робота протоколу маршрутизації OSPF. Розглянуто та обґрунтовано необхідність його використання, виявлені переваги і недоліки. Проаналізовано основні особливості. Порівняльний аналіз протоколів OSPF і RIP. На підставі виконаної роботи зроблені висновки.

Ключові слова: *OSPF, RIP, метрики, вартість інтерфейсу, таблиця маршрутизації, стрибки пакетів, Cisco Packet Tracer.*

Барбарук Л.В., Михайлова А.А., Бакитько Д.Э.
Анализ и моделирование динамических протоколов сети маршрутизации

В этой статье анализируется работа протокола маршрутизации OSPF. Рассмотрена и обоснована необходимость его использования, выявлены достоинства и недостатки. Проанализированы основные особенности. Сравнительный анализ протоколов OSPF и RIP. На основании проделанной работы сделаны выводы.

Ключевые слова: *OSPF, RIP, метрики, стоимость интерфейса, таблица маршрутизации, прыжки пакетов, Cisco Packet Tracer.*

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METHODOLOGICAL APPROACH TO COMPUTER NETWORK DESIGN

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МЕТОДОЛОГІЧНИЙ ПІДХІД ДО ДИЗАЙНА КОМП'ЮТЕРНОЇ МЕРЕЖІ

Барбарук Л.В., Лавриненко О.О., Квасов І.О.

This article proposed a methodological approach to modeling computer network for business center. It describes the main problems that can be encountered when designing a network. Developed by method will help to minimize costs, quickly implement the designed net-work to the enterprise and save time. When selecting a program, all criteria were taken into account, and only after that was NetCracker selected.

Keywords: simulation modeling, NetCracker, design, statistical data.

Introduction. From year to year information technologies are developing more and more in all fields of human's activity. Such field as data transmission networks, without which information exchange of data is practically impossible, isn't left without attention. In such situation, analysis of technical characteristics remains the main most urgent task in the field of information technologies.

Network design is very hard work, especially for multi-element networks in large enterprises and in different business centers.

System administrators may not always know how it will work in real life. Risks, which connected with loss of network's workability, are high, and the costs are too high. This could be avoided with help of simulating modeling, which allows simplifying design and to test, checking all modules are correctly selected, as well as evaluate and conduct experiments with the proposed system without direct influence on it.

Defining and solving a problem with simulation modeling of networks is actual too, it allows to plan prematurely, analyze the possibility of problems' existence in the process of development and exploitation, conduct validation of correctness and ability of network to work on various functional positions, conduct the research of new technologies and mechanisms, but the main thing – is to save money.

Problem definition. At this stage it is necessary to foresee all possible problems and factors, with influence

on goal of this work, namely modeling computer network with help of program NetCracker [1].

It should be noted, that package NetCracker is developed especially for a big circle of people, so the proposed program can be used in teaching specialists in field of telecommunications, the choice also due to the fact that this comprehensive program is available for every user.

To carry out modeling of network, it is necessary to solve the following problems:

- size of network (number of users, users' location/equipment's location);
- number of data, which was transferred or received;
- data's safety;
- another important factors as requirements to connection (wired, wireless or combined), cable type, type of used computers/devices and their location;
- network assignments – exchange of information/data between computers, programs/database hosting.

This article will be considered computer network of business center.

In order to automate the work of business center, it is proposed to design information system, which consists of:

- cable network and active network equipment;
- computer peripheral equipment;
- storage equipment (server);
- system (operation systems, database management systems), special (monitoring and network management systems) and application software.

In order to research the possibilities of the developed information system of a business center, its modeling is necessary at the design stage. In this case, the modeling process is a research of the information system by conducting a series of computational experiments using specialized software.

Based on the fact that the physical basis of the information system consists of a cable network [2], active network and computer peripheral equipment,

modeling is reduced to the development of a local computer network model.

In order of reduction the time and financial costs of developing computer networks on a local scale, it is necessary to develop a methodological approach to designing a computer network for a business center through modeling.

The design of network. Network design is a hard process that involves topological design. In the network design process, it is necessary to determine where to place the components and how connect them. The designed network must necessarily meet the needs of subscriber and operator. Therefore, to achieve this goal, it was necessary to follow clear rules for network design. However, there are two important elements that affect network design – bandwidth and data transfer delay.

Bandwidth in computer network refers to the speed at which data can be transmitted through a network connection or interface. When processing various types of network data, an important element of speed is data transfer delay. Utilities such as ping and traceroute typically estimate delay by determining the time it takes a network packet to move from source to destination and back.

A. Analysis of computer network modeling software.

Currently, the use of expert assessment theory is the most common approach to the design of computer networks. Specialists, based on their own experience, design a system that provides a solution to a specific task or class of problems in the field of computing facilities [3]. This approach allows:

- at the design stage to minimize costs;
- quickly estimate the cost of implementation of information system.

However, the solutions which were obtained with the help of expert assessments have their disadvantages:

- difficulty in obtaining reliable results;
- research depend on the knowledge and preparedness of the expert;
- subjectivity of the method;
- collection of information requires large labor costs;
- requests for highly qualified specialists to conduct a survey.

Another variant, which can be used in an approach involving the improvement of the network and the research of its work with the help of special modeling-oriented computer networks. Using such software tools, you can create a network model based on the source data:

- network topology and protocols, which are used in it;
- feature of request flows between networks;
- length of communication lines;
- hardware and software [4].

The main indicators that influence the choice of modeling tools are the availability of a database of software and hardware network equipment, which

determines the adequacy of developed models, the ability to analyze network parameters, recover from a failure, and their cost. Therefore, to achieve this goal was selected system NetCracker.

The NetCracker program has many features; with its help you can create a network model almost any scale –from local for several users to the region level. There will be no difficulties with this program, as it is easy to configure and relatively easy to use thanks to the user-friendly interface and the use of the «drag and drop» technology.

NetCracker contains a very large database that contains about 5000 different devices (repeaters, switches, network adapters, servers from different manufactures) and contains information about them. Also, there is information about the load generated by various software. If the database doesn't contain the necessary elements, then it can be updated through the Internet through the official website from the manufacture's server.

Every device contains a set of features, which describe such data in details as:

- data transfer speed;
- delay;
- filtering and forwarding packets;
- used protocols;
- types of ports, their availability;
- description of the interface card.

Software and hardware in total amount allow to describe various network architectures: client-server, VLAN (virtual local area network), intranet, wireless networks.

B. Methodological approach to design computer network of business center

Using approaches and principles of organization and functioning of networks, a methodological approach to the design of a computer network of business center has been proposed, which involves the implementation of the main stages:

- 1) analysis and description of the design area;
- 2) determination of the overall structure of the business center;
- 3) implementation of the topological synthesis of the optimal network structure;
- 4) formation of the description of the technical equipment of the business center;
- 5) research of the local computer network using method of simulation modeling.

According to the first design stage, the analysis and description of the design area, the business center, was carried out.

At the second stage, the general structure of the local network is determined.

The third is the choice of topology. The optimal topology for this network is a tree (Fig.1).

At the fourth stage, following actions were performed to build the network. Following elements are selected: Digital PC 5510 short-tower-300MHz, ProFast Switch/DES-810, StepServer VL PCI и Cisco 803-BT1. A connection has been created between clients and

switches, between switches and router, as well as between a server and a switch. The characteristics of the channel indicate the type of cable (twisted pair), its length and the maximum transmission rate (100 Mbps).

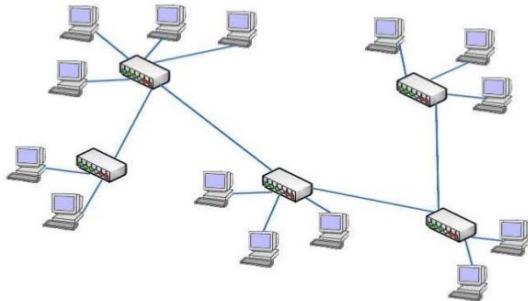


Fig. 1. Tree topology

Results of experiment. At the fifth stage experiment in developed simulation model was conducted.

To obtain statistical data on the distribution of the percentage of packets' traffic used by various devices, a traffic distribution law was established with the following data:

- 1) The exponential law of traffic distribution.
- 2) The time between transactions (batches) is 0,05 seconds.
- 3) The packet size transferred between clients and the server was set to 50 Mbps.
- 4) Simulation time is 10 seconds.

Traffic type has been set: LAN peer-to-peer traffic; FTP; E-Mail (SMTP); HTTP.

The process of simulation modeling according to scheme is shown on Fig. 2. The same applies to the Erlang laws and the Uniforms law. Figure shows the statics of the packets used, obtained during the simulation experiment.

Data that was displayed:

- average load of nodes;
- number of received packets;
- average delay.

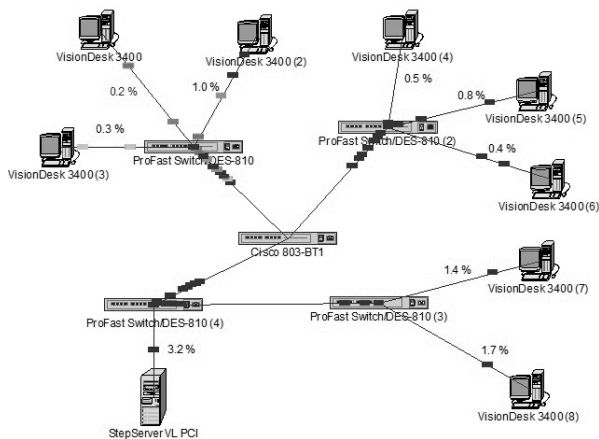


Fig. 2. NetCracker network modeling scheme

After the completion of the simulation experiment, statistical data were obtained – the percentages of the used packets, which were listed in Table.

Table

Statistical data of the utilized packages' percent

The size of the utilized packages distributed after the Exhibitor	The size of the utilized packages at distribution under the law of the Erlang	The size of the utilized packages of the Uniforms distributed under the law
1,8	1,8	1,8
1,1	1	1,1
0,5	0,4	0,7
15,1	21,3	18,8
4,4	6,2	4,4
1,3	1,4	2,9
1	1,3	2,1
0,3	0,2	0,8
14,9	21,2	16,7
0,4	0,5	0,4

The results of simulation modeling of the department's local network indicate that the average load on communication channels, depending on the operating modes, is 10-50 Mbit/s, and the channels are used by no more than 50%, which meets the requirements.

The calculation was made according to the formula:

$$U = \frac{\max(Q_{\max}, Q_{gen})}{Q_{\max}} * 100\%, \tag{1}$$

where U is the utilization rate of the mono channel;

Q_{\max} - maximum throughput without taking into account the cost of waiting between packet transmission [bit/s];

Q_{gen} - bandwidth, demanded from the mono channel by the station [bit/s];

$Q_{gen} = k * Q_i$, where Q_i - loads from each class of the application, [bit/c].

Conclusions. The proposed approach is a methodological tool for the developer and allows reducing the time needed for designing local computer networks, as well as improving the quality of developing projects for local computer networks by using specialized software at the stage of analyzing possible topological structures and choosing software and hardware.

A methodological approach to the design of a computer network of a business center has been proposed. On its basis, a local network was designed, which would allow individual users to easily and quickly interact with each other. The main tasks performed by this network:

- joint work with documents;
- archiving and saving work performed on the server, to save space on the hard disk;
- simplified workflow.

Also, simulation network modeling was done in various conditions. The results of the study indicate that using the proposed approach allows designing in cases where analytical calculations are cumbersome, and sometimes impossible, to identify problem areas of networks and take appropriate measures at the design stage, to select active network and cable equipment.

The prospect of further research may be designing a corporate network based on the proposed methodological approach.

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Барбарук Л.В., Лавриненко О.О., Квасов І.О. Методологічний підхід до дизайну комп'ютерної мережі

В даній статті запропоновано методологічний підхід до моделювання комп'ютерної мережі для бізнес-центру. Описуються основні проблеми, з якими можна зіткнутися при проектуванні мережі. Розроблений метод допоможе мінімізувати витрати, швидко впровадити спроектовану мережу на підприємстві і заощадити час. При виборі програми були враховані всі критерії, і тільки після цього був обраний NetCracker.

Ключові слова: імітаційне моделювання, NetCracker, дизайн, статистичні дані.

Барбарук Л.В., Лавриненко О.А., Квасов И.А. Методологический подход к дизайну компьютерной сети

В данной статье предложен методологический подход к моделированию компьютерной сети для бизнес-центра. Описываются основные проблемы, с которыми можно столкнуться при проектировании сети. Разработанный метод поможет минимизировать затраты, быстро внедрить спроектированную сеть на предприятии и сэкономить время. При выборе программы были учтены все критерии, и только после этого был выбран NetCracker.

Ключевые слова: имитационное моделирование, NetCracker, дизайн, статистические данные.

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REMOTE PARKINSON'S DISEASE MONITORING SYSTEM: FROM SMARTPHONE TO CLOUD PLATFORM

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СИСТЕМА ВІДДАЛЕНОГО МОНИТОРИНГУ ХВОРОБИ ПАРКІНСОНА: ВІД СМАРТФОНА ДО ХМАРНОЇ ПЛАТФОРМИ

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Parkinson's disease (PD) is a slowly progressive disorder that affects movement, muscle control, and balance. The earlier treatment can prevent the disease from developing and to prolongate the diseases prodromal phase. In this context, home monitoring services are potentially powerful tools for remote diagnosis and can improve healthcare services. Tremor is the most common symptom of a PD disorder and it has several advantages for continuous PD symptoms monitoring. The developing of solution based on smartphone sensors that allow remote monitoring of the monitored user is present. The connection between the smartphone application and cloud platform for smartphone sensors data transmission for early tremor symptoms detection is developed. It includes developing of configuration of smartphone application for sensor data transmission and developing of configuration of a cloud platform for tremor symptoms monitoring. The active tests were developed to capture a motor disorder, that indicates PD symptom such as tremor. Initial trials of the developing demonstrated that the monitoring system has the ability to real-time data acquisition and transmission using smartphone sensors and cloud storage. The connection settings developed for the system proved to be efficient when sensor data transmitted from the smartphone to cloud storage. The period of time required to transfer data to the cloud equal to the period of time less than one second.

Keywords: health monitoring system, smartphone application, Parkinson's disease, data transmission

1. Introduction

Parkinson's disease (PD) is a slowly progressive disorder that affects movement, muscle control, and balance.

In recent years, it has become clear that some symptoms of PD occur decades before the development of motor symptoms and clinical diagnosis, and that monitoring these symptoms may provide earlier PD detection. This may enable earlier treatment to prevent the disease from developing and to prolongate the diseases prodromal phase [1].

Using data from wearable devices, such as smartphone sensors, for movement measurements, the

earlier detection of motor symptoms will become possible [2].

Parkinson's disease is characterized by four motor disorders: muscle rigidity, hypokinesia, tremors, and postural instability. The authors [3] present a method to quantify PD motor symptoms using an accelerometer, and researchers have extensively tested the validity of such technologies for examining specific motor tasks in controlled experimental settings [4, 5]. The findings suggest that technologies have high sensitivity and specificity for differentiating PD-specific mobility patterns from those of healthy controls and for classifying PD severity and progression within PD patients [6, 7].

Tremor is the most common symptom of a movement disorder [8] and it has followed advantages for continuous PD monitoring. Tremor is

- the most common symptom of movement disorder;
- appears at the early stage of diseases;
- the most obvious symptom;
- easy to detect.

Longer monitoring of tremors can make a diagnosis of Parkinson's disease more reliable. Outside the clinic, patient monitoring is used to monitor tremors. However, inconsistencies between these reports and objective tremor assessments are most often found. Long-term recordings at home can be useful for obtaining an objective assessment of tremor and identifying changes in tremor presentation that cannot be observed in the clinic. However, the inconvenience of long-term records lies in a large amount of data generated. Analysis and processing of these data will take a very long time [9].

In this context, home monitoring services are potentially powerful tools for remote diagnosis and can improve healthcare services.

A large variety of biomedical sensors is used to obtain a variety of human physiological signals [10]. The processing and analysis of these signals to monitor human health can be performed using a user's mobile device or server in cloud storage.

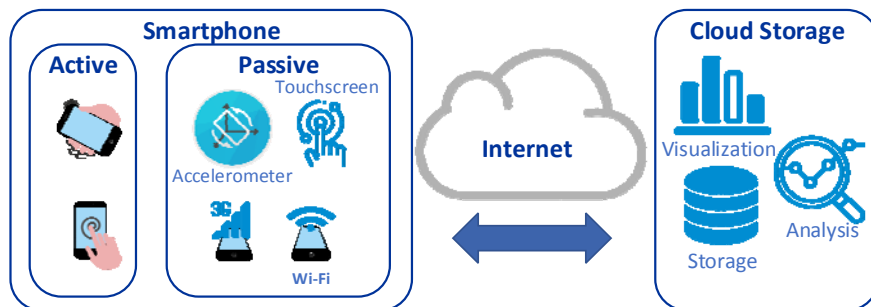


Fig. 1. Architecture of PD monitoring system

Smartphone sensors and web-based cloud platform enable remote monitoring, evaluation and daily monitoring of person with PD and earlier detection of PD symptoms.

The paper presents developing of solution based on smartphone sensors that allow remote monitoring of the monitored user. The system can detect and quantify the motor symptom of PD such as tremor.

The proposed solution consists of a smartphone application, a cloud platform that receives and processes daily motion information of a monitored user, gathered from a data of smartphone sensors.

The system aims to provide a tool for the objective and efficient monitor the status of a monitored user in Parkinson's disease context.

The goal of the research is developing connection between mobile application and cloud platform for smartphone sensors data transmission for early tremor symptoms detection. The objectives are:

- developing of configuration of smartphone application for sensor data transmission;
- developing of configuration of a cloud platform for tremor symptoms monitoring.

2. System Architecture

The proposed system allows the monitoring of PD symptoms remotely by using an application installed on the users' own smartphone. The most significant benefit using of smartphone-based approach is high accessibility. Smartphone-based approach helps to enable automated acquisition, transmission, processing and analyzing of the monitored user data. The core of the smartphone application is the testes to monitor and assess PD symptoms, which consists of active tests, that are initiated and self-administered by the participants at various times during the day. The accelerometer and touchscreen used in these tests. The tests are designed to measure symptom of motor function, such as tremor. The system can detect and quantify the motor symptom of PD such as tremor. The system is used Back4App platform to data collection, the processing will be done in the cloud while allowed users can view and manage all the information related to the monitored user using a web browser.

The system architecture include smartphone, communication channel, cloud storage.

2.1. Cloud platform for tremor symptoms monitoring

The Back4App platform is offered as cloud storage [11]. The platform provides the features discussed below.

Live Query function enables to subscribe to a specific query, store and synchronize app data in real-time.

JSON Import / Export function help import and export JSON files using Parse Dashboard.

The function of Manage Parse Server Versions allows ensuring full compatibility between app and server versions.

Parse Command Line Tool can be used to perform various actions on your Parse app. It can be used to create new Parse apps, deploy Cloud Code to an app, view all releases, and more.

Back4App platform allows monitoring of several users.

In order to use the system, users need only have a smartphone or tablet and Internet access to upload their data to the server. Any device that logged in with a user account can then access data from the server through Wi-Fi or a mobile data network. The system includes an Internet server that is responsible for storing and processing secure data readings.

Thus, the platform allows to reliably track user data without significantly filling up the phone memory and using the smartphone's energy resources. The collected data is stored locally in the memory of the smartphone, and then transmitted to the cloud via the device, initiating an authenticated HTTP push request.

2.2. Smartphone applications requirements

Constant breakthroughs in medical sensor technology and mobile devices fields, combined with growing wireless communication capabilities, have made possible the emergence of new health monitoring paradigms. A smartphone has many additional abilities like a Wi-Fi, Bluetooth, infrared, large memory and an operating system. These technologies make smartphones a personal device that is not always on but is always somewhere on us providing an always-available computing environment with many applications that can be used for continuous health state monitoring.

The mobile application of the personal health monitoring system is used to obtain data on the presence or absence of tremor symptoms. Data acquisition occurs when conducting two tests using the built-in mobile phone sensors described above. The tremor test is performed using an accelerometer and a capacitive touchscreen.

Also, the developed smartphone application is used for preliminary processing of the obtained data. It consists of assigning timestamps to test data. The mobile application store obtained data and processed it in the internal memory of the phone (in the absence of an

Internet connection). It is transmitted data to the cloud using a wireless Wi-Fi or a mobile 2G network.

The experiment run on the conditions, includes follow parameters (but not limited of). The minimum system requirements of the mobile application have been determined. The smartphone app module should run on Android 4.4 and higher. Minimal requirements to characteristics of smartphone and Internet connection are presented in Table.

Table

Smartphone Characteristics	
Characteristics	Requirements
Display	5.5 "
RAM	2 Gb
Internal storage	16 Gb
Wi-Fi connection	~20 Mb/s
2G connection	~473,6 Kb/s

3. Case study

3.1. Active test for tremor symptoms monitoring.

In the current release, the personal mobile sensing system includes two tests for evaluating motor symptoms of Parkinson's disease. They are tremor tests using an accelerometer and tremor test using a touchscreen.

This is the simplest test performed with the smartphone at arm's end. The software for tremor testing via accelerometer performs the following functions: data acquisition from the smartphone accelerometer; time-series data preprocessing; sampling; data transformation for processing and analysis; transferring to the cloud storage; normalizing the values of the accelerometer data array to gravity "g."

The software for tremor testing via the touchscreen assumes the following operations: user login; data acquisition from the results of spiral test execution; data processing; data transferring to the cloud storage.

The target object on the screen is a spiral line. User actions during the spiral test using a touchscreen are as follows. At the first stage, it is necessary to go over the spiral on the screen. The person should perform flowing motion by their index finger and avoid sharp movements as much as possible. On the second stage, the spiral line becomes flashing. The task is the same, to run the finger along the spiral line.

3.2. Developing setting of a smartphone application for data transmission

Developing settings of a smartphone application for data transmission.

Consider the developing of settings of a configuration for a smartphone application for data transmission. At this stage, Android Studio [12] is used. In order to demonstrate the developing of settings of a configuration for data transmission, the accelerometer tremor test is used. The developing consist of several steps.

The first step is follows. The new layouts for smartphone application are created as follow. Using path "app → res → layout" create the following files: activity_accelerometer; activity_login; content_accelerometer; content_login.

The next step is checking to create files using path "layout → New → Layout resource file". The "toolbar" was created in follow files: "activity_accelerometer" and "activity_login". The next step is applied path "palette" → "container" → "AppBarLayout". And the next step, the creating "include" in follow files: "activity_accelerometer" and "activity_login" with links to "content_accelerometer" and "content_login" respectively. The next one is applied path "palette" → container → <include>. Choose "content_accelerometer", use window "component tree", and do follow constraintLayout→ convert view→ relativeLayout→ apply. The elements from "palette" placed on the screen and insert text from brackets on the bottom respectively in the ID field of attributes.

```

TableLayout
TableRow
    textView (txtXLabel)
TableRow
    Button (read_btn)
TableRow
    LinearLayout (Layout_Graph_Container)
    
```

The "content_login" was be chosen, the button (element "button") is placed, and the "btn_login" is written to ID field. In menu file "menu_menu" the element "item" with ID "action_logout" must be created. The developing code [13] was copied to res → values → strings.

3.3. Data transmission to cloud platform using smartphone application

The free cloud storage platform [11] is used. The new app was build and key of "Application ID" and "Client key" are copied. To access the device, the Internet and the ability to data synchronize, determined the permissions using follow path "app → manifest → AndroidManifest.xml"[14]. The following line was added to "AndroidManifest.xml".

```

<?xml version="1.0" encoding="utf-8"?>
<manifest
xmlns:android="http://schemas.android.com/apk/res/android"
package="com.example.myapplication">
.....
<uses-permission android:name="android.permission.INTERNET" />
<uses-permission android:name="android.permission.ACCESS_NETWORK_STATE" />
<uses-permission android:name="android.permission.GET_ACCOUNTS" />
<uses-permission android:name="android.permission.READ_PROFILE" />
<uses-permission android:name="android.permission.READ_CONTACTS" />
<uses-permission android:name="android.permission.VIBRATE" />
.....
    
```

The next step is the "Java com.example.appname" using and the "new → Java Class" choosing, and following files are created: AccelAnalysis; AccelData; Login; MainActivity; ParseApp; ParseFunctions; Statistics.

The configuration settings [15] are used.

For connecting the smartphone application to cloud storage, the "Application ID" and "Client key" were added to the ParseApp file.

For correct connecting of the smartphone application to cloud storage and data visualization, the libraries [16] must be copied follow path "app → libs".

The following code was written to file build.gradle(Project: appname).

```
allprojects {
    repositories {
        ...
        maven { url "https://jitpack.io" }
    }
}
```

The following code was written to the end of file build.gradle(Module:app).

```
dependencies {
    implementation 'com.github.parse-community.Parse-SDK-Android:parse:1.18.5'
}
```

4. Testing and evaluation

In order to demonstrate the connection reliability of the monitoring system, the active tests provided on 2 healthy individuals with no previously diagnosed motor conditions. As a comparison, the tests were also run an additional 2 times with simulated Parkinson's disorder, such as tremor. The data was transmitted from smartphone application using Wi-Fi network to cloud storage. The time delay of data transmission is up to 1 seconds. The dashboard on Back4Upp platform used for real-time data visualization. Viewing the real-time data using a web browser is shown in Fig. 2.

5. Conclusion and future work

We have developed settings of configuration connection of a monitoring system for the continuous home assessment of PD symptoms, such as tremor, using smartphone embedded sensors. The configuration connection consists of settings for two components: a smartphone application and cloud storage. The active tests were developed to capture a motor disorder, that indicates PD symptom such as tremor. Initial trials of the developing demonstrated that the monitoring system has the ability to real-time data acquisition and transmission using smartphone sensors and cloud storage.

The connection settings developed for the system proved to be efficient when sensor data transmitted from the smartphone to cloud storage. The period of time required to transfer data to the cloud equal to the period of time less than one second.

In addition, future work will involve developing and implementation of a technique for tests data processing and analysis for PD symptoms detection.

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Бережний О.В., Білобородова Т.О., Скарга-Бандурова І.С. Система віддаленого моніторингу хвороби Паркінсона: від смартфона до хмарної платформи

Хвороба Паркінсона - це повільно прогресуюче захворювання, яке впливає на рухову активність, м'язовий контроль і баланс. Більш раннє лікування може запобігти розвитку хвороби і продовжити продромальну фазу захворювання. У цьому контексті домашній моніторинг є потенційно потужним інструментом для дистанційної діагностики та може поліпшити надання медичної допомоги. Тремор є найбільш поширеним симптомом хвороби Паркінсона і має кілька переваг для постійного моніторингу її симптомів. Представлена розробка рішення на основі сенсорів смартфонів, що дозволяють здійснювати віддалений моніторинг спостережуваного користувача. Розроблено підключення між додатком для смартфона і хмарної платформою для передачі даних з датчиків смартфона для раннього виявлення симптомів тремору. Воно включає розробку конфігурації програми для смартфона для передачі даних з датчиків і розробку конфігурації хмарної платформи для моніторингу симптомів тремору. Активні тести були розроблені для виявлення рухового розладу, який вказує на симптом хвороби Паркінсона, такий як тремор. Початкові випробування розробки продемонстрували, що система моніторингу має можливість в реальному часі збирати і передавати дані за допомогою датчиків смартфона в хмарне сховище. Параметри підк-

лючення, встановлені для системи, виявилися ефективними при передачі даних датчика зі смартфона в хмарне сховище. Період часу, необхідний для передачі даних в хмару, дорівнює періоду часу менше однієї секунди.

Ключові слова: система моніторингу здоров'я, додаток для смартфонів, хвороба Паркінсона, передача даних.

Бережний А.В., Белобородова Т.А., Скарга-Бандурова І.С. Система удаленного мониторинга болезни Паркинсона: от смартфона к облачной платформе

Болезнь Паркинсона - это медленно прогрессирующее заболевание, которое влияет на двигательную активность, мышечный контроль и баланс. Более раннее лечение может предотвратить развитие болезни и продлить продромальную фазу заболевания. В этом контексте домашний мониторинг является потенциально мощным инструментом для удаленной диагностики и может улучшить оказание медицинской помощи. Тремор является наиболее распространенным симптомом болезни Паркинсона и имеет несколько преимуществ для постоянного мониторинга ее симптомов. Представлена разработка решения на основе сенсоров смартфонов, позволяющих осуществлять удаленный мониторинг наблюдаемого пользователя. Разработано подключение между приложением для смартфона и облачной платформой для передачи данных с датчиков смартфона для раннего выявления симптомов тремора. Оно включает разработку конфигурации приложения для смартфона для передачи данных с датчиков и разработку конфигурации облачной платформы для мониторинга симптомов тремора. Активные тесты были разработаны для выявления двигательного расстройства, которое указывает на симптом болезни Паркинсона, такой как тремор. Начальные испытания разработки продемонстрировали, что система мониторинга имеет возможность в реальном времени собирать и передавать данные с помощью датчиков смартфона в облачное хранилище. Параметры подключения, разработанные для системы, оказались эффективными при передаче данных датчика со смартфона в облачное хранилище. Период времени, необходимый для передачи данных в облако, равен периоду времени менее одной секунды.

Ключевые слова: система мониторинга здоровья, приложение для смартфонов, болезнь Паркинсона, передача данных.

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A WEARABLE SYSTEM FOR REAL-TIME OUTPATIENT ECG MONITORING

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НОСИМА СИСТЕМА ДЛЯ АМБУЛАТОРНОГО МОНІТОРИНГ У ЕКГ В РЕАЛЬНОМУ ЧАСІ

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Functional state of the cardiovascular system is an important factor for human physical well-being. To perform analysis of the cardiovascular state, the wearable continuous ECG monitoring system is essential. In this paper, a wearable ECG monitoring system based on IoT is proposed. The systems architecture is presented. Wearable devices design employs few optimal components for the acquisition of acceptable ECG signal. The R peaks corresponding to each heartbeat, and T waves, a morphological feature of the ECG are detected. It enables to perform heart rate and heart rate variability analyses, as well as extract, store and analyze the long term ECG measurements.

Keywords: health monitoring system, wearable device, ECG signal acquisition, QRS-complex detection

1. Introduction

Cardiovascular diseases (CVD) are the leading cause of fatalities representing 30% of all global deaths. Due to inadequate preventive measures, CVD related fatalities continue to rise. Electrocardiogram (ECG) is widely used to monitor heart function. At present, an expert cardiologist analyzes short-duration ECG plots to detect abnormalities. Since certain kinds of heartbeat arrhythmias occur sporadically over an extended period, patients require long term monitoring. Monitoring of person ECG changes is important as far as preventive events of pathology cardiovascular diseases.

The recent technologies as a Big Data, Internet of Things (IoT), mobile technologies, and wearable devices step-by-step take up the art of cardiovascular diseases diagnostic to a new level. In this context, the goal is development of wearable ECG monitoring systems.

The human computer interface systems [1] are widely used to extract the context from the implicit information received, collected, processed by wearable devices, which characterizes the situation of a person or place related to a conversation, helps us transfer ideas to each other and respond accordingly [2, 3]. X. Li et al. [4] presented a wearable heart rate monitoring system. They have developed the wearable device for real-time

acquisition and analysis of heart rate signal. Data is stored on the server and it's available for viewing status. Data transmission is carried out using a smartphone. T.O. Meservy et al. [5] developed the mobile health monitoring application. It includes a real-time signal obtaining, ECG signal processing, visualization, and data management. M. M. Baig et al. [6] presented a comprehensive survey of more than 120 wireless and wearable ECG monitoring systems for adults. The results of the review show the main advantages and drawbacks of deployed ECG monitoring systems including short battery life, lack of user acceptability and medical professional's feedback, and lack of security and privacy of essential data. Moreover, in spite of the wide variety of academic works, the ECG monitoring systems still require improvements to deliver the best quality of monitoring and data processing.

In this paper, the IoT wearable system for ECG monitoring with signal acquisition, processing for QRS-complex detection are proposed. Section 2 describes the health monitoring system architecture and ECG wearable device configuration. In Section 3 the system development process and techniques of ECG signal acquisition and processing for QRS-complex detection are discussed. The result of ECG monitoring system implementation and QRS-complex elements detection is present in Section 4. Section 5 contains the paper conclusions and future work.

2. Health Monitoring System Design

2.1. Health Monitoring System Architecture

The architecture of a wearable biomedical information monitoring system is represented by three main components, presented in Fig.1.

The first necessary component is various types of wearable devices and sensors that perceive the physical signals of the human body, which are directly wearable devices.

Biomedical sensors can also be directly integrated into garments and accessories, thus forming a wearable body area network (WBAN) [9].

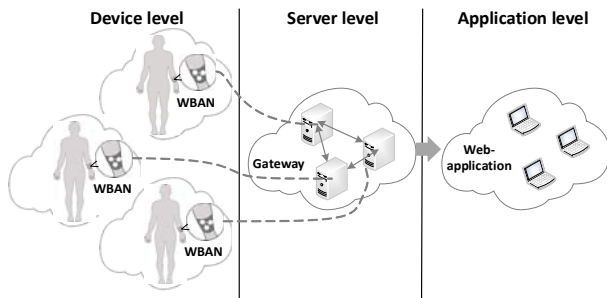


Fig. 1. Health monitoring system architecture (Adapted from [7,8])

WBAN is a subset of wearable biomedical sensors and systems that can be used to control, stimulate, treat, and replace the biological and physical functions of the human body [10].

Such integration requires consideration of two general limitations when developing a biomedical information monitoring system: limited memory capacity of the device and limited power capacity. These restrictions affect the storage, processing and transmission of data:

1. Data received by the device cannot be stored on it for a long period of time and must be transferred to another device / server.

2. When developing a wearable system for monitoring biomedical information, energy-saving data processing algorithms have an advantage.

These factors determine the need for a second component of the system — external storage, processing, and data transfer devices. Data can be transmitted directly from sensors or using external devices with more computational power (e.g. a smartphone). Continuous processing of data in conjunction with the operation of the wireless network adapter consumes a lot of energy resources, which can quickly be exhausted and as a result, disrupt the execution of its direct purpose. External devices usually perform primary signal processing and transfer data to the next level (cloud storage, servers) for further analysis and long-term storage.

As an external device, WBAN can control the physiological parameters of the human body and be used for their collection and transmission.

The third component is represented by cloud storages, servers. Since wearable biomedical information monitoring devices and base stations have limited resources, the resulting data is usually sent to servers, cloud storage for processing and long-term storage.

2.2. Wearable Device Configuration

A wearable ECG device is responsible for collecting ECG data from human skin, and then transmitting this data to an access point through a wireless channel. As shown in Fig. 2, the ECG monitoring node in our system mainly includes: (1) a sensor module; (2) controller module with wireless adapter; and (3) power module.

(1) Sensor module is the core component of the monitoring device, which is responsible for obtaining human ECG data.

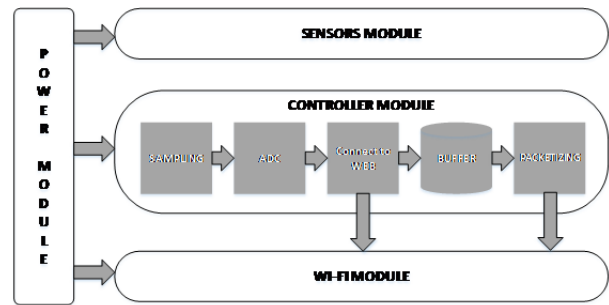


Fig. 2. Devices configuration

Recorded physiological signals usually consist of a source signal and noise. Noise occurs at each stage of data collection, before they are digitized. Noise of the power supply module, muscular noise, noise of the analog-digital converter suppresses ECG signals.

Power line interference is an electromagnetic field from a power line, causing sinusoidal interference at 50 or 60 Hz.

The noise causes problems when interpreting low frequency signals such as an ECG. Consequently, there are many methods have been used to denoising of power line noise in ECG signals [11]. Thus, S. Pooranchandra and N. Kumaravel [12] proposed a nonlinear function of wavelet coefficient shrinking to remove the power line frequency, in [13] they developed an approach based on adaptive noise removing; K. Ziarani and A. Konard [14] proposed the technique to subtract the power line interference from the ECG, which employs to almost all possible causes sampling frequency and interference frequency.

This module filters and amplifies the received ECG signal. The frequency of the ECG signal lies between 0.5 Hz and 100 Hz [15] and this must be taken into account when choosing the method of filtering the ECG signal. To eliminate this kind of noise, an Infinite impulse response (IIR) filter can be used. The equation for this filter can be represented as follows (Eq. 1).

$$y[n] = \sum_{k=0}^M b_k x[n-k] + \sum_{k=1}^N a_k y[n-k], \quad (1)$$

where M is the feedforward filter order; N is the feedback filter order; b_k are the feedforward filter coefficients; a_k are the feedback filter coefficients; $x[n]$ is the input signal; $y[n]$ is the output signal.

To eliminate the baseline wander in the ECG, which can be caused by breathing, electrode impedance, body movement, various methods are used. Often used is a base level interference suppression method based on a Butterworth bandpass filter. After filtering, the signal is amplified using an operational amplifier.

(2) A controller module with a wireless adapter is used to process and transmit the received ECG signal. In the controller module, it is possible to set the necessary parameters for additional signal processing, its buffering, packaging for further transmission via a wireless channel. This provides fast and convenient access to the

Internet for transmitting ECG data in real time to a server or IoT cloud storage.

(3) Power module provides reliable power supply of each module in the ECG monitoring device.

2.3. Detection of a QRS complex and measurement of heart rate

Detail waves of ECG signals are important information for health/medical application. Usually, the following elements can be distinguished on an ECG, as shown in Fig. 3, among them are the P, Q, R, S, T wave. Sometimes we can see the inconspicuous U wave. The P wave reflects the process of depolarization of the atrial myocardium, the QRS complex - depolarization of the ventricles, the ST segment and the T wave reflect the processes of repolarization of the ventricular myocardium.

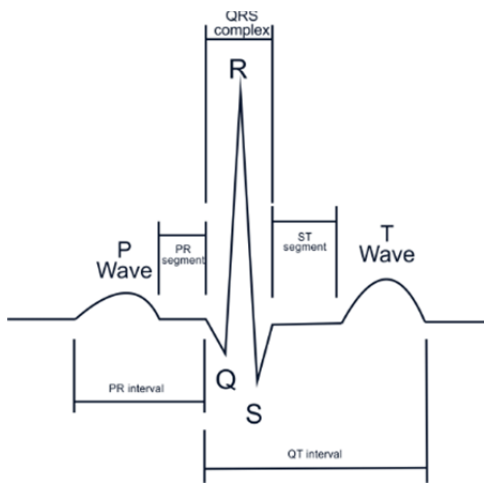


Fig. 3. Elements of ECG complex

The QRS complex can be identified using a common method for determining ECG parameters. R-peak is easier to distinguish from noisy components, as it has large amplitude (Fig. 4).

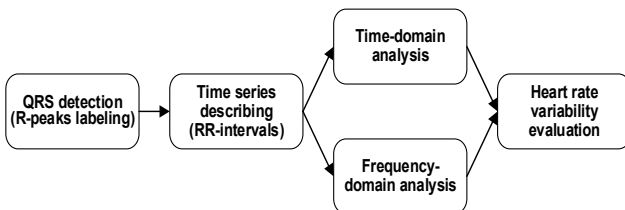


Fig. 4. The general stages of heart rate variability evaluation process

After the pre-processing, variable threshold method can be used to further detect the R-peak. The R-peaks allow heart rate and heart rate variability analyses to be performed, extracting the wanted long term physiological measurements. The formula for variable threshold value is defined as follows.

$$V_{TN} = [x(n) - x(n-1)] \cdot 70\%$$

The threshold makes it possible to differentiate R peak from the baseline, which is corresponding to 70% of ECG peak data detection. We were able to find QRS complex based on the detected R-peak. Detection of QRS complex is particularly important in ECG signal processing. In our system, we used a robust real-time QRS detection algorithm [16]. This algorithm reliably detects QRS complexes using slope, amplitude, and other information. The information obtained from QRS detection, temporal information of each beat and QRS morphology information can be further used for the other ECG parameter detection. In order to detect QRS complex, the signal is initially passed through a band-pass filter. It is composed of cascaded high-pass and low-pass filters. Subsequent processes are five-point derivative (Eq. 2), square (Eq. 3), moving window integrator (Eq. 4), and detection.

$$y(nT) = \frac{2x(nT) + x(nT - T) - x(nT - 3T) - 2x(nT - 4T)}{8} \quad (2)$$

$$y(nT) = [x(nT)]^2 \quad (3)$$

$$y(nT) = \frac{1}{N} [x(nT - (N-1)T) + x(nT - (N-2)T) + \dots + x(nT)] \quad (4)$$

The instantaneous heart rate computed directly from R-R interval. In clinical settings, heart rate is measured in beats per minute (bpm). So, the formula for determining heart rate from RR interval is given below (Eq. 5).

$$Heart_rate = \frac{60,000}{RRInterval(ms)} \quad (5)$$

3. Implementation Result

3.1. EEG wearable Device Specification

EEG wearable device hardware includes follow components: ESP-WROOM-32 DEV KIT, OLIMEX SHIELD-EKG-EMG, Breadboard MB-102 830 holes, SHIELD-EKG-EMG-PRO, ECG-GEL-ELECTRODE, USB 2.0 Micro B Cable, Male/Male Jumper Wires 150mm, Poweradd Slim2 5000mAh Portable Charger Power Bank.

3.2. ECG signal acquisition technique

Place the electrodes on the body as follows Fig. 5: white electrode on the left arm, red electrode on the right arm, black electrode on the left leg.

The network of short-range and long-range communications for ECG monitoring is used. The stages of network hardware configuration using Wi-Fi router are defined as follows: Wi-Fi setup, turn on DHCP, connect a router to computer, edit an ESP32 firmware (change IP address, SSID, password), connect ECG electrode to your body, run special Python script and get the ECG signal.

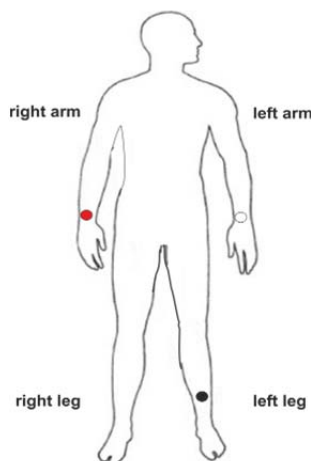


Fig. 5. The electrodes location

Achieved ECG signal is present in Fig. 6.

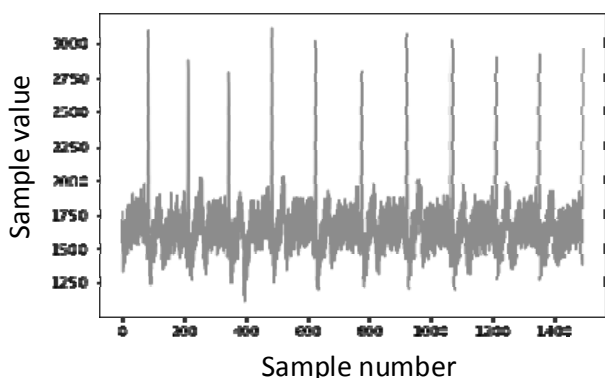


Fig. 6. Fragment of ECG signal

The frequency of a signal measures the cyclic rate and is measured in Hertz (Hz). A frequency of 1 Hz means a signal repeat itself every one second. The heart produces electrical activity, which records by electrodes as a signal. The sinoatrial node beat about 50 to 90 beats per minute. That means the heart has a frequency of 1 Hz at this heart rate. According to this, the ECG elements (P, QRS, and T) will occur at or above this frequency.

The ECG signal obtained from multiple sources. The recording includes signals from several electrodes on the skin, which capture more than just the electrical activity of the heart. The primary electrical elements captured are the myocardium, muscle, skin-electrode interface, and external interference.

3.3. ECG Component Frequencies

The basic frequencies of the important components on the ECG can be presented as follow: heart rate 0.67 – 5 Hz, P-wave 0.67 – 5 Hz, QRS 10 – 50 Hz, T-wave 1 – 7 Hz, high-frequency potentials 100 – 500 Hz. The basic frequencies of the artifacts and noises on the ECG can be presented as follow: muscle noise 5 – 50 Hz, respiratory noise 0.12 – 0.5 Hz, external electrical activity 50 or 60 Hz (A/C mains or line frequency), and other

electrical activity, typically, >10 Hz.

The skin-electrode interface needs special attention, as it is the largest source of interference, producing a DC component about 200-300 mV. Comparing this to the electrical heart activity, which is in the range of 0.1 to 2 mV. The interference seen from this component is increased by motion, either person movement, or respiratory variation.

For the time-series analysis of the heart rate signal, are using intervals between the heartbeats and its variation over time. The most important of ECG signals analysis is to determine the position of the R-peaks since they correspond to the heartbeat and the position of other peaks and waves can be found relative to the defined R-peak. The R-peaks are detected using moving window integrator (Fig. 7).

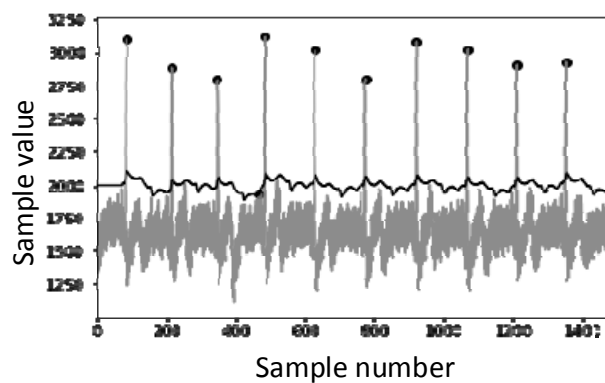


Fig. 7. Fragment of ECG signal with detecting R-peaks

From a signal processing the position of all R-peaks, RR-intervals between R-peaks and differences between adjacent RR-intervals are found. From these parameters, the analysis of the heart health state can be implemented and the potential heart state disorders will be predicted.

Thus, relatively stable real-time ECG signal is successfully monitored and diagnostic ECG elements, such as R-peaks, are detected.

Conclusion

In summary, we developed the wearable system for outpatient ECG monitoring. The architecture of ECG monitoring system is based on the three-level scheme. The configuration of ECG wearable device to provide healthcare service was designed. The acquisition and processing of ECG signal are presented. The diagnostic ECG elements, such as R-peaks, are detected. Analysis of continuous heart rate signal and procedures for extracting of heart rate parameters are described.

Future work will focus on monitoring additional health related parameters and implementing the anomaly detection techniques, and on improving system reliability and robustness for patient movement and connectivity losses.

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Білобородова Т.О., Скарга-Бандурова І.С., Дерев'янченко В.С. Носима система для амбулаторного моніторингу ЕКГ в реальному часі

Стан серцево-судинної системи є важливим фактором фізичного здоров'я людини. В багатьох випадках, для аналізу стану серцево-судинної системи потрібна носима система безперервного моніторингу ЕКГ. У цій статті ми запропонували варіант системи для амбулаторного моніторингу ЕКГ. Представлена архітектура системи. При проектуванні носяться пристроїв використовується кілька компонентів для отримання прийняттого сигналу ЕКГ. Піки R, відповідні кожному серцевому циклу, і Т-хвилі - морфологічна особливість ЕКГ. Це дозволяє проводити аналіз серцевого ритму і варіабельності серцевого ритму, витягуючи необхідні довгострокові вимірювання ЕКГ.

Ключові слова: система моніторингу здоров'я, носимий пристрій, сигнал ЕКГ, виявлення QRS-комплексу.

Білобородова Т.А., Скарга-Бандурова І.С., Дерев'янченко В.С. Носимая система для амбулаторного мониторинга ЭКГ в реальном времени

Состояние сердечно-сосудистой системы является важным фактором физического здоровья человека. Во многих случаях, для анализа состояния сердечно-сосудистой системы требуется носимая система непрерывного мониторинга ЭКГ. В этой статье мы предложили носимую систему для постоянного амбулаторного мониторинга ЭКГ. Представлена архитектура системы. При проектировании носимых устройств используется несколько компонентов для получения приемлемого сигнала ЭКГ. Пики R, соответствующие каждому сердечбиению, и Т-волны - морфологическая особенность ЭКГ. Это позволяет проводить анализ сердечного ритма и вариабельности сердечного ритма, извлекая требуемые долгосрочные измерения ЭКГ.

Ключевые слова: система мониторинга здоровья, носимое устройство, сигнал ЭКГ, обнаружение QRS-комплекса.

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MODEL-ORIENTED FAKE NEWS DETECTION ON SOCIAL MEDIA

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МОДЕЛЬ-ОРІЄНТОВАНИЙ ПІДХІД ДО ВИЗНАЧЕННЯ ФЕЙКОВИХ НОВИН В СОЦІАЛЬНИХ МЕРЕЖАХ

Давіденко М.О., Білобородова Т.О.

Nowadays, fake news (FN) have actively penetrated throughout the social media reducing our ability to critical assess and proceed the information. Most of existing approaches to handle with FN require a labeled FN training datasets but in some cases these datasets are unavailable. In this paper, we present a model-oriented approach for FN detection and feature extraction. The unsupervised technique for FN identification without the training data is designed and developed. It includes four main steps, namely data preprocessing, text feature extraction, vectorization, and clustering using k-means algorithm. The results of the last step was evaluated through several parameters: homogeneity, completeness, V-measure, Adjusted Rand index and Silhouette coefficient.

Keywords: FN detection, text mining, model-oriented approach, clustering, word2vec

1. Introduction

The researches of Stanford University defined FN like the news that are intentionally and verifiably false and can mislead [1].

After the presidential election with Donald Trump and Hillary Clinton at 2016 in the USA, the actual topic was the “Fake News” [2]. Some political pundits claim that FN affected the election. Fake news posts have used social media to disseminate during the internet.

Nowadays, big social networking services companies are developed solutions for FN recognizing. For example, Facebook allows users scoring the news that is possibly suspicious [3]. Recently, a new online service “Google News Initiative” that is proposed by Google to fighting FN [4].

There are many researches provided in this area. The authors [5] investigated and characterized FN and data related to it as follows (Fig.1).

The research approaches for FN detection can be defined in the following categories [6]: data-oriented, feature-oriented, model-oriented, application-oriented.

According to our goal, we detailed investigation and analysis of the model-oriented FN research.

Most approaches include extracting various features and follow using these features into supervised classification models [7, 8]. The conjunction of several weak classifiers into ensemble methods is more successful than any single classification model alone. The ensemble methods have been widely applied to FN detection and have a more accurate result [9].

However, the accuracy of FN detection, is still challenging, due to the dynamic nature of social media, and the complexity and diversity of online text data. Also, in the absence of high-quality training data is a problem for the creation of detection models.

One of the major challenges for FN detection is the fact that each feature, such as source trustworthiness, style of news text, or social response, has some restriction to directly predict FN singly. The process of obtaining a reliable FN dataset is difficult for the following reasons [10]:

- the real-world online dataset is usually big, incomplete, unstructured, unlabeled, and noisy;
- everyday a large amount of false information with diverse intentions and different linguistic characteristics is created via social media.

Also, most existing approaches require a labeled FN train dataset to train a model. It is important to consider scenarios where limited or no labeled FN items are available in which semi-supervised or unsupervised models can be applied. The models created by supervised learning be more accurate given a quality training dataset, unsupervised models can be more useful on wide availability of unlabeled data.

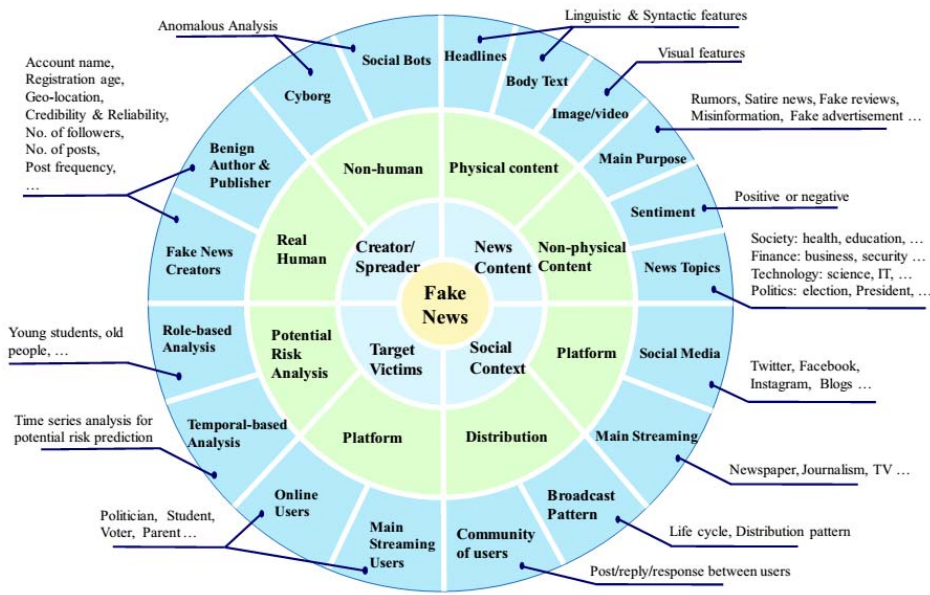


Fig. 1. Characteristic of FN and data related to it [5]

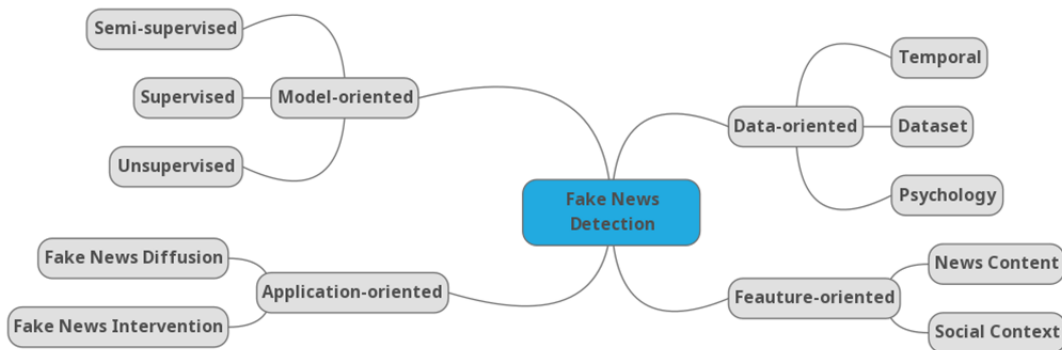


Fig. 2. The categories of research approaches for FN detection

It is necessary to design an approach which is able to identify FN even without the training samples. It is important to design effective, automatic and applicable approaches for high-quality online FN detection.

The goal is effectiveness model-oriented approaches for FN detection. The objectives can be defined as follow:

- study and analyzed related work for FN detection and feature extraction;
- designed and development of unsupervised technique for FN detection consisting of data preprocessing, text feature extraction, converting words to vectors and clustering using k-means algorithm;
- clustering evaluation.

The outline of the paper is as follows. In Section 2, we describe the major definitions of model-oriented approaches for FN detection. The method of feature extraction is considered in Section 3. The model-oriented method such as clustering is provided and experiment process is presented in Section 4. The clustering evaluations are present in Section 5. Finally, we conclude our research.

2. Definitions of model-oriented approaches

According to the model-oriented approach for FN detection can be used unsupervised and supervised machine learning technique. We study classification as supervised learning, and perform clustering as unsupervised learning.

The clustering in the context of FN detection can be defined as follow [11]. Given a corpus of FN $J = \{j_1, j_2, j_3, \dots, j_n\}$ with size of n where each document \vec{n}_i is a vector of terms in a dictionary, $\Sigma = \{t_1, t_2, t_3, \dots, t_T\}$ with size of $T = |\Sigma|$. The problem is clustering of documents based on their terms into homogeneous classes with respect to FN categories. To this end, we first cluster documents based on appearance positions of each term in an article and its correlations with other terms (Spatial relation extraction) following by designing an automatic ensemble co-clustering to cluster documents according to their positions in different factors among various low-rank decompositions.

Mathematically, the classification for FN detection define as follows [12]. A news item is called fake if its content is verified to be fake and true otherwise. Let $X = \{X_1, X_2, \dots, X_n\}$ denote a dataset containing n news items. Each new item $j \in [1, n]$ contains k resources of data and is denoted as $X_j = \{X_j^1, X_j^2, \dots, X_j^k\}$. Additionally, let $Y = \{y_1, y_2, \dots, y_n\}$ is a set of class labels related with news samples of dataset X . Each class label $y_i \in Y$ from the label set, where m is the number of recognized class of news in dataset and $l_j \in L$ is a class meaning: fake or true.

With the aforementioned notations and definitions, the problem of multi-source multi-class FN detection is formally defined as follows. Given the dataset X and its corresponding labels Y , the goal of classification is to learn the model M mapping X to Y , which predicts the degrees of fakeness for unlabeled news.

3. Feature extraction

The wor2vec model is a popular technique for feature extraction in text mining. It can be describing as follow. The word2vec model takes a large text corpus as input and maps each word to a vector, giving the coordinates of the words in the output. At the first stage, it creates a dictionary through learning on the input text data, and then calculates the vector of words. The vector is based on contextual proximity: words found in the text follow to identical words (therefore having similar meanings) in the vector have close coordinates of word vectors. The parameters and corpus sizes are affected to the model accuracy. Accuracy increases overall if the

number of words used increases, and if the number of dimensions increases [13].

The optimization of word2vec model is a classification problem [14] and defined as follow. The word embedding layer is a matrix of a number of unique words in the corpus and words embedding size. Suppose a textual source contains x words [12]. The neural network model applying, the text represents by an input matrix of word embeddings denoted as $W \in R^{x \times e}$ where e is the dimension of the word embedding. More specifically, $w_j \in W$ is a e dimensional vector representing j -th word of the text and populates j -th row of matrix W . In other words, each row of the matrix represents a word in the corpus. Words embedding size is a hyperparameter to be decided and how many features that can be defined to each word. The last stage of the model is a logistic regression in a neural network form.

4. Experiment

4.1. Data Description

The dataset by George McIntire [15] was used. The dataset was prepared in 2017. It consists of data from 5279 articles. The articles came from media organizations such as the New York Times, WSJ, Bloomberg, NPR, and the Guardian and were published in 2015 or 2016. The dataset consists of the headline and text of a news article as input variables and output variable with the two classes: FAKE or REAL.

The FN detection includes follow steps.

4.2 Data preprocessing

The raw data was preprocessed. The bad characters, tokenize and stop words are removed. The raw data is present as follow (see Fig.3).

Unnamed: 0		title	text	label
0	8476	You Can Smell Hillary's Fear	Daniel Greenfield, a Shillman Journalism Fello...	FAKE
1	10294	Watch The Exact Moment Paul Ryan Committed Pol...	Google Pinterest Digg Linkedin Reddit Stumbleu...	FAKE
2	3608	Kerry to go to Paris in gesture of sympathy	U.S. Secretary of State John F. Kerry said Mon...	REAL
3	10142	Bernie supporters on Twitter erupt in anger ag...	— Kaydee King (@KaydeeKing) November 9, 2016 T...	FAKE
4	875	The Battle of New York: Why This Primary Matters	It's primary day in New York and front-runners...	REAL

Fig. 3. Data before processing

Unnamed: 0		title	text	label
0	8476	[smell, hillarys, fear]	[daniel, greenfield, shillman, journalism, fel...	FAKE
1	10294	[watch, exact, moment, paul, ryan, committed, ...	[google, pinterest, digg, linkedin, reddit, st...	FAKE
2	3608	[kerry, go, paris, gesture, sympathy]	[us, secretary, state, john, f, kerry, said, m...	REAL
3	10142	[bernie, supporters, twitter, erupt, anger, dn...	[kaydee, king, kaydeeking, november, lesson, t...	FAKE
4	875	[battle, new, york, primary, matters]	[primary, day, new, york, frontrunners, hillar...	REAL
5	6903	[tehran, usa]	[im, immigrant, grandparents, years, ago, arri...	FAKE
6	7341	[girl, horrified, watches, boyfriend, left, fa...	[share, baylee, luciani, left, screenshot, bay...	FAKE
7	95	[britains, schindler, dies]	[czech, stockbroker, saved, jewish, children, ...	REAL
8	4869	[fact, check, trump, clinton, commanderinchief...	[hillary, clinton, donald, trump, made, inaccu...	REAL
9	2909	[iran, reportedly, makes, new, push, uranium, ...	[iranian, negotiators, reportedly, made, lastd...	REAL

Fig. 4. Data after preprocessing step

Data after preprocessing without bad characters, tokenize and stop words can be present as follow (see Fig.4).

4.3. Train word2vec model

After training the model with the data generated from the example sentence above, we can see that the model can output most of the similar words for each word as an input word.

Take the sentence for example, given a context word "go" we would like the model to generate one of the underlying words (one of the words in [stay, come, get, sit, throw, wait, happen, alone, roll, let] in the follows case.).

model.wv.similar_by_word("go")

```
[
('stay', 0.7747250199317932),
('come', 0.7660486698150635),
('get', 0.751580536365509),
('sit', 0.7376989722251892),
('throw', 0.7257541418075562),
('wait', 0.7247833013534546),
('happen', 0.6911652088165283),
('alone', 0.6910232305526733),
('roll', 0.6893036365509033),
('let', 0.6857764720916748)
]
```

On another case, given a context word "politic" we would like the model to generate one of the underlying words (one of the words in [destructive, healthcareaboveall, karma, potent, distributionthe, interlocking, ecologically, intolerable, divine, oneness]).

model.wv.similar_by_word("politic")

```
[
('destructive', 0.8911725282669067),
('healthcareaboveall', 0.888471782207489),
('karma', 0.8859128952026367),
('potent', 0.8848767876625061),
('distributionthe', 0.8825998902320862),
('interlocking', 0.8820247054100037),
('ecologically', 0.8805824518203735),
('intolerable', 0.8803092837333679),
('divine', 0.8801225423812866),
('oneness', 0.8792058229446411)
]
```

The follow steps after word2vec are converting words to vectors and using K-Means algorithm for clustering.

5. Clustering evaluation

There are many parameters are used for clustering evaluation. The follow parameters are used in our experiment: homogeneity, completeness, V-measure, silhouette, Adjusted Rand index, Adjusted Mutual Information and Silhouette coefficient.

Formally, homogeneity h , completeness c , V-measure V are determined using the functions of entropy as follow.

$$h = 1 - \frac{H(C|K)}{H(C)}, c = 1 - \frac{H(K|C)}{H(K)},$$

where K is the result of clustering, C is the true partitioning of the sample into classes. Thus, homogeneity measures how much each cluster consists of objects of the same class, and completeness measures how much objects of the same class belong to the same cluster. These measures are not symmetrical. Both values take values in the range $[0,1]$, and large values correspond to more accurate clustering. These measures are not normalized and depend on the number of clusters.

To take into account homogeneity and completeness, a V-measure is introduced at the same time as their harmonic mean. It is symmetrical and shows how the two clusters are similar to each other.

The V-measure calculated as follow.

$$V = (1 + \beta) * h * c / (\beta * h + c)$$

The Rand index (RI) expresses the similarity of two different clusters of the sample. In order for this index to give values close to zero for random clustering for any n and the number of clusters, it is necessary to normalize it. This is how the Adjusted Rand Index is defined. Adjusted Rand index (ARI) is a symmetric measure, independent of label values and permutations. This index is a measure of the distance between different sample partitions. ARI takes values in the range $[-1,1]$. Negative values correspond to "independent" clusters, values close to zero correspond to random partitions, and positive values indicate that the two partitions are similar. The Rand Index and Adjusted Rand index can be defined as follow.

$$RI = \frac{2(a+b)}{n(n-1)}, ARI = \frac{RI - E[RI]}{\max(RI) - E[RI]},$$

where n is the number of objects in the set, a is the number of both of objects that have the same labels and are in the same cluster, b is the number of pairs of objects that have different labels and are in different clusters.

Silhouette coefficient is a method of interpretation and validation of data consistency in clusters.

The silhouette value is a measure of how similar an object is to its own cluster is it compare to other clusters. It takes values as follow $[-1, 1]$. A high value means that the object is well similar to its own cluster and badly similar to other clusters.

The results of evaluations parameters are:

Homogeneity: 1.000

Completeness: 1.000

V-measure: 1.000

Adjusted Rand Index: 1.000

Silhouette Coefficient: 0.326

Conclusion

The most of approaches require a labeled data for accurate FN detection. The models created by supervised classification methods may be more accurate given a high-quality dataset for training. However, unsupervised models don't require a labeled data and can be more practical because unlabeled datasets are more available to obtain. The unsupervised technique to identify FN without the training data is designed and development. It consists of follow steps: data preprocessing, text feature extraction, converting words to vectors and clustering using k-means algorithm.

We provide clustering evaluation through several parameters: homogeneity, completeness, V-measure, silhouette, Adjusted Rand index and Silhouette coefficient. Based on the results of the Silhouette clustering coefficient as the main evaluation method, we can conclude that the clustering model is accurate.

Follow clustering evaluation, the word2vec model showed quality results of vectorizing and searching similar words to build distances between objects for the follow clustering analysis.

The future research is additional settings such as doc2vec method for feature extraction and cross-validation for find better configurations for clustering model accuracy improving.

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Давіденко М.О., Білобородова Т.О. Модель-орієнтований підхід до визначення фейкових новин в соціальних мережах

На даний час фальшиві новини (FN) активно проникають в соціальні мережі, знижуючи нашу здатність критично оцінювати і обробляти інформацію. Більшість існуючих підходів для роботи з FN вимагають маркованих навчальних наборів даних FN, але в деяких випадках ці набори даних недоступні. У цій статті ми представляємо модельно-орієнтований підхід для виявлення FN і виділення ознак. Неконтрольована методика ідентифікації FN без навчальних даних спроектована і розроблена. Вона включає в себе чотири основні етапи: попередню обробку даних, вилучення текстових ознак, векторизацію і кластеризацію з використанням алгоритму k-середніх. Результати останнього етапу оцінювалися за кількома параметрами: однорідність, повнота, V-мера, скоригований індекс Ренді і коефіцієнт силуєту.

Ключові слова: визначення фейк новин, інтелектуальний аналіз тексту, модельно-орієнтований підхід, кластеризація, word2vec.

Давыденко Н.А., Белобородова Т.А. Модель-ориентированный подход для определения фейковых новостей в социальных сетях

В настоящее время фальшивые новости (FN) активно проникают в социальные сети, снижая нашу способность критически оценивать и обрабатывать информацию. Большинство существующих подходов для работы с FN требуют маркированных обучающих наборов данных FN, но в некоторых случаях эти наборы данных недоступны. В этой статье мы представляем мо-

дельно-ориентированный подход для обнаружения FN и выделения признаков. Неконтролируемая методика идентификации FN без обучающих данных спроектирована и разработана. Она включает в себя четыре основных этапа: предварительную обработку данных, извлечение текстовых признаков, векторизацию и кластеризацию с использованием алгоритма k-средних. Результаты последнего этапа оценивались по нескольким параметрам: однородность, полнота, V-мера, скорректированный индекс Ренда и коэффициент силуэта.

Ключевые слова: обнаружение фейк новостей, интеллектуальный анализ текста, модельно-ориентированный подход, кластеризация, word2vec.

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ALGORITHM FOR DYNAMIC ROUTE ASSIGNMENT IN COMPLEX STREET LAYOUTS

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АЛГОРИТМ ДИНАМІЧНОГО ПРИЗНАЧЕННЯ МАРШРУТУ НА КОМПЛЕКСНИХ ПЛАНАХ ДОРІГ

Деркач М.В., Скарга-Бандурова І.С.

In some scenarios, public transport vehicles do not have permanently fixed routes that make it hard to implement optimal automatic routing techniques and use forecasting algorithms. To solve the problem of route destination, a mathematical model of the dynamic route assignment is developed. It is based on the graph model of the street layouts and includes the results of the arrival of vehicles in certain points. The proposed algorithm enables to dynamically recalculate the routes, depending on the intersection of the four types of nodes representing the key points of the transport network. A case study for the route assignment in city of Severodonetsk is discussed.

Keywords: algorithm, route assignment, public transport, graph, model, transport system.

Introduction. The increase in vehicles affects the overall dynamics of the transportation system; cities of medium and small size usually have mixed traffic [1], or several transit routes. Road traffic requires accurate and up-to-date information about the current situation and available services. Improving the quality of road conditions is important for all infrastructures. However, this improvement alone can not meet the ever-increasing demands for safe, convenient, cost-effective and convenient road services. Under certain circumstances city transport operators can change routes of their vehicles without direct assignment in the overall information system.

The possibilities of improving existing public transportation through the introduction of advanced technologies into the transport system are provided through the concept of intelligent transport systems (ITS) and Internet of Things technology (IOT), which in turn allows real-time management of the park, dispatching and planning services, emergency alerts, security services and passenger information services.

The goal of the research is development of an adaptive algorithm for assigning routes, by selecting

targeted points so that the resulting geo-zone belongs to the unique route.

Work related analysis. Public vehicles are not assigned to a specific route for various reasons. It can be vehicle breakdown, internal rules of corporate carrier, etc. In this case, every day at the beginning of the working day each vehicle is given a new route. This problem was considered by R. van Nes *et al.* in [2], where the routes of the network are selected by assigning frequencies using linear programming. The objective is to maximize the number of transfers saved by changing from a link network (transfers at every node) to a public transport network (transfers only at intersections). C. Bai *et al.* [3] claim that route choice model requires at least an origin, a destination, and a set of route alternatives to choose from. The choice of a route follows more or less behavioral principles and is guided by the routes' properties.

However, the task of assigning routes is still open [4]. To solve this problem the following approaches could be applied: daily manual update, or automatic route assignment. In relation to the latter, there is a need for a unique procedure for assigning routes.

Mathematical model. Let's assume that mathematical model of the city's street layout transport network is given by a graph:

$$G=(U, E), \quad (1)$$

with set of nodes:

$$U=U_1 \cup U_2 \cup U_3 \cup U_4, u=|U|, \quad (2)$$

set of arcs:

$$e=|E|, \quad (3)$$

where U_1, U_2, U_3, U_4 - set of nodes first, second, third and fourth type, u - number of nodes, e - number of arcs, $|\cdot|$ - power sign set.

Arcs are sections of roads between nodes, which in turn form a route. Routes are given by the matrix:

$$R = \left\| r_{i,j} \right\|_{u \times u}$$

$$i, j = \overline{1, u}$$

$$i \neq j, \quad (4)$$

where r denotes a route from the node i in the node j .

Then the procedure of route assignment could be performed. For all routes, the set of targeted points is selected, and their geo-zones are determined.

A geo-zone is understood as a certain section of the road, which corresponds to a targeted point with a territory adjacent to it. The number of points equals the number of existing routes in the city.

The algorithm for setting route number to the vehicles. Since we assume that vehicles do not have

permanent routes and follow along the assigned route only within one working day, at the beginning of each work shift, it is necessary to perform the routing setup.

For all routes, the set of control points is selected, and their points are determined. Each control point is selected so that it belongs to only one route. This placement of control points avoids the problem of crossing routes and allows assigning the route to the vehicle when it gains the specific zone [6].

The assignment of the route is very simple and is performed as follows.

When a vehicle crosses a specific geo-zone, it is assigned a route. The assignment algorithm is shown in Figure 1.

Case study

Consider the transport network of the city Severodonetsk for public transport routes (fig. 1).

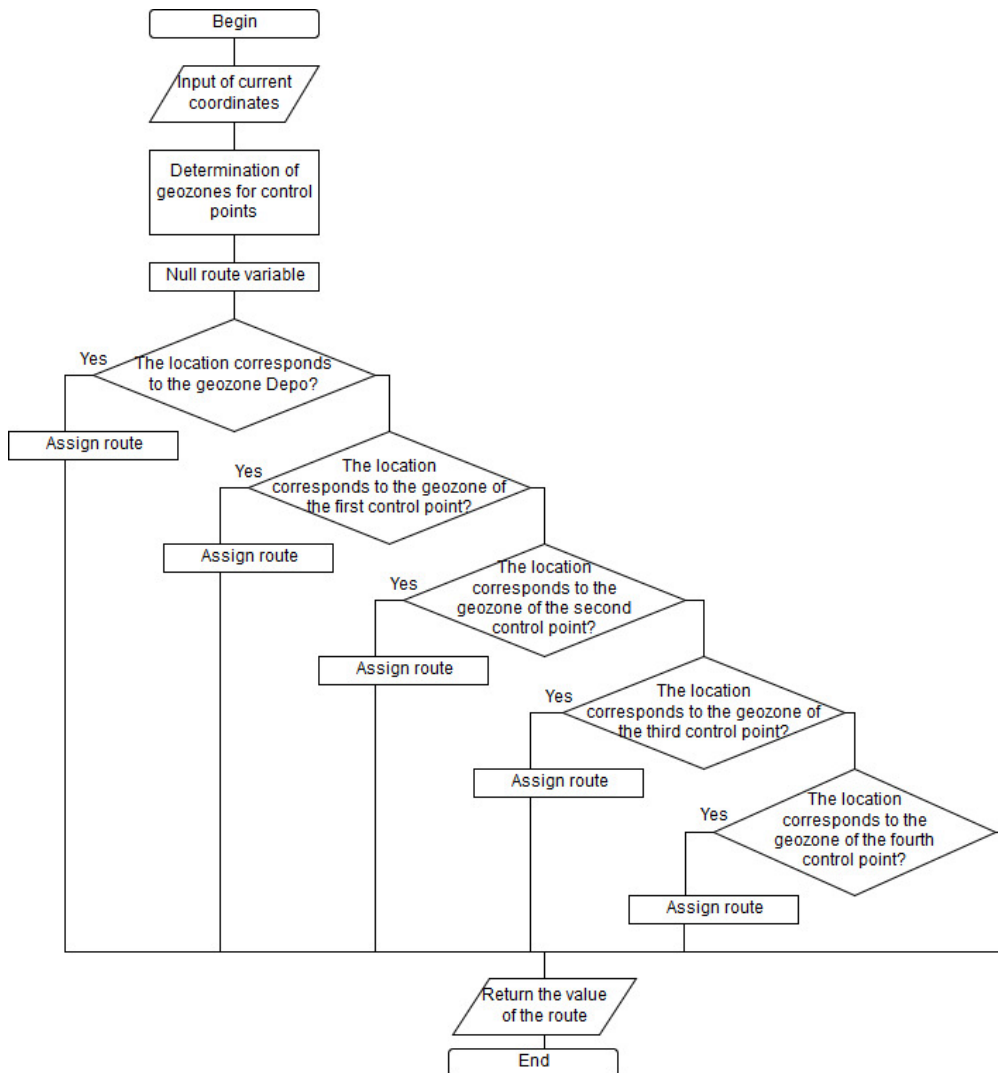


Fig. 1. The algorithm for setting route number to the vehicles

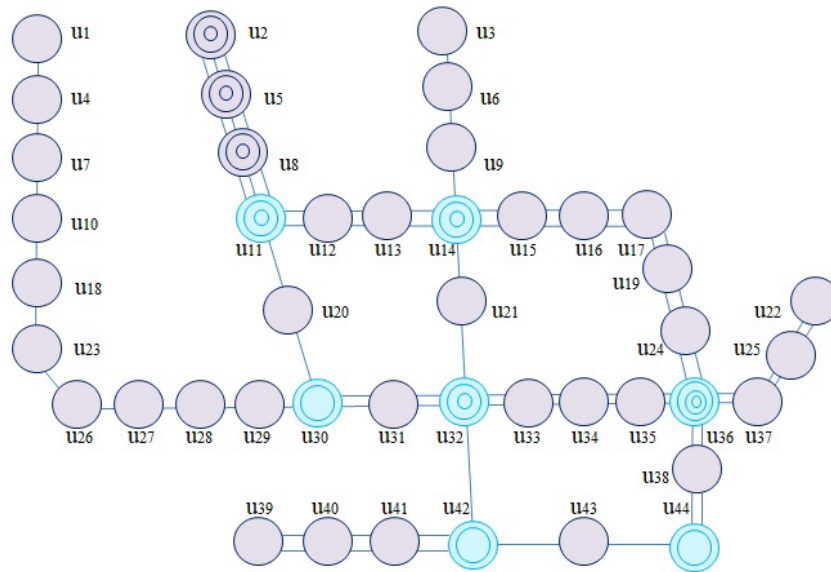


Fig. 2. Graph of the routes with the unique routing points

The first type set includes nodes:

$$U_1 = \{u_1, u_3, u_4, u_6, u_7, u_9, u_{10}, u_{18}, u_{20}, u_{21}, u_{23}, u_{26}, u_{27}, u_{28}, u_{29}, u_{43}\}.$$

The second type set includes nodes:

$$U_2 = \{u_{12}, u_{13}, u_{15}, u_{16}, u_{17}, u_{19}, u_{22}, u_{24}, u_{25}, u_{30}, u_{31}, u_{33}, u_{34}, u_{35}, u_{37}, u_{38}, u_{39}, u_{40}, u_{41}, u_{42}, u_{44}\}.$$

The third type set includes nodes:

$$U_3 = \{u_2, u_5, u_8, u_{11}, u_{14}, u_{32}\}.$$

Appropriately, the fourth type set includes nodes:

$$U_4 = \{u_{36}\}.$$

Resulting matrix of routes in the city:

$$R = \begin{pmatrix} u_1 & u_4 & u_7 & u_{10} & u_{18} & u_{23} & u_{26} & u_{27} & u_{28} & u_{29} & u_{30} & u_{31} & u_{32} & u_{33} & u_{34} & u_{35} & u_{36} & u_{37} & u_{25} & u_{22} \\ u_2 & u_5 & u_8 & u_{11} & u_{20} & u_{30} & u_{31} & u_{32} & u_{33} & u_{34} & u_{35} & u_{36} & u_{37} & u_{25} & u_{22} & & & & & \\ u_2 & u_5 & u_8 & u_{11} & u_{12} & u_{13} & u_{14} & u_{15} & u_{16} & u_{17} & u_{19} & u_{24} & u_{36} & u_{38} & u_{44} & u_{43} & u_{42} & u_{41} & u_{40} & u_{39} \\ u_2 & u_5 & u_8 & u_{11} & u_{12} & u_{13} & u_{14} & u_{15} & u_{16} & u_{17} & u_{19} & u_{24} & u_{36} & u_{38} & u_{44} & & & & & \\ u_3 & u_6 & u_9 & u_{14} & u_{21} & u_{32} & u_{42} & u_{41} & u_{40} & u_{39} & & & & & & & & & & \end{pmatrix}$$

According to the obtained matrix, it was discovered that the city routes are transit, that is, several routes simultaneously have the same road sections, namely:

$$\begin{aligned} r_{1,22} \cap r_{2,22} &= \{u_{30}, u_{31}, u_{32}, u_{33}, u_{34}, u_{35}, u_{36}, u_{37}, u_{25}, u_{22}\} \\ r_{2,39} \cap r_{2,44} &= \{u_2, u_5, u_8, u_{11}, u_{12}, u_{13}, u_{14}, u_{15}, u_{16}, u_{17}, u_{19}, u_{24}, u_{36}, u_{38}, u_{44}\} \\ r_{2,39} \cap r_{3,39} &= \{u_{42}, u_{41}, u_{40}, u_{39}\} \\ r_{2,22} \cap r_{2,39} \cap r_{2,44} &= \{u_2, u_5, u_8, u_{11}\} \\ r_{1,22} \cap r_{2,22} \cap r_{3,39} &= \{u_{32}\} \end{aligned}$$

We also received nodes $u_{11}, u_{14}, u_{30}, u_{32}, u_{36}, u_{42}, u_{44}$, in which there are intersections of routes.

Then, the procedure for establishing a route is reduced to finding unique points or segments, in the center of which is the targeted point belonging to only one, unique route.

Example,

$$\begin{aligned} r_{2,22} \setminus r_{1,22} \setminus (r_{2,22} \cap r_{2,39} \cap r_{2,44}) &= \{u_{20}\} \\ r_{2,39} \setminus r_{2,44} \setminus r_{3,39} &= \{u_{43}\} \end{aligned}$$

Conclusion. The problem of mixed traffic and dynamic transit routes, typical for medium and small cities is considered. Due to public transport vehicles often do not have a permanently fixed route an approach for automatic route assignment is in demand. Therefore, for the automation of the procedure, an adaptive algorithm for assigning routes was developed that allows the route to be assigned as a result of the arrival of vehicles in certain points, based on the graph model of the city's transport system. The procedure for establishing a route reduces to finding unique points, in the center of which is a targeted point belonging to only one route. This algorithm can be useful both for fixed-route and dynamic route systems.

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Деркач М.В., Скарга-Бандурова І.С. Алгоритм динамічного призначення маршруту на комплексних планах доріг

У деяких сценаріях транспортні засоби громадського транспорту не мають постійно встановлених маршрутів, які ускладнюють впровадження оптимальних методів автоматичної маршрутизації та використання алгоритмів прогнозування. Для вирішення проблеми призначення маршруту розроблено математичну модель призначення динамічного маршруту. Вона базується на графічній моделі вуличних макетів і включає результати прибуття транспортних засобів у певні точки. Запропонований алгоритм дозволяє динамічно перераховувати маршрути в залежності від перетину чотирьох типів вузлів, що представляють ключові точки транспортної мережі. тематичне дослідження призначення маршрутів обговорюється на прикладі м. Северодонецьк.

Ключові слова: алгоритм, призначення маршруту, громадський транспорт, графік, модель, транспортна система.

Деркач М.В., Скарга-Бандурова І.С. Алгоритм динамического назначения маршрута на комплексных планах дорог

В некоторых сценариях, транспортные средства общественного транспорта не имеют постоянно фиксированных маршрутов, что затрудняет реализацию оптимальных методов автоматической маршрутизации и использование алгоритмов прогнозирования. Для решения задачи назначения маршрута разработана математическая модель динамического назначения маршрута, основанная на графической модели планировок дорог, которая включает в себя результаты прибытия транспортных средств в определенные точки. Предложенный алгоритм позволяет динамически пересчитывать маршруты в зависимости от пересечения четырех типов узлов, представляющих ключевые точки транспортной сети. Тематическое исследование для назначения маршрута представлено на примере г. Северодонецк.

Ключевые слова: алгоритм, назначение маршрута, общественный транспорт, граф, модель, транспортная система.

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UDC: 004.074.32

COLOR IMAGE CONTROL INFORMATION WITHOUT HARDWARE RESOURCES OF MICROCONTROLLER USING DIRECT MEMORY ACCESS

Нюха М.В.

УПРАВЛІННЯ ВІДОБРАЖЕННЯМ КОЛЬОРОВОЇ ІНФОРМАЦІЇ БЕЗ АПАРАТНИХ РЕСУРСІВ МІКРОКОНТРОЛЕРА З ВИКОРИСТАННЯМ ПРЯМОГО ДОСТУПУ ДО ПАМ'ЯТІ

Гора М.В.

The approach of the control the color informational display using modern technologies to simplify the implementation of the data transfer protocol and minimize the use of hardware costs in the conditions of instantaneous and extra-large data transfer in continuous mode was considered in the paper. The software and hardware implementation of the control based on STM32F103C8T6 microcontroller using ARM Cortex-M3 technology, WS2812B color LED ribbon and direct memory access technology was proposed.

Keywords: data transfer protocol, non-return-to-zero line code, direct memory access, hardware abstraction layer WS2812B, Cortex-M technology, STM32 microcontroller's unit

1. Introduction

Currently, information technologies are widely used in various solutions related to software and hardware implementations: control devices, hardware platforms for applications, and software and hardware implementation of data transfer.

Let's consider one of the best software and hardware implementations. It is color display controls the information and, in particular, implements data transfer. This implementation is one of the best, as it contains a small but comprehensive stack of modern technologies that allows you to significantly speed up the data transfer and, thereby, release the main device (microcontroller) from the temporary memory buffer monitoring.

2. Data transfer protocol

2.1. The Protocol Description

WS2812B is an intelligent control LED light source with control circuit and RGB chip, are integrated in a package. It internal device includes intelligent digital port data latch and signal reshaping (amplification) drive circuit.

The data transfer protocol uses single non-return-to-zero (NRZ) communication mode. It is a binary line code in which ones are represented by one significant

condition, usually a positive voltage, while zeros are represented by some other significant condition, usually a negative voltage, with no other neutral or rest condition [1,2]. After the pixel power on reset, the input port receives data from controller. The first pixel collects initial 24bit data then sends to the internal data latch. The other data which is reshaping by the internal signal is reshaping (amplification) circuit sends to the next cascade pixel through the output port. After transfer for each pixel, the signal reduces to 24bit.

Pixel adopts auto reshaping transmit technology, making the pixel cascade number is not limited. The signal transfer depends only on the speed of signal transfer.

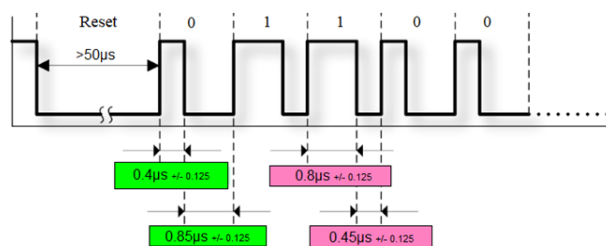


Fig. 1. Data transfer time intervals for protocol realization (an NRZ enterprise)

2.2. The Reason for the Inefficient Use of Hardware Resources

The LED strip on the WS2812B has only one digital input – DIN, connected to the first LED on the strip. It is supplied with a special pulse sequence encoding the bits, as shown in Figure 1. Each LED has one digital output – DOUT connected to the DIN input of the next LED on the bar. Each LED needs to transmit 24 bits (8 bits for each color: red, green and blue). Thus, in order to light all LEDs, 24*N bits must be transmitted, where N is the number of LEDs on the strip.

When LEDs have accepted the bits, they are light up and statically glow until receiving a new bit sequence. Each bit sequence begins with the installation of DIN into the logical zero for at least 50 μ s.

The bits are encoded by rather short pulses with tight tolerances. To generate them using microcontroller resources and software delays principle it's necessary to disable all interrupts to avoid the reset or the failed bit forming. The processor time resources are also wasted irrationally. For example, in order to ignite 100 LED's the microcontroller needs to work 3ms. If the state of the LEDs is updated with 100 Hz frequency, this "protocol" will take up 30% of the processor time.

3. Direct memory access

3.1. The meaning

Direct memory access (DMA) is a feature that allows certain hardware subsystems to access main system memory (random-access memory – RAM), independent of the microcontroller unit (MCU). This feature is useful at any time that the MCU cannot keep up with the rate of data transfer, or when the MCU needs to perform work while waiting for a relatively slow input/output (I/O) data transfer [2].

3.2. The advantage of use

The one packet transfer time with the reset and bit sequence is 53 μ s. The transfer of one packet is the color of one strip LED only. The more LEDs, the more packets need to be sent in order to glow them. Figure 2 shows that even the one packet transfer almost completely loads the microcontroller's processor. If you need additional logic to work with the same data, the use of DMA is impractical.

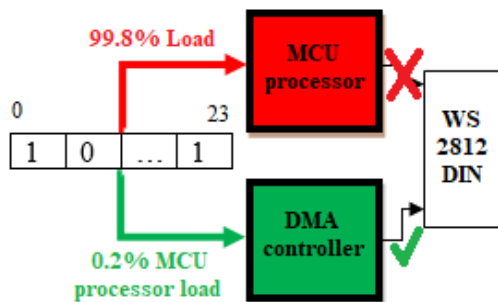


Fig. 2. The DMA feature advantage

The advantage of DMA is to minimize the use of microcontroller resources or completely eliminate its participation in data transfer to interact with other microcontroller's systems (timers, interrupts, input-output ports, analog-to-digital converter (ADC), etc.).

This feature does not affect the MCU at all, because it shares with DMA shared access to RAM and system bus. But measurements have shown that in this case this slowdown does not exceed 0.2%.

4. Software implementation

4.1. Protocol implementation

For the software implementation of the data transfer protocol, you need to perform several initial settings:

1. Enable the microcontroller timer in the PWM measurement mode.

2. Depending on the clock frequency of the microcontroller bus on which the connection with the timer is located, set the overflow counter with a certain coefficient that depends on the timer prescaler (a special parameter that divides the timer frequency by the specified integer coefficient) and satisfies the condition:

$$\text{timer frequency(MHz)} / 0.8 \text{ MHz} = \text{overflow factor}$$

The 0.8 MHz is a constant condition for the correct signal transfer intervals implementation according to the protocol. The signal transfer period lasts 1.25 μ s, which corresponds to:

$$1 / 1.25 \cdot 10^{-6} \text{ s} = 0.8 \cdot 10^5 \text{ MHz}$$

It should be noted that the coefficient of the timer overflow counter is a direct indication of the pulses number, which are needed to transmit a signal. This will help to set the duty cycle and specify the number of pulses to transmit a logical one and a logical zero (need to specify the number of pulses + 1 to bring the signal transfer time closer to the time parameters in the documentation) with the necessary intervals of time respectively. For example, the frequency of the microcontroller is 72MHz. The code implementation looks like this:

```
#define HIGH_IMPULSES 65
#define LOW_IMPULSES 26
```

Also, need to specify the periods number of data transfer reset, which is 50 μ s. Consider that one period is 1.25 μ s, the result after dividing is:

```
#define DELAY_LEN 48
```

Need to create a buffer of a certain size to transfer the generated data, which contains information about the number of LEDs, the reset time before each packet transfer and the packet length, which has constant 24 bits in size:

```
#define LED_COUNT 6
#define ARRAY_LEN DELAY_LEN +
    LED_COUNT*24
uint16_t BUF_DMA [ARRAY_LEN] = {0};
```

These settings are the basis for the implementation of the protocol data transfer function. The code fragment shows below:

```
...
volatile uint16_t i;
for(i=0;i<8;i++){
    if ((Rpixel & (1<<(7-i))!= 0) == 1){
        BUF_DMA[DELAY_LEN+posX*24+i+8] = HIGH; }
    else{ BUF_DMA[DELAY_LEN+posX*24+i+8] =
        LOW; }
    ...
```

It is necessary to given the fact that this protocol need to implement the data transfer via the G-R-B sequence and not R-G-B. This fact is described in the WS2812B specification.

4.2. Data transfer implementation using the DMA

It is necessary to implement a mechanism for transferring data from the MCU to the LED strip to image data in the form of color. Need to use DMA technology for the best decision. The use of technology is based on a pair of interrupts that control the data transfer process. The code description is made using the HAL (Hardware Abstraction Layer) library.

At the time of the data transfer start, it is necessary to notify the microcontroller about the event, which is a prerequisite for calling the event/interrupt handler.

The event (the role of the event is provided to the data transfer start function using DMA) should receive a reference to the used timer, the timer channel (the channels are designed to perform the most frequently used tasks in generating pulse signals and to measure the parameters of external pulse signals and can operate in the output or input mode accordingly. The channels performing can be implemented in software theoretically, but the hardware implementation offloads the processor, increases speed and accuracy of actions [3]), the reference to the data buffer with the conversion uint32_t* type and size of the buffer, as parameters. The example of a code description is presented below:

```
HAL_TIM_PWM_Start_DMA(&htim4,TIM_CHANNEL_1,(uint32_t*)&BUF_DMA,ARRAY_LEN);
```

Then an event / interrupt handler is automatically called which the data transfer must be completed in. Otherwise, an endless transfer of data from the buffer will follow. Continuous data flow will not allow to change the color on the LED strip further.

The completion of the transfer is also a function that plays the role of an event. It notifies the microcontroller when the transfer is over without losing and duplicating information. The parameters of this function are the reference to the timer and its used channel. The example of a code description is presented below:

```
HAL_TIM_PWM_Stop_DMA(&htim4,TIM_CHANNEL_1);
```

Conclusion

The use of the modern STM32 family microcontroller with built-in DMA technology allows significantly to increase the speed and volume of information processing, in particular, data transfer, which makes this device the leader in the implementation of software and hardware solutions, both in terms of software and hardware and in material costs comparing with such families as AVR or PIC.

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Гога М.В. Управління відображенням кольорової інформації без апаратних ресурсів мікроконтролера з використанням прямого доступу до пам'яті

У даній статті розглядається підхід до управління кольоровим відображенням інформації з використанням сучасних технологій, що дозволяють спростити реалізацію протоколу передачі даних і мінімізувати використання апаратних витрат в умовах миттєвої передачі даних великого обсягу в безперервному режимі. Пропонується програмна і апаратна реалізація управління з використанням мікроконтролера STM32F103C8T6, на основі технології ARM Cortex-M3, кольорової світлодіодної стрічки WS2812B і технології прямого доступу до пам'яті, реалізованої в мікроконтролері.

Ключові слова: протокол передачі даних, код без повернення до нуля, прямий доступ до пам'яті, WS2812B, технологія Cortex-M, мікроконтролер STM32.

Гога М.В. Управление отображением цветной информации без аппаратных ресурсов микроконтроллера с использованием прямого доступа к памяти

В данной статье рассматривается подход к управлению цветным отображением информации с использованием современных технологий, позволяющих упростить реализацию протокола передачи данных и минимизировать использование аппаратных затрат в условиях мгновенной передачи данных большого объема в непрерывном режиме. Предлагается программная и аппаратная реализация управления с использованием микроконтроллера STM32F103C8T6, на основе технологии ARM Cortex-M3, цветной светодиодной ленты WS2812B и технологии прямого доступа к памяти, реализованной в микроконтроллере.

Ключевые слова: протокол передачи данных, код без возврата к нулю, прямой доступ к памяти, WS2812B, технология Cortex-M, микроконтроллер STM32

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MATHEMATICAL MODEL OF DIFFUSION PROCESS FOR SOLVING HYDROECOLOGICAL PROBLEMS

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МАТЕМАТИЧНА МОДЕЛЬ ПРОЦЕСУ ДИФУЗІЇ ДЛЯ ВИРІШЕННЯ ГІДРОЕКОЛОГІЧНИХ ЗАВДАНЬ

Гулевська К.В., Шумова Л.О., Мохонько В.І.

The article discusses the actual tasks of adaptive control of local water treatment plants to ensure the rational use of water. The software solutions for modeling the diffusion process in a porous medium with the absorption of a diffusing substance on the pore surface are considered in detail.

Keywords: simulation modeling, automated systems, wastewater, water purification, adsorption, software.

The development of the productive forces of Ukraine is accompanied by an accelerated rate of water consumption. Taking into account the fact that, according to the international classification, Ukraine is among the European powers, the least endowed with its own water resources, the rational use of water becomes of paramount importance for it and is one of the most important tasks of ensuring environmental safety and sustainable development of the country's economy.

Optimal water supply can be achieved as a result of the introduction of water-saving technologies and technologies with low water consumption or as a result of improved water supply systems [1].

One of the effective ways of rational use of water resources is to protect them from pollution by improving systems and methods of wastewater treatment. The most current way to achieve the required quality of water purification are adaptive methods of managing the purification process. The implementation of adaptive control requires the creation and use of a mathematical modeling tool.

The article presents the results of solving problems of modeling water preparation processes. The adsorption purification method is considered. This method is used for deep treatment of wastewater from dissolved organic substances after biochemical treatment, as well as at local sewage treatment plants of industrial effluents, which are multicomponent mixtures [2]. In this method, the molecules of the dissolved pollutant are transferred from the solution to the surface of a highly absorbing substance (adsorbent) under the action of the

force field of the surface. Based on the studies presented in [3], adsorption can be considered as a process of stationary diffusion with absorption on the surface of particles in regions with a fine-grained random boundary.

The purpose of the study is to improve the local wastewater treatment system based on adaptive control methods using simulation modeling of the diffusion process in a porous medium with absorption of a diffusing substance on the surface of pores.

The limiting model of diffusion in a porous medium with absorption on the pore surface is based on Dirichlet problem [4]:

$$\begin{cases} -D\Delta u(x) + C(x, u) = f(x), & x \in \Omega, \\ u(x) = 0, & x \in \partial\Omega \end{cases}, \quad (1)$$

where D is the diffusion coefficient, Δ is the Laplace operator, $C(x, u)$ describes the limiting absorption of the system, $f(x)$ is the given function of external sources, Ω is the area of a substance that diffuses.

The required function $u(x)$ sets the concentration of a substance that diffuses at every point of the Ω area.

The universal methods for the approximate solution of differential equations applicable to a wide class of equations in mathematical physics are numerical methods, in particular, the finite difference method (or the grid method). The finite difference method is as follows. The area of continuous change of arguments is replaced by a finite (discrete) set of points (nodes), called a grid with step division (h) by spatial variables (Fig. 1.).

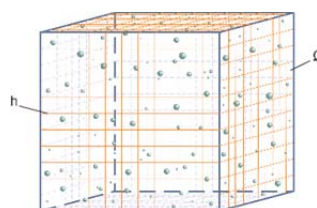


Fig. 1. Finite difference method illustration

Instead of functions of a continuous argument, functions of a discrete argument are defined, which are defined at the grid nodes and are called grid functions. Derivatives included in the differential equation are replaced (approximated) using the appropriate difference relations. The differential equation is replaced by a system of algebraic equations (difference equations). The initial and boundary conditions are also replaced by the difference initial and boundary conditions for the grid function.

The finite difference method was applied to the model (1), after which the system of difference equations acquired the following form (2).

$$\begin{cases} \frac{D}{h^2} [u(i-1,j,k)+u(i+1,j,k)+u(i,j-1,k) + u(i,j+1,k) + \\ u(i,j,k-1)+u(i,j,k+1)-6u(i,j,k)-C(i,j,k,u)+f(i,j,k)]; \\ i=1,\dots,n_1-1; j=1,\dots, n_2-1, k=1,\dots, n_3-1; \\ u(0,j,k)=u(i,0,k)=u(i,j,0)=0; \\ i=0,\dots,n_1; j=0,\dots,n_2; k=0,\dots,n_3. \end{cases} \quad (2)$$

Jacobi's iterative method is used to solve a system of difference equations. The computational algorithm of the method is that the new value at each grid point is determined as the average of the previous values of the four neighboring points (left, right, top and bottom). This process is repeated to the last point.

Computational algorithm was compiled for a system of difference equations (2). This algorithm consists of performing the following formal procedures:

- 1) Set $u^0[i,j,k]=0; i,j,k=\overline{0,\dots,n};$
- 2) Calculate $u^1[i,j,k], u^2[i,j,k], \dots, u^n[i,j,k]$

$$\text{bye } |u^{n-1}[i,j,k]-u^n[i,j,k]| < \varepsilon,$$

where ε - accuracy is 0.001;

$$\begin{aligned} u^n[i,j,k] = & \frac{1}{6} (u^{n-1}[i+1,j,k]+u^{n-1}[i-1,j,k]+u^{n-1}[i,j+1,k] + \\ & +u^{n-1}[i,j-1,k]+u^{n-1}[i,j,k+1]+u^{n-1}[i,j,k-1]) + \\ & + \frac{h^2}{6} (C(x_1^i, x_2^j, x_3^k, u^{n-1}[i,j,k]) - f(x_1^i, x_2^j, x_3^k)); \\ u^n[0,j,k] = & u^n[n,j,k] = u^n[i,0,k] = u^n[i,n,k] = \\ & = u^n[i,j,0] = u^n[i,j,n] = 0 \end{aligned}$$

The final stage of mathematical modeling is the development of a modeling tool - a set of programs that implement the presented methods and computational algorithms. A visual interface has been created to present the results of computational experiments using the Delphi development environment. This interface is convenient to use, buttons and windows are arranged so that they are easy to manipulate, related data is placed in one window, and moderate colors is used. One of four models is proposed for calculating the optimal amount of adsorbent: for moderate absorption, critical absorption, strong absorption, and for ultra-small particles.

The the program working window is shown in the figure (Fig. 2), where objects are indicated by numbers:

1. method selection switch;
2. input fields for diffusion parameters;
3. input fields for region parameters;
4. output field of the concentration matrix;
5. section layer illustration;
6. calculation start button.

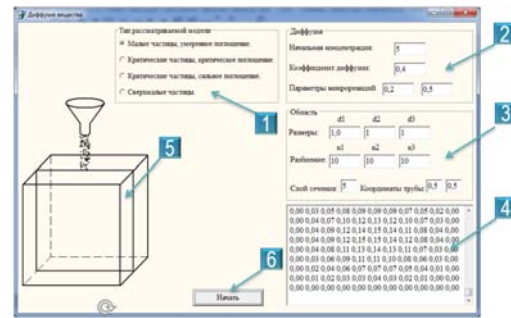


Fig. 2. The working window of the program

The results illustrate the effectiveness of the developed algorithms for determining the optimal parameters of the wastewater treatment process.

The introduction of the developed simulator into the control system of local water treatment plants will improve the accuracy of calculations of the required volume of the adsorbent, ensure the implementation of control system adaptation algorithms to the changing characteristics of wastewater, as well as obtain high quality water treatment.

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Гулевська К.В., Шумова Л.О., Мохонько В.І.
Математична модель процесу дифузії для вирішення гідроекологічних завдань

У статті розглядаються актуальні завдання адаптивного управління локальними водоочисними спорудами для забезпечення раціонального використання води. Детально розглянуті програмні рішення для моделювання дифузійного процесу в пористій середовищі з поглинанням дифундує речовини на поверхні пір.

Ключові слова: імітаційне моделювання, автоматизовані системи, стічні води, очищення води, адсорбція, програмне забезпечення.

Гулевская К.В., Шумова Л.А., Мохонько В.И.
Математическая модель процесса диффузии для решения гидроэкологических задач

В статье рассматриваются актуальные задачи адаптивного управления локальными водоочистными сооружениями для обеспечения рационального использования воды. Подробно рассмотрены программные решения для моделирования диффузионного процесса в пористой среде с поглощением диффундирующего вещества на поверхности пор.

Ключевые слова: имитационное моделирование, автоматизированные системы, сточные воды, очистка воды, адсорбция, программное обеспечение.

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DESIGN OF TECHNOLOGICAL PROCESSES CONTROL ALGORITHMS USING THE SOFTWARE LIBRARY OF ALGORITHMIC ELEMENTS

Kardashuk V.S.

РОЗРОБКА АЛГОРИТМІВ КЕРУВАННЯ ТЕХНОЛОГІЧНИМИ ПРОЦЕСАМИ З ВИКОРИСТАННЯМ БІБЛІОТЕКИ ПРОГРАМНОГО ЗАБЕЗПЕЧЕННЯ АЛГОРИТМІЧНИХ ЕЛЕМЕНТІВ

Кардашук В.С.

The results of designing the program library of algorithmic elements for the creation of algorithms and construction of control schemes for technological processes are presented in order to accelerate the formation of the final structure of the system.

Keywords: software library, algorithmic element, technological process, control system

1. Introduction

The main function, which relies on the automatic control system of technological processes - providing information about the state of the system and its management in case of rejection of parameters.

The degree of availability of information functions of the system, centralized control and measurement of the parameters of the state of the technological process is based on both the software and hardware implementation of the system.

Algorithmic design is to develop algorithms for the functioning and creation of software for computer systems.

Acceleration of the creation of control algorithms, the construction of schemes of interconnections of the system, the identification of priority control channels - is a topical issue in the design of control systems of technological processes.

Circuits of control and executive mechanisms, which constantly interact with the software system, receive commands from the controller, which provides centralized control of the technological process.

Modern design technologies for the creation of control systems for technological processes involve the use of pre-drawn templates that are made out in software libraries of algorithmic elements.

The purpose of the project is to create a program library of algorithmic elements for accelerating the design of control systems, and, if necessary, rapid modernization of algorithms.

2. Proposed approach

To provide information when designing a control system, an important role is played by the program library of algorithmic elements, which contains information about the function of the element and greatly accelerates the process of creating the final version of the system.

Issues in the design of software libraries of algorithmic elements are devoted to publications [1, 2].

A significant contribution to the development of modern technological design systems is provided by Altium, a software company Altium Designer [3].

The process of creating the finite control algorithms at the design stages consists in solving complex problems - from the creation of adaptive parametric models to the construction of a work process using computer technology.

When implementing control algorithms, the software library needs constant updating and support.

The proposed software library of algorithmic elements used in the design systems of process control circuits contains:

- combinational logic elements (AND, NOT, OR, MOD2, encoders, decoders, multiplexers, etc.);
- elements of a serial type (RS-trigger, D-trigger, registers, counters, etc.);
- dynamic elements (elements of integration, differentiation and filtering);
- static elements (adder, elements of subtraction, division, square root product, etc.)
- elements of nonlinearity (elements of restriction zones, insensitivity, elements of the relay with hysteresis, etc.);
- elements of regulation (regulators of the laws of regulation).

Here is an example of using a simple element in the implementation of a list of static elements that performs subtraction of two analog input values $Y = X1 - X2$ (fig. 1).

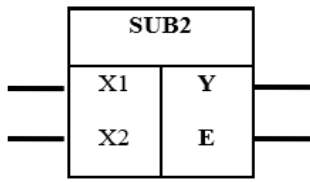


Fig. 1. Graphic representation of the subtraction element

The element contains two analogue inputs X1, X2 and a discrete output E of the overflow characteristics on the analog output Y of the subtraction element. There are no parameter settings for this item.

Here is an example of implementing a more complex element from a set of constraint elements that is used to simulate the constraint characteristics. The element contains the analog input X, the analog output Y and the index of the working area (fig. 2).

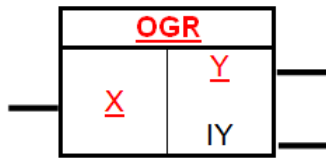


Fig. 2. Graphic representation of the restriction element
The element implements as follows

The element implements the following expression:

$$y = \begin{cases} YH, & \text{при } x \leq a \\ K \cdot X, & \text{при } a < X < b. \\ YB, & \text{при } x \geq b \end{cases} \quad (1)$$

Unlike the previous one, this item has parameters YN (lower limit of measurement of the output value), YB (upper limit of measurement of the output value and K (proportionality factor). Such elements may be present, for example, when generating schemes of different types of regulators for checking the input range signal and limit the range of the output signal in case of critical situations.

The diagram below shows the principle of the limitation element (fig. 3).

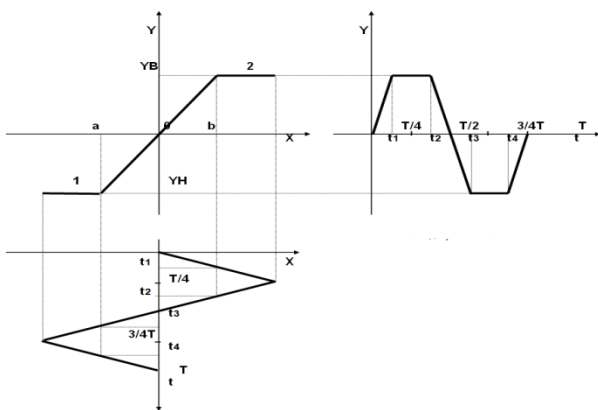


Fig. 3. Limit work element diagram

In more complex technological schemes, such as the digital proportional–integral–derivative controller (PID controller), which is more versatile than other regulators, it is possible to use one of the well-known regulatory laws.

In the XZ, the digital PID controller analyzes the XOS feedback and issues the control signal Y in case of deviation (fig. 4).

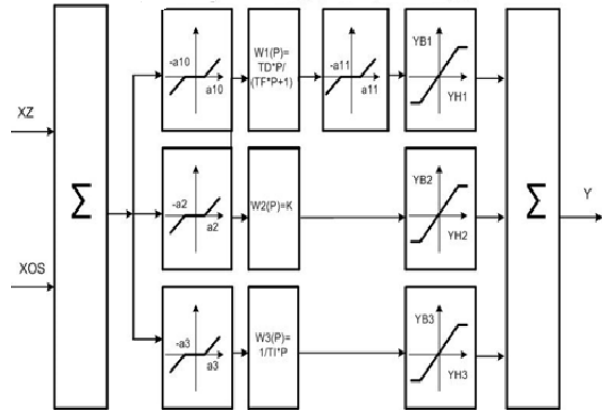


Fig. 4. Digital PID controller

The output signal of the digital controller is determined by three components: the proportional, differential and integral parts of the equation.

The presented regulator is a program element that implements a discrete part of the equation:

$$W_{PID}(p) = K_p \left(1 + \frac{1}{T_i \cdot p} + T_d \cdot p \right) \quad (2)$$

Graphic editor of functional schemes is used to solve the following tasks of the technological chain:

- constructing / editing a graphic image of a single element of a functional schema;
- build / edit a functional schema.

The development of graphic images for constructing algorithms is carried out with the help of Altium Designer software company Altium, which, according to the developers of the company, reduces the time for designing the final solution in 2 times [3]. It should be noted that the company creates products not only for industrial systems, but also for the educational process. Among the advantages of the Altium Designer system should be noted:

- intuitive keys and commands that are commonly accepted;
- online help system;
- the mechanism of synchronization of the design stages to achieve the final result.

For a program description of the functional purpose of algorithmic elements, the programming language C++ [4] is used, which allows the use of software in various operating systems.

At the final stage of design, a set of automata (algorithms) of control on the basis of algorithmic elements is combined into a single program, loaded into the controller's memory and launched for execution in sequence in the order of the set queue or when receiving control in accordance with the conditions.

For example, the technological circuit (control machine) of the equipment may look as shown in fig. 5.

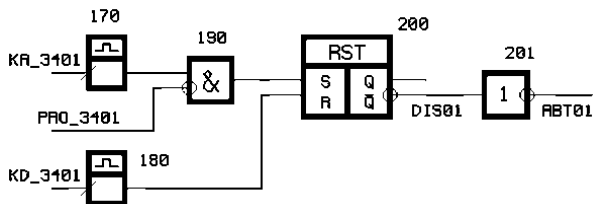


Fig. 5. Technological scheme of the control automaton

In case of necessity the introduction of changes in the technological scheme is carried out by replacing one element with another or by adding the necessary element / elements, which reduces the time for the program implementation of the control system.

Conclusion

Modern approaches to the design of algorithms, software and hardware require acceleration of final decisions, and, if necessary, a reduction in the time for their modernization.

On the example of designing the software library of algorithmic elements, it is shown for its application for the construction of algorithms of automata and implementation of control schemes of technological devices.

Application of the software library will significantly reduce the time for designing and upgrading the final decisions of the technological process.

The advantages of using such software libraries are the study of many options for using the model at any stage of the design without the restructuring of the control system, rapid upgrading of algorithms, thus creating precise models of objects consisting of dozens of elements.

As a result of implementing the goal of designing a database of existing graphic images (Schematic Library Document), stored in *.PsbSch format, is supplemented with new elements that allow the implementation of elements of integration, differentiation, adder, etc.

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Кардашук В.С. Розробка алгоритмів керування технологічними процесами з використанням бібліотеки програмного забезпечення алгоритмічних елементів

Представлені результати розробки програмної бібліотеки алгоритмічних елементів для створення алгоритмів і побудови схем управління технологічними процесами з метою прискорення формування кінцевої структури системи.

Ключові слова: бібліотека програмного забезпечення, алгоритмічний елемент, технологічний процес, система управління

Кардашук В.С. Разработка алгоритмов управления технологическими процессами с использованием библиотеки программного обеспечения алгоритмических элементов

Представлены результаты разработки программной библиотеки алгоритмических элементов для создания алгоритмов и построения схем управления технологическими процессами с целью ускорения формирования конечной структуры системы.

Ключевые слова: библиотека программного обеспечения, алгоритмический элемент, технологический процесс, система управления

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USING INTELLECTUAL MEANS FOR DIAGNOSIS OF WIRELESS SENSOR NETWORK

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ВИКОРИСТАННЯ ІНТЕЛЕКТУАЛЬНИХ ЗАСОБІВ ДЛЯ ДІАГНОСТУВАННЯ БЕЗДРОТОВОЇ СЕНСОРНОЇ МЕРЕЖІ

Кривуля Г.Ф., Сергієнко В.І.

The paper discusses the adaptive neuro-fuzzy inference system ANFIS for intellectual diagnostics of large-scale wireless sensor networks. The solution for functional diagnostics of wireless sensor network is realized by the expert system designed on the knowledge base in the form of a neuron-fuzzy network.

Keywords: ANFIS, wireless sensor network, diagnostic parameters, neural network, fault detection, fault tolerance.

1. Introduction

Last advances in low-power wireless technologies have enabled us to expand of wireless sensor networks (WSN) on different new networked systems. There is wide variety of WSN applications, such as environment monitoring, scientific observation, emergency detection, field surveillance, and structure monitoring, and so on. In those applications, hundreds or even thousands of sensor nodes are assumed to be deployed in the target fields. Besides many algorithmic studies that focus on designing efficient schemes or protocols to coordinate large-scale sensor networks, there are also systematic studies that make efforts in optimizing sensor networks in practice, which are usually tested on lab scale test beds or small scale deployments.

In the general case, WSN is a cluster of the small nodes that are organized into a supportive network. It comprises from the sets of spatially disseminated independent devices using sensors to monitor the physical or environmental conditions: temperature, light, sound, pressure, humidity, vibration etc.

Remote sensor devices commonly have insufficient vitality and transmission limit, which cannot coordinate the transmission of a substantial number of information gathered by sensor nodes. WSN are normally fault-prone and their good quality is vigorously impacted by issues. A fault is essentially a sudden change in a framework, in spite of the fact that it might happen because of different reasons including battery exhaustion, radio impediment,

de - synchronization, or separation. These failed nodes may decrease the quality of service (QoS) of the entire WSN. That is why it is important to study the fault detection methods for nodes in WSN.

Existing approaches to diagnosing sensor networks are generally sink-based and grounded on actively pulling state information from all sensor nodes to the central point what is referred to as “centralized analysis”. However, the sink-based diagnosis tools incur huge communication overhead to the traffic sensitive sensor networks. Also, due to the unreliable wireless communications, sink often obtains incomplete and sometimes suspicious information, leading to highly inaccurate judgments. We observe that it is always more difficult to obtain state information from the problematic or critical regions.

2. Related works

The WSN node status can be divided into two types [1-3]: normal and faulty. Faulty in turn can be “permanent” or “static”. The so-called “permanent” means failed nodes will remain faulty until they are replaced, and the so-called “static” means new faults will not generated during fault detection. In [2, 3], node faults of WSN were divided into two categories: hard and soft. The so-called “hard fault” occurs when a sensor node cannot communicate with other nodes due to the failure of a certain module (e.g., communication failure due to the failure of the communication module, energy depletion of node, being out of the communication range of entire mobile network because of the nodes moving and so on). The so-called “soft fault” happened when the failed nodes can continue to work and communicate with other nodes (hardware and software of communication module are normal) but the data sensed or transmitted is not correct.

In [4] is given the fault types of the classification for the WSN: data-centric viewpoint; system centric viewpoint; distributed viewpoint; duration viewpoint; and component viewpoint. The intelligent diagnostic

system (IDS) is proposed in [5, 6]. Expert diagnosis of the IDS uses neuro-fuzzy knowledge base. For the formation of logical conclusions knowledge is used in the form of fuzzy function with linguistic variables [7]. The use of the IDS with neuro-fuzzy knowledge base to solve problems of diagnosing complex technical objects extends the capabilities of such a class of intellectual systems, allows for an expert estimation of more variants, with increasing the reliability and accuracy of the obtained results, with equal computational resources.

3. Setting the task

WSN node faults are usually due to the following causes: the failure of modules (such as communication and sensing module) due to fabrication process problems, environmental factors, enemy attacks and so on; battery power depletion; being out of the communication range of the entire network.

The main purpose of this work is the development of automated methods for intelligent functional diagnosis for WSN.

In the process of achieving the main goal, the following tasks are formulated and solved: conducting a continuous analysis of the technical state of the WSN in the process of functioning without disturbing functional links; operational receipt of information about the technical state of the WSN at an arbitrary time; elimination of the need for additional stimulus signals for WSN in the diagnostic process; possibility of predicting deviations of the technical state of the WSN from normal in the process of obtaining current data from sensors.

4. Intellectual diagnostic of wireless sensor network

Information part of IDS provides accumulation, storage and transfer of information to other parts of it, and also implements the interface of the end user. Data from sensors is unstructured and requires further processing. The need for real-time decision-making results in the fact that the number of decision trees constructed according to incoming data should be equal to the number of counts (analogue of conveyor data processing). Tree decision trees for each time interval require significant memory costs for the IDS, so averaging for input data is usually used to reduce such costs. However, information on current changes in data from sensors over a period of time may be lost, which is a significant disadvantage of the methods for calculating averages. The problem of a significant amount of complex object data

can be solved by using these data as a training sample for neuro-fuzzy knowledge base.

There are mainly two sorts of node faults in WSN. The primary type is function fault, in which the sensor node cannot convey the data packet suitably. The second type is data fault, in which the node can convey the information bundle effectively yet the information gathered by sensor node is off base.

To evaluate the health of a sensor node, a binary logic function X is often used with a set of its values $\{0,1\}$. At the same time, if x is 1, then the node is operational and if x is 0, then the node is inoperable. However, fuzzy X values are required to use in the IDS.

For the fuzzification of input the crisp values convert of the input variables X and output variables Y into fuzzy, select the appropriate distribution functions and the number and values terms.

We consider a crisp variable between “0” and “1” and it has five terms with the following limits. – “0-0.1” - “Very Close to 0” ; – “0.1-0.2” - “Close to 0”; – “0.2-0.8” - “AverageValue”; – “0.8-0.9” - “Close to 1”; – “0.9-1” - “Very Close to 1”.

We apply this fuzzification for all input variables and for output variables. At the figure 1 is shown five membership functions of the input variable X .

To implement the diagnostic algorithms, we use the MatLab and ANFIS system.

The adaptive network-based fuzzy inference systems (ANFIS) is used to solve problems related to parameter identification. ANFIS is basically a graphical network representation of Sugeno-type fuzzy systems endowed with the neural learning capabilities. The network is comprised of nodes with specific functions collected in layers. ANFIS is able to construct a network realization of IF / THEN rules. All computations can be presented in a diagram form. ANFIS normally has 5 layers of neurons of which neurons in the same layer are of the same function family.

Layer 1 (L1): Each node generates the membership grades of a linguistic label.

Layer 2 (L2): Each node calculates the firing strength of each rule using the *min* or *prod* operator. In general, any other fuzzy AND operation can be used.

Layer 3 (L3): The nodes calculate the ratios of the rule’s firing strength to the sum of all the rules firing strength. The result is a *normalised firing strength*.

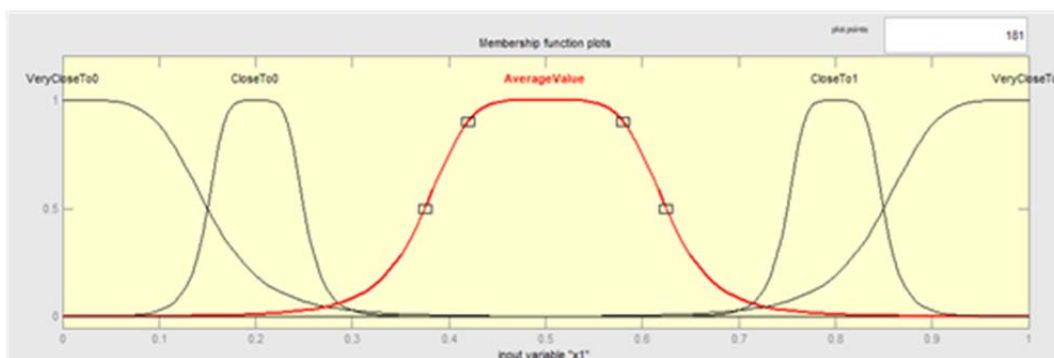


Fig. 1. Membership functions of the input variable X

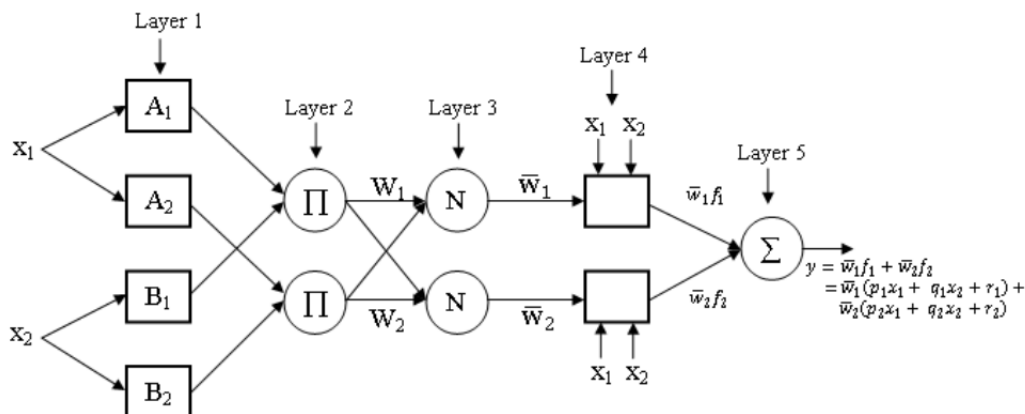


Fig. 2. Structure of the ANFIS network

Layer 4 (L4): The nodes compute a parameter function on the layer 3 output. Parameters in this layer are called *consequent parameters*.

Layer 5 (L5): Normally a single node that aggregates the overall outputs the summation of all incoming signals

For an example of the functioning of the IDS, we believe that it is possible to measure numerical values for 24 diagnostic parameters (DP1, ..., DP24). The values of the sensor readings are obtained at discrete moments of time $t_0, t_1, t_2, \dots, t_i$. The time interval (t_i+1-t_i) between two adjacent dimensions is selected taking into account the speed of the change of diagnostic parameters. All 24 characteristics will play the role of diagnostic parameters in the process of intellectual diagnosis.

Conclusion

The IDS considered in this paper, along with the use of traditional knowledge base, allows us to use the neural networks and to formalize the above practical problems that arise during the operation of various technical objects to achieve the main goal of work.

The ANFIS algorithm is used in order to improve the efficiency and accuracy of diagnostic sensor node. Because of using different ways to train and simulate ANFIS data within a single wireless sensor node, we generate a kind of intelligent system.

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Кривуля Г.Ф., Сергієнко В.І. Використання інтелектуальних засобів для діагностування бездротової сенсорної мережі

Запропоновано систему адаптивного нейро-нечіткого висновку ANFIS для інтелектуальної діагностики масштабних бездротових сенсорних мереж. Рішення задачі функціональної діагностики реалізується експертною системою на основі бази знань у вигляді нейро-нечіткої мережі.

Ключові слова: ANFIS, бездротова сенсорна мережа, діагностичні параметри, нейронна мережа, виявлення несправностей, відмовостійкість.

Кривуля Г.Ф., Сергієнко В.І. Использование интеллектуальных средств для диагностирования беспроводной сенсорной сети

Предложено использование адаптивной системы нейро-нечеткого вывода ANFIS для интеллектуальной диагностики крупномасштабных беспроводных сенсорных сетей. Решение задачи функциональной диагностики реализуется экспертной системой на основе базы знаний в виде нейро-нечеткой сети

Ключевые слова: ANFIS, беспроводная сенсорная сеть, диагностические параметры, нейронная сеть, обнаружение неисправностей, отказоустойчивость.

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DATA MINING TECHNIQUES FOR IOT ANALYTICS

Krytska Y.O., Biloborodova T.O., Skarga-Bandurova I.S.

ІНТЕЛЕКТУАЛЬНИЙ АНАЛІЗ ДАНИХ ДЛЯ ІОТ АНАЛІТИКИ

Критська Я.О., Білобородова Т.О., Скарга-Бандурова І.С.

Data mining (DM) is one of the most valuable technologies enable to identify unknown patterns and make Internet of Things (IoT) smarter. The current survey focuses on IoT data and knowledge discovery processes for IoT. In this paper, we present a systematic review of various DM models and discuss the DM techniques applicable to different IoT data. Some data specific features were analyzed, and algorithms for knowledge discovery in IoT data were considered. Challenges and opportunities for mining multimodal, heterogeneous, noisy, incomplete, unbalanced and biased data as well as massive datasets in IoT are also discussed.

Keywords: Data Mining, Internet of Things, IoT, Knowledge Discovery in Database, KDD, massive data set

Introduction. IoT applications generate more than 2.5 quintillion data bytes daily [1]. To convert this data into knowledge, data mining systems are increasingly in demand. Data mining (DM) enables to find and discover novel, interesting, and useful patterns from large data sets and generate new knowledge from information obtained from IoT devices. However, basic data mining algorithms and technologies are not quite sufficient for IoT framework. So, it becomes a great challenge to collect, analyze and manage IoT data as well as to generate and update data mining algorithms for IoT purposes. In this paper, we discuss some DM approaches applicable for IoT data. An important aspect of DM of the IoT-based system is the effective structure of the system, which should take into account security, data privacy, data sharing mechanisms, scalability, etc. Such a DM system for IoT includes data acquisition devices, raw data properties, extraction levels, processing, data analysis, it is necessary to take into account the properties of the IoT devices when planning DM for IoT [5]. Technically, every IoT thing can create data, but technical issues and challenges on how to handle this data and how to obtain useful information have still emerged.

The general purpose of any DM process is to build a best predictive or descriptive model of a large amount of data that not only fits or explains it but is also able to generalize to new data [3, 4]. It is assumed that the con-

cept of DM for IoT will stimulate business models for IoT. Based on a broad understanding of DM functionality, data mining is the process of finding interesting knowledge from large amounts of data stored in any database, data repositories, or other data repositories.

Data mining techniques for IoT based applications has been widely presented in literature for different decision tasks, such as supervised and unsupervised learning for IoT applications [5, 14, 32], frequent pattern recognition and association analysis [4, 19, 21], massive IoT data mining [22, 24], stream data mining [36], etc.

The detailed surveys on the approaches, tools and techniques employed in existing for IoT data mining can be found in [2, 23]. Practical approaches in massive data processing for IoT applications are present in [31, 32, 33] for parallel and distributed data processing.

This survey focuses on IoT data and knowledge discovery processes for IoT. Our main contribution in this paper is that we targeted on data specific features and selected some well-known algorithms best suited for knowledge discovery in different IoT applications.

1. IoT data characters

IoT devices and sensors have two general limitations that must be considered when designing and planning the operation of IoT data mining systems:

- Limited energy resource device.
- Limited device memory.

The instability of the network connection and availability of the thing due to the unpredictable mobility of devices, different battery discharge rates, equipment failures and lack of a priori knowledge of the hardware and software characteristics of devices [6-8].

The power source must match the data, i.e. be sufficient for IoT computations. Storing information leads to the expenditure of battery energy. The solution to this problem is provided by storing and performing computational operations using remote IoT computing resources, such as a server and / or cloud. So far as IoT systems create a huge amount of dynamic data, analysis and extracting useful information from this data with DM can facilitate the automation of intelligent decision making.

IoT data can be:

- multimodal and heterogeneous;
- noisy and incomplete;
- unbalanced and biased;
- dependent on time and location;
- dynamic, different data quality;
- almost always require real-time analysis.

Given that IoT data is the basis for extracting knowledge, it is important to have high quality information. This condition can directly affect the accuracy of knowledge extraction.

Figure 1 shows an overall level for transformation of data and depicts a level of services where big DM for IoT is applicable.

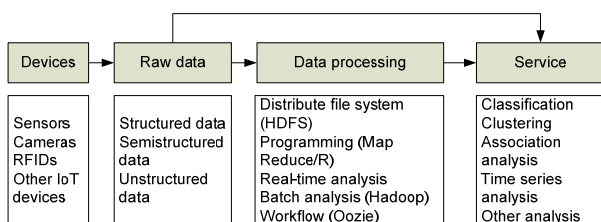


Fig. 1. Big data mining based on IoT (Adapted from [2])

2. Basic idea of using data mining for IoT

One of the most important questions that knowledge discovery in databases (KDD) and data mining technology can solve is how to transform the data generated or captured by IoT into knowledge that serve to the environment and people.

The main characteristics of the source data of IoT-based system are the following [2]:

1. They are really big data.
2. Heterogeneity of the sources being combined and the types of data: the data of the IoT-based system may include several data sources, for example, data from sensors, historical data, which may also have different formats: numerical, categorical, textual, binary, etc.
3. The complexity of recoverable knowledge: due to heterogeneity and a large amount of data when extracting knowledge, it is necessary to analyze their properties and the interrelation of various data sources. These characteristics require special attention in the process of DM of the IoT-based system for obtaining an effective and high-quality result.

In the process of extracting useful knowledge,

there are the following issues.

1. Data extraction: data can be combined from various sources, they are diverse and heterogeneous, and noisy.

2. Uncertainty and incompleteness of data: compliance with data security and confidentiality causes uncertainty and incompleteness of data in the extraction of useful knowledge.

To solve these problems, approaches and methodologies are being developed that try to minimize their consequences. Tracking and detection of data errors, preprocessing filtering, and data reduction mechanisms are used. To combine data from several sources, parallel programming models are used, for which classical approaches to DM are adapted.

The selection of models depends on the area of IoT in which they are applied. For example, in ecology: pollution prediction, anomaly detection, prediction and interpolation of missing events are common. In medicine, traditional models used to predict a patient's conditions can include his history, clinical data as input along with real-time status monitoring data. It is also important to consider that IoT includes temporary and massive data.

The merging of data or data fusion is associated with combining data from different sources so that the information obtained has less uncertainty than would be possible when these sources were used individually. The term "reducing uncertainty" in this case may mean more accurate, more complete or more reliable, or refer to the result of an emerging presentation based on combined information.

The DM process for IoT is similar to the base one, but there are some big differences. The process of extracting useful patterns from raw data is known as Knowledge discovery in databases (KDD). It is illustrated in Fig. 2.

The KDD process takes raw data as input and provides statistically significant patterns found in the data (i.e., knowledge) as output. From the raw data, a subset is selected for processing and is denoted as target data. Target data is preprocessed to make it ready for analysis using DM algorithm. Data mining is then performed on the preprocessed (and transformed) data to extract interesting patterns. The patterns are evaluated to ensure their validity and soundness and interpreted to provide insights into the data.

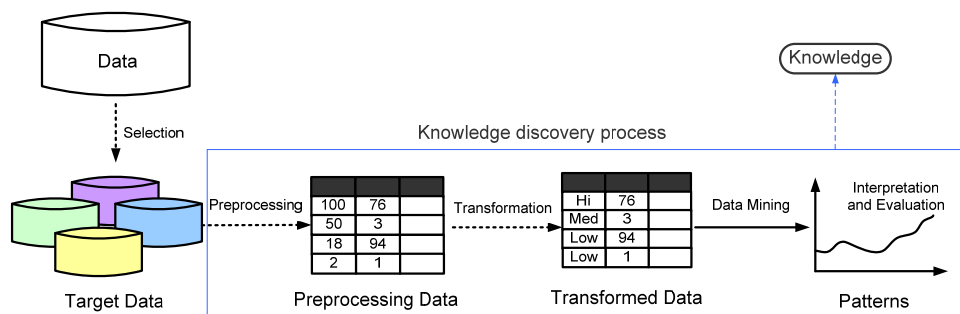


Fig. 2. Traditional KDD process

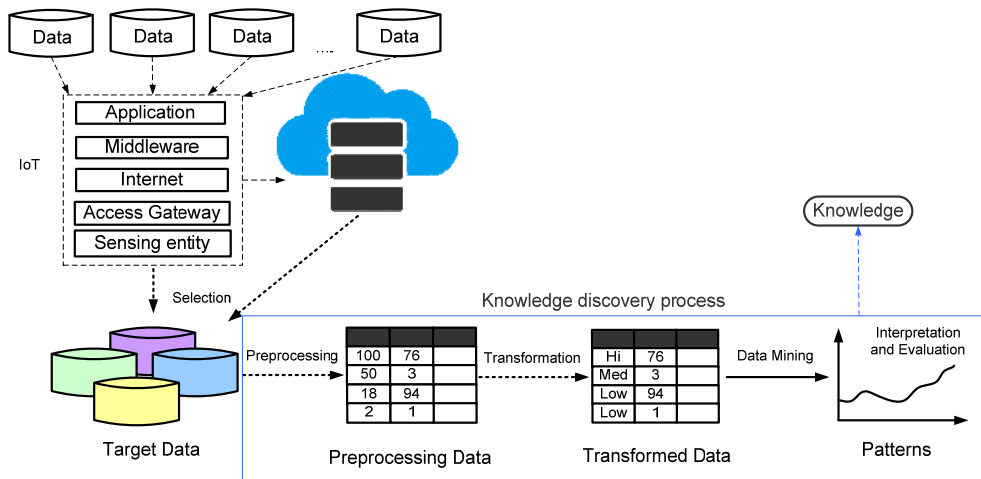


Fig. 3. KDD process for IoT data

Based on the DM and IoT overview, the data mining in IoT process is as follows (see Fig. 3): DM for IoT begins with the first step of capturing data generated from IoT devices which includes: Sensor networks, Actuators, Wireless Sensor Network (WSN), Wireless Sensor and Actuator Network (WSAN), Radio Frequency Identification (RFID) Tags, Cameras, GPS etc.

To store and analyze such large amount of data, data warehouses are used where data preprocessing (cleaning the data (removing noisy, inconsistent and incomplete data), vectorization the data), data transforming which includes converting the data into the forms appropriate for data analyzing, and data reducing are performed.

Next step is selecting an appropriate DM methodology for converting the preprocessed data into knowledge.

KDD, when applied to IoT, will convert the data collected by IoT into useful information that can then be converted into knowledge.

In many cases, only small scale data from IoT systems can be mined. Therefore, it is a big challenge to implement existing DM techniques to a large scale IoT distributed systems [9].

3. Applying data mining algorithms for IoT data

To determine which algorithm to use for a particular task, we need to first define the task and aim of analysis. Some of tasks include finding unusual data points, predicting values or categories, structures discovery, feature extraction and more.

Table shows some examples of using data mining algorithms for IoT data [10, 11].

3.1. Classification for IoT

Classification is an important technique in DM that assigns items in a collection of target categories or classes. Classifying the data sets into different categories enables to understand the data more easy. There are two big categories of classification, they are supervised and unsupervised learning that are widely used in IoT data mining [12]. The goal of supervised learning is to predict the corresponding output vector for a given input

Table

Application of DM algorithms for IoT data		
DM algorithm	Goal	Data Source
Classification	Device recognition	RFID
	Traffic event detection	GPS, smart phone, and vehicle sensor
	Parking lot management	Passive infrared sensor
	Inhabitant action prediction	RFID, sensor, video camera, microphone, wearable
	Inhabitant action prediction	kinematic sensor, and so on
	Inhabitant action prediction	Video camera
Clustering	Network performance enhancement	Wireless sensor
	Inhabitant action prediction	X10 lamp and home application
	Provisioning of the needed services	Raw location tracking data
	Housekeeping	Vacuum sensor
	Managing the plant zones	GPS and sensor for agriculture
	Relationship in a social network	RFID, smart phone, PDA, and so on
Frequent Pattern	RFID tag management	RFID
	Spatial colocation pattern analysis	GPS and sensor
	Purchase behavior analysis	RFID and sensor
	Inhabitant action prediction	RFID and sensor
Anomaly Detection	Smart Traffic	GPS, smart phone, and vehicle sensor
	Smart Environment	Wireless sensor, smart phone
	Traffic Prediction	GPS, smart phone, and vehicle sensor
	Finding Anomalies in Power Dataset	RFID, wireless sensor
Hybrid	Inhabitant action prediction	RFID and sensor

vector. Tasks in which the output label value is discrete are known as classification problems. Classification assumes some prior knowledge to guide the partitioning process to construct a set of classifiers to represent the possible distribution of patterns.

Generally, the classification task can be defined as follows: for given a set of labeled data L and a set of unlabeled data NL , we need to find a classifier or set of classifiers (i.e., the hyperline or prediction function) for NL using the set of labeled data L .

The use of classification methods is a solution to the problem of uncertainty and incompleteness of IoT data. In this context, the use of DM always includes solving two related tasks: defining regular links between data elements and using these patterns to solve classification problems: predicting the values of some elements from known values of other elements.

There are a vast number of classification methods, they also includes decision tree learning, naïve Bayes classifier, k-nearest neighbor classifier, classification with neural network and regression methods such as linear regression and logistic regression, etc.

3.2 Clustering for IoT

One of the main goals of unsupervised learning is the process of identifying similar cluster patterns in the input data, called clustering [12]. In addition, the goal of DM may be to open a useful internal representation for the input data by preprocessing the original input variable, to transfer it to a new space of variables [13].

One of the most important parameter that needs to be determined during the clustering is a measure of similarity (or dissimilarity) between individual objects that are clustered [15]. One of the criteria to measure the similarity between two vectors x_1 and x_2 in d -dimensional space is the Euclidean distance

$$d(x_1, x_2) = \|x_1 - x_2\| = \sqrt{\sum_{r=1}^d (x_{1r} - x_{2r})^2}, \quad (1)$$

$$d(p, q) = \sum_{k=1}^n (p_k - q_k).$$

Many clustering algorithms have been developed for data analysis, which can be grouped into the following main categories: Partitioning-based clustering; Hierarchical clustering; Grid-based clustering; and Density-based (DB) clustering algorithms. It should be mentioned that characteristics of data streams do not allow the use of traditional DB clustering. Recently, many DB clustering algorithms have been extended tailored to data streams. The main idea of these algorithms is to use the DB method in the clustering process and at the same time overcome the limitations that are determined by the nature of the data flow. There are two broad groups of DB clustering algorithms called density micro-clustering and density grid-based clustering algorithms.

Clustering helps to solve the following IoT data analysis tasks:

- Processing of data of high dimension. Often complex concepts of the real world are accompanied by

a large number of functions. This strengthens the assessment tool (for example, a classifier) to deal with a large number of functions for learning and in order to be able to generalize afterwards. Inside these functions it is often either redundant or irrelevant, and their use usually affects the complexity and the need for computational resources.

- Cluster heterogeneity. Distance-based clustering algorithms tend to find spherical clusters with the same size and density. Clustering algorithms that can detect clusters of arbitrary shape, size, density, and data coverage help to gain a deeper understanding of the various correlations between functions, which, in turn, can greatly facilitate the decision-making process.

- Interpretable results. The high dimension of the data space is cumbersome for rendering methods.

Clustering is also widely used to handle streaming data [14].

3.3. Frequent Pattern Mining for IoT

Recently, much attention has been paid to new promising methods for extracting interesting knowledge from data from the IoT-based system. DM algorithms that have low computational complexity are being developed [16-18]. The processes of forming frequently occurring patterns, creating association rules are computationally simple in this respect and are often used as methods for finding interesting knowledge.

The disadvantage of this analysis is the detection of patterns, rules that do not contain meaningful information.

Since IoT-based systems generate large amounts of data, it is necessary to use appropriate measures of significance, which have a strong correlation between the data, to search for frequently occurring patterns, associations.

The basic prerequisites of the model for the effective detection of commonly occurring patterns in IoT data are [19]:

1. Determination of the relevant significance parameters for the detection of patterns that meet the downward closure property; when all subsets of the frequent set of features are frequent, to reduce the search space.

2. Compactness of the structure of the model, obtained by using the distributed and parallel methods of DM.

3. Adaptability of the model structure for effective analysis of the latest relevant information and extraction of relevant patterns in the data. To fulfill this condition, the optimal size of the data window is determined, which helps to avoid the rapid obsolescence of information.

The dimension of the rule space depends on the minimum threshold of parameters defining the significance of the rules. If the minimum threshold is set high, then we can extract valuable knowledge. On the other hand, at a low minimum threshold of the rule significance parameter, an extremely large number of association rules are generated, most of which are non-informative. In this case, the actual correlation in the da-

ta is hidden among a huge number of insignificant rules [20].

Frequent pattern mining (FPM) in some domain often involve real challenges arise from their nature and the field of application. Frequent pattern and associations rules involve many items that hard to interpret and generate a lot of outcomes. In many cases, the obtained association rules can either be too obvious, or contradict a priori knowledge, or contain redundant information. The task of FPM and mining association rules is to generate minimal set of rules providing complete coverage of outcomes with objective parameters, such as support and confidence greater or equal than some pre-specified thresholds of minimum support and minimum confidence, respectively. FPM process includes several steps.

Data transformation into the nominal scale is among the first steps in FPM. The transformation process realizes different goals depending on the approach. In a normative-oriented approach, the reduction of indicators makes it possible to determine the value of a variable with respect to certain generally accepted norms, or to compare the results, giving a definition of the value of a variable with respect to the other values.

When the criterion-oriented approach is given, the value shows the percentage of compliance with the value of the variable to a specific criterion.

Next stage is sorting the rules according to the class and reducing the number of rules by the elevator parameter as follows.

Step 1: set formation L_1 of one-item sets c_1 , that often meet and determine their support;

Step 2: set formation L_k k -item sets, that often meet. Each member of the set has a set of ordered $(i_j < i_v, \text{ if } j < v)$ itemes F and he support value of the set $supp_F > supp_{min}$:

$$L_k = \{(F_1, supp_1), (F_2, supp_2), \dots, (F_q, supp_q)\}, \quad (2)$$

where $F_j = \{i_1, i_2, \dots, i_k\}$.

The definition from the set L_k of k -item sets, corresponding to a certain minimum threshold value of support.

Step 3: based on the specific sets of element sets from step 2, the formation of the set C_k rules k -item sets is potentially often encountered. Each member of the set has a set of ordered $(i_j < i_v, \text{ if } j < v)$ itemes F and a support value of the set of $supp$.

Formation of a set k -item sets into frequent sets. According to this, the integration into k -item rules of $(k-1)$ -item sets, s carried out, often encountered. Each rule $R \in C_k$ is formed by adding v to an $(k-1)$ -item set v , that frequently occurring item with another $(k-1)$ -item set q , that frequently occurring.

Step 4: reduction of all uninteresting rules using measures of determining the interestingness of rules.

3.4. Association analysis

The results of DM are certain patterns and trends whereby we have to find out the interesting patterns best

suit to our needs. However, after applying the some DM methodologies for IoT environments, a large number of patterns are evaluated. Many of these patterns are non informative and that is why not interesting for further analysis. Patterns become interesting when they are unknown till yet and not expected. With this purpose, associative analysis can be used.

The goal of associative data analysis is to identify associations between input and output data, identify the most specific factors for the qualitative separation of variables into classes, and quantitatively describe the relationship between these events. When defining associations in the data, a large number of rules are usually obtained. To determine their information value, it is necessary to use methods to reduce their number and determine from them potentially interesting ones.

In general case, association analysis algorithms generate a huge number of items and can produce up to hundreds of association rules. An association rule is an implication expression

$$R : X \rightarrow Y,$$

where X denoted antecedent and Y denotes consequent $X \cap Y = \emptyset$. Both X and Y are considered as a set of conjuncts of the form $c_1, c_2 \dots, c_k$. The strength of the association rule is measured in terms of its support (s), confidence and interestingness.

For pair of rule-candidates, binary variables R_1 and R_2 the lift is equivalent to interest factor, which is defined as follows:

$$I(R_1, R_2) = \frac{s(R_1, R_2)}{s(R_1) \cdot s(R_2)}. \quad (3)$$

The measure of interestingness in this case can be interpreted as follows:

$$I^1(R_1, R_2) \begin{cases} = 1, & \text{if } R_1 \text{ and } R_2 \text{ are independent,} \\ > 1, & \text{if } R_1 \text{ and } R_2 \text{ are positively correlated,} \\ < 1, & \text{if } R_1 \text{ and } R_2 \text{ are negatively correlated.} \end{cases} \quad (4)$$

In order to increase the information importance of rules, it is necessary to reduce their number and focus on potentially interesting ones. Further exploration of interestingness leads us to discovering different subjective and probabilistic measures of interestingness. To determine the interestingness of the rule, various probabilistic measures are used: support, confidence, Goodman-Kraskal, Pyatetsky-Shapiro, Laplace, etc. In the present study, for reducing number of rules we applied three level technique proposed in [21] beginning with detection of deviations in data, then testing of differences among adjusted attributes and finally, quantifying the interestingness of association rules.

1. Detecting deviations in data is performed as follows.

The every conjunct c_j from association rule set is represented in the form $\langle A = V \rangle$, where A is an item

name (attribute), $\text{Dom}(A)$ is the domain of A , and I (value) $\in \text{Dom}(A)$. Degree of deviation is defined as deviation between two conjuncts $\Delta(c_i, c_j)$ and is calculated on the basis of the comparison between the items of the two conjuncts. For conjuncts c_i, c_j deviation of c_i with respect to c_j is defined as a Boolean function as follows:

$$\Delta(c_i, c_j) = \begin{cases} 0, & \text{if } A_i = A_j \text{ and } V_i = V_j, \\ 1, & \text{if } A_i = A_j \text{ and } V_i \neq V_j. \end{cases} \quad (5)$$

2. The differences among adjusted attributes can be calculated using the following formula:

$$\bar{d}(R_1, R_2) = \begin{cases} 0, & \text{if } |R_1| = |R_2| \forall c_i \in R_1, \exists c_j \in R_2, \text{ that } \Delta(c_i, c_j) = 0, \\ 1, & \forall c_i \in R_1, \neg \exists c_j \in R_2, \text{ that } \Delta(c_i, c_j) = 1, \\ \frac{\sum_{c_i \in R_1, c_j \in R_2} \min \Delta(c_i, c_j)}{|R_1|}, & \text{otherwise,} \end{cases} \quad (6)$$

where R_1 and R_2 are considered as two sets of conjuncts c_i and c_j .

Parameter value $\bar{d} = 0$ indicates that R_1 and R_2 are identical, $\bar{d} = 1$ indicates the maximum deviation between rule sets, and the other \bar{d} values between 0 and 1 are defined as a transient deviation.

3. Quantifying the interestingness of association rules

Let $R_1 : X_1 \rightarrow Y_1$ and $R_2 : X_2 \rightarrow Y_2$ be two association rules, then interestingness of a rule R_1 with respect to the rule R_2 is calculated as follows:

$$I^{\text{II}}(R_1, R_2) = \begin{cases} 0, & \text{if } \bar{d}(X_1, X_2) = 0 \text{ and } \bar{d}(Y_1, Y_2) = 0, \\ \left(\frac{\min_{\text{SER}} \bar{d}(X_1, X_2) + \bar{d}(Y_1, Y_2)}{2} \right), & \text{if } \bar{d}(X_1, X_2) \geq \bar{d}(Y_1, Y_2), \\ \left(\frac{\bar{d}(X_1, X_2) + \min_{\text{SER}} \bar{d}(Y_1, Y_2)}{2} \right), & \text{if } \bar{d}(X_1, X_2) < \bar{d}(Y_1, Y_2), \\ 1, & \text{if } \bar{d}(X_1, X_2) = 1 \text{ and } \bar{d}(Y_1, Y_2) = 1. \end{cases} \quad (7)$$

According to formula (7), $I^{\text{II}} = 0$ indicates that R_1 and R_2 are identical, $I^{\text{II}} = 1$ denotes maximum deviation between R_1 and R_2 . Other cases indicate different deviations in the interestingness of association rules. To select interesting rules the user should specify the threshold of their interestingness. The anti-monotone property based on the threshold of the measure of interest can be applied to reduce the dimension of the resulting rule set. The anti-monotone property is that the measure of the interest of any set of elements should not exceed the minimal measure of interest of any of its subsets. This property greatly facilitates the mining rules.

4. Mining of Massive Datasets

IoT systems include multiple heterogeneous networked embedded devices that generate massive amounts of data. Massive Data IoT leads to different is-

ssues in processing and DM [22]. Figure 4 presents the main challenges associated with processing and mining massive data sets. The large amount of data, the high transfer rate and the variety of properties of large IoT data necessitate a new requirement for intelligent analysis of such data and the diversity in data sources is also a problem [23].

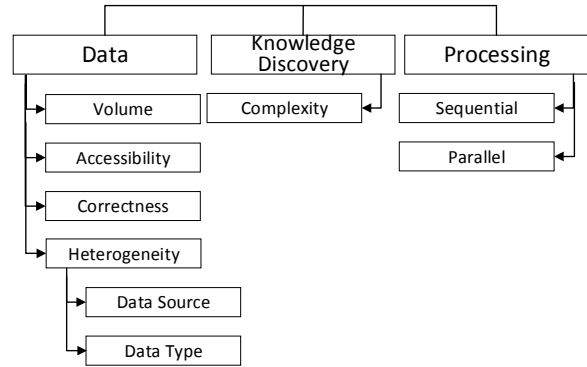


Fig. 4. Data mining issues in IoT

In addition, compared to small data sets, massive data sets contain more anomalies and ambiguities that require additional preprocessing steps [24]. Another problem is to extract accurate and useful information from large volumes of diverse data.

In accordance to [25], the massive data are generally collected from different heterogeneous sources (e.g., video cameras, sensors, RFID, other IoT devices, people, etc.) providing heterogeneous sensing data (e.g., text, video, sound). In this context, heterogeneous data processing (e.g., fusion, classification) brings new challenges and open new possibilities for systems. Obviously, these random variables from heterogeneous sensors have different probability distributions.

Define z_n as the data from the n -th sensor and $Z = \{z_n\}_{n=1}^N$ as the heterogeneous data set, the margins $\{z_n\}_{n=1}^N$ are generally differently or heterogeneously distributed.

In many IoT applications, datasets are often modeled as multi-sensor data fusion, distribution estimation or distributed detection. For detection, this tasks joint probability density function $f(Z)$ of the heterogeneous data set Z is needed to get from the marginal probability density function $\{f(z_{\bar{\nu}})\}_{n=1}^N$.

In these cases, one often uses simple models such as the product model or multivariate Gaussian model, which lead to suboptimal solutions [26]. Other approaches are based on copula theory, to tackle heterogeneous data processing in IoT. In copula theory, it is the copulas function that couples' multivariate joint distributions to their marginal distribution functions, mainly thanks to the Sklar theorem.

Sklar' theorem can be present as follow. Let F be an N -dimensional cumulative distribution function with continuous marginal probability density function $F_1, F_2,$

..., F_N . Then there is a unique copulas function C such that for all z_1, z_2, \dots, z_N in $[-\infty, +\infty]$

$$F(z_1, z_2, \dots, z_N) = C(F_1(z_1), F_2(z_2), \dots, F_N(z_N)) \quad (8)$$

Next, the probability density function can be obtained by the N -order derivative of (8)

$$\begin{aligned} f(z_1, z_2, \dots, z_N) &= \frac{\partial^N}{\partial_{z_1} \partial_{z_2} \dots \partial_{z_N}} C(F_1(z_1), F_2(z_2), \dots, F_N(z_N)) \\ &= f_p(z_1, z_2, \dots, z_N) c(F_1(z_1), F_2(z_2), \dots, F_N(z_N)) \end{aligned} \quad (9)$$

where $f(z_1, z_2, \dots, z_N)$ is the product of the marginal probability density function $\{f(z_i)\}_{i=1}^N$ and $c(\cdot)$ is the copula density weights the product distribution appropriately to incorporate dependence between the random variables. The technique on the selection of proper copula functions is presented in [27].

4.1. CRISP-DM methodology for IoT domain

CRISP-DM (Cross Industry Standard Process for Data Mining) is an interdisciplinary data mining standard [28]. CRISP-DM uses six steps for data mining.

1. Understanding the business - involves understanding how the goals and requirements of the project are related to the business goals, formulating the problem of DM based on this understanding.

2. Understanding data - includes the initial stages of collecting and analyzing data to obtain initial information about their properties, determining the quality of data, identifying preliminary patterns and forming hypotheses.

3. Data preparation - includes the definition and execution of all actions that convert the raw data into the final data set. The stage includes the selection of tables, observations, variables, as well as conversion and data cleansing that are compatible with the modeling methods used.

4. Modeling - selection, application, optimization of modeling methods.

5. Evaluation - the constructed models are tested and, using selected criteria, their effectiveness is evaluated.

6. Deployment - includes the organization and presentation of knowledge generated by the model in an easily interpretable form for the end user.

Consider the steps of CRISP-DM in the context of the IoT in accordance with Data Science for IoT - The Problem Solving Methodology. In the context of IoT, solving a problem means solving the original problem and providing incremental feedback.

The preparation stage, unlike the standard process, must take into account the diversity of data sources and the architecture of IoT systems.

Proceeding from this, at this stage the following processes are distinguished, which should be carried out iteratively:

- definition of data requirements;
- IoT architecture design;
- collection, cleaning, intelligence data analysis;
- continuous improvement.

The determination of the necessary data is carried out taking into account the scope of IoT usage. This could be IoT for health and healthcare, smart homes and cities, smart transportation, industrial, energy systems, etc.

When designing architecture, it is necessary to take into account the technology of IoT systems, which includes sensors, networks and analytical tools.

There are several factors that influence the choice of components when solving a specific problem. The choice is determined by the accuracy and reliability, availability and security, data transfer speed, energy efficiency.

The selected constituent elements will determine some characteristics of the data and, accordingly, analytical tools.

This is followed by the collection, purification and intelligence analysis of available data. This process is typical of CRISP-DM technology and allows you to isolate additional information based on the available data, for example, incorrect, inappropriate operation of one of the network devices, problems with receiving, transmitting data. This information is used to refine the IoT architecture until an optimal solution is reached.

The modeling stage is the stage of building a model, evaluating its effectiveness and the quality of solving the problem. The stage includes the following processes:

- model design to solve a specific problem;
- model evaluation;
- model and architecture deployment.

As in the preparation stage, these processes should be carried out iteratively, until the optimal parameters of the model are reached.

Evaluation of the model is carried out using classical statistical methods and parameters. Also, it should be evaluated in terms of solving the problem. If the model does not improve the basic state of the problem, then iteration of all stages is necessary, starting from the preparation stage. Since some assumptions about the data could be erroneous.

After obtaining an optimal assessment of the model, the architecture and model are deployed.

All the above steps in the context of IoT require continuous improvement. This is due to the rapidly evolving nature of IoT technology, Data Mining methods. Also, this is due to the problem being solved, which can also change and, therefore, the models used are changed to correct it. The continuous improvement phase includes the following iterative processes:

- feedback and understanding;
- specification of the IoT architecture;
- refinement model;

- deployment of a new model and architecture.

Also, depending on the context, there are several elements that can stimulate the improvement of IoT, for example, such as:

- change in performance of the current architecture and model;
- additional user needs;
- the emergence of new tools, methods, algorithms that can help solve the problem in a cheaper or faster way;
- the emergence of new data streams.

As it was mentioned above, IoT-based systems generate large amounts of data. Often, they are presented in the form of time series, analyzed in real time, which determines the methods of intellectual analysis at the modeling stage. The main task of time series analysis is the detection of anomalies. For this, the classical classification models used to detect anomalies are most often used. However, new approaches are being developed, which show good results for analyzing streaming data by fusion data from several sources.

4.2. Map reduce

In IoT applications, mass data processing such as MapReduce is constructed for parallel and distributed data processing [29]. Querying and reasoning for data can be adapted to large data is a more flexible approach.

One of the most popular parallel processing methods in cloud platform is MapReduce [30] and its open source implementation Hadoop for cloud-based parallel or distributed data processing. For the parallelization, scalability, load balancing, and fault-tolerance is MapReduce is widely used in cloud platforms for query processing for data analysis.

The MapReduce disadvantage does not directly support more complex operations such as fusion. More research on high-level, declarative management of complex data such as RDF is required for massively parallel processing of IoT data in the cloud.

1) Parallel processing methods for complex operations: a processing framework is used for massive data processing, incremental calculation, and iterative processing. The framework is implicitly used to synchronize the parallel programs execution without any user specification for events and trigger reactions to process the data. The Selective Embedded Just-InTime Specialization (SEJITS) [31] executes complex analytic queries on massive semantic graphs in big-data analytics.

2) Parallel processing methods for semi-structural data: for the RDF data processing task, effectiveness and tunable data partitioning framework SPA [32], that use at distributing processing of big RDF data, is presented to fast processing support of different size as well as complexity. A MapReduce framework is designed to carry out SPARQL query processing. Thus, RDFS reasoning can be involved in deductive databases and thus recursive query processing techniques are implemented.

3) Parallel processing methods for data stream: the stream data that push up to cloud storage and the pro-

cessing algorithm is tasked with data without explicitly storing it.

The disadvantage of parallel frameworks in the cloud such as MapReduce and its variations is an unable to support complex parallel processing effectiveness. Basic algorithms of the sequential pattern may raise the scalability challenge when dealing with large data.

For problems decision of optimizing parallel data mining, a heuristic cloud bursting algorithm, Maximally Overlapped Bin packing driven Bursting (MOBB), is developed. It considers the time overlap to improve data mining parallelization. The authors [33] present Ripple, a middleware that is built on iterated MapReduce for distributed data analytics with the support of different styles of analytics in the same platform and on the same data.

Mainly, distributed processing in cloud environment is based on MapReduce. It can be carrying out, after the expansion of different type (structured, semi-structured and unstructured) data. However, on consideration of some MapReduce disadvantages, such as high communication cost, unneeded processing and lack of interaction ability in real-time processing, the methods of high-performance distributed data processing without MapReduce are required in some application related to complex processing.

In large IoT data environment, data can be defined by types, state and analysis tasks. Parallel and particle data processing framework is needed to enable the execution MapReduce pattern in dynamic cloud infrastructures, in contrast with centralized master server implementations. These re-build and execution data mining algorithm are not applicable for big data analysis system. Despite its evident merits such as scalability, fault-tolerance, ease programming, and flexibility, MapReduce has limitation in interactive or real-time processing on handling IoT data processing and is not a uniform decision for every large-scale analytical task. Its high communication cost and redundant processing is an IoT application problems.

Conclusion

The DM technique is top-of-the-agenda in the IoT concept that arises from the need to manage and analyze big sensors data. With that, DM algorithm selection for IoT is not a huge challenge itself, it mainly depends on the task and also the type of data that we are dealing with. Instead, many other issues should be resolved, they are cleaning the data; transforming all data in a unified format; struggling with missing values and/or reducing massive data sets; understanding the informational content of the data or data interestingness rate; establishing whether the data is sufficient to the purpose of DM or not.

The using of DM techniques for IoT are directs to map reduce, finding similar items. It helps to develop, control and monitor the IoT-based application in different areas.

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Критська Я.О., Білобородова Т.О., Скарга-Бандурова І.С. Інтелектуальний аналіз даних для IoT аналітики

Інтелектуальний аналіз даних є однією з найбільш цінних технологій, що дозволяють виявляти невідомі шаблони і підвищувати ефективність технології Інтернет речей (IoT). Поточне дослідження присвячене процесам виявлення даних і знань для IoT. У цій статті ми представляємо систематичний огляд різних моделей інтелектуального аналізу даних і обговорюємо методи, що застосовуються для різних даних IoT. Проаналізовано деякі специфічні особливості даних і розглянуті алгоритми виявлення знань для даних IoT. Обговорюються проблеми і можливості для видобутку мультимодальних, гетерогенних, зашумлених, неповних і незбалансованих даних, а також масивних наборів даних в IoT.

Ключові слова: інтелектуальний аналіз даних, Інтернет речей, IoT, виявлення знань в базі даних, KDD, масивні набори даних.

Критская Я.А., Белобородова Т.А., Скарга-Бандурова И.С. Интеллектуальный анализ данных для IoT аналитики

Интеллектуальный анализ данных является одной из наиболее ценных технологий, позволяющих выявлять неизвестные шаблоны и повышать эффективность Интернета вещей (IoT). Текущее исследование посвящено процессам обнаружения данных и знаний для IoT. В этой статье мы представляем систематический обзор различных моделей интеллектуального анализа данных и об-

суждаем методы, применимые для различных данных IoT. Проанализированы некоторые специфические особенности данных и рассмотрены алгоритмы обнаружения знаний для данных IoT. Обсуждаются проблемы и возможности для добычи мультимодальных, гетерогенных, зашумленных, неполных и несбалансированных данных, а также массивных наборов данных в IoT.

Ключевые слова: интеллектуальный анализ данных, Интернет вещей, IoT, обнаружение знаний в базе данных, KDD, массивные наборы данных.

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IMAGE PROCESSING TECHNIQUE IN THE STUDY OF CELL STRUCTURES OF BIOMEDICAL DATA

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ОБРОБКА ЗОБРАЖЕННЯ ПРИ ДОСЛІДЖЕННІ КЛІТИННИХ СТРУКТУР БІОМЕДИЧНИХ ДАНИХ

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Image processing methods are used in all areas of research. These methods provide additional information, a better understanding of the object that is being studied. Among the areas of using image processing methods, medicine occupies a special place. Biomedical data allow us to assess human health, to identify diseases in the early stages. Images of cellular structures of cytological preparations are one of the examples of biomedical data. Based on image analysis methods, we can isolate various components of cellular structures of cytological preparations. To do this, we apply the methods of wavelet analysis for different color components of the input image. Applying morphological analysis, we can identify individual cellular structures. The results are shown on the example of images of cellular structures of cytological preparations.

Keywords: image processing, biomedical data, cell structures, wavelet analysis, color space, cytological preparations

Introduction. The analysis of biomedical data is of practical importance. Such an analysis helps to make an initial preliminary assessment of the state of human health. At the same time, we can identify possible diseases in the early stages of their development. This allows for timely treatment and save the patient from a possible disease.

Analysis of recent research and publications. Biomedical data can be presented as a time series of data, descriptive statistics, or some image. Biomedical images can be obtained as a result of tomography, X-ray examination, registration of cellular structures under a microscope [1]. One of the most common methods for recording biomedical data is images obtained under a microscope.

For automatic analysis of biomedical data presented in the form of an image, various methods of image analysis are used [2, 3]. Among such methods, there are: methods for improving the quality of the original image, methods for removing noise in the image, methods for selecting areas of interest, methods

for recognizing [2, 4]. We can also use various tools to implement image analysis procedures: the theory of fuzzy sets, the theory of groups, the ideology of wavelets [5, 6].

The purpose of the article. However, we must take into account the specifics of biomedical images. Therefore, it is important not to lose information as a result of the implementation of individual procedures for analyzing the original image. Also, one of the tasks is to obtain additional information as a result of applying various image processing procedures.

Thus, the main objective of this study is to consider such a sequence of procedures for analyzing the original image, as a result of which we can obtain additional information. This is an important task for the study of cellular structures whose images were obtained under a microscope.

Research results. To solve the goal of the study, we will use the wavelet analysis methodology. This methodology shows good results for image processing [7].

Wavelet methodology is based on finding the differences of gray levels in the original image. To search for such differences, we consider the original image: in rows, in columns. With the help of wavelets, we determine the differences in brightness levels separately for each row of the image and separately for each column of the image. Then, for the original image $B(i, j) = k$, where B is the input biomedical image size $M \times N$, (i, j) is the current coordinates of the points of the original image $B (i = \overline{1, M}, j = \overline{1, N})$, k is the brightness value of the image at the point $B(i, j)$, we have differential luminance values of a plurality of pixels for each line of the original image and a plurality of differential luminance values of pixels for each column of the original image B .

Then we select the most characteristic points of change in brightness – points that occur both in the processing of rows and in the processing of the columns of the original image. As a result, we have an image of differences that characterizes a certain area of interest. This image is the basis for further analysis. This procedure is described in detail in the work of the authors of [7].

It should also be borne in mind that microscopic images are usually color. This is due to the peculiarities of visualization of individual parts of such images. At the same time, wavelet analysis can be used only for black-white images. Thus, the procedure for transforming a color image into a black-white image is necessary. But with such a transition, we may lose some of the information.

One of the formats for representing color images is RGB. The image in RGB color system consists of three color channels - R (red), G (green) and B (blue) [8, 9]. Each color channel allows you to consider a specific frequency region of the image. This is very important for image analysis using wavelets. This allows you to take into account all the features of the image.

Thus, we propose to consider the original image $B(i, j) = k$ as a combination of three images:

$BR(i, j) = rk$ – original image in color channel R, where rk is the brightness value of the image at the point $BR(i, j)$;

$BG(i, j) = gk$ – original image in color channel G, where gk is the brightness value of the image at the point $BG(i, j)$;

$BB(i, j) = bk$ – original image in color channel B, where bk is the brightness value of the image at the point $BB(i, j)$;

Then we apply the wavelet analysis procedure for each color channel of the original image. We get three images that define the set of points of difference of brightness values in each color space. This provides additional information about the image we are analyzing. Based on this information, we can concretize various areas of interest.

Result of experimental studies. We will consider cellular structure which is presented on Fig. 1.

In Fig. 1 we can see: cells megaloblastic anemia, segments in the nucleus of neutrophils and erythrocytes.

The image in Fig. 1 is a typical example of the cell structure of a cytological preparation.

In Fig. 2 shows the results of the wavelet analysis for the data in Fig. 1.

We considered the original image without dividing it into separate color channels. To do this, we converted the original image (Fig. 1)

to a black-white image (see Fig. 3). Then we applied wavelet processing (see Fig. 2).

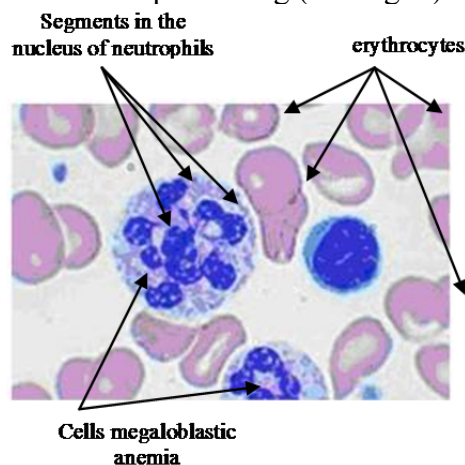


Fig. 1. Cell structure of a cytological preparation

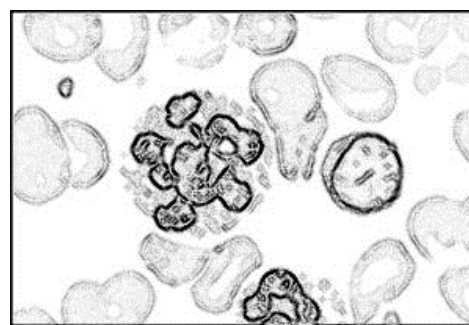


Fig. 2. Results of the wavelet analysis for the data in Fig. 1.

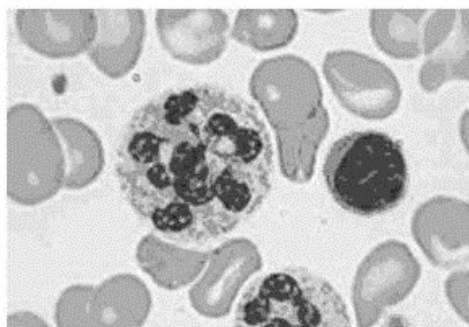


Fig. 3. Black-white image for the data in Fig. 1.

In Fig. 2 shows the different areas of interest. These areas of interest have the same degree of brightness to identify them (except for segments in the nucleus of neutrophils).

In Fig. 4 shows the results of the wavelet analysis for the R components the color space of the original image in Fig. 1.

In Fig. 5 shows the results of the wavelet analysis for the G components the color space of the original image in Fig. 1.

In Fig. 6 shows the results of the wavelet analysis for the B components the color space of the original image in Fig. 1.

For Fig. 4, Fig. 5 and Fig. 6, we see that the regions of interest have different degrees of brightness for their identification (in comparison with the data of Fig. 2).

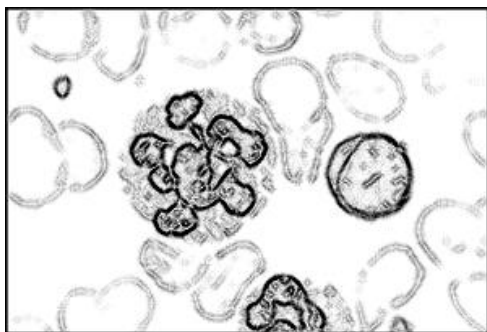


Fig. 4. Results of the wavelet analysis for the R components the color space of the original image in Fig. 1

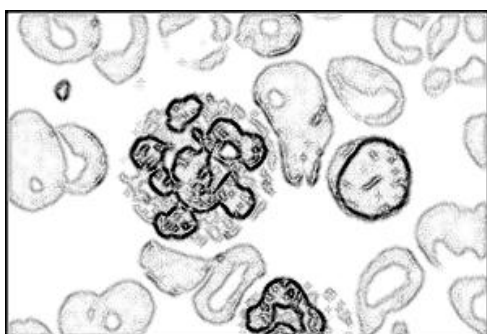


Fig. 5. Results of the wavelet analysis for the G components the color space of the original image in Fig. 1

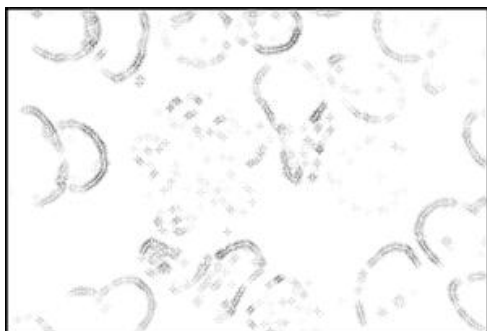


Fig. 6. Results of the wavelet analysis for the B components the color space of the original image in Fig. 1

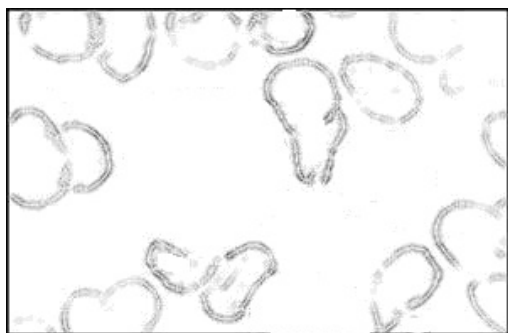


Fig. 7. Results of morphological analysis (images from Fig. 4 and Fig. 6. were used)

Thus, we have additional information. This allows for more accurate analysis. For this you can use morphological image analysis [10]. In Fig. 7 presents the results of morphological analysis for images in Fig. 4 and Fig. 6. As a result of this analysis, we identified erythrocytes.

In Fig. 8 presents the results of morphological analysis, which allow to isolate the cells of megaloblastic anemia.

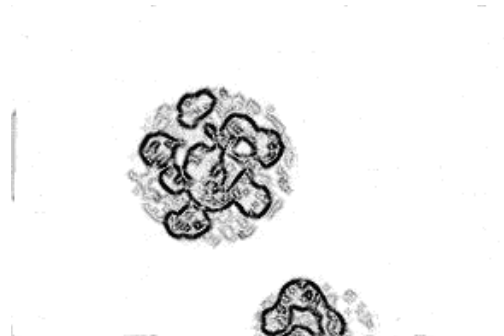


Fig. 8. Results of morphological analysis (images from Fig. 4, Fig. 5 and Fig. 6. were used)

We can specify a different morphology to identify the desired area of interest.

Conclusions. For more information about the objects of interest in the image, we used the wavelet methodology and the technique of decomposing the image into colored components. With the help of morphological analysis, we have identified various components of images of cellular structures of cytological preparations. For further research, it is necessary to automate the process of identifying components of images cell structures the cytological preparations.

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Ляшенко В.В., Кобилін О.А., Рязанцев О.І., Рязанцев І.О., Обробка зображення при дослідженні клітинних структур біомедичних даних

Методи обробки зображень використовуються у всіх областях досліджень. Ці методи дозволяють отримати додаткову інформацію, краще зрозуміти об'єкт, який досліджується. Серед напрямків використання методів обробки зображень особливе місце займає медицина. Біомедичні дані дозволяють оцінити здоров'я людини, виявити захворювання на ранніх стадіях. Зображення клітинних структур цитологічних препаратів - це один з прикладів біомедичних даних. На основі методів аналізу зображень ми можемо виділяти різні компоненти клітинних структур цитологічних препаратів. Для цього ми застосовуємо методи вейвлет аналізу для різних кольорних компонент вхідного зображення. Застосувавши морфологічний аналіз ми можемо виділити окремі клітинні структури. Результати показані на прикладі зображень клітинних структур цитологічних препаратів.

Ключові слова: обробка зображень, біомедичні дані, клітинні структури, вейвлет аналіз, кольорний простір, цитологічні препарати

Ляшенко В.В., Кобылин О.А., Рязанцев А.И., Рязанцев И.А., Обработка изображения при исследовании клеточных структур биомедицинских данных

Методы обработки изображений используются во всех областях исследований. Эти методы позволяют получить дополнительную информацию, лучше понять объект, который исследуется. Среди направлений использования методов обработки изображений особое место занимает медицина. Биомедицинские данные позволяют оценить здоровье человека, выявить заболевания на ранних стадиях. Изображения клеточных структур цитологических препаратов – это один из примеров биомедицинских данных. На основе методов анализа изображений мы можем выделять различные компоненты клеточных структур цитологических препаратов. Для этого мы применяем методы вейвлет анализа для разных цветовых компонент входного изображения. Применив морфологический анализ мы можем выделить отдельные клеточных структур. Результаты показаны на примере изображений клеточных структур цитологических препаратов.

Ключевые слова: обработка изображений, биомедицинские данные, клеточные структуры, вейвлет анализ, цветовое пространство, цитологические препараты

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ABOUT FEATURES REMOTE CROPS OF WHEAT, WITH USE OF THE UAV, ON A CONDITION OF A FLAG LEAF**Lysenko V.P., Opryshko O.O., Komarchuk D.S., Martsyfei A.I., Pasichnyk N.A., Lukin V.E.****ПРО ОСОБЛИВОСТІ ВІДДАЛЕНОГО ПОСІВУ ПШЕНИЦІ, З ВИКОРИСТАННЯМ UAV, ЗА УМОВИ ПРАПОРЦЕВОГО ЛИСТКА****Лисенко В.П., Опришко О.О., Комарчук Д.С., Марцифей А.І., Пасічник Н.А., Лукін В.Є.**

Question of use of local resources for ensuring energy needs and in particular production of biogas remains relevant. Grain crops which condition at initial stages of vegetation is inadmissible for receiving a qualitative harvest can become a prospect of raw materials for creation of biogas. The optimum tool for monitoring of a condition of vegetable cultures is considered UAV which use does not depend on the existence of clouds. The purpose of this research is an assessment by results of the use of the UAV of potential quality of winter wheat in the phrase "exit in a tube" about the expediency of its use for the production of biogas. Measurements of intensity of components of the color of wheat were taken in the conditions of a research hospital, the condition of a flag leaf was estimated visually at land researches. By results of work it was offered the indicator stressful index, it is constructed on the definition of a condition of a flag leaf which is the indicator of the formation of grain yield in wheat. It was shown expediency of account on monitoring of wheat, except the average value of intensity, the brightness of the channel of color and size of semi-distribution. This size can be considered as an additional parameter during the creation of stressful indexes, and also to testify about a condition of transition between stages of growth and development of plants. It is experimentally proved that color portraits of wheat have to be created under concrete stages of organogenesis. Taking into account that the duration of stages is several days, namely the UAV that can directly be used by agricultural producers, is the optimum tool for requirements of exact agriculture..

Keywords: UAV, biogas, stress index, yield programming, digital camera, nitrogen nutrition level, the vegetation index.

Introduction

Considering a trend of current issues of food and energy security of the countries of Europe and, in particular, Ukraine, is extremely important. On increase of needs in energy the accurate trend on attempts to reduce dependence on supplying countries and transistors of gas is observed.

Diversification of suppliers of gas improves a situation in the market, however causes new risks, in particular terrorist threats that it is specified by A. Rezazadeh et al. (2018) [1] for pipelines and also environmental safety of their construction and operation, R. Lidskog et al. (2012) [2]. Orientation to renewables with use of local resources, in particular biogas, becomes relevant even for the countries of exporters of oil and gas, such as Azerbaijan of N. Vidadili et al. (2012)[3]. In comparison with wind generation and solar photo cells, biogas has the powerful advantages caused by a possibility of accumulation of energy and management of its power. It is extremely relevant for the agricultural enterprises having rather small power consumption at estimated peak loadings that was shown in the works devoted to development of biogas technologies in the rural areas of China by Z. Song et al. (2012) [4].

Use of biogas reactors commercially demands attraction of considerable volumes of raw materials. A perspective source of raw materials in EU countries of P. Schroder et al. (2018) [5] consider use of grounds with a difficult relief or low fertility for cultivation of power cultures. However, their area can be insufficient. It is possible to provide necessary amount of raw materials for biogas reactors when using waste of crop production, for example, at cultivation of corn on grain as it is specified in works of M. Narra et al. (2018) and Sergej Ustak et al. (2018) [7] where after harvesting there are considerable volumes of the vegetable remains. As raw materials for creation of biogas it is potentially possible to use also low-quality products of crop production and also its surplus for which storage there are no refinery capacities and elevators. Under such circumstances for management of a harvest and, in particular, the choice of plantings, will be used for biogas production, landowners are interested to obtain ob-

jective information about a condition of plants as soon as possible. Among winter crops as raw materials for biogas, most often use wheat straw. Technological aspects of this process Gabriele Mancini et al. (2018) [8] and Asad Ayub Rajput et al. (2018) [9] is described. In program work of Colin Wrigley et al. (2017) [10] it is proved that the maximum profit on cultivation of grain it will be reached when processing all available bio-material what both cultures, and technical and technological means have to be at the same time adapted to. Considering a winter wheat as a raw materials source for biogas reactors, the best from the point of view of agronomists, the period for monitoring is the vegetation phase "an exit in a tube". This circumstance is explained by the following circumstances: plants are already rather created, to change culture already late.

Specifics of monitoring is the limited term of making decision on carrying out technological operations and therefore tools for implementation of monitoring is optimum unmanned aerial vehicles (UAVs) V. Lysenko et al. (2017) [11]. The choice of the UAV, in comparison with satellites, is caused essentially smaller dependence on overcast, provides high distributive ability in comparison with low to the cost of pictures.

Assessment of a condition of flag and sub flag leaves as indicators of a condition of a winter wheat, it is caused by their role for formation of a grain yield. By the generalized results of researches about a half from the lump of grain provide assimilates which were formed in a flag leaf, and about a third - formed in a sub flag leaf.

The purpose of work is assessment by results of use of the UAV of a potential winter wheat of quality in the phase "exit in a tube" about expediency of its use for production of biogas.

Condition of a question. Methodical questions of use of mobile robots are presented in many works, such as Nevliudov et al. (2018) [12], G. Ponomaryova et al. (2018). However, approaches to the choice of the spectral touch equipment for monitoring remain debatable as it is presented in survey work of David R. Green et al. (2019) is relative to use for monitoring, in particular wheat, specialized and universal spectral devices. The equipment from various producers with various spectral parameters leads to emergence of stressful indexes under concrete brands of sensors even for monitoring of one culture. In work of V. Lysenko et al. (2016) [15] the technique of calibration of spectral data, suitable for UAV sensors is presented, however it is calculated first of all on optical range, and for the specialized equipment it is possible to use also NIR spectrum range.

Use of stressful indexes for monitoring of conditions of vegetable plantings with use of the UAV is carried out in the way:

- loan of indexes from satellite technologies, such as NDVI;

- creation of own indexes on the basis of use of the regression analysis.

The stressful indexes constructed on the concept of "the line of the soil" such as NDVI, SAVI etc., submitted in works of F. Rodriguez-Moreno et al. (2016) [16], Qiang Cao et al. (2014) [17] and M.A. Hassan et al. (2018) [18] vulnerable to accuracy, selectivity and problems arising with lighting change. The indexes constructed on the basis of the regression analysis, submitted in works of M.M. Saberionna et al. (2014) [19] and Cao Q. et al. (2014) [20] more convenient for technologies of exact agriculture, however are adapted for a concrete grade or a hybrid of a plant and touch the equipment.

For the choice of sites of plants which are expedient for choosing as a raw materials source for biogas reactors it is desirable for operator to have extreme criterion by which it is possible to distinguish high-quality crops from the others. Based on the experience described of use of stressful indexes, the spectral criterion has to be steady against lighting changes. Such criterion of definition of a stressful state in the conditions of monitoring from a board of the UAV used assessment of a flag leaf as it was shown on the example of barley in work of R. Vicente et al. (2018) [21].

High efficiency of monitoring of a flag leaf for a winter wheat by spectral methods from a board of the land platform it is presented in work of S. Kipp et al. (2014) [22].

Thus, the analysis of references allows to draw a conclusion on a possibility of use as extreme criterion of indicator assessment of quality of crops of a winter wheat a condition of a flag leaf which can be determined by results of the spectral analysis with use of the UAV.

Experiment Methodology

Organization of measurements and pilot sections. Pilot studies were conducted on the oP NUBIP fields of Ukraine "Agronomical experimental station" in a long field hospital of department of agrochemistry and quality of products of crop production (GPS of coordinate: 50°4'28 "N, 30°13'20"). For monitoring used the RGB PHANTOM VISION FC200 camera which is the regular equipment for the DGI Phantom 3 UAV. Researches were conducted on uniform lighting in cloudless weather (the Light Source setup in the manual mode - Fine Weather). Flight altitude of the UAV is 100 meters. Before the research's crops were visually checked for lack of drops of water on upper leaves of plants.

For experience with a winter wheat, Colonia sort, the following options of application of fertilizers were used: 1) without fertilizers (control); 2) P; 3) RK; 4) NPK (the recommend norm) 5) NPK (1.5 recommend norms) (fig. 1).



Fig. 1. Photos of crops of a winter wheat, Colonia grade, on a research hospital (sites with various application of fertilizers - the growing norm from left to right (03.05.2018). Photographing was carried out at different stages of an organogenesis (fig. 2)



Fig. 2a. Picture of pilot sites of a winter wheat taken during the separate periods of vegetation (organogenesis stages on EPA)
Date of shooting: 03.05.2018
37 stage: there is a flag leaf which is still twisted. 39 stage: ligula stage (sheet uvula): the ligula of a flag leaf is noticeable, the flag leaf is completely developed



Fig. 2b. Picture of pilot sites of a winter wheat taken during the separate periods of vegetation (organogenesis stages on EPA)
Date of shooting: 11.05.2018
41 stages: sheet the vagina of a flag leaf is extended. 43 stage: the sheet vagina of a flag leaf begins to flow



Fig. 2c. Picture of pilot sites of a winter wheat taken during the separate periods of vegetation (organogenesis stages on EPA)
Date of shooting: 18.05.2018
45 stage: the sheet vagina of a flag leaf bulk up 47 stage: the sheet vagina of a flag leaf opens

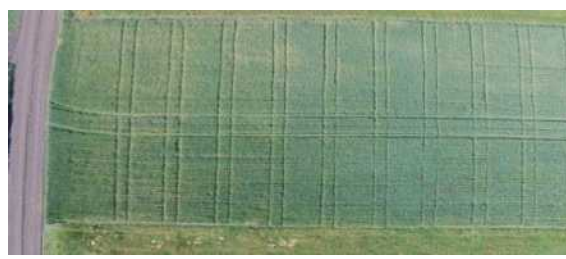


Fig. 2d. Picture of pilot sites of a winter wheat taken during the separate periods of vegetation (organogenesis stages on EPA)
Date of shooting: 29.05.2018
49 stage: the last sheet vagina opens, over a uvula of the top leaf there are noticeable awns



Fig. 2e. Picture of pilot sites of a winter wheat taken during the separate periods of vegetation (organogenesis stages on EPA)
Date of shooting: 08.06.2018 50-51 stages: beginning of emergence of an inflorescence (sprouting): it is visible the top part of a whisk or a cone 52 stage: emergence of 20% inflorescence

Obtained results and discussion

Data processing received from digital photographing. At assessment of color space of plants, proceeding from digital pictures, instead of the RGB format the model of appearance of CIECAM02 color presented in works of H. Ali et al. (2017) [23] and Asim Kumar Roy Choudhury (2014) [24] can be used. CIECAM02 model is more convenient in view of the fact that instead of three separate channels RGB the only channel which changes in the range 0-360° is used and describes all color space. For a transfer of data with RGB in CIECAM02 the free software BreedPix (USA) described in work of B. Zhou et al. (2015) [25] on researches of diseases of wheat and work of R. Vicente et al. (2018) [26] for carrying out researches of a nitric stress can be used. Despite convenience of perception and ease of work only with one channel instead of three, the transfer from one color space in another demands considerable computational capabilities that needs to be considered at orientation to industrial production. Therefore in researches processed experimental graphic data of the RGB format with use of the software of mAtHCAD that is suitable for graphic data processing of the JPEG format. Advantages of such approach were shown in work of J. Agrisuelas et al. (2017) [27]. At calculation of data according to the technique used in the BreedPix program distribution of number of pixels concerning values of intensity of each of three components of color was considered. The algorithm and the program in the environment of MathCAD was for this purpose developed for calculation of number of pixels with the corresponding intensity of RGB, for each component of color, for selected in the manual mode picture sections. For statistical processing of data retrieved they were exported to the Origin Pro SR4 v8.0951 software package of the OriginLab Corporation company intended for numerical data analysis and scientific graphics.

The received results and discussion. Assessment of nature of distribution and the choice of the equation for approximation of experimental data. In fig. 3 typical distribution of number of pixels in size of intensity of a component of color is presented.

Along with studying directly of sites of the field, were considered also the site of the dirt road (B_gt), for establishment of a possibility of influence of existence of the soil on results of assessment of spectral parameters of crops. By results of the received estimates, the conclusion was drawn on lack of need of preliminary data filtering as influence of the pixels caused by the soil will be insignificant. The dependence of number of pixels on value of intensity of a component of color is described by normal distribution and can be approximated typical by the equations. For approximation the equation of Amplitude version of Gaussian peak function (Gauss Amp) and Lorentzian peak function (Lorentz) was chosen.

Apparently from the provided data, a certain value of a maximum of distribution (I) is approximately identical to both used approximation equations. The Lorentz function gives the best the similarity for the maximum

value of distribution, however determines value worse on the half-width of distribution (w) which is defined as one-half-amplitude width. Accuracy of determination of half-width of distribution, in comparison with establishment of its amplitude, more relevant as the quantity of points can change over a wide range. Besides, the coefficient of determination (R^2) at approximation of experimental data for the equation of Gauss Amp was above, then in Lorentz therefore in researches for approximation selected Gauss Amp equations.

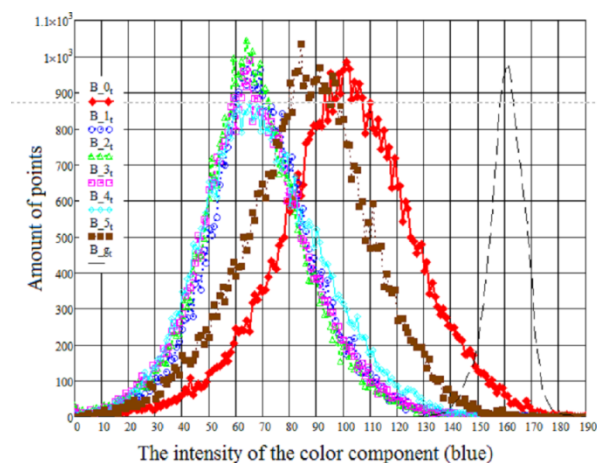


Fig. 3. Distribution of Number of Pixels for a blue component of color for research sites with a winter wheat with various doses of mineral fertilizers (2018.05.11)

The received results of approximation of experimental data on determination of parameters of color portraits of crops of a winter wheat of a sort of Colonia are presented in table.

Notes:

- sites where it was recorded are highlighted with gray color the flag leaf is well developed;
- with underlining data where the nature of distribution of intensity of the plants making colors differed from the general are highlighted in bold type (fig.5).

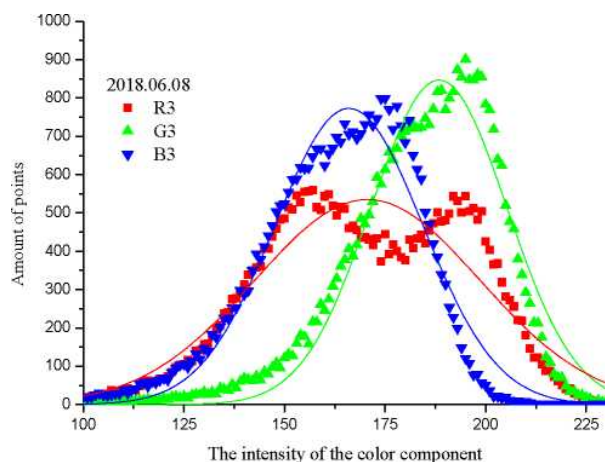


Fig.5. Dependence of number of pixels for the relevant channels of components of color from the size of their intensity for the third pilot site (the beginning of emergence of an inflorescence), 2018.06.08 are recorded

Table
Results of approximation of color portraits of sites of a winter wheat

№	R			G			B			11
	1	2	3	4	5	6	7	8	9	
2017.05.03										
5	95	12,3	0,996	139	11,9	0,994	110	11,8	0,995	1,7
4	92	13,8	0,991	135	13,4	0,989	103	13,1	0,990	1,6
3	92	15,4	0,994	135	14,4	0,988	102	14	0,989	1,6
2	96	18,1	0,995	134	16,0	0,997	99	14,2	0,996	1,4
1	95	17,5	0,996	134	15,4	0,997	99	13,9	0,996	1,5
0	108	20,5	0,995	140	16,7	0,997	104	15,7	0,995	1,3
2018.05.11										
5	71	22,0	0,983	115	22,0	0,985	88	22,3	0,987	2,0
4	58	20,0	0,989	99	21,0	0,988	69	21,8	0,985	2,0
3	58	18,0	0,987	97	18,9	0,990	67	18,9	0,989	1,9
2	63	17,2	0,986	100	17,5	0,988	66	17,2	0,986	1,7
1	65	17,8	0,986	103	17,0	0,987	69	17,7	0,986	1,7
0	111	27,5	0,990	140	23,0	0,991	102	23,8	0,991	1,2
2018.05.18										
5	92	11,0	0,996	131	11,2	0,996	108	12,3	0,995	1,7
4	85	10,7	0,998	125	10,5	0,997	94	11,8	0,991	1,6
3	87	11,3	0,998	126	10,6	0,997	95	11,1	0,996	1,6
2	92	12,7	0,992	129	10,8	0,995	91	9,8	0,993	1,4
1	94	11,5	0,995	132	9,8	0,995	94	9	0,993	1,4
0	106	14,4	0,990	138	11,5	0,991	98	10,5	0,989	1,2
1	2	3	4	5	6	7	8	9	10	11
2018.05.29										
5	123	26,3	0,976	153	24,0	0,974	133	24	0,973	1,4
4	119	25,7	0,977	148	24,0	0,977	124	23,8	0,975	1,3
3	117	27,5	0,970	145	24,1	0,968	121	24,6	0,963	1,3
2	118	29,6	0,969	143	26,1	0,964	114	26,0	0,967	1,2
1	116	26,4	0,970	141	23,8	0,967	112	23,5	0,970	1,2
0	122	25,2	0,970	143	22,6	0,969	112	22,4	0,970	1,1
2018.06.08										
5	160	23,0	0,989	182	17,1	0,994	165	17,2	0,990	1,2
4	162	20,8	0,990	184	15,2	0,980	162	15,1	0,983	1,1
3	170	28.0	0.930	187	16.9	0.973	166	18.4	0.972	1.1
2	179	21,0	0,970	189	14,3	0,970	165	17	0,980	1,0
1	176	18,4	0,977	189	14,3	0,970	163	14,8	0,982	1,0
0	183	15,8	0,974	191	12,9	0,960	166	13,8	0,977	1,0

Apparently from the data provided in the drawing, the nature of dependence for a red component of color significantly differs from green and blue - instead of one maximum there are two. A probable explanation of it is that fixing took place for transition state - upon transition from one stage of an organogenesis to another. Starting from this, it is possible to assume that the size of half-width of distribution by a peculiar indicator of a transitional growth phase and development of plants of a winter wheat. This indicator can be perspective at creation of stressful indexes as in experiences from 2018.05.03 it was recorded dependence between a condition of half-width of distribution and a condition of application of fertilizers for the considered channels.

Analyzing dependences of spectral channels of plants on providing them with batteries, by us it is recorded that such dependences have to be under construction under concrete phases of vegetation or stages of an organogenesis. So, 05.11, 05.18 and 06.08 dependence

were recorded for red and green, and 05.29 - for is green also blue channels. Proceeding from it it is offered to use the indicator index for a flag leaf:

$$F = \frac{G \times B}{R^2}$$

where F – is the stressful index for indication of a flag leaf, R, G, B – are red, green and blue channels.

Such indicator index allows estimating quickly crops which have the potential of receiving a qualitative harvest that is extremely relevant when choosing raw materials for biogas reactors.

Directions of further researches. In work it is shown that stressful indexes need to be created under the corresponding stages of an organogenesis or a phase of vegetation, however it is expedient to study a possibility of remote assessment of a stage of vegetation. Use of additional information from farms on grades of culture and real terms of crops and also data of meteorological stations can become the possible decision that will allow counting a phase of vegetation and a stage of an organogenesis with certain accuracy.

Flag leaves have specific coloring therefore we consider expedient for creation of the indicator index of establishment of a condition of a flag leaf of use of the infrared channel of monitoring.

Conclusions

It is offered the indicator stressful index constructed on certain conditions of a flag leaf which is the indicator of formation of a grain yield in wheat;

The expediency of account on monitoring of wheat, except average value of intensity, brightness of the channel of color and size of half-width of distribution is shown. This size can be considered as additional parameter during creation of stressful indexes and also to confirm a condition of transition between stages of growth and development of plants.

It is experimentally proved that color portraits of wheat have to be created under concrete stages of an organogenesis. Taking into account that duration of stages is several days, the UAV, can directly be used by agricultural producers, is a best tool for needs of exact agriculture.

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Лисенко В.П., Опришко О.О., Комарчук Д.С., Марцифей А.І., Пасічник Н.А., Лукін В.Є. Про особливості віддаленого посіву пшениці, з використанням UAV, за умови прапорцевого листка

Питання використання місцевих ресурсів для забезпечення енергетичних потреб і, зокрема, виробництва біогазу залишається актуальним. Перспективою сировини для створення біогазу може стати зернова культура, стан якої на початкових етапах вегетації неприпустимо для отримання якісного врожаю. Оптимальним інструментом для моніторингу стану овочевих культур вважається UAV, використання якого не залежить від наявності хмар. Метою даного дослідження є оцінка за результатами використання UAV потенційного якості озимої пшениці в фазі «вихід в трубу» про доцільність його використання для виробництва біогазу. Вимірювання інтенсивності компонентів кольору пшениці проводилися в умовах дослідницької лікарні, стан прапорцевого листка оцінювалося візуально при наземних дослідженнях. За результатами роботи було запропоновано індикатор стрессового індексу, побудований на визначенні стану прапорцевого листка, який є індикатором формування врожайності зерна в пшениці. Була показана доцільність обліку по пшениці, крім середнього значення інтенсивності, як-ривості колірних каналів і величини напіврозподілу. Цю величину можна розглядати як додатковий параметр при створенні стрессових показників, а також свідчити про стан переходу між етапами зростання і розвитку рослин. Експериментально доведено, що кольорові портрети пшениці повинні створюватися під конкретні стадії органогенезу. Беручи до уваги, що тривалість етапів становить кілька днів, а саме UAV, який може безпосередньо використовуватися сільськогосподарськими виробниками, є оптимальним інструментом для вимог точного землеробства.

Ключові слова: UAV, біогаз, індекс стресу, програмування врожайності, цифрова камера, рівень азотного живлення, вегетаційний індекс.

Лысенко В.П., Опришко А.А., Комарчук Д.С., Марцифей А.И., Пасичник Н.А., Лукин В.Е. Об особенностях удаленного посева пшеницы, с использованием UAV, при условии флагового листа

Вопрос использования местных ресурсов для обеспечения энергетических потребностей и, в частности, производства биогаза остается актуальным. Перспективой сырья для создания биогаза может стать зерновая культура, состояние которой на начальных этапах вегетации недопустимо для получения качественного урожая. Оптимальным инструментом для мониторинга состояния овощных культур считается UAV, использование которо-

го не зависит от наличия облаков. Целью данного исследования является оценка по результатам использования UAV потенциального качества озимой пшеницы в фазе «выход в трубу» о целесообразности его использования для производства биогаза. Измерения интенсивности компонентов цвета пшеницы проводились в условиях исследовательской больницы, состояние флагового листа оценивалось визуально при наземных исследованиях. По результатам работы был предложен индикатор стрессового индекса, построенный на определении состояния флагового листа, который является индикатором формирования урожайности зерна в пшенице. Была показана целесообразность учета по пшенице, кроме среднего значения интенсивности, яркости цветового канала и величины полураспределения. Эту величину можно рассматривать как дополнительный параметр при создании стрессовых показателей, а также свидетельствовать о состоянии перехода между этапами роста и развития растений. Экспериментально доказано, что цветные портреты пшеницы должны создаваться под конкретные стадии органогенеза. Принимая во внимание, что продолжительность этапов составляет несколько дней, а именно UAV, который может непосредственно использоваться сельскохозяйственными производителями, является оптимальным инструментом для требований точного земледелия.

Ключевые слова: UAV, биогаз, индекс стресса, программирование урожайности, цифровая камера, уровень азотного питания, вегетационный индекс.

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ABOUT NUMBER OF EFFECTIVELY PERFORMED STREAMS IN MULTI-CORE COMPUTERS WITH SHARED MEMORY

Nedzelskyi D.O.

ЕФЕКТИВНІСТЬ ВИКОНАННЯ ПОТОКІВ У БАГАТОЦІЛЬОВОМУ КОМП'ЮТЕРІ З ЗАГАЛЬНОЮ ПАМ'ЯТТЮ

Недзельський Д.О.

The article investigates the dependence of the number of effectively executed programs in multi-core computers with shared memory on the parameters of programs and computers. All computer cores execute parallel streams of a single program developed in accordance with the OpenMP API. There are no interactions between streams program. Conflicts can occur only when cores are accessed into shared memory. Suggested the necessary models. Analytical expressions are obtained for the dependence of the number of effectively executed programs on the properties of programs, core and shared memory parameters. The main reason for limiting the number of effectively executed programs is the overload of the shared memory. The threshold value of the number of effectively executed programs has been determined.
Keywords: multi-core computer, core, shared memory, acceleration factor, efficiency, stream

1. Introduction

Efficient utilization of the cores in the computers with high number of cores is one of the most important problems for designers of software for these systems. Multi-core computers performance is defined using acceleration rate when executing an application with parallel streams or a set of applications without parallel streams when utilizing n cores. In reality, the acceleration depends on many factors.

In [1-7] multi-core computer utilization is obtained by testing/running real applications on the system. These experimental approaches do not generalize well and discovered accelerators are not always applicable or even partially applicable to the next application. Also the mentioned articles do not analyze the features which caused acceleration and the reasons for the limit of acceleration where an increase in number of cores does not increase the performance any longer.

The author is not aware of model analytical approaches to model/calculate efficient utilization (performance) of multi-core computers. Existing works in multi-core computer systems do not have an analytical

approach estimating of the number of effectively used cores.

The purpose of the article is to study the efficiency of using cores (threads) in multi-core computers with shared memory depending on the number of cores, properties program performed by the cores, core and shared memory parameters when executing parallel programs developed in accordance with the OpenMP API.

2. Efficient utilization of a multi-core computer with n cores executing single parallel application

Efficient utilization of multi-core computer is calculated using the acceleration rate. The acceleration rate of a multi-core computer is defined as:

$$S = \frac{T_1}{T_n} = \frac{Pr_n}{Pr_1}, \quad (1)$$

where T_1 – application execution time of a single core, T_n – application execution time using n cores where the application consists of exactly n streams, Pr_1 – performance of a single core when there is no influence from other cores, Pr_n – performance of an n core computer.

Since all n cores perform the same stream of a parallel application the core utilization rate is the same for all cores and utilization rate of the multi-core computer in this case equals the single core utilization rate $H_k = H_i$, where H_i – single core utilization rate, when all n cores are executing a parallel program; H_k – multi-core computer utilization rate when all n cores are executing a parallel program.

Multi-core computer performance where all n cores are utilised is defined as

$$Pr_n = \sum_{i=1}^n H_i * Pr_1 = Pr_1 * \sum_{i=1}^n H_i = Pr_1 * n * H_k .$$

Multi-core computer acceleration rate in this case equals

$$S = \frac{Pr_n}{Pr_1} = \frac{Pr_1 * n * H_k}{Pr_1} = n * H_k .$$

3. Model of a multi-core computer with shared memory with all cores are busy

Preconditions:

- All cores are busy executing non-interacting streams of parallel applications. In other words, there are no interactions between executable code. The next instruction is executed by core straight away unless all of the following conditions exist:

- It requires memory access.
- The requested data is not present in the memory cache.
- The cache is full. If all these conditions are exist the core is blocked and the instruction is not executed.
- Each core while executing its application generates data requests to the shared memory. Data requests frequency from a single core is calculated according to the formula:

$$\lambda_i = \frac{N_i * \omega_{MEM}^i P_{MEM}^i}{N_i * t_{INS}^i} = \frac{\omega_{MEM}^i P_{MEM}^i}{t_{INS}^i} ,$$

where N_i - the number of instruction in the running program; ω_{MEM}^i - the probability of instructions to access to memory in the i-th program; P_{MEM}^i - of contacting of instruction to access the memory in the i-th program; t_{INS}^i - average time to execute one instruction in the core.

- Data requests from all cores to the shared memory are exponentially distributed.
- Memory is a compound device, where new requests are served only once the previous request has been completed.
- Served memory requests are also distributed according to an exponential distribution.
- Memory serves requests from all cores with intensity $\mu_{MEM} = 1 / t_{MEM}$, where t_{MEM} - average time to execute one request by memory.
- Data requests to the memory are served using FIFO.

Multi-core computers can be described as a 2-phase system serving a high volume of requests. Phase 1 comprises of n cores executing applications and generating requests to the shared memory. Phase 2 occurs in shared memory itself. Buffers with capacity for k requests are placed between phases.

Due to difficulties in analytical representation of this general model this article explores a simplified equivalent version of the model (Fig.1).

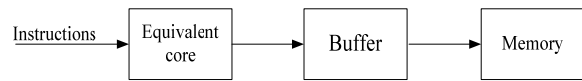


Fig. 1. Simplified equivalent version of the multi-core computer model

Phase 1 of the equivalent model consists of an equivalent core. The equivalent core performance (frequency of generated requests) is assumed to be a sum of performances of all original model cores

$$\lambda_{eqv} = \sum_{i=1}^n \lambda_i = \sum_{i=1}^n \frac{\omega_{MEM}^i P_{MEM}^i}{t_{INS}^i} .$$

The equivalent model has a single buffer and its size is the sum of the original model buffer sizes.

Phase 2 of the equivalent model is memory. Its performance (execution frequency) is equal to that of the original model. Buffer selection and core blocking logic are identical in both models.

Hence, from the performance point of view, the original and simplified models of a multi-core computer are equivalent.

The overall load rate of the shared memory for the n-core computer is calculated according to the formula

$$\rho_{MEM}^{\Sigma} = \frac{\sum_{i=1}^n \lambda_i}{\mu_{MEM}} = \frac{\sum_{i=1}^n \frac{\omega_{MEM}^i P_{MEM}^i}{t_{INS}^i}}{\mu_{MEM}} = \sum_{i=1}^n \rho_{MEM}^i ,$$

where ρ_{MEM}^{Σ} - memory load rate from all cores; ρ_{MEM}^i - memory load rate from i-th core.

Solving simultaneous equations for selected overall load rate ranges we obtain the following expressions for the model utilization rates:

Equivalent core utilization rate:

$$H_K = 1 \quad \text{if } \rho_{MEM}^{\Sigma} < 1 ; \quad (2)$$

$$H_K = \frac{k + 1}{k + 2} \quad \text{if } \rho_{MEM}^{\Sigma} = 1 ; \quad (3)$$

$$H_K = \frac{1 - (\rho_{MEM}^i)^{k+1}}{1 - (\rho_{MEM}^i)^{k+2}} \quad \text{if } \rho_{MEM}^{\Sigma} > 1 ; \quad (4)$$

Shared memory utilization rate:

$$E = \frac{\rho_{MEM}^{\Sigma} * [1 - (\rho_{MEM}^{\Sigma})^{k+1}]}{1 - (\rho_{MEM}^{\Sigma})^{k+2}} \quad \text{if } \rho_{MEM}^{\Sigma} < 1 ; \quad (5)$$

$$E = 1 \quad \text{if } \rho_{MEM}^{\Sigma} > 1 ; \quad (6)$$

$$E = \frac{k + 1}{k + 2} \quad \text{if } \rho_{MEM}^{\Sigma} = 1 . \quad (7)$$

$$\rho_{MEM}^{\Sigma} = \sum_i^n \rho_{MEM}^i = 1.$$

Consider an example, displaying multi-core computer efficient utilization (acceleration rate) dependency on the number of cores utilised when executing a parallel application.

To simplify calculations, we assume an infinite buffer size between a core and the shared memory. The limit of core utilization rate with infinite buffer size for selected ranges of shared memory load rates is defined below:

$$\lim_{n \rightarrow \infty} H_k = \frac{1}{\rho_{MEM}^{\Sigma}} \quad - \text{ if } \rho_{MEM}^{\Sigma} > 1$$

$$\lim_{n \rightarrow \infty} H_k = 1 \quad - \text{ if } \rho_{MEM}^{\Sigma} \leq 1.$$

Intermediate conclusion:

with $n = 8$: $\rho_{MEM}^i = 0.125$;

$$\rho_{MEM}^{\Sigma} = 8 * 0.125 = 1;$$

$$H_k = 1; S = 8;$$

with $n = 12$: $\rho_{MEM}^i = 0.125$;

$$\rho_{MEM}^{\Sigma} = 12 * 0.125 = 1.5; H_k = 2/3; S = 8;$$

with $n = 16$: $\rho_{MEM}^i = 0.125$;

$$\rho_{MEM}^{\Sigma} = 16 * 0.125 = 2; H_k = 0.5; S = 8.$$

The example demonstrates that there is an upper limit (threshold) on the number of cores after which the performance of a multi-core computer does not improve.

This threshold (practical number of cores (n)) for parallel applications designed using OpenMP API defines the overall shared memory load rate generated by all cores of the multi-core computer.

$$\rho_{MEM}^{\Sigma} = \sum_i^n \rho_{MEM}^i = 1.$$

The multi-core computer acceleration rate (S) while executing parallel applications can be calculated using defined above overall shared memory load rate:

$$S = n \quad - \text{ when } \rho_{MEM}^{\Sigma} \leq 1;$$

$$S = \frac{n}{\rho_{MEM}^{\Sigma}} \quad - \text{ when } \rho_{MEM}^{\Sigma} > 1.$$

Conclusion

1. The multi-core computer acceleration rate while executing parallel applications consisting of n streams is a product of the number of cores (application streams) and a single core utilization rate

$$S = n * H_i.$$

2. The practical number of streams of a parallel application defines the threshold of the overall shared memory load rate generated by all cores of the multi-core computer

$$\rho_{MEM}^{\Sigma} = \sum_i^n \rho_{MEM}^i = 1.$$

3. The number of effectively used cores (streams in these cores) can be determined by the formulas

$$n = S \quad - \text{ when } \rho_{MEM}^{\Sigma} \leq 1;$$

$$n = S * \rho_{OII}^{\Sigma} \quad - \text{ when } \rho_{MEM}^{\Sigma} > 1.$$

4. The proposed methodology can be used to estimate from above the number of threads and, accordingly, the number of cores when developing parallel applications in accordance with the OpenMP API

5. Shared memory overload is the main cause of a multi-core computer sublinear acceleration rate when executing parallel application using OpenMP API. The overload will cause the cores to be idle for a significant percentage of time.

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Недзельський Д.О. Ефективність виконання потоків у багатоцільовому комп'ютері з загальною пам'яттю

У статті досліджується залежність кількості ефективно виконуваних програм в багатоядерних комп'ютерах із загальною пам'яттю від параметрів програм і комп'ютерів. Всі комп'ютерні ядра виконують паралельні потоки однієї програми, розробленої відповідно до API OpenMP. Там немає взаємодії між потоками програми. Конфлікти можуть виникати тільки при зверненні до ядер в загальній пам'яті. Запропоновано необхідні моделі. Отримано аналітичні вирази для залежності кількості ефективно виконуваних програм від властивостей програм, параметрів ядра і розділяється пам'яті. Основною причиною обмеження кількості ефективно виконуваних програм є перевантаження розділяється пам'яті. Визначено граничне значення кількості ефективно виконуваних програм.

Ключові слова: багатоядерний комп'ютер, ядро, колективна пам'ять, коефіцієнт прискорення, ефективність, потік

Недзельський Д.А. О Эффективность исполненных потоков в многоцелевых компьютерах с общей памятью

В статье исследуется зависимость количества эффективно выполняемых программ в многоядерных компьютерах с общей памятью от параметров программ и компьютеров. Все компьютерные ядра выполняют параллельные потоки одной программы, разработанной в соответствии с API OpenMP. Там нет взаимодействия между потоками программы. Конфликты могут возникать только при обращении к ядрам в общей памяти. Предложены необходимые модели. Получены аналитические выражения для зависимости количества эффективно выполняемых программ от свойств программ, параметров ядра и разделяемой памяти. Основной причиной ограничения количества эффективно выполняемых программ является перегрузка разделяемой памяти. Определено пороговое значение количества эффективно выполняемых программ.

Ключевые слова: многоядерный компьютер, ядро, разделяемая память, коэффициент ускорения, эффективность, поток

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DATABASE QUERY OPTIMIZATION

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ОПТИМІЗАЦІЯ ЗАПИТІВ БАЗИ ДАНИХ

Нестеров М.В., Бакитко Д.Е., Михайлова А.О.

This article reviewed the methods directed at optimizing the database. The goal was to find the most suitable method for the quick execution of queries.

Keywords: database, indexing, clusters, optimization, partitioning, statistics, SQL.

Introduction. The processing time of the request also determines the speed of the database, which characterized by amount of time per request processing. The execution time of a request may also depend on complexity of the request. As a rule, the request could be substantially simplified or you can do several simple requests that will do the same job as a complicated one, but much faster.

Formulation of the problem. If a web service loads for a very long time, then this causes a delay in the business processes of the application and service. By optimizing database queries, you can increase the speed of the application. The request processing time is a very important criterion for evaluating database performance. When designing a system, it is important to predict an increase in database queries, as well as an increase in data volumes. The increase in performance consists of the execution time of queries, the speed of information retrieval in non-indexed fields, the greatest number of parallel access to data. MySQL database will be used as an object of research in the article.

Methods of setting productivity. Methods such as indexing, query code optimization, clustering, and partitioning will be considered.

A. INDEXING. The index is an acceleration of the search operation for records in the table and performance of other operations that relate to the search: sorting, retrieving, modifying. All information about indexes stored in index files, which consist of data and indexes of record numbers. The index field requires data from the index file, and the pointer serves to link the index file entries. To create an index, it is necessary to specify the field of the table to which it is necessary to assign indexing.

The created indexes could be used in such ways as:

- 1) Sequential data access in a given sequence of values of the index field.

- 2) Direct access to individual records of the index file in a given sequence of the index field.

Information storage with indexing involves the use of two stored files.

Indexes are used to speed up data retrieval, which retrieved faster by reducing the number of disk I/O operations for which pointers are used.

Not necessarily every entry in the indexed file must contain an index. This index called loose. Loose indexes are small, due to which browse the contents of the database.

- 1) The file of the table in which data stored, such as, information about users of the resource.

- 2) File with indices of blogs that users have created on the resource.

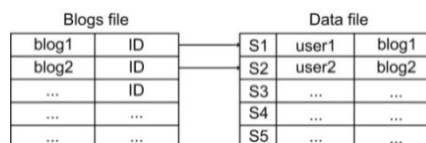


Fig. 1. Index data storage structure [1]

The file with indexes of blogs will be arranged alphabetically, and the file with data depending on the content. If you need to organize by personal information, you need a file that stores it.

Indexing is very effective if the number of records sought does not exceed 10-15%. If the proportion of the files you are looking for is too large, the index file will be used too often, which will lead to a losing strategy for using it. In these cases, it is necessary to execute a direct search, without using indexing [2].

All found data follow each other, which means that their position is very quickly determinate and read. Identifiers of the fields found a point to the required records [3].

Each index must be unique. Unique indexes exclude the same data. Creating uniquely makes sense only if the data itself could be unique. In the case of duplication of data, there will be an error and it will not be possible to save the entered information.

Unique indexes have such advantages as [4]:

- Integrity of the data in the columns of the tables.
- Provide more information.

There are such types of indices [5]:

- Bitmap indexes.
- With reversed key.
- With a compressed key.
- Based on features.
- Partitioned.
- Global.
- Local.
- Invisible.

To create indexes in Oracle, you must adhere to the recommendations:

- Do not create indexes for small tables.
- It is necessary to create primary keys for all tables. In the case of the name of the primary key will be automatically created an index on the primary key.
- It is necessary to index the columns of the tables that take part in table connections.
- Indexing will be very efficient for using the column by the WHERE clause.
- Columns that updated should not be indexed.

For each table, the index must take into account the operations that will be performed on the columns. Creating an index in Oracle:

```
CREATE INDEX blog_id ON blog(blog_id)
TABLESPACE INDEX_BLOG;
```

When creating indexes, you should follow the recommendations:

- Do not create indexes for columns on which INSERT, UPDATE, and DELETE operations are often performed.

```
Do not use indexing for small tables.
Create SQL index:
CREATE INDEX idx1 ON blogs (col1);
```

Indexing allows you to not view the entire table for data retrieval, thereby increasing database performance.

B. PARTITIONING. Partitioning meant breaking a large table into less to promote the execution of necessary queries. Partitioning capabilities include partition independence, which makes it possible to carry out backup, restore, and index creation operations specifically on a partition, rather than on the entire large table, which will significantly reduce database idle time [6].

Partitioning improves the performance of information processing in large tables, but it does not protect against poor-quality queries.

The advantages of partitioning [6]:

- Accessing data subsets while maintaining their integrity.

- Fast execution of maintenance operations achieved by working with one or several sections, and not with the entire table.

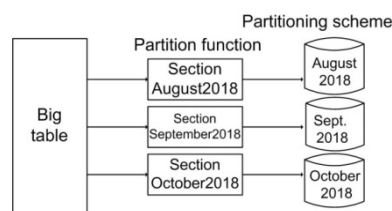


Fig. 2. Partitioning structure [7]

In Oracle Databases, archiving old data that older than the set date is common. With partitioning, this procedure is very simple and effective. This property is typical for large repositories.

There are six ways to partition tables in Oracle:

- Partitioning by key ranges.
- Interval partitioning.
- Hash partitioning.
- According to the list of key values.
- Reference partitioning.
- System partitioning.

Using interval partitioning, it is possible to create sections based on ranges of values:

```
partition by range (sales_dt)
(
    partition b0001 values less than (to_date('2019-04-01','yyyy-mm-dd')),
    partition p0002 values less than (to_date('2019-05-01','yyyy-mm-dd'))
```

Sections are indicated for April and May 2019.

The table will be divided into sections by date range.

If the data are unevenly distributed over time intervals and it is necessary to know not only the data for April and May but also the data that were before the specified interval, then you should use hash partitioning. To do this, you need to select the number of sections, after which Oracle will define the hash value of the key of each row and put it into the necessary section [8].

```
CREATE TABLE users_data
(ticket_no NUMBER,
user_id INT NOT NULL,
user_name INT NOT NULL,
user_bir INT NOT NULL)
PARTITION BY HASH (user_key)
PARTITIONS 4
* STORE IN (ts1,ts2,ts3,ts4);
```

It is also possible to partition by key, even if the given key does not exist in the table itself. The data method called virtual column partitioning. Early versions of Oracle memorized a non-existent column into a trigger, due to which performance was reduced due to calls to the trigger. The Oracle Database 11g specifica-

tion makes it possible to create a column without storing it in a table. This column will be calculated during operation [9]. The complexity of the virtual column may depend on the amount of computational data.

C. CLUSTERING. The term “clustering” means a group of servers, which is interconnected and behaves like a single database that is capable of processing incoming requests [10].

To check the status of the nodes, the local and cluster network used. Checks such as LooksAlive and IsAlive performed. The first command executed every 5 seconds, which tries to make sure that no network problems detected. The second command performs a deeper check every 60 seconds. In case the second command detects an error, the check will be performed 5 more times. When an error detected again, the cluster will transfer the group to another node and transfer all network resources to another server. When transferring data, the group will be ready for servicing customer requests [11].

The advantages of using clusters [12]:

- Eliminate long database downtime. Resources could be delivered to another server without losing the connection to the database.
- Small time and effort when replacing a cluster with better performance. To do this, add a new node to the cluster, install the necessary updates and exclude the old cluster from the network.

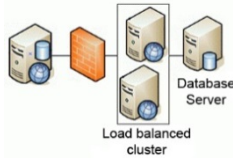


Fig. 3. The structure of the cluster network [12]

There are the following types of building cluster systems [12]:

- With shared disks.
- With shared memory.

Each node of such systems specifically serves its own database fragment. Such systems lack shared memory and storage devices.

When a database uses shared memory and I/O devices, it called Shared everything.

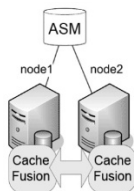


Fig. 4. Shared everything [11]

Such systems characterized by high-speed between nodes and have shared access to storage devices. The strength of the system is fault tolerance, parallel processing, and ability of the network to expand.

A major disadvantage of the system is competition of nodes for input devices and memory. These shortcomings manifest themselves when the network is busy and when executing INSERT, UPDATE, DELETE commands, which need many processor resources to execute.

The Shared Nothing model fixed all the flaws of Shared Everything. Competition disappears due to the lack of shared access of nodes to memory and devices. Each node of the network performs its work separately. Due to this, and increases system performance.

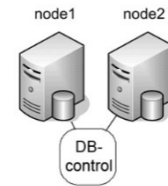


Fig. 5. Shared Nothing [11]

The disadvantage of such an organization is complexity of the network since it is necessary to check the state of each network node, which will entail overhead costs. Backup issues may occur during host status issues. To ensure integrity of the nodes, you must restart the nodes that process execution of the request.

D. Optimization SQL queries. To optimize execution of data change statements, use the EXPLAIN PLAN statement, which allows you to view the execution plan of an SQL statement.

EXPLAIN PLAN allows you to see an execution plan that the analyzer can use to execute an expression [13]. The constructed expression plan is written to the table without saving the SQL expression.

The optimizer's query execution plan runs faster with checking the column index stores than using index row stores [3]. The selection of columns is based on a lower cost value than on rows.

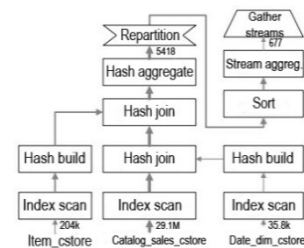


Fig. 6. Optimization using column index repositories [3]

This example demonstrates scanning two tables and building on the basis of hash table scanning. After that, several threads scan the indexes of the column storage indexes and simultaneously check the hash tables. Result sets are collected in one output stream. Such a model is capable of processing more than 144 million tuples of less than a third of a second [3].

Expression plans could be viewed in SQL * Plus using the DBMS_XPLAIN package. This package consists of five functions [14]:

- 1) DISPLAY - output formatted execution plan.
- 2) DISPLAY_AWR - output a formatted execution plan from the AWR directory.
- 3) DISPLAY_CURSOR - output a formatted plan from any loaded cursor.
- 4) DISPLAY_SQL_PLAN_BASELINE - formatted output of one or several SQL plan expressions by headers.
- 5) DISPLAY_SQLSET - output execution plan, which stored in the SQL Tuning set.

After generating the execution plan, the PLAN TABLE table is automatically generated, which is a global temporary table that could be used by all users.

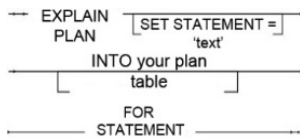


Fig. 7. EXPLAIN PLAN command structure [14]

E. Collecting statistics. During the execution of each SQL query, optimizer looks for the best solution for its execution. Optimizer relies on statistical data, which includes information about distributed data, characteristics of tables and indexes. [15]

For Oracle, automatic database gathering of all optimizer statistics recommended.

Since the release of Oracle Database 10g, a statistics collection tool has been introduced.

Conducting an experiment. A table was created in the database, which consists of 101158 rows.

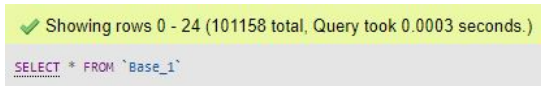


Fig. 8. Created table

Based on this table, the methods described will be used. The table consists of columns:

- ID - identifier.
- Users - workers.
- Age - their age.
- City - city of residence.
- Work_with - the date from which the employee got a job.

To create an index, the Work_with column was selected, be able to select the ranges of the dates work of employees:

```
CREATE INDEX Work_with ON
Base_1(Work_with);
```

To extract information on the date range, the following command executed:

```
SELECT * FROM `Base_1` WHERE Work_with
BETWEEN '1970-04-26' AND '2019-04-26'
```

The result of the query is an alphabetically sorted list of employees by range.

The index file will look like this:

Table 1

Index file	
ID	Index
ID user	Date work
...	...

The file stores the user ID and the date of his employment. By identifier, data will be searched from the main table. The main feature of indexing is: there is no need to compare each row of the table with the query condition, just refer to the index file.

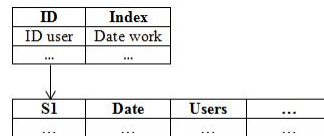


Fig. 9. Index file accesses to the main table

To check the query to the indexed table, a SQL script was created that will give the statistics of the query. SQL script consists of commands:

```
USE database;
FLUSH STATUS;
SELECT * FROM `Base_1` WHERE Work_with
BETWEEN '1920-04-26' AND '2019-04-26';
SHOW SESSION STATUS;
```

This statistic will show the cost of resource consumption when executing a query (Last_query_cost)

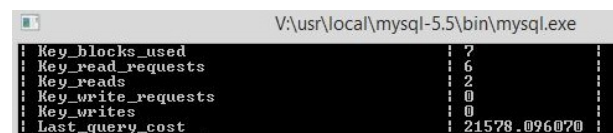


Fig. 10. Indexing statistics

The Last_query_cost parameter is 21578.

To get conclusions from the query optimizer, you must enter a query:

```
EXPLAIN SELECT * FROM `Base_1` WHERE
Work_with BETWEEN '1970-04-26' AND '2019-04-26'
```

select_type	table	type	possible_keys
SIMPLE	Base_3_i	range	Work_with

Fig. 11. Displays query optimizer

Based on the query optimizer output, it could be concluded that MySQL uses an index for execution of this query, which finds the necessary information in the index file in a certain range (Type: range). 8948 rows were found for this query. There were no failures when executing commands.

To check statistics of execution of a partitioning request, a SQL script launched.

```

V:\usr\local\mysql-5.5\bin\mysql.exe
Innodb_truncated_status_writes      0
Key_blocks_not_flushed              0
Key_blocks_unused                   7
Key_blocks_used                     0
Key_read_requests                   0
Key_reads                           0
Key_write_requests                  0
Key_writes                          0
Last_query_cost                     27672.299000

```

Fig. 12. Partitioning statistics

The Last_query_cost parameter is 27672.3.

The first method consumes fewer system resources for its execution. The fewer system resources consumed, the faster the request executed.

To get conclusions from the query optimizer, you must enter a query:

```

EXPLAIN PARTITIONS SELECT * FROM
`Base_3_p` WHERE Work_with BETWEEN '1970-04-
26' AND '2019-04-26'

```

select_type	table	partitions	type
SIMPLE	Base_3_p	p2019	range

Fig. 13. Query query optimizer output

To execute the query, a call made to partition of the table, which stores the ranges of dates.

As a result, a query for sampling dates taken not from the main table, but from its sections, which means that execution of the query is faster than comparing all the records of the main table with the condition in the query.

Table 2

	Query time		
	Index	No Index	Partitioning
Query time (sec)	0.0007	0.0055	0.0007

The query indexed and partitioned tables executed in 0.0007 seconds, which is 7.85 times faster than to the usual similar table.

As a result of the analysis of productivity tuning methods, an index method chosen. This method allows you to quickly process a query to the table due to less load on system resources and the ability not to compare each row of the table with the condition in the query, but to directly access the index files. Index files allow you to process a query faster and their implementation in practice is easier than partitioning a table. Indexing should be applied to those rows that are not confirmed by data changes. In the example, this table does not change; it serves to collect company statistics on employees. And also indexing reduces resource consumption when executing a query.

Conclusions. According to the results of the analysis of database productivity methods, it could be concluded that each method has its own advantages and may affect the speed of the query to the database. How-

ever, each method implies that to successfully carry out the method, it is necessary to carefully work out the structure of the database in the required subject area. Great emphasis should be placed on the ability to update the columns and operate on their data.

In the analysis performed, the method that most suitable for the database optimization problem was chosen.

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Нестеров М.В., Бакитко Д.Е., Михайлова А.О. Оптимізація запитів бази даних

У цій статті розглянуті методи, спрямовані на оптимізацію бази даних. Мета полягала в тому, щоб знайти найбільш підходящий метод для швидкого виконання запитів.

Ключові слова: база даних, індексація, кластери, оптимізація, розділення, статистика, SQL.

Нестеров М.В., Бакитко Д.Э., Михайлова А.А.
Оптимизация запросов базы данных

В этой статье рассмотрены методы, направленные на оптимизацию базы данных. Цель состояла в том, чтобы найти наиболее подходящий метод для быстрого выполнения запросов.

Ключевые слова: база данных, индексация, кластеры, оптимизация, разбиение, статистика, SQL.

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STATISTICAL IMAGE ANALYSIS FOR INFORMATION SYSTEM

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СТАТИСТИЧНИЙ АНАЛІЗ ЗОБРАЖЕНЬ ДЛЯ ІНФОРМАЦІЙНОЇ СИСТЕМИ

Рязанцев А.О., Хорошун Г.М., Рязанцев О.І.

The surface Kirchhoff integral is numerically calculated by the fourth-order Newton – Cotes method with high accuracy. The intensity is normalized. Implemented quantization of the signal with a unit step for different distances of observation is carried out. The cross section of the central topological object intensity and its characteristics are shown. Variation curves and cumulates are constructed for intensity distributions at different observation distances. The basic statistical parameters of distributions are determined, such as, the mode, the mean, the median and the standard deviation.

Keywords: optical image, statistical analysis, information optical system

Introduction. Information technology [1-3] is the broad subject concerned with all aspects of managing and processing information. It includes different levels — from the physical hardware to the operating systems, applications, databases, storage, servers etc. Database is set of independent materials, presented in an objective form and systematized in such a way that these materials can be found and processed using a computer. In the research laboratory usually a big volume of data is analyzed. The functions of automated measuring information optical system (AMIOS) include: data collection and analysis, storage and retrieval of information, protection and transmission of information on laser radiation characteristics. An optical image contains topological objects such as: maxima, minima and zeroes of intensity. Based on them we can define the systematization method for database creating. Computer science is focused entirely on efficiently programming computers using mathematical algorithms.

Calculation of data and its statistical analysis.

The problem of passing laser beam through a set of optical elements can be solved by the Kirchhoff integral:

$$A(x_1, y_1, z) \sim \iint A_0(x, y) \exp(i\Phi_0(x, y) + if(x - x_1, y - y_1)) dx dy \quad (1)$$

where $A_0(x, y)$ - initial amplitude in the plane of the diffraction element XY, $\Phi_0(x, y)$ - the initial phase in

the plane of the diffraction element, $f(x - x_1, y - y_1)$ - the function of describing the diffraction phenomenon, which is observed at a distance z from the screen on the plane X_1Y_1 . The Kirchhoff integral is calculated numerically by Newton-Cotes formula of the closed type with high accuracy.

For the scalar light field an optical image has information parameters: beam intensity and phase; identifying parameters: wavelength of laser radiation, beam waste radius, initial distribution of phase and beam intensity; as well as the structural parameter - the image observation distance z from the exit window of the laser.

Let's consider the intensity distribution for a quasi-plane wave (QPW) passing through a double-phase-ramp (DPR) converter at the distance of observation $z=40\text{cm}$ (Fig. 1a). We normalize the received data for intensity, so that the maximum value is 255, which corresponds to the maximum value for experimental images obtained with a CCD camera. The next step is quantization of the data with a unit interval. The central segment (Fig. 1b) is taken from the initial image (Fig. 1a) for more detailed analysis. The cross-section of this segment, which includes maxima and minima of the intensity is shown in Fig. 1c. The systematization method for database creating is based on coordinates of topological objects and their parameters, such as core ellipticity and angle of inclination. Sharp jumps on the curve (Fig. 1c) are stipulated by the image marking, placed for further determination of topological object parameters.

After this images are ready for implementation of statistical analysis methods. First of all, carry out a data grouping using the variation series [4-7], which shows how the numerical values of the intensity from 0 to 255 are related to their repetition. Variation curves (Fig. 1d) obtained at different distances are analogous to each other. The central part of variation curves is similar to the normal distribution with a positive excess. It has a high narrow peak, indicating the accumulation of frequencies in the middle, the typicality and reliability of

the average value. The mean value \bar{I} is calculated by the formula:

$$\bar{I} = \frac{\sum_1^N I_i}{N}, \quad (2)$$

where I_i – the observed intensity in the i -th group N – the number of quantized intensities. The standard deviation σ represents the degree of scatter of data around the mean value and is defined by the

$$\sigma = \sqrt{\frac{\sum_1^N (I_i - \bar{I})^2}{N}}. \quad (3)$$

In result, we get the following statistical values for the image at $z=40\text{cm}$: the arithmetic mean is 139, the mode is 141 and the standard deviation is about 48 are changed slowly with a distance.

Another one method of data representation is a cumulative curve. The cumulative curves for the intensity patterns are shown in Fig. 1e at different distances z . We want to emphasize that curve for smaller distance has a more expressive form, due to the fact that a light field decreases with the growing of observation distance. The point of lines intersection is determined the median, which is about 141.

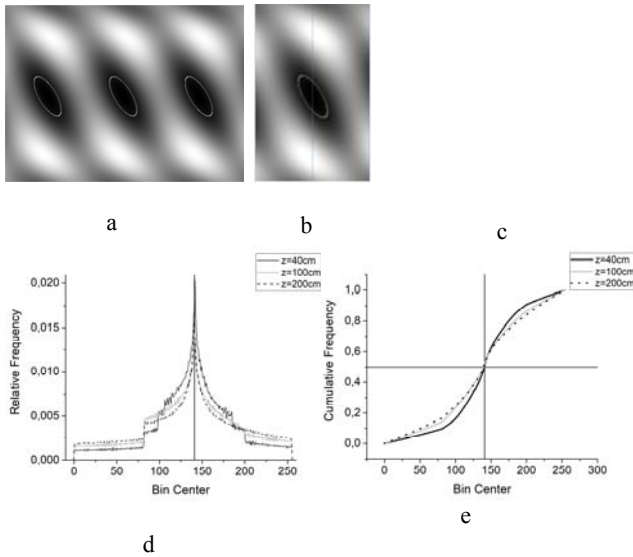


Fig. 1. Distribution of intensity in the diffracted field at the distance $z=40\text{cm}$ (a), segment of intensity distribution for analysis (b), cross-section of distribution of intensity by line $x = 0$ (c), variance curves of the points number (d), cumulates (e) depending on the intensity for different distances

Conclusions. The statistical method is highly precise and effective for data analysis. The data obtained by the theoretical investigation of the diffracted field is performed by the surface Kirchhoff integral, which is numerically calculated, using the fourth-order Newton – Cotes method. The intensity is normalized and quantized with a unit step for different distances of observation. The cross section of the central topological object intensity and its characteristics are shown. Variation

curves and cumulates are constructed for intensity distributions. The basic statistical parameters of distributions are determined, such as, the mode and the median from the graph, the mean and the standard deviation by calculations.

In the future, it is planned to investigate the structure of data and to check how consistent the obtained statistical descriptions of theoretical data are with experimental descriptions according to the Pearson and Kolmogorov consent criteria.

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Рязанцев А.О., Хорошун Г.М., Рязанцев О.І. Статистичний аналіз зображень для інформаційної системи

Поверхневий інтеграл Кірхгофа чисельно розраховується за допомогою методу Ньютона-Котса четвертого порядку з високою точністю. Нормалізується інтенсивність. Реалізовано квантування сигналу з одиничним кроком для різних відстаней спостереження. Показані перетини інтенсивності центрального топологічного об'єкта і його характеристики. Варіаційні криві і кумуляти побудовані для розподілів інтенсивності на різних відстанях спостереження. Визначаються основні статистичні параметри розподілів, такі як мода, середнє значення, медіана і стандартне відхилення.

Ключові слова: оптичне зображення, статистичний аналіз, інформаційна оптична система

Рязанцев А.А., Хорошун А.Н., Рязанцев А.И. Статистический анализ изображений для информационной системы

Поверхностный интеграл Кирхгофа численно рассчитывается с помощью метода Ньютона-Котса четвертого порядка с высокой точностью. Нормализуется интенсивность. Реализовано квантование сигнала с единичным шагом для разных расстояний наблюдения. Показаны сечения интенсивности центрального топологического объекта и его характеристики. Вариационные кривые

вые и кумуляты построены для распределений интенсивности на разных расстояниях наблюдения. Определяются основные статистические параметры распределений, такие как мода, среднее значение, медиана и стандартное отклонение.

Ключевые слова: *оптическое изображение, статистический анализ, информационная оптическая система*

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TOWARDS AN EMPIRICAL HYPERPARAMETERS OPTIMIZATION IN CNN

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ЗАБЕЗПЕЧЕННЯ ЕМПІРИЧНОЇ ОПТИМІЗАЦІЇ ГІПЕРПАРАМЕТРІВ ЗГОРТКОВОЇ НЕЙРОННОЇ МЕРЕЖІ

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The necessity of creating a model of recognition of gestures based on convolutional neural network that effective not only in pattern recognition, but also in terms of learning speed and resource intensity, is substantiated. In this regard, the work solved the problem of optimization of hyperparameters and the selection of the best optimizer backpropagation errors. To implement the tasks, a model was created that can recognize hand gestures, both from a single image and from streaming video. When choosing an optimizer, two adaptive methods were tested - Adadelta and Adam. The experiments confirmed the high efficiency of Adadelta, however, when compared with Adam, it showed more than twice as long network training.

Keywords: hyperparameter, convolutional neural network (CNN), adaptive methods

Introduction. Model optimization is one of the challenging tasks in the development and implementation of machine learning solutions. According to [1], hyperparameters are settings that can be configured to control the behavior of a machine learning algorithm. General speaking, hyperparameters are outside the model, but they are in a direct connection with it. A feature of the hyperparameters is that they are specific to the type of machine learning model that needs to be optimized. In some cases, the parameter is modeled as a hyperparameter, because it cannot be studied from the training set. A striking example of such a situation is the settings that control the capacity of the model (a set of functions that the model can represent). If the deep learning algorithm studies these parameters directly from the training set, then it will probably try to optimize this data set. As a result, it can lead to retraining the model. Examples of hyperparameters are the following: speed of model learning (a hyperparameter that can be used to optimize model capabilities); the number of hidden units (a key parameter for regulating the representative ability of the model); convolutional kernel width (the hyperparameter affects the number of parameters in the model, which, in turn, affects its throughput), etc.

The criteria for defining the hyperparameters are very abstract and flexible. Data science specialists usually spend a lot of time setting up hyperparameters to achieve the best performance for a particular model. In many cases, the hyperparameter optimization is considered as a global optimization of a black-box error function f whose evaluation is expensive [2]. Solving this problem is very challenging due to high complexity of the function f and depends on the current task.

In this context, our goal was to create a gesture recognition model based on a convolutional neural network (CNN), effective not only in pattern recognition but also in terms of learning speed and resource intensity. In this connection, the optimization problems of hyperparameters and the selection of the best backpropagation optimizer were solved.

During the experiments, we used our own database containing six gestures: "fist", "one", "palm", "letterSH", "two", "zero." The total number of video files is 7674. The model was built using the Keras library and the TensorFlow framework. In the process of learning, preprocessing was carried out: the image of the hand was segmented and transferred to the grayscale format, after which the Canny edge detector was used to highlight the hand contours. The processed images were normalized and fed to the input of CNN with three convolution layers and three fully connected. The last layer was the Softmax classifier whose number of neurons is equal to the number of object classes. When choosing an optimizer, two adaptive methods were tested - Adadelta and Adam.

Experimental Setup. CNN solves two problems: (1) determining the attributes of objects (2) determining the probability of the object belonging to a particular class.

In the convolutional core layer, a linear transformation is applied to each pixel of the image, revealing the characteristic features of this class of images. The kernels are matrices of weights of odd sizes, whose val-

ues are set so that any spatial or color features can be detected. At the output, we have feature maps, whose number is equal to the number of applied convolution kernels. Convolution can be presented as

$$(I * K)_{ij} = \sum_{a=0}^{m-1} \sum_{b=0}^{m-1} \omega_{ab} y_{(i+a)(j+b)}^{l-1}, \quad (1)$$

where ω is the core of size $m \times m$, y are the inputs from the previous layer, f is the activation function of neurons.

The size of the output from the convolution layer is calculated by the formula:

$$n_{out} = \left\lfloor \frac{n_{in} + 2p - k}{s} \right\rfloor, \quad (2)$$

where n_{in} is the size of the input data from the previous layer, p - padding, k is the size of the core, s is the step size with which the core is shifted in the image.

Convolution kernels form feature maps equal to their number. In our case, three convolutional layers were used, which yielded 16, 32, and 64 feature maps, respectively. The use of three convolutional layers seems to be optimal in terms of the quality of training to a small number of parameters. The number of parameters for a convolutional layer is defined as:

$$p = d * k * w + b, \quad (3)$$

where d is the depth of the input data (the number of channels), k is the core, w is the weights, b is bias. For example, for the first convolutional layer, this will look like, that is, 160 parameters. For the second layer, that is 4640 parameters.

The result of the convolution must be passed through the nonlinear activation function. Nonlinearity can be written as an expression:

$$y'_{ij} = f(x'_{ij}). \quad (4)$$

In our case, the activation function was the Rectified Linear Unit ReLU [3]:

$$f(x_i) = \begin{cases} x_i, & x_i > 0 \\ a_i x_i, & x_i \leq 0 \end{cases}, \quad (5)$$

where x_i is the input data of the i -th channel, a_i is the coefficient controlling the slope at negative values. ReLU is significantly superior to other functions in the gradient damping resistance, and the learning rate according to [4] is six times faster than the hyperbolic tangent.

The feature maps formed on each layer are fed to the max-pooling sub-sampling layer.

The max-pooling layer with a 2x2 filter follows

each convolution layer, enhances the features identified on the previous layer and reduces the dimension of the input data and, as a result, the number of parameters. Max-pooling is calculated as:

$$y^{l+1} = \max_{0 \leq i < H, 0 \leq j < W} x_{i^{l+1} \times H + i, j^{l+1} \times j, d}^l, \quad (6)$$

where H and W are the height and width of the downsampling filter, x is the input data.

The size of the output from the max-pooling layer is defined as:

$$n_{out} = \left\lfloor \frac{n_{in} - k}{s} \right\rfloor + 1. \quad (7)$$

Max-pooling has no options for training. In order to prevent retraining, in which the trained model too closely matches a given data set, losing the ability to generalize, a dropout is used in the developed neural network [5]. Dropout enables to exclude random neurons in a certain layer with a predetermined probability. The excluded neuron returns the value 0. The probability that a neuron of the current epoch will remain in the network is $q = 1 - p$.

This approach does not allow the neural network to simply remember the correct answers, but gives flexibility in recognizing patterns that are not included in any of the training datasets. Individual nodes are excluded from the network with an established probability of 0.25, that is, at each iteration 25 percent of random neurons will be excluded from the operation of the network.

The second part of the created network is a multi-layered perceptron and is intended for training the hand gesture classifier on the identified features. Data from the last down sampling layer is fed to the Flatten layer, thereby transforming into a one-dimensional vector. Since 64 1313-size trait cards are received from the Flatten input, the first layer of the fully connected part of our network consists of 10816 neurons.

The next layer is fully connected and contains 256 weights, which is quite enough to solve the problem, without requiring a lot of resources. As a result, the number of parameters on this layer is $10816 \cdot 256 + 256 = 2769152$ parameters.

The calculation of the values of neurons for a fully connected layer occurs by the formula:

$$x_i^l = \sum_{k=0}^m w_{ki}^l y_k^{l-1} + b_i^l, \quad (8)$$

where w_{ki}^l is the weight from the k -th neuron of the $l-1$ layer to the i -th neuron of the current layer l , b is the offset of the current layer, y is the incoming data from the previous layer.

The last layer of the network with the number of outputs equal to the number of recognized categories, implements the softmax activation function.

Softmax assigns a value, represented by a non-negative real number, to each class, expressing the probability of belonging:

$$S_i = P(y = i | a), \tag{9}$$

where y is the output class numbered as $1..n$, a is a vector of dimension n .

The sum of all output signals expressing the probability of belonging is equal to one. The output value of the i -th neuron corresponds to the probability that the correct answer is i :

$$S_i = \frac{e^{z_i}}{\sum_{j=1}^n e^{z_j}}, \tag{10}$$

where n is the number of classes. The value of S_i is always positive and is in the range $(0, 1)$.

The created CNN consists of two parts: a) three blocks of alternating convolutional and subsampling layers that form the input feature vector for learning; b) three fully connected layers.

Convolutional layers apply a 3×3 convolution kernel and form 16, 32, and 64 feature maps, respectively. Feature maps pass through subsampling layers with a max-pooling of 2×2 , each time halving the data dimension.

The classifying part of the network consists of a flatten layer, each node of which corresponds to one value of the feature vector, and two fully connected layers dense. The last layer is the output and implements the softmax function.

CNN training. Network training is based on the backpropagation algorithm. Backpropagation can be viewed as a differentiation of a complex function with the search for derived loss with respect to variables. The loss function is categorical cross-entropy [6]:

$$H(y, \hat{y}) = -\sum_i y_i \log \hat{y}_i = -y \log \hat{y} - (1 - y) \log(1 - \hat{y}), \tag{11}$$

where y is the desired result, \hat{y} is the actual result, between which it is necessary to minimize the cross entropy. For a training sample of size m , the minimization of the cross entropy between the predicted and real values is:

$$E(w) = -\frac{1}{m} \sum_{i=1}^m [y_i \log \hat{y}_i + (1 - y_i) \log(1 - \hat{y}_i)], \tag{12}$$

where m is the number of classes. In case the output signal is close to the expected one, the value of the loss function is close to zero:

$$\lim_{\hat{y} \rightarrow y} E = 0. \tag{13}$$

Depending on the results of calculating the loss function, the parameters change at each iteration as:

$$w_{ij}^l = w_{ij}^l - \alpha \frac{\partial}{\partial w_{ij}^l} E(W, b), \tag{14}$$

where α is the learning rate.

Changing the values of weights will be carried out through the gradient descent:

$$\Delta w_{ij} = -\alpha \frac{\partial E}{\partial w_{ij}}. \tag{15}$$

Thus, the task of training the classifier S is to minimize the loss function in the space of weights:

$$\min_w E(S(X, W)M), \tag{16}$$

where X is the feature space, W is the network weights, M is the set of classes. Based on this, it is necessary to calculate the loss function gradient

$$\nabla E(S(X, W)M). \tag{17}$$

Choosing an optimizer. When choosing an optimizer, two adaptive methods were tested - Adadelta [8] and Adam [7].

Adadelta is essentially an extension of another AdaGrad optimizer [9], which had a problem with reducing learning speed. The problem arose due to the accumulation of the sum of squares of gradients, as can be seen from the AdaGrad formula itself:

$$w_{N+1} = w_N - \frac{\alpha}{\sqrt{G_N + \varepsilon}} g_N, \tag{18}$$

where w_N is the value of the parameter w in step N , G_N is the diagonal matrix containing the sum of squares of updates of the partial derivatives of the parameter w from the beginning of work to N , is the smoothing parameter for avoiding division by zero.

In Adadelta, instead of the total sum of updates, the averaged square of the gradient is used, for which the exponentially decaying running average is used. The exponentially average is calculated as:

$$E[g^2]_N = \gamma E[g^2]_{N-1} + (1 - \gamma) g_N^2, \tag{19}$$

where γ is the attenuation coefficient in time.

Due to the mean of the squares of the gradients looks like

$$RMS = \sqrt{E[g^2]_N + \varepsilon} \tag{20}$$

this rule of weights update for Adadelta takes the form:

$$w_{N+1} = w_N - \frac{RMS[\Delta w]_{N-1}}{RMS[g]_N} g_N. \quad (21)$$

The second tested optimizer of gradient descent was the Adam adaptive inertia method. It calculates adaptive learning rates based on the first and second gradient moment scores. The estimate of the first moment is calculated from the previously obtained partial derivative values, as a moving average of gradients. The estimate of the second moment is calculated on the basis of the squares of the gradients of the values of the latter values for the weight

$$\begin{aligned} m_t &= \beta_1 m_{t-1} + (1 - \beta_1) g_t, \\ v_t &= \beta_2 v_{t-1} + (1 - \beta_2) g_t^2, \end{aligned}$$

where β_1 is the exponential decay rate for the first moment, β_2 is the exponential decay factor for estimating the second moment. Due to the fact that the moment estimates are initialized with zeros, and the values of the coefficients β_1 and β_2 are recommended by the authors close to one (0.9 and 0.999, respectively), the shift to zero is preserved. To prevent this, to change the parameters use:

$$\begin{aligned} \hat{m}_p &= \frac{m_p}{1 - \beta_1^p}, \\ \hat{v}_p &= \frac{v_p}{1 - \beta_2^p}. \end{aligned}$$

Recalculation of parameters is made according to the formula:

$$w_p = w_{p-1} - \frac{\alpha}{\sqrt{v_p + \varepsilon}} m_p, \quad (22)$$

where $\varepsilon = 10^{-8}$ is introduced to prevent possible division by zero. In our case, the learning rate $\alpha = 0.002$. A significant increase in speed reduced the effectiveness of network training and increased the number of incorrect answers. Decreasing speed made the network long-learning.

The experiments performed show a sufficiently high Adadelta performance, however, when compared with Adam, it showed more than twice the network's long learning ability.

Having error values, we calculate the partial derivative of the objective function E with respect to each output of the neuron. To calculate the loss derivatives for the variables in the embedded equation, the chain rule is applied:

$$\frac{\partial E}{\partial x_{ij}^l} = \frac{\partial E}{\partial y_{ij}^l} \frac{\partial y_{ij}^l}{\partial x_{ij}^l} = \frac{\partial E}{\partial y_{ij}^l} \frac{\partial}{\partial x_{ij}^l} (f(x_{ij}^l)) = \frac{\partial y_{ij}^l}{\partial x_{ij}^l} f'(x_{ij}^l)$$

For a convolutional layer, the backpropagation procedure looks like:

$$\begin{aligned} \frac{\partial E}{\partial y_{ij}^{l-1}} &= \sum_{a=0}^{m-1} \sum_{b=0}^{m-1} \frac{\partial E}{\partial x_{(i-1)(j-b)}^l} \frac{\partial^{(i-1)(j-b)}}{\partial y_{ij}^{l-1}} = \\ &= \sum_{a=0}^{m-1} \sum_{b=0}^{m-1} \frac{\partial E}{\partial x_{(i-1)(j-b)}^l} w_{a,b}. \end{aligned}$$

In the max-pooling layer, an error from the previous layer passes through a single maximum value. Since this layer does not train the network, the error passes through it unchanged.

For the softmax layer, it is necessary to differentiate the loss function J with respect to z_i :

$$\begin{aligned} \frac{\partial J}{\partial z_i} &= -\sum_k y_k \frac{\partial \log \hat{y}_k}{\partial z_i} = -\sum_k y_k \frac{1}{\hat{y}_k} \frac{\partial \hat{y}_k}{\partial z_i} = \\ &= -y_i (1 - \hat{y}_i) - \sum_{k \neq i} y_k \frac{1}{\hat{y}_k} (-\hat{y}_k \hat{y}_i) = -y_i (1 - \hat{y}_i) + \sum_{k \neq i} y_k (\hat{y}_i) = \\ &= -y_i + y_i \hat{y}_i + \sum_{k \neq i} y_k (\hat{y}_i) = \hat{y}_i (\sum_k y_k) - y_i = \hat{y}_i - y_i \end{aligned}$$

The experiments confirmed the high efficiency of Adadelta, however, when compared with Adam, it showed more than twice as long network training. As a result of experiments on a test subset with a size of 1,535 images, recognition accuracy of 94% was achieved.

Conclusion. In this work, we performed optimization hyperparameter manually that is exhausting and unexpanded. To address these challenges, the algorithms such as Grid Search and Random Search that automatically infer a potential set of hyperparameters and attempt to optimize them could be used. In the course of testing with gesture recognition, a high degree of correct network responses was obtained in real-time on a webcam, including people who did not participate in the creation of an image database. Future work will focus on the development of the effective method for automatic optimizing hyperparameters of deep learning algorithms.

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Сиряк Р.В., Скарга-Бандурова І.С., Білобородова Т.О. Забезпечення емпіричної оптимізації гіперпараметрів згорткової нейронної мережі

Обґрунтовано необхідність створення моделі розпізнавання жестів на основі згорткової нейронної мережі, ефективною не тільки в точності розпізнаванні зображень, але й з точки зору швидкості навчання і використання обчислювальних ресурсів. У зв'язку з цим в статті представлено вирішення завдання оптимізації гіперпараметрів і вибору найкращого оптимізатора помилок зворотного поширення. Для реалізації завдання створена модель, здатна розпізнавати жести рук як по одному зображенню, так і по потоковому відео. При виборі оптимізатора були протестовані два адаптивних методу - Adadelta і Adam. Експерименти підтвердили високу ефективність Adadelta, однак, у порівнянні з Adam, він показав вдвічі більший час навчання мережі.

Ключові слова: гіперпараметр, згорткова нейронна мережа, адаптивні методи

Сиряк Р.В., Скарга-Бандурова І.С., Білобородова Т.А. Обеспечение эмпирической оптимизации гиперпараметров сверточной нейронной сети

Обоснована необходимость создания модели распознавания жестов на основе сверточной нейронной сети, эффективной не только в точности распознавании изображений, но и с точки зрения скорости обучения и использования вычислительных ресурсов. В связи с этим в статье представлено решение задачи оптимизации гиперпараметров и выбора наилучшего оптимизатора ошибок обратного распространения. Для реализации задачи создана модель, способная распознавать жесты рук как по одному изображению, так и по потоковому видео. При выборе оптимизатора были протестированы два адаптивных метода - Adadelta и Adam. Эксперименты подтвердили высокую эффективность Adadelta, однако, по сравнению с Adam, он показал вдвое большее время обучение сети.

Ключевые слова: гиперпараметр, сверточная нейронная сеть, адаптивные методы.

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СИСТЕМА СТАБИЛИЗАЦИИ ТЕМПЕРАТУРЫ ВОЗДУХА В СУДОВОМ КОНДИЦИОНИРУЕМОМ ПОМЕЩЕНИИ

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STABILIZATION SYSTEM FOR AIR TEMPERATURE IN A SHIP AIR-CONDITIONED ROOM

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Описана работа традиционной системы стабилизации температуры воздуха в кондиционируемой каюте морского судна с пропорционально-интегральным регулятором в контуре управления. Показано, что существующие системы кондиционирования воздуха при изменениях тепловых нагрузок не удовлетворяют требованиям к динамическим режимам стабилизации температуры. Предложена структура системы стабилизации с нечетким ПИД-регулятором, отличающаяся простым принципом фазификации и логического вывода. Методами моделирования показано, что предложенная система обеспечивает высокое качество процессов стабилизации температуры воздуха и обладает свойствами робастности.

Ключевые слова: нечеткий регулятор, двухканальная система, кондиционер, динамика, фаззи.

Введение. При эксплуатации морского судна температура, влажность и давление воздуха в его каютах, служебных и производственных помещениях существенно изменяются. Кроме того, воздух насыщается различными парами, газами, влагой, пылью. Чтобы обеспечить комфортные условия для обитаемости судового экипажа и пассажиров, в помещениях судна необходимо поддерживать постоянным качество (кондицию) воздуха. Поддержание в каютах и иных помещениях морского судна комфортных климатических условий - значимая и актуальная задача, решение которой неоднозначно и является крайне важным, поскольку обеспечивает организму человека необходимые условия труда и отдыха в любое время года и в любом районе плавания судна.

Постановка задачи в общем виде. Организм человека находится в комфортном состоянии, когда отдает в окружающую среду ровно столько же тепла, сколько и вырабатывает [1]. В любом состоянии человеческим организмом непрерывно производится тепло, количество которого, в основном, зависит от его активности - физической нагрузки. Выделяе-

мая теплота (от 50 Вт в состоянии покоя до 180 Вт при большой физической нагрузке) передается окружающему воздуху через кожный покров (явная теплота), испарением влаги с поверхности кожи (скрытая теплота) [1-3].

Любой тепловой или влажностный дисбаланс организма человека с окружающей средой приводит к перегреву или переохлаждению. При этом физиологический терморегуляционный аппарат человека перераспределяет теплоотвод, стремясь акклиматизироваться к изменившимся условиям среды обитания. Например, при увеличении температуры окружающего воздуха в суммарном теплообмене резко увеличивается доля отвода тепла испарением пота, а уже при температуре воздуха меньше 15 °С теплоотдача с поверхности кожи испарением пота минимальна. Пот, испаряясь отбирает от организма избыток тепла (скрытая теплота парообразования пота составляет до 0,79 кДж/г). Если температура окружающего воздуха выше температуры тела, то тепловыделение, в основном, осуществляется испарением. При температуре окружающей среды около 20 °С и умеренных физических нагрузках (100 Вт) отвод тепла от организма человека распределяется, в среднем, на такие части: 22 % на испарение, 32 % на конвекцию и 46 % на радиацию [1, 2]. Количество теплоты, передаваемой конвекцией и испарением, зависит от температуры, влажности и скорости перемещения окружающего воздуха, от теплопроводности одежды и ее вида. Теплообмен между человеком и поверхностями стен и иных ограждений происходит радиацией, а количество и направление радиационного теплообмена зависит от температуры ограждений. Если температура ограждений помещения выше температуры тела, то испарением будет отводиться не только теплота, выделяемая организмом, но и теплота, получаемая телом от ограждений конвекцией и радиацией.

Так, для морского судна [1, 3], в жаркое время года в каютах температура воздуха должна поддерживаться на 6-12 °С ниже температуры наружного воздуха (по существующим нормам, допустимый перепад температуры наружного воздуха и воздуха в каюте составляет от 3 до 12 °С). Например, при температуре наружного воздуха +36 °С, в каюте должна поддерживаться температура воздуха не ниже +24 °С [1, 3-5]. Кроме того, очень важно, чтобы состояние воздуха в каюте допускало дальнейшее его насыщение водяными парами - в воздухе должен существовать дефицит влаги: если влажность воздуха велика, то воздух не поглощает выделенную человеком влагу, возникает обильное потоотделение, дыхание становится тяжелым и учащенным, человек испытывает жажду и быстро утомляется. Воздух с очень низкой влажностью также оказывает негативное воздействие - кожа пересыхает и растрескивается, пересыхает слизистая оболочка и повышается восприимчивость организма к простудным заболеваниям. Чтобы обеспечить в каютах нормальную влажность в зависимости от заданной температуры, воздух осушают в жаркое время и увлажняют зимой. Важное значение в процессах теплообмена имеет скорость движения воздуха в каюте: с ее повышением конвективная теплоотдача и испарение осуществляются интенсивней. Но при высокой скорости воздуха, при которой достигается тепловой баланс, возникает ощущение "сквозняка" [1, 2, 5, 6], обычно сопровождаемого повышенным шумом.

Таким образом, задача кондиционирования воздуха в каютах и помещениях морского судна - поддержание комфортных условий обитания. Но эти условия определяются, главным образом, температурой и соответствующей ей влажностью воздуха (безусловно, в сочетании со скоростью его движения, определенным химическим составом и очисткой воздуха от вредных примесей). Таким образом, фундаментальной основой обеспечения комфортных условий обитаемости в помещениях судна является необходимость стабилизации температуры воздуха в его каютах, служебных и производственных помещениях, что и является основной задачей исследования.

Анализ последних публикаций. Обеспечение комфортного теплового режима человека за счет стабилизации температуры воздуха в каютах морского судна осуществляется различными способами [1-3, 5-7], имеющими свои преимущества и недостатки. В зависимости от способов обработки воздуха, системы комфортного кондиционирования воздуха (СККВ) на судне подразделяют на [2-4] централизованные, автономные и комбинированные. Централизованные - обрабатывают воздух в центральной климатической станции (ЦКС). Из ЦКС воздух вентиляторами нагнетается и распределяется по соответствующим помещениям судна. Автономные системы обрабатывают воздух непосредственно в кондиционируемом помещении. Комбинированные системы - обеспечивают первичную об-

работку воздуха в ЦКС, а его окончательную обработку - в доводочных воздухораспределительных нагревающе-охлаждающих устройствах. По числу воздухопроводов системы кондиционирования на судне подразделяют на одноканальные, двухканальные и местные (автономные). В одноканальных системах воздух обрабатывается до заданных параметров и поступает в кондиционируемое помещение по одному каналу. Холодный и горячий воздух в двухканальных системах движется по двум воздухопроводам и перед подачей в каюты смешивается до заданных параметров. Бесканальные системы применяют в помещениях с местными или автономными кондиционерами [2-4, 5-7].

Очевидно, что при столь различных существующих конструктивных решениях СККВ, способы и системы стабилизации температуры воздуха в кондиционируемых помещениях судна существенно различны.

Расчет необходимой мощности СККВ обычно, не вызывает затруднений и является статической задачей [2, 5, 7]. Однако построение системы стабилизации температуры воздуха требует учета динамических свойств конкретного помещения, исполнительных органов, компрессорно-конденсаторных агрегатов [8-10] и иных элементов СККВ, без которых действие синтезированных регуляторов температуры становится неэффективным. В [11] синтезирован регулятор температуры для судового помещения, однако в предложенной системе не учитывается тот факт, что динамические свойства объекта управления (например, каюты) существенно изменяются от режима и условий работы СККВ. Построение робастной [12, 13] системы стабилизации температуры в судовом помещении позволяет существенно повысить точность ее поддержания, вне зависимости от района плавания, времени года и изменяющихся тепловых нагрузок. Создание теоретических предпосылок для реализации такой, слабо чувствительной к изменениям параметров объекта управления (каюты, служебного помещения судна) СККВ является целью статьи.

Основной материал исследования. Рассмотрим, применяющуюся в большинстве морских и речных судов, двухканальную СККВ каюты (рис. 1). Считаем, что объектом управления в СККВ является каюта III, в которой необходимо стабилизировать температуру t_n воздуха на заданном уровне.

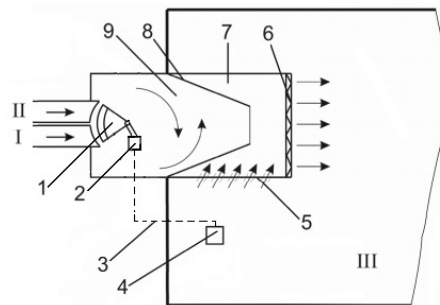


Рис. 1. Общая схема двухканальной СККВ

От СККВ в каюту III воздух поступает по двум воздуховодам I и II (I - холодный, II - теплый воздух). Соотношение массового расхода воздуха определяется положением заслонки 1. При ее перемещении, например, в сторону воздуховода I, расход холодного воздуха уменьшается, а теплого - возрастает. Эти два потока смешиваются в первой смесительной камере 9, причем, из условий работы СККВ, суммарное количество воздуха, поступающего в каюту III (при любом положении заслонки 1) остается неизменным. Относительное значение φ теплого воздуха (в суммарном расходе теплого и холодного воздуха) определяется очевидным образом:

$$\varphi = G_T/G_C = G_X/(G_T + G_X), \quad (1)$$

где G_T и G_X - расход, соответственно, теплого и холодного воздуха, кг/с, а G_C - суммарный расход, кг/с, обработанного воздуха.

Из первой камеры 9 смешивания воздуха, через сопло 8, воздух попадает во вторую, смешивающе-фильтрующую, камеру 7. В сопле 8 предусмотрены специальные жалюзи 5, через отверстия которых осуществляется инъекция внутрикаютного воздуха. Струи обработанного воздуха, через фильтр 6, попадают в каюту. Создающееся избыточное давление вытесняет часть воздуха из каюты через специально предусмотренные вентиляционные решетки или удаляется системой принудительной вентиляции.

Система автоматического управления (САУ) функционирует следующим образом. Сигнал t_{II} от датчика температуры 4 по каналу отрицательной обратной связи 3 непрерывно сравнивается с сигналом задания t_3 и эта ошибка регулирования $\varepsilon = t_3 - t_{II}$ обрабатывается по алгоритму управления регулятором температуры - исполнительным механизмом (РТ-ИМ) 2. Исполнительный механизм ИМ регулятора температуры своим штоком перемещает заслонку 1 относительно ее среднего (нулевого) положения на угол, пока станет равной нулю ошибка регулирования ε . До тех пор, пока тепловые потоки в каюте компенсируются теплом, поступающим из смешивающе-фильтрующей камеры 7, заслонка 1 неподвижна. Как только появится возмущение (избыточный теплоприток Q_{II}), САУ обрабатывает ненулевую ошибку ε и перемещает заслонку так, чтобы восстановить тепловое равновесие.

Используя принципы построения математических моделей (ММ) поршневых холодильных установок и их компрессорно-конденсаторных агрегатов (в данном случае - при условии постоянства температуры конденсации хладагента) [8, 10] и методики, изложенные в [9-11, 13, 14], ММ каюты, как управляемого объекта, относительно температуры воздуха t_{II} , можно представить в виде

$$T_{OY} \frac{d\psi}{dt} + \psi = k_{OY} \cdot \mu + f(\tau), \quad (2)$$

где T_{OY} - постоянная времени каюты, о.е.; k_{OY} - коэффициент передачи объекта, рассчитанный на основе базовых значений φ_0 и t_{II0} ; $f(\tau)$ - внешнее возмущение, о.е.; $\psi = \Delta t_{II}/t_{II0}$ - выходной сигнал объекта управления, о.е.; $\mu = \Delta\varphi/\varphi_0$ - входной сигнал объекта управления, о.е. Параметры (2) рекомендовано [11] определять по выражениям:

$$T_{OY} = \frac{V\gamma C_p}{\frac{\partial Q_{II}}{\partial t_{II}} - \frac{\partial Q_C}{\partial t_{II}}}; k_{OY} = \frac{t_{II0} \frac{\partial \varphi}{\partial t_{II}}}{\frac{\partial Q_{II}}{\partial t_{II}} - \frac{\partial Q_C}{\partial t_{II}}}; f(\tau) = \frac{t_{II0} \cdot \Phi(\tau)}{\frac{\partial Q_{II}}{\partial t_{II}} - \frac{\partial Q_C}{\partial t_{II}}}, \quad (3)$$

где Q_C - суммарное количество тепла, вносимого СККВ в каюту, кВт; Q_{II} - суммарные теплопотери каюты, кВт; V - объем воздуха в каюте, м³; γ - плотность воздуха, кг/м³; C_p - изобарная массовая теплоемкость воздуха, Дж/кг·град; $\Phi(\tau) = -F(\tau) + \Delta t_{II} \cdot (\partial Q_C/\partial t_{II})$ - функция внешнего возмущения, кВт, учитывающая постоянный и переменный во времени теплопритоки.

Динамические свойства датчика температуры и исполнительного механизма можно упрощенно описать выражением

$$T_{PI} \frac{d\eta}{d\tau} + \eta = k_1 \cdot \psi, \quad (4)$$

где $\eta = \Delta S/S_0$ - относительное положение штока РТ-ИМ; k_1 и T_1 - суммарный коэффициент усиления и постоянная времени датчика температуры и ИМ. Свойства заслонки - безинерционные, и потому описываются пропорциональным коэффициентом:

$$\mu = k_2 \cdot \eta, \quad (5)$$

где k_2 - коэффициент усиления управляющего органа (заслонки); $\mu = \Delta\varphi/\varphi_0$ - относительное изменение доли теплого воздуха в суммарном потоке.

После нормирования и приведения сигналов всех элементов, а также последующего перехода к передаточным функциям (ПФ), структурная схема САУ температуры может быть представлена (см. рис. 2) в виде, близком к приведенному в [8-11]. На рис. 2 обозначено: Р - регулятор температуры, описываемый ПФ $W_p(p)$, ИМ - исполнительный механизм, описываемый ПФ апериодического звена первого порядка с постоянной времени $T_{им}$ и коэффициентом передачи $k_{им}$, УО - управляющий орган, с коэффициентом передачи $k_{УО}$, ОУ - объект управления, описываемый ПФ апериодического звена первого порядка с постоянной времени T_{OY} и коэффициентом передачи k_{OY} ; $t_{Зад}$, $t_{Вых}$, $f(\tau)$ - соответственно, заданная и выходная температуры каюты, а также приведенное к ходу УО результирующее возмущение.

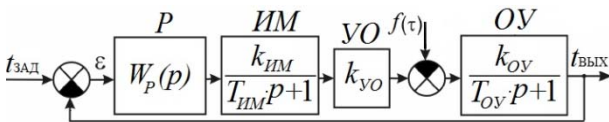


Рис. 2. Структурная схема САУ температуры воздуха в каюте

Предварительно, для определения основных коэффициентов структурной схемы САУ температуры воздуха, проведен расчет теплопритоков для типовой одноместной каюты 2,5×1,5×2,2 м с одной внешней стенкой и одним иллюминатором. При расчете коэффициентов САУ учтены различные конструктивные параметры каюты (площади поверхностей, удельная плотность материалов ограждений и другие), а также теплофизические параметры воздуха (влажность, относительная влажность, давление насыщенных водяных паров, вязкость и другие). Для режима охлаждения каюты приняты следующие значения: $t_c = 29\text{ }^\circ\text{C}$ температура воздуха в соседних помещениях и коридоре; $M = 9,57\text{ кг}$ - масса воздуха в каюте; $G_c = 0,0656\text{ кг/с}$ - расход приточного воздуха при условии одновременного выделения в каюте тепла и влаги; удельная теплоемкость воздуха $1005\text{ Дж/кг}\cdot\text{град}$; наружная температура воздуха $+34\text{ }^\circ\text{C}$, требуемая в каюте температура воздуха $+27\text{ }^\circ\text{C}$. Использование методик [8-11] позволило установить следующие коэффициенты структурной схемы САУ: $T_{IM} = 0,8\text{ с}$, $k_{IM} = 1,8\text{ В/В}$, $k_{YO} = 0,025\text{ м/В}$; $T_{OY} = 110\text{ с}$; $k_{OY} = 3,3\text{ град/м}$; $t_{3AD} = 27\text{ }^\circ\text{C}$.

Регулятор температуры P настроен на симметричный оптимум, описывается ПФ пропорционально-интегрального закона:

$$W_p(p) = k_p + 1/(p \cdot T_p), \quad (6)$$

где $k_p = 7\text{ В/град}$, $T_p = 10\text{ с}$.

Результат моделирования, основанный на использовании методик [8, 13-15], процесса стабилизации температуры воздуха в каюте, при указанных выше параметрах объекта управления, коэффициентах и настройках ПИ-регулятора, приведен на рис. 3, граф. 1. Из рисунка видно, что примерно через 2,5 минуты температура в каюте установилась на практически заданном уровне ($+27\text{ }^\circ\text{C}$), а ее максимальное динамическое отклонение не превысило $0,6\text{ }^\circ\text{C}$. Такой результат можно считать вполне удовлетворительным. Однако следует отметить, что: а) в ходе нормального функционирования САУ температуры параметры ПФ ОУ не остаются постоянными; б) регулятор ПИ-типа имеет фиксированные настройки и не учитывает изменения свойств ОУ при изменениях условий окружающей среды и тепловых нагрузок, давления конденсации. Например, в таблице приведены изменения теплофизических свойств воздуха при изменении его температуры в относительно небольших пределах (от 10 до $40\text{ }^\circ\text{C}$).

Изменения теплофизических свойств воздуха в кондиционируемой каюте

Таблица

Параметр	Температура воздуха	
	10°С	40°С
Плотность, ρ , кг/м ³	1,247	1,128
Динамическая вязкость, $\mu \cdot 10^6$, Па·с	17,6	19,1
Кинематическая вязкость, $\nu \cdot 10^6$, м ² /с	14,16	16,96
Теплопроводность, $\lambda \cdot 10^2$, Вт/(м·град)	2,51	2,76
Температуропроводность, $a \cdot 10^6$, м ² /с	20	24,3
Число Прандтля, Pr	0,705	0,699

Очевидно, что совокупное изменение параметров ОУ (от изменения параметров воздуха (табл. 1), тепловых нагрузок, давления конденсации и других) будет существенно влиять на результирующие динамические свойства САУ при неизменных настройках ПИ-регулятора температуры. Анализ выражений (2), (3), а также источников [2, 3, 9-11], позволяет утверждать, что постоянная времени T_p коэффициент передачи k_p могут изменяться на $\pm 20\%$. На рис. 3, граф. 2, показаны результаты моделирования процесса стабилизации температуры воздуха в каюте при $k_{OY} = 0,8\text{-}3,3\text{ град/м}$ и $T_{OY} = 1,2\text{-}110\text{ с}$, а граф. 3 иллюстрирует этот же процесс, но при $k_{OY} = 1,2\text{-}3,3\text{ град/м}$ и $T_{OY} = 0,8\text{-}110\text{ с}$. Приведенные графики показывают существенные отклонения динамических режимов от желаемых.

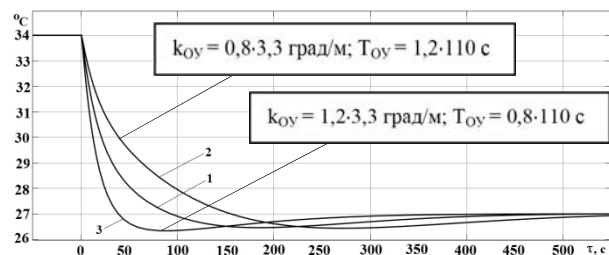


Рис. 3. Динамические процессы стабилизации температуры воздуха в каюте с применением в САУ ПИ-регулятора с фиксированными настройками при различных параметрах ПФ ОУ

Известны различные способы управления объектами с переменными параметрами (адаптивные регуляторы с сигнальной и/или параметрической самонастройкой, системы с эталонной моделью, с наблюдателями состояния и другие). Следует отметить, что для многих прикладных задач применение классических методов теории робастного и адаптивного управления не всегда рационально, поскольку предполагает существенное усложнение САУ за счет перехода к управлению с идентификацией переменных объекта в реальном времени (с помощью наблюдателей состояния). Хорошо известны и достаточно распространены методы управления объектами с переменными параметрами и параметрами, не имеющими однозначного аналитического описания, либо имеющими крайне сложное математическое описание. Эти методы основаны на применении нечетких (фаззи) регуляторов [16-19] и,

в настоящее время, имеют хорошую программно-аппаратную поддержку.

Так, для рассматриваемой САУ температуры диапазоны вариации параметров ОУ и нагрузок, в целом, известны и обуславливают ухудшение показателей качества только динамических процессов. При таких условиях задача обеспечения грубости системы узка и может быть решена без применения эталонных моделей и наблюдателей состояния – путем формирования нелинейных характеристик регуляторов. Если принять, что характеристики регуляторов функционально зависят от амплитуды и скорости изменения ошибки регулирования, то можно перейти к системам с нечетким управлением [16-19].

Известно, что нечеткое управление обладает определенными свойствами грубости [16, 19], а объединение нескольких нечетких регуляторов (НР) позволяет получение хороших динамических свойств системы, причем небольшое число правил НР придает улучшенные свойства обобщения. Следует отметить, что с целью обеспечения совместимости различного оборудования, техническая реализация НР должна соответствовать стандарту МЭК IEC 61131-7 (Part 7. Fuzzy logic standartization). Этот стандарт вводит ограниченные законы описания элементов нечеткого управления на языках программирования контроллеров, зафиксированных IEC61131-3. Для аналоговых объектов управления, это, например, язык *Function Block Diagram (FBD)*. Стандартом определяются модель и функциональные элементы НР: размытие (*fuzzification*), обратное уплотнение (*defuzzification*), производящие правила по алгоритму последовательных операций объединения (*agreggation*), активации (*activation*), накопления (*accumulation*), определяются команды родового языка *Fuzzy Control Language (FCL)* для разработки нечетких систем управления. Выполнение требований стандарта IEC61131-7 резко ограничивает весьма разнообразные, теоретически возможные, решения по созданию НР, тем самым заметно упрощая задачу технической реализации и совместимости конкретного НР.

Для рассматриваемой в статье САУ предлагается применить такой НР [18], построение которого не требует привлечения экспертов, формирующих правила фаззификации, формирования и настройки правил объединения, активации, дефаззификации (рис. 4). Представляемый НР, по сути: а) является универсальным [18], поскольку предлагает применять однозначную систему логического вывода; б) может применяться во многих технических решениях; в) в своем алгоритме использует, как общепринято, производную от сигнала ошибки.

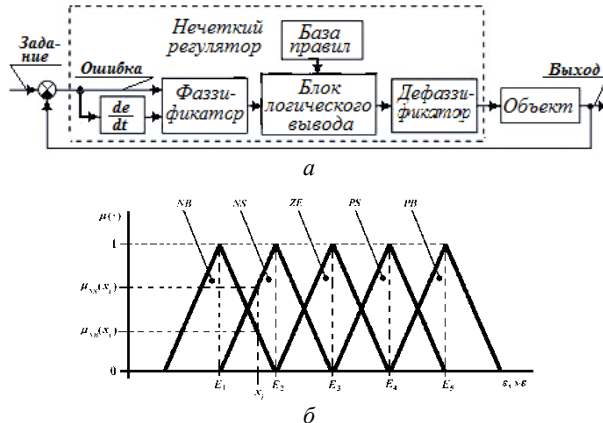


Рис. 4. Нечеткая система управления (а) и пример (б) процедуры фаззификации (5 термов) входных переменных

Рассмотрим двухканальный регулятор (см. рис. 5), содержащий два нечетких регулятора с одинаковой структурой – F1 и F2, выходные сигналы которых суммируются:

$$y(p) = y_1(p) + y_2(p). \tag{7}$$

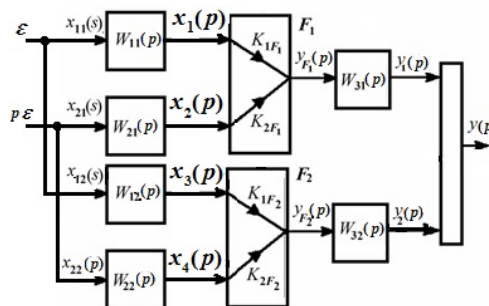


Рис. 5. Структура универсального нечеткого регулятора

Пусть ПФ $W_{11}(p)$, $W_{21}(p)$ и $W_{12}(p)$, $W_{22}(p)$ входных сигналов – масштабирующие, пропорциональные звенья; входных сигналов два – $x_{11}(p) = x_{12}(p)$ и $x_{21}(p) = x_{22}(p)$, причем первый из них является ошибкой регулирования $\varepsilon(p)$, а второй – производной $p \cdot \varepsilon(p) \Rightarrow d\varepsilon(\tau)/d\tau$ от ошибки; ПФ $W_{31}(p)$ первого НР осуществляет пропорциональное усиление, а второго НР $W_{32}(p)$ – операцию интегрирования с постоянной времени T_{ii} ; нелинейные коэффициенты передачи K_{1F1} , K_{2F1} и K_{1F2} , K_{2F2} нечетких регуляторов по каждому из термов $x_1(p), \dots, x_4(p)$ линеаризованы.

При этих условиях можно записать:

$$\left. \begin{aligned} W_{11}(p) &= k_{D1}; W_{21}(p) = k_{D1}; W_{12}(p) = k_{I2}; \\ W_{22}(p) &= k_{D2}; \varepsilon(\tau) \Rightarrow \varepsilon(p) = x_{11}(p) = x_{12}(p); \\ d\varepsilon(\tau)/d\tau &\Rightarrow p \cdot \varepsilon(p) = x_{21}(p) = x_{22}(p); \\ K_{1F1} &= \frac{\partial F_1(\tau)}{\partial x_1(\tau)}; K_{2F1} = \frac{\partial F_1(\tau)}{\partial x_2(\tau)}; \\ K_{1F2} &= \frac{\partial F_2(\tau)}{\partial x_3(\tau)}; K_{2F2} = \frac{\partial F_2(\tau)}{\partial x_4(\tau)}; \end{aligned} \right\} \tag{8}$$

$$W_{31}(p) = k_n; W_{32}(p) = \frac{1}{p \cdot T_u}$$

Из (8), согласно рис. 5, получим

$$\left. \begin{aligned} y_1(p) &= \varepsilon(p) \cdot k_{П1} \cdot K_{1F1} \cdot k_{П} + s \cdot \varepsilon(p) \cdot k_{Д1} \cdot K_{2F1} \cdot k_{П}; \\ y_2(p) &= \varepsilon(p) \cdot k_{П2} \cdot K_{1F2} \cdot \frac{1}{p \cdot T_u} + \\ &+ \varepsilon(p) \cdot k_{Д2} \cdot K_{2F2} \cdot \frac{1}{T_u}; \\ y(p) &= y_1(p) + y_2(p), \end{aligned} \right\} \quad (9)$$

откуда ПФ НР по ошибке

$$W_{НР}(p) = \frac{y(p)}{\varepsilon(p)} = k_{П1} \cdot K_{1F1} \cdot k_{П} + k_{Д1} \cdot K_{2F1} \cdot \frac{1}{T_u} + k_{П2} \cdot K_{1F2} \cdot \frac{1}{p \cdot T_u} + p \cdot k_{Д2} \cdot K_{2F2} \cdot k_{П}, \quad (10)$$

соответствует ПФ идеального ПИД-регулятора:

$$W_{НР}(p) = K_{нНР} + \frac{1}{p \cdot T_{иНР}} + p \cdot T_{дНР}, \quad (11)$$

$$\text{где } K_{нНР} = k_{П1} \cdot K_{1F1} \cdot k_{П} + k_{Д1} \cdot K_{2F1} \cdot \frac{1}{T_u};$$

$$T_{иНР} = T_u / (k_{П2} \cdot K_{1F2}); T_{дНР} = k_{Д2} \cdot K_{2F2} \cdot k_{П}.$$

Этапы формирования базы правил и логического вывода формализованы согласно [11, 16, 18, 19] и приведены на рис. 6. Входные сигналы разбиты на пять термов, выходной - на семь.

Этап дефаззификации основан на применении известного метода "центра тяжести" [16, 19]. Если установить в каждый из каналов двухканального, релязирующего свойства нечеткого ПИД-регулятора (см. рис. 5), два абсолютно одинаковых, с одинаковыми масштабными коэффициентами $k_{П1}$ и $k_{Д1}$ (т.е. $k_{П1} = k_{П2} = k_{П}$ и $k_{Д1} = k_{Д2} = k_{Д}$) НР, то результирующую структурную схему можно упростить (см. рис. 7) и оставить лишь один канал нечеткой обработки, объединив одним каналом этапы фаззификации, логического вывода и дефаззификации.

		$\downarrow \mu(x_1)$					
		E_1	E_2	E_3	E_4	E_5	$x_1 = \varepsilon$
	$x_2 = p \cdot \varepsilon$	NB	NS	ZE	PS	PB	
	E_5	PB	ZE	PS	PB	PBS	
	E_4	PS	NS	ZE	PS	PB	PBS
	E_3	ZE	NB	NS	ZE	PS	PB
	E_2	NS	NBS	NB	NS	ZE	PS
	E_1	NB	NBS	NBS	NB	NS	ZE
		$\downarrow \mu(y)$					

Рис. 6. Формирование базы правил и логического вывода НР

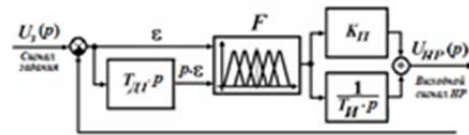


Рис. 7. Участок структурной схемы универсального нечеткого ПИД-регулятора

Для рассматриваемой САУ СКВ каюты с НР, принимаем прежние значения k_p и T_p , т.е. $k_{П} = k_p = 7$ В/град, $T_{И} = T_p = 10$ с. Дифференциальную составляющую вычисляем приближенно, с фильтрацией, согласно ПФ:

$$T_{Д1} \cdot p \approx \frac{T_{Д1} \cdot p}{0,1 T_{Д1} \cdot p}, \quad (12)$$

где $T_{Д1} = 1$ с.

На рис. 8 приведены результаты моделирования процесса стабилизации температуры воздуха в кондиционируемой каюте с САУ, содержащей НР, который построен согласно схеме, приведенной на рис. 7 и по изложенной выше методике.

Графики 1, 2 и 3, приведенные на рис. 8, соответствуют отклонениям ПФ ОУ на $\pm 20\%$, как и для предыдущей (см. рис. 3) процедуры моделирования САУ с классическим ПИ-регулятором.

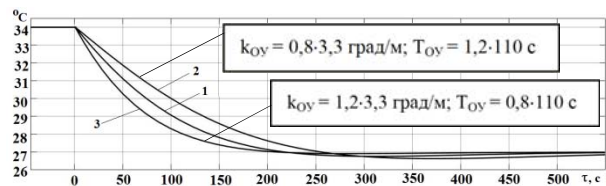


Рис. 8. Динамические процессы стабилизации температуры воздуха в каюте с применением в САУ нечеткого регулятора при различных параметрах ПФ ОУ

Полученные в результате моделирования графики процесса стабилизации температуры каюты в СКВ с НР позволяют сформировать следующее заключение.

Результаты исследования. На основе анализа принципов функционирования традиционной системы управления комфортным кондиционированием каюты морского судна с ПИ-регулятором температуры воздуха, установлено, что такая система, при изменениях тепловых нагрузок и теплофизических свойств воздуха, не удовлетворяет требованиям к динамическим режимам стабилизации температуры воздуха.

В традиционной системе с ПИ-регулятором температуры, в зависимости от изменения условий окружающей среды, наблюдается либо заметное увеличение перерегулирования (граф. 3, рис. 3), либо затягивание времени переходного процесса (граф. 2, рис. 3).

Предложена САУ СКВ в каюте с нечетким регулятором температуры воздуха. Для такого нечеткого регулятора приведена методика его синтеза,

характеризуються простотою формування логічного вивода (рис. 6) і упрощенням структури регулятора (рис. 7).

Математическое моделирование (рис. 8) процессов стабилизации температуры воздуха в каюте с САУ, содержащей НР, показало: а) заметное улучшение динамических процессов стабилизации температуры воздуха; б) свойства робастности САУ к изменениям параметров ПФ объекта управления, связанные с изменениями параметров окружающей среды.

Анализ результатов моделирования позволяет утверждать, что использование в различных помещениях морских и речных судов предложенной системы управления с нечетким регулятором в СККВ позволит улучшить условия обитаемости членов экипажа и пассажиров.

Л и т е р а т у р а

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Василюк Д. І., Козьмініх М. А., Налева Г. В., Онищенко О. А. Система стабілізації температури повітря у суднових кондиціонованих приміщеннях.

Описана роботу традиційної системи стабілізації температури повітря у кондиціонованій каюті морського судна з пропорційно-інтегральним регулятором у контурі управління. Показано, що існуючі системи конди-

ціонування повітря при змінах теплових навантажень не задовольняють вимогам до динамічних режимів стабілізації температури. Наведена структурна схема системи стабілізації з нечітким ПІД-регулятором, що відрізняється простим принципом фазифікації і логічного висновку. Методами моделювання показано, що запропонована система забезпечує високу якість процесів стабілізації температури повітря і має властивості робастності.

Ключові слова: нечіткий регулятор, двоканальна система, кондиціонер, динаміка, фаззи.

Vasilets D. I., Kozminykh N. A., Naleva G. V., Onishchenko O. A. Stabilization system for air temperature in a ship air-conditioned room.

The operation of the traditional system for stabilizing the air temperature in an air-conditioned cabin of a sea vessel is described. The system uses a proportional-integral controller in the control loop. It is proved that the existing air conditioning systems are significantly affected by thermal loads and variable air parameters. Existing air conditioning systems do not work satisfactorily under changes in heat loads. In such systems, poor dynamics. There is either overshoot or delayed process. The structure of the stabilization system with a fuzzy PID controller is proposed. Such a system is distinguished by the simple principle of fuzzification and logical inference. Using mathematical modeling methods, it is proved that a new system with a fuzzy controller functions better. The new system provides high quality stabilization processes for air temperature and is robustness properties.

Keywords: fuzzy controller, two-channel system, air conditioning, dynamics, fuzzy.

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