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Fuzzy Model of Digital Assessment of Donation Systems' Level in COVID-19

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ABSTRACT
The digitalization of the healthcare system, consisting of the use of digital tools in patient treatment procedures, takes the donation system and the Blood Service to a new level of development. The most important components of the donation systems' management are digital models that reduce the role of a person in making various decisions and increase the level of effectiveness. Assessment of the donation systems' level of development on a global scale as a whole and in various regions of Russia, in particular, has been and remains an essential component of effective management in the context of the health care system digitalization. As part of this work, it is proposed to build a digital model for assessing the effectiveness and development of donation systems, based on the one hand on fuzzy management technologies, and on the other, on a systematic analysis of data in conditions of incomplete information. The proposed model allows ranking donor systems, distributing them into classes of "low", "medium", "high". The article shows the principles of constructing a fuzzy management model based on real data from the regional donor system of the Sverdlovsk region, taking into account COVID-19.

Keywords: *blood donation system, Blood Service, digital assessment, COVID-19, fuzzy control technology*

1. INTRODUCTION

One of the main goals of digitalization in the healthcare sector is to improve the provision of timely qualified and high-tech medical care. This leads to an increasing need for medical organizations for blood components and donors. In the context of the COVID-19 pandemic, when transfusion of a patient's blood plasma from a donor who has undergone a coronavirus infection is recognized as one of the basic treatment methods, the quality of treatment directly depends on the donor system. That is why the donation goes beyond the narrowly medical problem and becomes, in fact, not only a medical, but also a social problem, reflecting the relationship between people and thereby affecting the interests of our entire society. Considering the territorial distribution of Russia, the development of donation is associated with the effective functioning of the federal system and regional subsystems, as well as the introduction of advanced technologies, first in the leading regions, and then gradually, scaling to all territories of the Russian Federation.
For the effective functioning and development of the donation system, the assessment of factors reflecting the general statistics of donation in the region, age, gender, the regularity of blood donation, the number of donors per 1000 people, as well as the number of people who have undergone coronavirus infection is of great importance. Therefore, to build a ranking of regions to assess the quality and development of the donation system, it is necessary to develop a model that, in conditions of incomplete information, will allow us to classify the regions of Russia and then scale this model to world space. The apparatus of the theory of fuzzy sets is best able to cope with such problems.
The purpose of the article is to develop a fuzzy model for assessing the development and quality of donor systems based on statistical data and implements it in the Fuzzy Tech system.

2.LITERATURE REVIEW

Blood service is an essential component of health care, which provides the ability to provide high-tech specialized medical care in peacetime and emergencies and uses a unique national resource - blood donors [1].
The main tasks of the blood service are to agitate and promote donation, organize the preparation of blood and its components, improve the methods of conservation, processing and storage of blood and its components. The principles of blood donation and (or) its components are:
- safety of donated blood and its components;
- voluntary blood donation and (or) its components;
- maintaining the health of the donor in the performance of its donor function;
- providing social support and respect for the rights of donors;

- encouragement and support of free blood donation and (or) its components [3].

Blood donation is a voluntary act of giving blood and its components for therapeutic use. An essential condition for participation in the donation is the compliance of the donor's health level with certain medical criteria. The problem of blood donation and its components is one of the most important for the government and plays a key role in domestic health care.

The ability and quality of providing high-tech medical care in peacetime and emergencies depend on the effective solution of donor issues at regional levels.

The development of mass donation in Russia began in 1926 when the world's first Institute of Blood Transfusion was opened in Moscow. The main course was taken for free donation [6]. This direction remains the main one in the global donor movement and is actively supported by the World Health Organization.

The program of the national priority project on digitalization of the Blood Service includes three areas:

1) modernization of the material and technical base of the Blood Service. Basic digital equipment has been purchased for blood transfusion stations, which provides a unified technological chain for the collection, processing, and storage of donated blood and its components;

2) the formation of a single information base for blood donation. To coordinate this activities computer and server equipment was supplied;

3) promotion of blood donation and its components - a large-scale program for the development of voluntary blood donation and its components. The main focus of the program was on a communication campaign aimed at the development of mass gratuitous blood donation [6].

Promising areas of donor development in the world are: increasing the number of active blood donors and its components, increasing the effectiveness of measures to attract donors to donate blood regularly, and introducing new forms of organizing work with donor staff to promote free donation.

To implement these areas, it is necessary to study the available statistics on donation in individual constituent entities of the Russian Federation, gender, age of donors, various factors that affect people and their ability to become a donor.

For this, we propose to use a model of digital assessment of the donation system (blood service) based on fuzzy management technologies, which will allow, in the absence of complete information, to classify a specific regional donation system into three strata “low”, “medium” and “high” level. Such a decomposition will allow more efficient and better implementation of the appropriate methods of treating coronary viral infections based on blood transfusion, which are currently being tested at the N.V. Sklifosovsky Moscow City Research Institute of Emergency Medicine.

3. RESEARCH METHODS

Fuzzy logic is designed to formalize human abilities for inaccurate or approximate reasoning, which allows more adequately describe situations with uncertainty. Fuzzy logic serves as the basis for the implementation of fuzzy control methods. It more naturally embraces the nature of human thinking, which often describes many processes inaccurately or approximately. The mathematical theory of fuzzy sets (fuzzy set) and fuzzy logic (fuzzy logic) are generalizations and additions of the classical theory of sets and classical formal logic and are used in conditions of incomplete and inaccurate information [4].

These concepts were first proposed by the American scientist Lotfi Zadeh in 1965 [8]. A fuzzy controller based on fuzzy logic implements a management strategy based on empirically acquired knowledge regarding the functioning of an object, presented as a set of rules.

The main reason for the appearance of a new theory was the presence of fuzzy and approximate reasoning and estimates in the verbal description of processes, systems, objects [9]. The use of fuzzy logic in control systems has significantly improved the quality of control of complex objects compared to traditional control.

Another integral part of fuzzy logic is the elimination of fuzziness or defuzzification, which is a transition from fuzzy values to certain physical parameters[8].

Defuzzification is performed by one of three methods:

- CoM - the method of the center of maximum, which is used when the result of fuzzy inference can be several terms of the output variable. This method is the most compromise;
- MoM - maximum method;
- CoA is the center of gravity method.

To conclude the knowledge base of the system, it is necessary to choose the rules for conditional fuzzy inference, in which the conditional part contains statements including an input variable with a linguistic value established during the fuzzification process [5]. Such rules describe the management strategy used in the task. Typically, the rules have the structure "IF ..., THEN".

There are various software solutions to solve problems using the fuzzy control procedure. The Fuzzy Tech package, developed by Inform Software Corporation, is used to design fuzzy systems. The final product in the development of the system is a software module generated using the package [5].

FuzzyTECH is a specialized tool that allows you to develop a variety of fuzzy systems in graphical mode, as well as translate them into a program in one of the programming languages, including its implementation in programmable microcontrollers [5]. The program implements methods for generating fuzzy rules "If-Then". The base of fuzzy rules is formed and each of the rules is assigned an importance coefficient.

There are two editors in the package:

- An editor for creating and working with linguistic variables;

- Editor for working with the base of fuzzy rules.

To model a system for assessing the level of development and the effectiveness of donation in the region using fuzzy management technologies, we will use the FuzzyTECH software package.

4. RESULTS

To develop and implement a system of fuzzy inference, which allows you to determine the level of development and effectiveness of donation in the region, it is necessary to determine the input and output variables, as well as the system of rules for fuzzy inference of regulations.
All input variables will be divided into two groups for greater reliability of the resulting model. Thus a block of rules will be built for both groups. The division of variables into groups is due to the different influence of factors on the assessment of the development's level and of the donation's effectiveness in the region.
The first group “General statistics” includes 6 input variables:
- Chisl - population, people;
- Kolna1000 - the number of donors per 1000 population, people;
- Krovot - blood supply, unit;
- Obdon - total number of donors, people;
- Otved - the number of people allotted from donation for various reasons (infections), people;
- Pervich - the number of primary donors, people.

The RB1 rule block for this group includes all the rules associated with changes to these variables. It1 is the output variable for this block.
The second group “Personal characteristics” also includes 6 input variables:
- Man - the number of male donors, people;
- Women - the number of female donors, people;
- V1824 - the percentage of donors aged 18 to 24 years,%;
- V2545 - the percentage of donors aged 25 to 45 years,%;
- V45 - the percentage of donors older than 45 years,%;
- COVID-19 - the percentage of donors who underwent coronavirus infection,%.

The RB2 rule block, which includes all the rules for the above variables, has the output variable it2.
We introduce the final variable “ITOG”, which will depend on the intermediate output variables it1 and it2 and have a separate set of fuzzy rules.
Term sets of input and output variables are represented as sets of values = {"Low" (low), "Medium" (medium), "High" (high)}.
The ranking of input variables in the fuzzy form is presented in Table 1. The maximum values of input variables are indicated in accordance with the official statistics of Russia in the field of the donation.

Table 1 Data fuzzification to build a fuzzy model for assessing the level of development and the effectiveness of donation in the region

Variable	Level	Values
Chisl – population, people	Low	0 – 1 000 000
	Medium	1 000 000 – 5 000 000
	High	5 000 000 – 7 599 647
Kolna1000 – the number of donors per 1000 population, people	Low	0 – 5
	Medium	5 – 13
	High	13 – 25
Krovot – blood supply, unit	Low	0 – 10 000
	Medium	10 000 – 50 000
	High	50 000 – 70 000
Obdon – total number of donors, people	Low	0 – 10 000
	Medium	10 000 – 30 000
	High	30 000 – 50 000
Otved – the number of people allotted from donation for various reasons (infections), people	Low	0 – 100
	Medium	100 – 500
	High	500 – 1 000
Pervich – the number of primary donors, people	Low	0 – 7 000
	Medium	7 000 – 15 000
	High	15 000 – 20 000
Man – the number of male donors, people	Low	0 – 7 000
	Средний	7 000 – 16 000

	High	16 000 – 20 000
Women – the number of female donors, people	Low	0 – 5 000
	Medium	5 000 – 12 000
	High	12 000 – 20 000
V1824 – the percentage of donors aged 18 to 24 years, %	Low	0 – 10
	Medium	10 – 30
	High	30 – 100
V2545 – the percentage of donors aged 25 to 45 years, %	Low	0 – 35
	Medium	35 – 60
	High	60 – 100
V45 – the percentage of donors older than 45 years,%	Low	0 – 7
	Medium	7 – 20
	High	20 – 100
Covid-19 – the percentage of donors who underwent coronavirus infection, %	Low	0 – 15
	Medium	15 – 25
	High	25 – 100

Since all the rules are automatically generated by the Fuzzy Tech program for all levels of variables (input and output), to identify the importance of a particular rule, the fuzzy system either learns from a specific data set or selects the most important rules that have the greatest impact on the weekend variables of the created model.

For the variable it1, the following main rules are compiled:

1. IF Chisl = «low» AND kolna1000 = «low» AND krovot = «low» AND Obdon = «medium» AND otved= «high» AND Pervich= «low» THEN it1= «low»
2. IF Chisl = «high» AND kolna1000 = «high» AND krovot = «medium» AND Obdon = «high» AND otved= «high» AND Pervich= «high» THEN it1= «medium»
3. IF Chisl = «high» AND kolna1000 = «high» AND krovot = «high» AND Obdon = «high» AND otved= «low» AND Pervich= «high» THEN it1= «high»
4. IF Chisl = «medium» AND kolna1000 = «medium» AND krovot = «medium» AND Obdon = «medium» AND otved= «high» AND Pervich= «medium» THEN it1= «low»
5. IF Chisl = «high» AND kolna1000 = «high» AND krovot = «high» AND Obdon = «high» AND otved= «low» AND Pervich= «high» THEN it1= «high»
6. IF Chisl = «low» AND kolna1000 = «low» AND krovot = «low» AND Obdon = «medium» AND otved= «low» AND Pervich= «low» THEN it1= «medium»

The main rules for the variable it2 are presented below:

1. IF Man = «high» AND women = «high» AND v1824 = «high» AND v2545 = «high» AND v45 = «high» AND Covid-19 = «low» THEN it1= «medium»
2. IF Man = «high» AND women = «high» AND v1824 = «high» AND v2545 = «high» AND v45 = «high» AND Covid-19 = «medium» THEN it1= «high»
3. IF Man = «low» AND women = «high» AND v1824 = «high» AND v2545 = «high» AND v45 = «high» AND Covid-19 = «high» THEN it1= «high»
4. IF Man = «high» AND women = «low» AND v1824 = «high» AND v2545 = «high» AND v45 = «high» AND Covid-19 = «high» THEN it1= «high»
5. IF Man = «low» AND women = «high» AND v1824 = «high» AND v2545 = «high» AND v45 = «low» AND Covid-19 = «medium» THEN it1= «medium»
6. IF Man = «high» AND women = «high» AND v1824 = «high» AND v2545 = «low» AND v45 = «high» AND Covid-19 = «high» THEN it1= «medium»
7. IF Man = «low» AND women = «low» AND v1824 = «low» AND v2545 = «low» AND v45 = «low » AND Covid-19 = «low» THEN it1= «low»

The intermediate output variable it1 has a greater influence on the resulting ITOG variable than it2. Therefore, the rules for the output final variable ITOG are as follows:

1. IF it1 = «low» AND it2 = «low», THEN ITOG = «low»
2. IF it1 = «low» AND it2 = «medium», THEN ITOG = «low»
3. IF it1 = «low» AND it2 = «high», THEN ITOG = «low»
4. IF it1 = «medium» AND it2 = «low», THEN ITOG = «medium»
5. IF it1 = «medium» AND it2 = «medium», THEN ITOG = «medium»
6. IF it1 = «medium» AND it2 = «high», THEN ITOG = «medium»

7. IF it1 = «high» AND it2 = «low», THEN ITOG = «high»
8. IF it1 = «high» AND it2 = «medium», THEN ITOG = «high»
9. IF it1 = «high» AND it2 = «high», THEN ITOG = «high»

The final model is as follows (Figure 1):

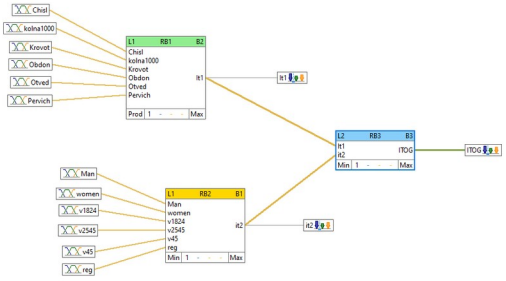

Figure 1 The final model of fuzzy control in FuzzyTech

Next you need to configure the input, output, and intermediate variables, configure the terms, ranges of values, and units.
Here is an example of setting the input indicator Chisl - the population in a particular year. According to the Federal State Statistics Service, the population of the Moscow region is 7,599,647 people [9]. Since in this model we consider only regions and autonomous areas, the indicator for the Moscow region is the maximum.
The resulting graph of the membership functions for the Chisl variable (Figure 2):

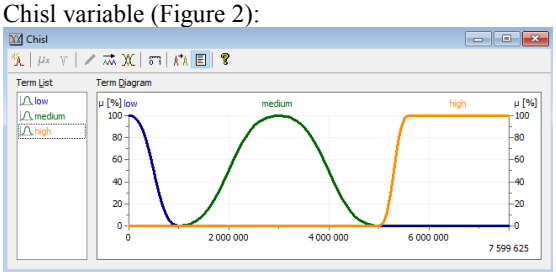

Figure 2 Membership Function for Chisl Variable

After the configuration of all variables and blocks in the final model is completed, the rule blocks are configured.
To analyze the obtained results, it is necessary to evaluate the adequacy of the constructed model for given variables and build 3D graphs. Open the windows of the editors of all linguistic variables of the project (Open All Variable Editors of Variable Group) to see all the graphs of the membership of functions (Figure 3).

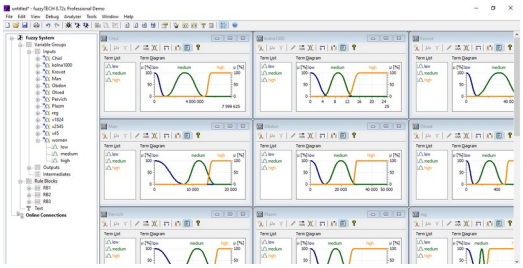

Figure 3 Fuzzy Tech Linguistic Variable Editor Windows

Let's take the data of the Sverdlovsk region for 2019 [7], to test the model: population - 1,664,089 people, total number of donors - 26,873 people, of which: primary donors - 6,845, total number of blood donations - 46,644 donations, number of donors per 1000 population - 16, allotted donors - 347, number of men - 16 016 people, women - 10 856 people, percentage of donors aged 18 to 24 years old - 28.9%, aged 25 to 45 years old - 58, 4%, aged 45 years and above - 12.7%, the percentage of donors who underwent coronavirus infection - 1.2%.
Already at this stage, we can conclude that the level of development and effectiveness of donation in 2019 was at an average level (for the data used).
For clarity of the findings, you can use the graphical window to view the three-dimensional surface of the fuzzy inference. To do this, select "New 3D Plot" on the "Analyzer" tab and the program will automatically build the model according to the input data (Figure 4).

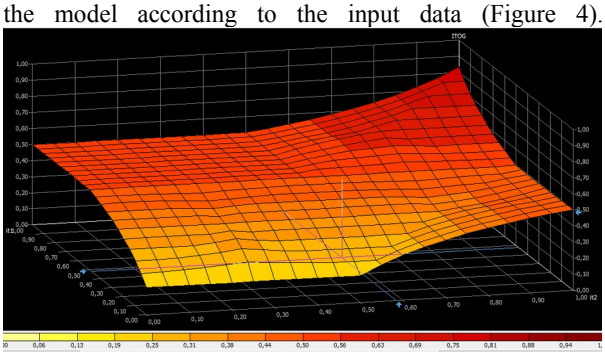

Figure 4. 3D Plot diagram of a fuzzy digital model, taking into account the indicator COVID-19

You can select various combinations of input fuzzy variables and track the dynamics of the model.

The earlier conclusion was confirmed: in 2019, the level of development and effectiveness of the donor system in the Sverdlovsk region was average.

5. CONCLUSION

This paper considers a topic related to the assessment of the donor system and the need for evaluating the level of development and effectiveness in Russia in terms of preserving the health of citizens. We built a model In the FuzzyTECH environment, containing 12 input, 3 output

variables, and 3 rule blocks to solve the problem of assessing the development and effectiveness of donation in the regions. Previously, the system was trained on the compiled rules and verified on specific data for 2019. It was found that the level of development and effectiveness of donation in the Sverdlovsk region for 2019 is average. Most indicators are at average marks, except for the Number of primary donors (low level), which indicates the need for systematic work to improve the efficiency of this system in the region. To increase the level of development and the effectiveness of blood donation, it is recommended to constantly monitor statistical and expert indicators, which will help to identify key factors of influence and effectively solve the problems associated with the use of donated blood in the treatment of coronavirus infection.

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