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USING THE THEORIES OF FUZZY SETS FOR RESEARCHING THE PROCESSES OF DIAGNOSTICS OF DATA COMMUNICATION NETWORKS

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Abstract

The article deals with the application of the queuing theory apparatus for analysing the diagnostic processes of data transmission networks (DTN). It is shown that with an increase in the complexity of DTN and existing tools and algorithms for their diagnostics, it seems expedient to create automated diagnostics systems that take into account the disadvantages and advantages of existing network diagnostics methods. The existing analytical methods (in the capacity of which probabilistic methods of the queuing theory are used) and statistical (methods of simulation modelling) are presented. In terms of the queuing system, the analysis of the closed, open (QS) is carried out and their characteristics are determined. The analysis of the statistical method for modelling the diagnostic system in the GPSS World environment is carried out. Models of the DTN diagnostics system are considered from the point of view of closed and open queuing systems. For analytical models of DTN diagnostic systems, the possibility of using the QS is considered, as a result of which the general structure of the main elements and procedures for the functioning of the diagnostic system are determined. The analysis of the possibilities of using the queuing theory made it possible to determine the analytical regularities for the model of diagnostic systems. The creation of automated diagnostic systems based on a queuing system provides a deep and accurate analysis of the characteristics of diagnostics and, therefore, is a promising direction in the development of systems for the technical operation and maintenance of DTN.

Keywords: data transmission systems, multiple in – multiple out fuzzy sets, diagnostics, MATLAB Simulink

1. INTRODUCTION

In recent years, there has been a rapid development of data transmission networks, each of which, being a complex organizational and technical system, must ensure the high-quality functioning of all its elements and the network as a whole.

The data transmission network, as an object of diagnostics, can be represented as a mathematical model that includes input (external influences), output (reactions to external influences) and internal (state) variables. Dependencies between the input, output and internal variables of the object, written functionally, can be put in correspondence with the space of technical states inherent in this object [11].

The use of traditional mathematical methods in solving problems related to the technical diagnostics of data transmission networks is ineffective when the initial information about the state of network elements is completely absent or is statistically incomplete [10].

A promising direction in the development of diagnostic methods and tools are methods based on fuzzy logic or fuzzy sets, which can significantly simplify the description of the model of control and diagnostic objects.

2. METHODOLOGY

The process of diagnosing data transmission networks includes such stages as collecting initial information, identifying a defect, and localizing a defect. At the same time, the initial information includes information about defects received from users, information about non-standard situations during maintenance, and other data collected by maintenance personnel, which, for simplicity, can be called symptoms. Then, in the general case, the simplified algorithm for the operation of an automated remote diagnostic system will correspond to the following. Initially, initial information is entered into the diagnostic system in the form of subjective symptoms. The system identifies the most significant among them, taking into account the proximity of symptoms to one of the defects, using the knowledge embedded in it during creation, and then collects more detailed information about the symptoms associated with a probable defect, and issues a conclusion. As knowledge in this case, general relationships between defects and symptoms are needed, in addition, some measure of such a relationship is needed, both for a defect from the point of view of a symptom, and for a symptom from the point of view of a defect [14].

Given the above, when implementing the system, it is initially necessary to establish theses for adapting knowledge to fuzzy conclusions. To do this, denote by $D=\{D_1, ..., D_m\}$ and $S=\{S_1, ..., S_n\}$ respectively, the set of all defects and the set of all symptoms. Then we introduce the following linguistic variables:

- A_i – "there is a defect D_i";
- B_j – "Symptom S_j is determined";
- R_{ij} – "defect D_i according to its characteristics corresponds to the symptom S_j".

These linguistic variables can take the following values from the term-set *CON* , which characterize their degree of reliability (truth):

- *un* - "unknown";
- *vt* - "very true";
- *rt* - "quite true";
- *pt* - "probably true";
- *pf* - "probably false";
- *rf* - "quite false";
- *vf* - "very false."

Each of these values is described by the membership function, which characterizes the degree of certainty of a particular statement, and takes a value from the interval [0; 1].

The linguistic variable R_{ij} is a reflection of the knowledge of an expert (or experts) about the correspondence of the observed symptoms to defects in the data transmission network. The set of all values R_{ij} can be represented as a matrix *M* from *m* rows and *n* columns:

	S_1	S_2	…	S_n
D_1	R_{11}	R_{12}	…	R_{1n}
D_2	R_{21}	R_{22}	…	R_{2n}
…	…	…	…	…
D_m	R_{m2}	R_{m2}	…	R_{mn}

In this case, the inference system will be built on the basis of the model proposed by Mamdani, according to the MIMO scheme (Multiple In – Multiple Out), i.e., will contain several inputs and several output variables. The values of B_j will be used as input variables, and the values of A_i will be used as output variables.

Thus, the fuzziness of the variable B_j may be due to the subjectivity of a person's opinion about the presence of a certain diagnostic symptom. To determine the fuzzy value of the variable B_j, depending on the specified parameters, one should introduce such linguistic variables as *OE* – "assessment of the presence of symptom S_j is objective" and *QoS* - "The quality of the communication channel is good. "These linguistic variables take values from the previously introduced term-set *CON* . It should be noted that either only *OE* or only *QoS* can affect the value of B_j at the same time. In cases where the quality of the communication channel of the remote diagnostic system or the objectivity of the assessment of the presence of the symptom S_j do not affect the value of B_j , the value of *vt* is assigned to the variable B_j. In all other cases, the value of B_j should be equal to *OE* or *QoS* , depending on which of these linguistic variables is used, i.e. depending on what exactly affects the objectivity of assessing the presence of a symptom S_j. It should be noted that, B_j as a rule, has the value *vt*. If information about the presence of a defect B_j has not been received by the system, B_j is assigned the value *un* [5].

In the general case, it is not enough for a diagnostic system to know the value of one linguistic variable B_j , i.e. when information about the presence of one diagnostic symptom enters the diagnostic system, there is a lack of initial information, which has a significant impact on the reliability of the decision made about the type of defect. In this case, the system should be able to request an assessment of the presence of symptoms closest to the original, in terms of belonging to one type of defect. Thus, it is possible to form a complete set (vector) of input variables $\{B_j\}$, $j=1, ..., n$, used to decide on the type of defect [6].

To implement a fuzzy inference system, it is necessary to organize a rule base based on the values of the linguistic variable R_{ij}, which will contain "if-then" type inference rules that express experts' knowledge about the belonging of diagnostic symptoms to a specific type of defect. Based on these rules, the system will decide on the type of defect [3].

To reduce the number of calculations in the diagnostic system, the matrix *M* describing the relationship between symptoms S_j and defects D_i can be divided into submatrices that will contain defects grouped according to certain characteristics (for example, defects in transmission systems, defects in switching and routing systems, etc.). P.).

In the diagnostic system, based on a survey of experts, a term set *CON is formed* , the elements of which have membership functions. Also, based on a survey of experts in the system, the following matrix *M was formed* and graphs of the membership functions of linguistic variables (Fig. 1) were constructed, which characterizes the relationship between symptoms and defects [14]:

	S_1	S_2	S_3	S_4	S_5
D_1	*vt*	*vt*	*pf*	*pf*	*vf*
D_2	*rf*	*rf*	*vt*	*vf*	*vt*
D_3	*pt*	*vt*	*vf*	*rt*	*pt*

In addition, the following rule base is implemented in the system (Figure 2):

RUL_1: "IF $B_1=vt$ AND $B_2=vt$ AND $B_3=pf$ AND $B_4=pf$ AND $B_5=vf$ TO $A_1=vt$ "

RUL_2: "IF $B_1=rf$ AND $B_2=rf$ AND $B_3=vt$ AND $B_4=vf$ AND $B_5=vt$ TO $A_2=vt$ "

RUL_3: "IF $B_1=pt$ AND $B_2=vt$ AND $B_3=vf$ AND $B_4=rt$ AND $B_5=pt$ Maintenance $A_3=vt$ "

RUL_4: "IF $B_1=vt$ AND $B_2=vt$ AND $B_3=vt$ AND $B_4=vt$ AND $B_5=vt$ TO $A_1=pf$ »

RUL_5 : "IF $B_1=vt$ AND $B_2=vt$ AND $B_3=vt$ AND $B_4=vt$ AND $B_5=vt$ TO $A_2=rt$ "

RUL_6: "IF $B_1=pt.$ AND $B_{2\_}=pt.$ AND $B_3=pt.$ AND $B_4=pt.$ AND $B_5=pt.$ Maintenance $A_3=pt.$ "

RUL_7: "IF $B_1=pt.$ AND $B_{2\_}=pt$ AND $B_3=pt$ AND $B_4=pt$ AND $B_5=pt$ TO $A_1=rt$ "

RUL_8: "IF $B_1=pt$ AND $B_{2\_}=pt$ AND $B_3=pt$ AND $B_4=pt$ AND $B_5=pt$ TO $A_2=pt$ "

RUL_9 : "IF $B_1=vt$ AND $B_2=vt$ AND $B_3=vt$ AND $B_4=vt$ AND $B_5=vt$ Maintenance $A_3=rt$ "

Consider the case when a message containing $B_2=rt$. Since there was no information about the presence of other symptoms, then $B_1=un$, $B_{3\_}=un$, $B_{4\_}=un$, $B_5\_=un$. Therefore, we can consider only that part of the rules in which $B_2=rt$.

On fig. Figures 3-6 show fuzzy inference surfaces for assessing defect cases for fuzzy models A_1, A_2, A_3.

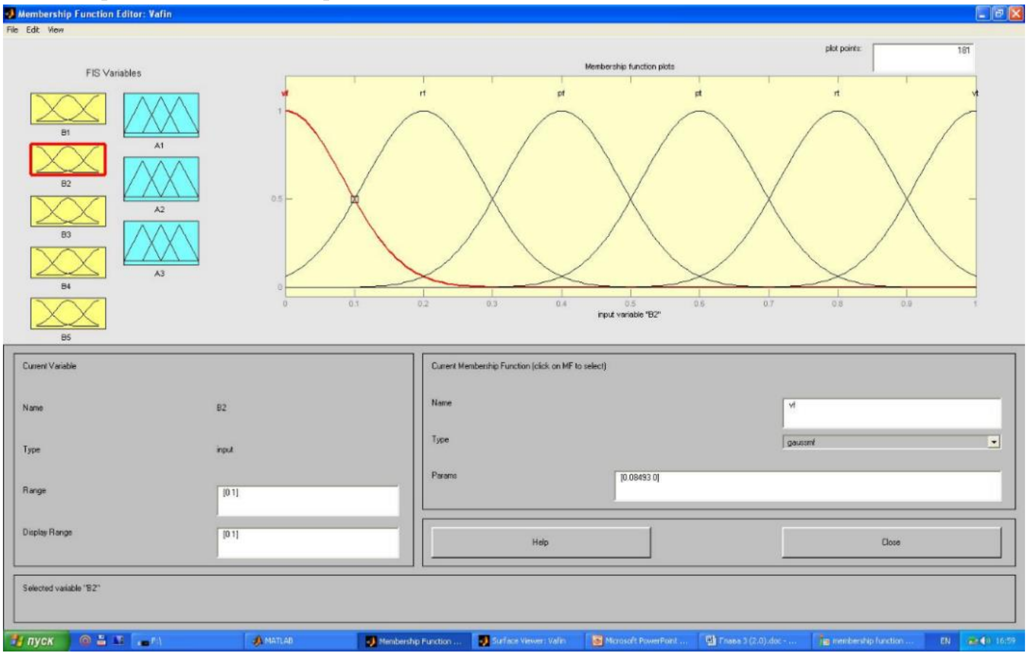

Fig. 1. Graph of membership functions of linguistic variables

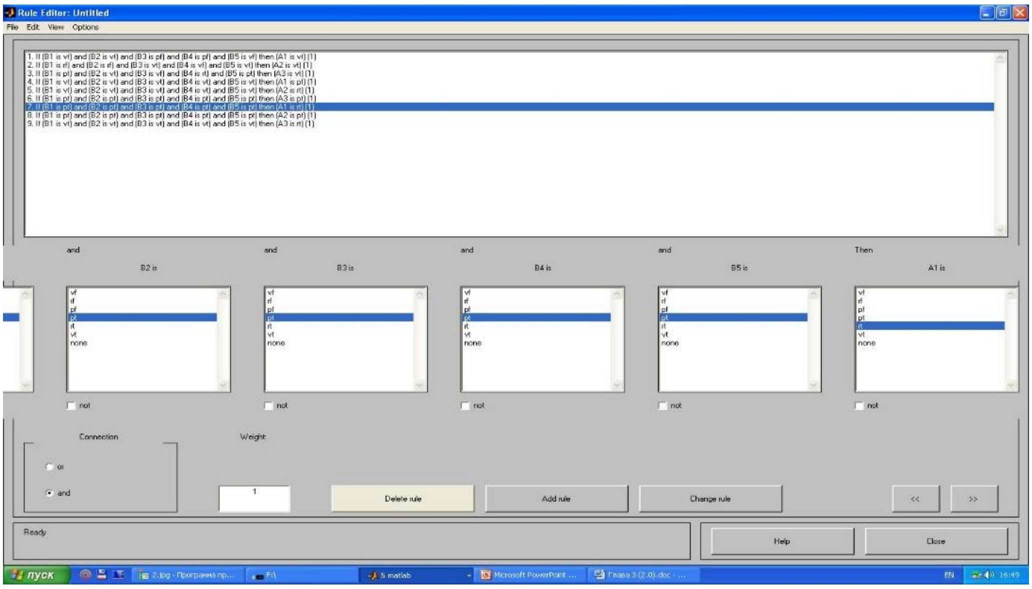

Fig. 2. Rules of fuzzy knowledge bases of fuzzy logical models

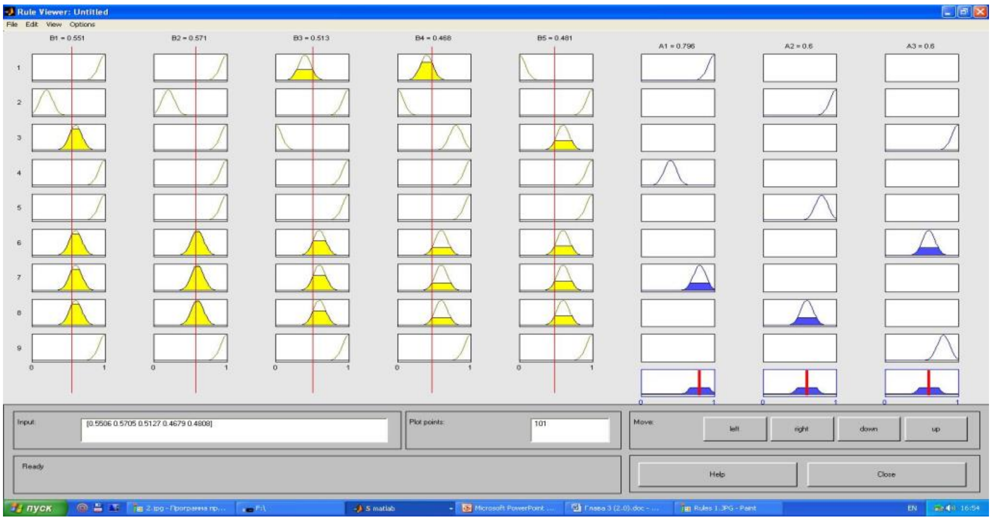

Fig. 3. Fragments of computational experiments

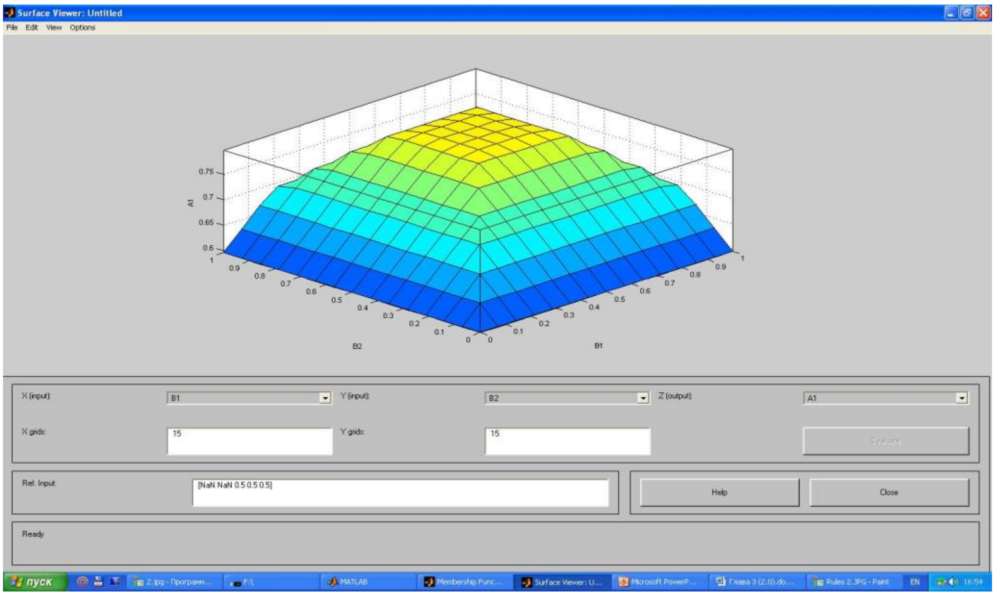

Fig.4. Fuzzy inference surface for case A_1

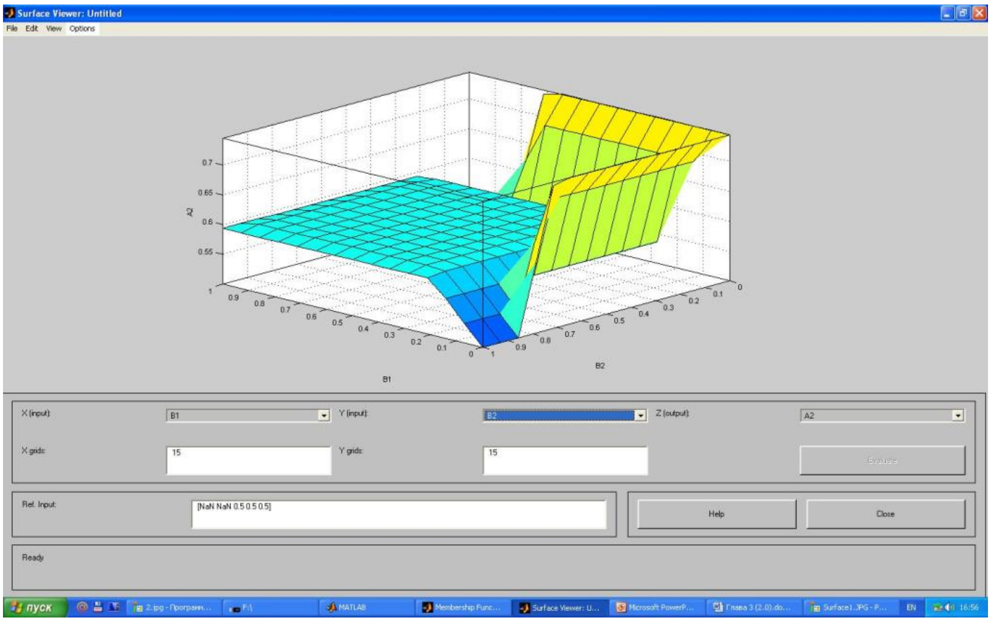

Fig. 5. Fuzzy inference surface for case A_2

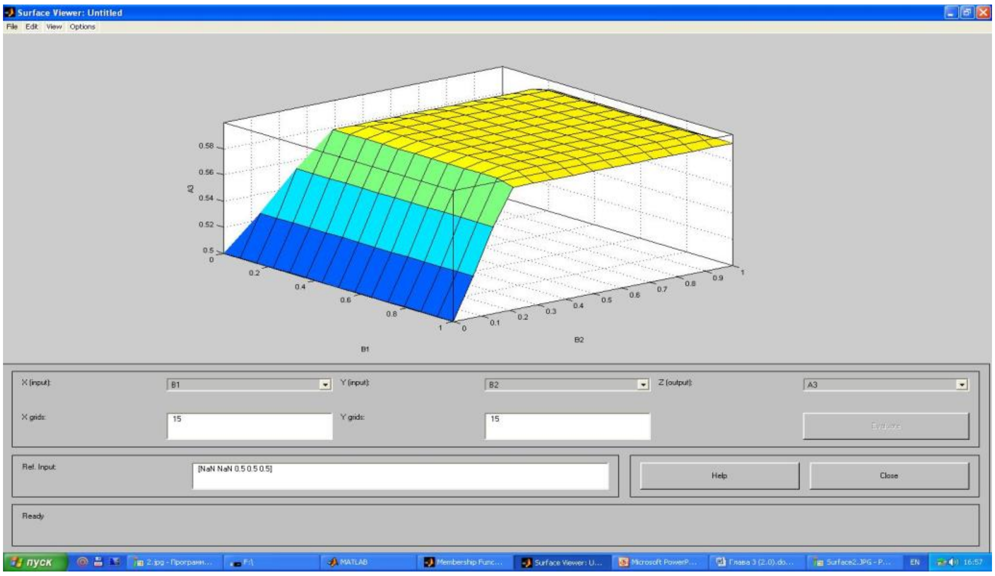

Fig.6. Fuzzy inference surface for case A_3.

At the first stage, the input values (ie B_2 values) are compared with the rule base implemented in the system. This comparison is equivalent to the operation of intersection of fuzzy sets. Based on this comparison, a modified membership function for A_1, A_2 and A_3 is determined in accordance with each of the rules. Further, to find the generalized membership functions A_1, A_2 and A_3, the operation of combining fuzzy sets is applied. After finding the generalized membership functions A_1, A_2 and A_3, the centroid method determines the quantitative values of A_1, A_2 and A_3 , the largest of which (in this case A_1) will correspond to the type of defect in the system (i.e. D_1)[13].

CONCLUSIONS

Thus, the increasing requirements for the reliability of data transmission networks necessitate the creation and implementation of promising methods and diagnostic tools. The given technique for estimating the classes of states of alleged defects in a data transmission network under conditions of incomplete information allows us to successfully solve the problem of diagnosing data transmission networks by applying the apparatus of fuzzy set theory [10].

Analytical expressions that determine the characteristics of fuzzy set elements for a data transmission network and the rules for making a decision about the type of defect, as well as methods for constructing membership functions of fuzzy sets and implementing rule bases, are the basis for building a system for diagnosing data transmission networks based on fuzzy set theory [10].

The use of the apparatus of fuzzy set theory makes it possible to create fairly simple diagnostic algorithms based on expert knowledge, taking into account both the objective characteristics of data transmission networks and the subjective states of service personnel, which is not possible using traditional diagnostic methods and algorithms [6].

Declaration of competing interest: *The author declares no conflict of interest.*

REFERENCES

1. Treano T, Asai K, Sugeno M. Applied fuzzy systems. - M. Mir, 1997 г.
2. Leonenkov A. Fuzzy modelling in MATLAB and fuzzyTECH. 2011.
3. Sugano M. Fuzzy measures and fuzzy integrals. – Amsterdam, North-Holland Publishing Company,0 1997.
4. Djurayev RK, Jabborov SY, Omonov II. Analysis of the open queuing system model of diagnostics of data transmission network elements. *ITN&T-2022*: 48.
5. Djurayev RK, Jabborov SY, Omonov II. Analysis of methods for calculating reference signatures in digital devices. Oriental Renaissance: Innovative, educational, natural and social sciences. 2021;9(1).
6. Djabborov SY, Ismailov SK., Omonov II. Imitation modeling the discrete communication chanel in Matlab stateflow on basis of petrovich model //Chemical Technology, Control and Management. – 2020. – T. 2020. – №. 5. – C. 201-209.
7. Shuhrat D, Erkinboy A, Ibratbek O. Partial selection method and algorithm for determining graph-based traffic routes in a real-time environment //ACADEMICIA: An International Multidisciplinary Research Journal. 2020; 10(10):763-770.
8. Gutten M, Brncal P, Sebok M, Kucera M, Korenciak D. Analysis of insulating parameters of oil transformer by time and frequency methods. Diagnostyka. 2020;21(4):51-56. https://doi.org/10.29354/diag/128607.
9. Varbanets RA, Zalozh VI, Shakhov AV, Savelieva IV, Piterska VM. Determination of top dead centre location based on the marine diesel engine indicator diagram analysis. Diagnostyka. 2020;21(1):51-60. https://doi.org/10.29354/diag/116585.
10. Djurayev RK, Jabborov SY, Omonov II. Analysis of methods for calculating reference signatures in digital devices. Oriental renaissance: Innovative, educational, natural and social sciences. 2021;1(9): 20-26.
11. Djabborov SY, Ismailov SK, Omonov II. Imitation modeling the discrete communication chanel in Matlab

stateflow on basis of petrovich model. Chemical Technology, Control and Management. 2020;5: 201-209.
12. Djurayev RX, Djabbarov SY, Matkurbonov DM. Methods for calculating route metrics in data transmission networks. 2020 International Conference on Information Science and Communications Technologies (ICISCT). 2020:20486823. https://doi.org/10.1109/ICISCT50599.2020.9351529.
13. Matyokubov UK, Davronbekov DA. The impact of mobile communication power supply systems on communication reliability and viability and their solutions. International Journal of Advanced Science and Technology. 2020;29(5):3374–3385.
14. Davronbekov DA, Matyokubov UK. Reliability of the BTS-BSC system with different types of communication lines between them. International Journal of Advanced Trends in Computer Science and Engineering. 2020;9(4): 6684–6689.
15. Bekimetov AF, Bobojanov SG, Samandarov BG, Kuchkarov VA. Modelinglling and analysis of Vivaldi antenna structure design for broadband communication systems. Acta of Turin Polytechnic University in Tashkent 2020;9(4):15-17.
16. Alisher B, Fazilbek Z. Feed line calculations of microstrip antenna. Int. J. Res. Appl. Sci. Eng. Technol. 2016;4:73-79.
17. Nurullayev YY. Iva software as a public safety system. ICISCT 2022, Cybersecurity. 2022.

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