15. Плескачевский Ю.М., Кубенко В.Д., Старовойтов Э.И., Леоненко Д.В. Колебания круговой металлополимерной пластины, связанной с упругим основанием, при тепловом ударе. ISSN 1995-0470. Механика машин, механизмов и материалов, №4(9), 2009, стр.50-54

16. Филиппов А.П. Колебания деформируемых систем. М.: Машиностроение, 1970.

УДК 004.891.3
ГРНТИ 28.23.39

Abdullaeva G.G.
Docent, PhD in Mathematics
Institute of Management Systems
of the National Academy of Sciences of Azerbaijan
Mirzazade I.Kh.
Docent, PhD in Physics and Mathematics
Institute of Mathematics and Mechanics
of the National Academy of Sciences of Azerbaijan
Naghizade H.R.
Institute of Mathematics and Mechanics
of the National Academy of Sciences of Azerbaijan

ARTIFICIAL INTELLIGENCE IN PROBLEMS OF DIAGNOSTICS OF ACUTE POISONINGS (USING AN EXAMPLE OF DIFFERENTIAL DIAGNOSIS OF CARBON MONOXIDE POISONINGS)

Abstract. Differential diagnosis during acute poisonings with chemical substances was and remains one of topical problems of toxicology. This paper treats chemical substances for which time is the predominant factor of consequence prevention, especially in cases of rendering the first prehospital aid. The training of quick actions in medical personnel brought to automatism is topical just in these cases of urgent therapy. Let us note that such chemical substances as carbon monoxide, cyanide, tranquilizers, antihistaminic substances and salicylates manifest themselves through identical symptoms in prehospital practice.

The aim of this research is the development of a system of differential diagnosis and decision making for poisonings with similar substances, i.e. rendering the urgent aid. The problem becomes complicated in those cases when diagnosis is made on the basis of clinical manifestations on the site of occurrence, especially if a patient is in a comatose state.

As material to be researched are taken data accumulated throughout 2006-2018 which are presented by the Central Ambulance and Emergency Station of Baku city. Currently knowledge-based information technologies can become the most important consultant tool for rendering the first aid and resolving diagnosis problems.

Keywords: carbon monoxide, differential diagnosis, neuronal network, antidote therapy, first prehospital aid.

1. Introduction. Problems of diagnostics in medicine can be correlated to the class of weakly structured and poorly formalized tasks, that is, tasks whose solution lies in the plane of the theory of artificial intelligence, where knowledge is actively used along with digital and tabular data. In this aspect, it is required to clarify what is meant by the term “knowledge”. In the theory of artificial intelligence, knowledge is, above all, information. It describes properties, and relationships of the studied processes in the subjective (man) and objective (science) expressions. The foundation of artificial intelligence systems is knowledge, on the basis of which data are processed and decisions are made through a logical inference machine. To represent knowledge, first of all, concept of internal interpretation, the definition of external and internal structure of data connections, etc. are necessary. Based on the concept, knowledge can be presented formally (on the basis of propositional calculus and predicate calculus), in formally (semantic, relational), which include production models, semantic networks, frames. There is also the third type of representation, the so-called integrated, which combines various types of knowledge representation. In case of deterministic knowledge, the above models are quite successfully used in diagnostics problems. But often, especially in pre-hospital practice, we are confronted with non-deterministic information. This situation is usually associated with vagueness, inaccuracy, uncertainty of available information, ambiguous interpretations of phenomenon, unreliability or incompleteness of information. Representation of knowledge can be difficult even in case of non-determinism of the procedures for the derivation of decisions, etc. [1]. In these cases, the methods of representation of fuzzy knowledge are used.

There are a large number of problems in medicine, where artificial intelligence methods are successfully used today. Most of them operate online (of course, here we exclude test programs), which has its undeniable advantages. In our work, we touch upon the area of medical diagnostics in which time is the dominant factor. These include the tasks of toxicology, especially in terms of acute poisoning, for example, poisoning with carbon monoxide, cyanides, ethyl alcohol, etc. Given laboratory tests, the possibilities of medical intervention are quite extensive, and it should be noted that in many cases these problems find a positive solution. The task is complicated in cases when the diagnosis is made on the basis of clinical manifestations at the place of the accident, especially if a victim is in a comatose state. The article deals with the cases of those acute poisonings, the clinic of which in pre-hospital cases appears quite similar. There exist a lot of conditions to be taken into consideration during differential diagnosis of carbon monoxide poisonings. The earliest symptoms, especially from the action of low levels, are frequently non-specific and can be easily confused with other diseases as a rule, grippe-like viral syndromes, depressions, chronic fatigue syndrome, chest pains, migraines, toxic poisonings with alcohol etc.. CO was termed "a great imitator" due to a variety of manifestations and for this reason it is necessary to perform differential diagnosis when carbon monoxide poisoning is suspected because prelaboratory clinic of CO poisoning is similar to poisonings with many toxic substances. For example, these include poisonings with carbon monoxide, cyanide, tranquilizers, antihistamines, salicylates. The paper treats the problem of elaboration of an intelligent system of differential diagnosis and rendering emergency aid in in case of poisonings with the above-mentioned chemical substances.

2. Review and literature analysis. As far back as 1994 R. M. Rigelman in his publication "How to Avoid Therapeutic Errors. The Book of a Practitioner" noted that only conducting information systems would help to avoid errors in diagnosing diseases which are differentiated ambiguously. The said diagnosing errors take place due to:

a) frequently encountered diseases which have atypical signs;

b) signs attributed to a certain pathology to which they do not relate at all and "chameleon" diseases bearing the mask of other pathologies;

c) the presence of rare diseases

Proceeding from this view Duke V.A. in the work "Data Mining Technology in Medico-biological Researches" [2] demonstrated on the example of ultrasonic cardiogram how it is possible to forecast the length of life of a patient suffering from cardiac insufficiency, making use of informationally significant data. For prognostication an expert system based on production rules, is offered. In [3] the authors state that carbon monoxide poisoning (CO) is the widespread cause of toxicological morbidity and lethality. Myocardium injury is a frequent sequence of carbon monoxide poisoning of medium and high severity. On the basis of studies conducted for many years it is concluded that myocardium injury is often observed in patients hospitalized due to carbon monoxide poisoning of medium and high severity and represents a meaningful predictor of lethality.

Researches of the last few years have shown that the problem of CO poisoning still remains burning. Below we will display official data on poisonings in Germany over a period between 2010 and 2016 [4,5].

Table 1.

Information table of carbon monoxide poisonings in Germany

	2010	2011	2012	2013	2014	2015	2016
Total number	4171	3914	4302	3960	3764	3981	3611
Number of deaths	481	494	582	514	594	648	-

Extensive researches for studying pathogenesis and prognosis of situations of carbon monoxide poisonings are under way at the Pittsburgh Institute of Heart, Lungs, Blood and Vascular Medicine. So, in [6] the authors comment that CO poisoning affects 15000 persons a year in the United States. In this work of interest to us is the fact that they draw attention to the management of patients requiring the revealing of concomitant medicine takings, especially under conditions of premeditated poisoning, toxic gases' action as a result of fire during inhalation.

In the United States are observed most of poisoning events in January month and in the state of Nebraska [7,8]. In 2000-2009 are observed 68,316 of carbon monoxide poisoning patients; 30,798 (45.1%) were provided on-site aid and

36,691 (53.7%) patients were treated in hospitals. 34,386 of poisoning patients are women, 30,257 are men. In spite of these quantity of poisoning persons has decreased: in 2006-0.31%, in 2009-0.24%. In 2000-2009, 16,447 death events are registered [9,10].

In the 10 years between 2001 and 2010, identified 5312 total admissions to hospital for CO poisoning in England, of these 47% (2500 admissions) were for accidental poisoning [11].

On the strength of real data observed in the course of eight years on information intelligent system of differential diagnosis of carbon monoxide poisonings is proposed in [12], its decision-makes is based on Bayes's statistical method which was successful in differentiating poisonings with such chemical substances as CO, aniline, atropine, barbiturates, codeine, dichloroethane, ethylene glycol, pachycarpa hydroiodide, isoniazid, ethyl alcohol, phosphorus-orgonic substances. The method was ineffective in differentiation of CO poisonings from those with the chemical substances treated in this paper – the method did not take into account the specificity of clinical pre-laboratory symptoms. Emphasis in [13] is put on the organization of monitoring for persons subjected to CO poisoning.

The review of literature related to carbon monoxide poisonings has demonstrated that contemporary information technologies have not yet found the required use. More often are encountered papers applying probability theory and mathematical statistics, knowledge-based expert systems are mentioned less frequently.

3. Formation of data. The solution of the problem is carried out in stages, for which it is necessary to solve the subtasks in the following sequence.

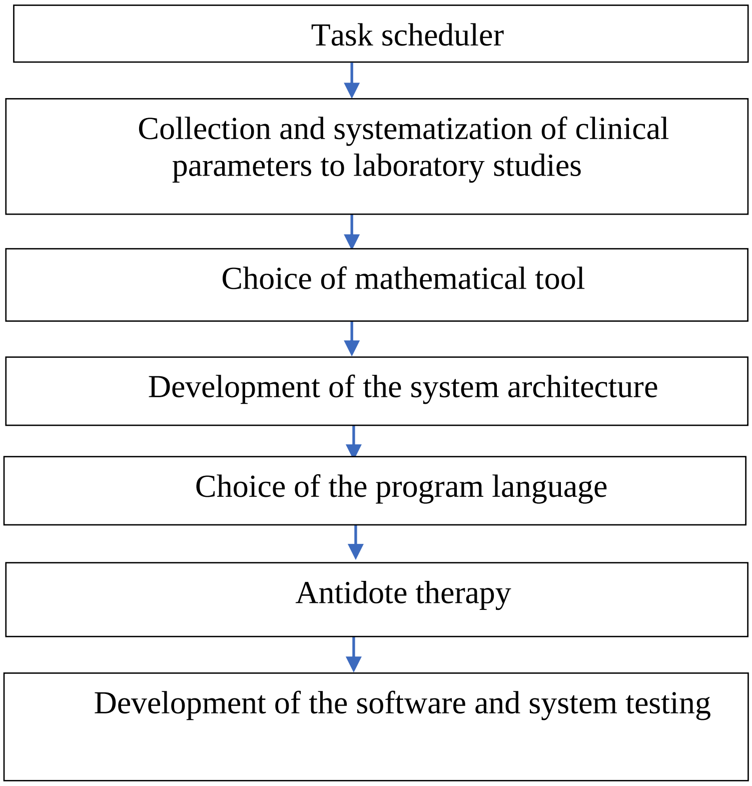

Fig.1. Stages of development of intelligence system

At the first stage, the scheduler determines the level of difficulty of the task, its division into dependent and independent blocks, the identification of knowledge and communication with experts (in our case with emergency and urgent care doctors), programmers and system testing conditions.

As the material under research were employed data collected throughout 2006-2019 and presented by the Central Ambulance and Emergency Station and Clinical Hospital №1 of Baku city (table 2).

Table 2.

The number of calls due to poisonings with carbon monoxide in Baku city

Baku city, districts	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Narimanov	41	38	38	48	69	121	127	118	105	137	77	42	56	46
Khatai	77	159	154	82	106	135	192	126	161	201	177	139	138	152
Sabayil	47	26	36	41	42	85	109	88	139	74	94	84	57	75
Yasamal	57	64	88	483	118	137	151	132	76	116	183	195	202	188
Nasimi	20	103	186	122	129	221	237	178	187	185	100	71	86	95
Nizami	-	40	63	54	64	123	171	200	197	175	159	100	112	154
Binegedi	53	70	217	129	190	316	395	378	371	419	493	352	345	393
Khazar	-	-	9		17	26	36	63	78	114	106	94	89	147
Surakhani	34	33	59	62	70	141	141	193	185	185	199	156	162	186
Sabunchi	30	43	111	72	107	147	221	202	158	177	271	189	241	229
Garadag	42	83	83	86	98	115	232	145	206	166	139	110	114	105
Total	401	659	1044	788	1010	1567	2012	1823	1863	1949	1998	1532	1602	1770

Data collection and systematization is carried out on the basis of scientific medical literature, the knowledge of specialists and real medical records of patients. In the course of the work, 19 primary symptoms were identified which accompany the indicated poisonings in complete absence of laboratory tests and other studies, on the basis of which a summary table 2 presented below was developed. The following notation are used in the table: + - mandatory presence of a symptom in the case of this hypothesis; ± - uncertainty associated with the minor severity of the symptom, which, in turn, strongly depends on the subject (age, weight, accompanying diseases, conditions of poisoning, etc.).

Table 3.

Summary Table of Primary Symptoms

№	SYMPTOMS	Chemical substances				
		Carbon monoxide	Cyanide	Tranquizers	Antihistamines	Salicylates
1	Myosis	±	+	±	±	±
2	Mydriasis	+	±	+	+	+
3	Pupils play	±	±	±	±	±
4	Myofibrilla synchronous	±	±	±	±	±
5	Myofibrilla asynchronic	±	±	±	±	±
6	Hyperkinesia of horeodic type	±	±	+	+	±
7	Rigidity of occiput muscles	+	±	±	±	±
8	Asynchronous cramps	+	±	±	±	+
9	Epileptiform convulsive states	±	±	±	±	±
10	Skin sweating	±	±	±	±	±
11	Skin dryness	±	+	±	+	±
12	Sharp cyanosis of skin	±	±	±	±	±
13	Skin hyperemia	±	±	±	±	+
14	Skin marbling	±	±	±	±	±
15	Bradycardia	±	±	±	±	±
16	Tachycardia	±	±	±	+	±
17	Paralysis of breath while maintaining reflexes	+	±	±	±	±
18	Paralysis of breath only against on the background of areflexia	±	+	±	±	±
19	Bronchorrhoea	±	±	±	±	±

This option is practical for reliation simple diagnostic models, in terms of mathematical precision. The network model that allows communication in the form of a graph, "hypothesis-symptom" identify addiction. As can be seen from table 3, with the exception of a few symptoms, most of them are characterized by uncertainty. Unlike [12], where the authors estimated the presence of the symptom and its insignificant manifestation by the same magnitude, we offer a slightly different attitude based on the experience and intuition of the experts. The solution of the problem in these conditions is seen in the application of the weighted belonging of the sign (symptom) introduced by L. Zadeh [14]. The value of the membership function shows with what degree of accuracy a symptom corresponds to the fact. Considering the above said, we introduce the variables μ_{ij} in the form of <name of the symptom / degree of belonging>. Then each symptom s_i can be represented by the following expression

$$s_i = \begin{Bmatrix} \mu_{i1/symptom\ exists} \\ \mu_{i2/expressed\ strongly} \\ \mu_{i3/expressed\ moderately} \\ \mu_{i4/expressed\ weakly} \\ \mu_{i5/is\ felt} \\ \mu_{i6/is\ absent} \end{Bmatrix}$$

For example, for the symptom *"mydriasis"* μ_{ij} are given as tab.4, where i (1-6) are linguistic variables, j (1-5) are chemical substances.

Table 4.

Fragment of the formation of linguistic variables for the symptom *"mydriasis"*

№	Linguistic variables (*i*)	Chemical substances (*j*) CO, cyanide, tranquilizer, antihistamines, salicylates				
1	Exists	1,00	1,00	0,77	1,00	1,00
2	Expressed strongly	0,78	0,82	0,43	0,81	0,69
3	Expressed moderately	0,54	0,47	0,30	0,57	0,48
4	Expressed weakly	0,22	0,25	0,21	0,33	0,20
5	Felt	0,06	0,02	0,01	0,01	0,01
6	Absent	0,00	0,00	0,00	0,00	0,00

Similar tables are prepared for all 19 symptoms. Thanks to the introduced linguistic variables, it becomes possible to conduct a more accurate differential diagnosis.

4. Methods. It is logical that in modern realities, knowledge based information technologies can become the most important consultant for solving the problem of diagnosing and providing primary care. Bringing in artificial intelligence methods, soft computing, creating databases can be invaluable in solving this task. Conceptionally, the solution of the problem can be presented as in Fig.2.

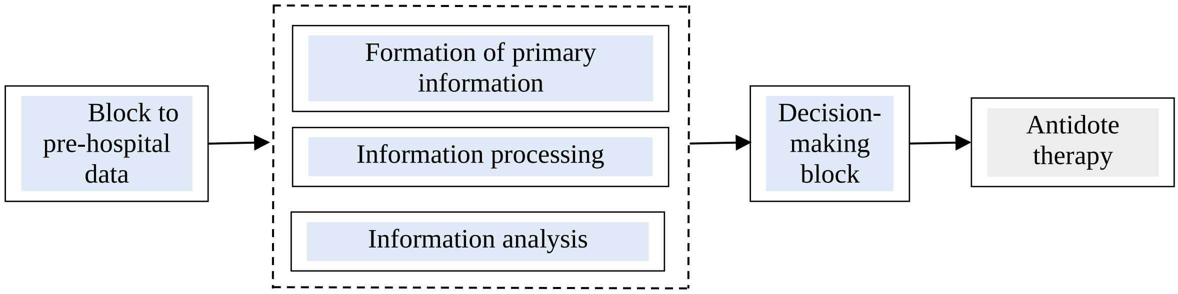

Fig.2. Conceptual model of primary care

To solve the problem, it is proposed to build a neural network with 114 inputs and 5 outputs on the second layer (Fig. 3).

The system is trained according to the algorithms of Levenberg-Marquardt [15].

114 inputs are due to possible manifestations of 19 symptoms (for each symptom, assessments similar to the presentation of the symptom in Table 3) are determined. The second layer gives a numerical estimate of possible poisoning with a specific chemical substance. Information is transmitted to the decision making block.

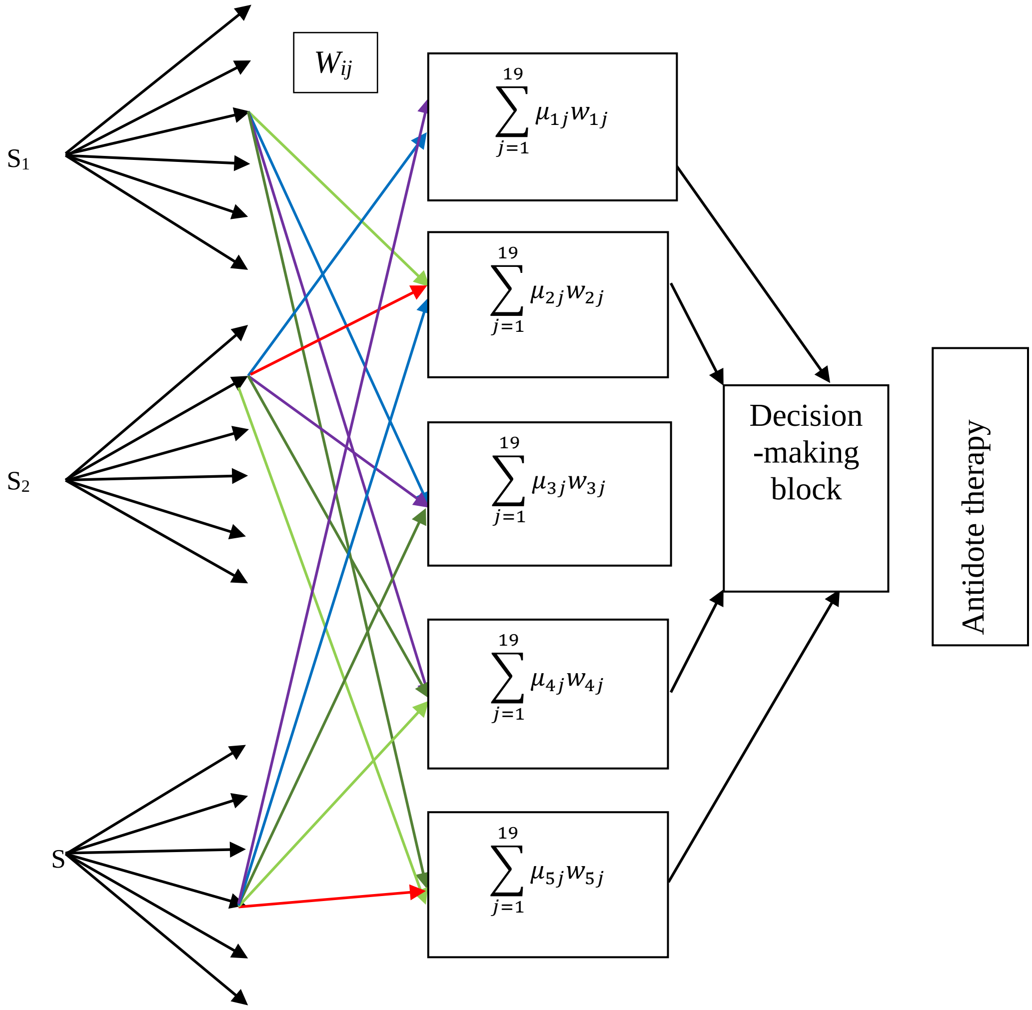

Fig.3. Neural network structure

The following cases are possible in the decision making block:

- If $D_i >> D_j$ for $i \neq j$ $(i,j=1,2,3,4,5)$, then D_i is accepted as a solution;
- If D_i is close in value to one of D_j, then:

a) in the presence of symptoms of stiffness of occiput muscles and respiratory paralysis while maintaining reflexes the answer is D_i = carbon monoxide;

b) in the presence of symptoms of myosis and respiratory paralysis only against the background of areflexia, the response is D_i = cyanide;

c) with the obligatory presence of symptoms of mydriasis and hyperkinesia of choreoid type against the background of weak presence of dry skin and tachycardia, the answer is D_i =tranquilizers.

d) in the presence of myosis, choreoid hyperkinesia, dry skin and the dominant symptom of tachycardia, the answer is D_i = antihistamines;

e) in the presence of mydriasis, asynchronous convulsions and skin hyperemia, the answer is D_i = salicylates.

The decision making block transmits the answer to the next block, the antidote therapy block. In tab.5 is given a fragment of primary care.

Table 5.

An example of antidote therapy in urgent and emergency care

№	Name of substance	Antidote therapy
1	**Carbon monoxide**	Oxygen inhalation, hyperbaric inhalation
2	**Cyanide (acid)**	Sodium nitrite (1% solution), natrium thiosulfate (1% solution), methyl ethylene abs. (1% solution)
3	**Tranquilizers**	Bemegrid (0,5% solution)
4	**Salicylates**	At methemoglobinemia – methyl abs. (1% solution), vitamin C (5% solution)
5	**Antihistamines**	Pilocarpine (1% solution), Physostigmine (0,1% solution)

Preparations for antidote therapy are enumerated in table 5 as an example, corrections are possible considering modern stage of development of pharmacology.

Discussion. With regard for complicated nature of CO and similarity of its pre-laboratory clinic to many other diseases, especially to poisonings with toxic substances, comparative tests were conducted for differential diagnosis of poisonings with carbon monoxide and chemical substances which could be differentiated from it with various degree of accuracy. For example, using Bayes's method on the basis of pre-laboratory symptoms of poisonings with carbon monoxide, barbiturates and dichloroethane were obtained results analogous to the graphs displayed in Fig.4.

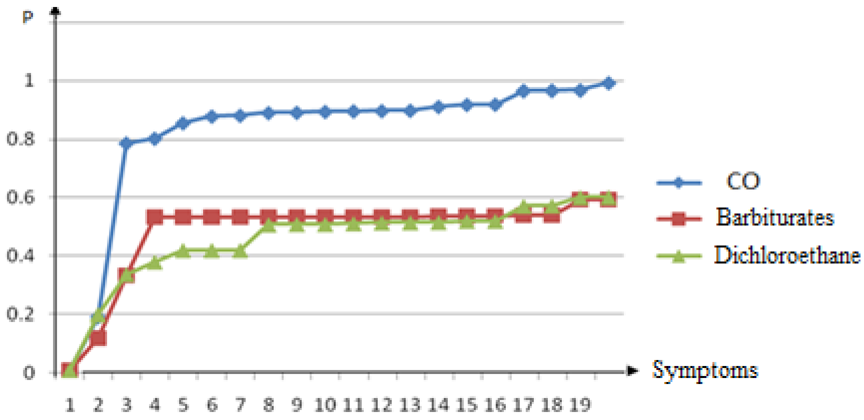

Fig.4. *Differential diagnosis of poisonings with CO, barbiturates and dichloroethane*

As is seen, starting from the third symptom the probability of carbon monoxide poisoning *p* is equal to 0,8 and more as the differentiation from these chemical substances is distinct. Now we will conduct an experiment with another group of substances. The result is displayed in Fig.5.

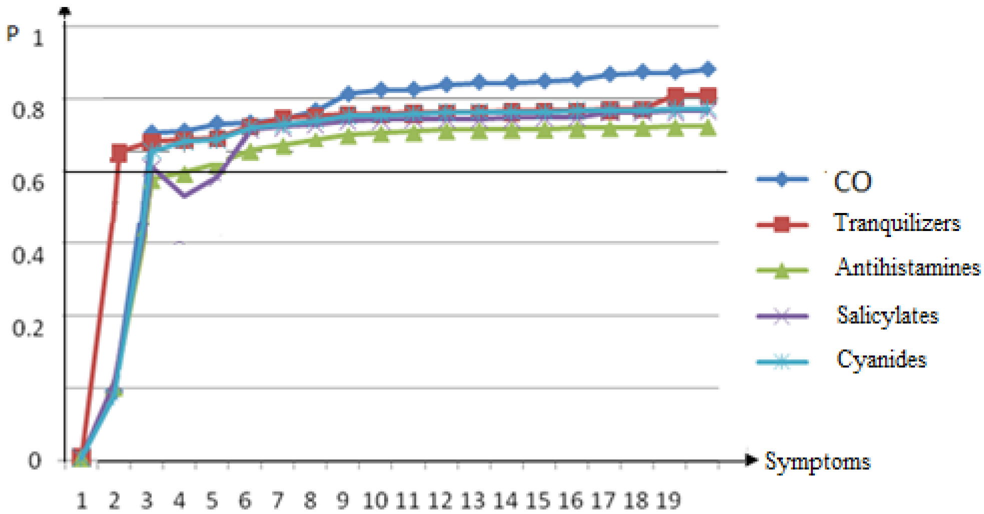

Fig.5. *Differential diagnosis of poisonings with CO, tranquilizers, antihistamines, salicylates and cyanides*

As seen, differentiation of poisonings with tranquilizers, antihistamines, salicylates and cyanides goes ambiguously and not clearly. An attempt to solve this problem with the help of neuronal networks was made in [6]. But it was not taken into consideration that the presence of a symptom does not yet determine the degree of its presence in a particular poisoning. The introduction of a linguistic variable has significantly increased the reliability of diagnosis.

6. Conclusion. The paper treats chemical substances for which time is the predominant factor of consequence prevention, especially in cases of rendering the first pre-hospital aid. A class of toxic substances with similar symptoms during pre-hospital period is discovered which complicates poisoning diagnosis. It is proposed to develop a neuronal network and train it using Levenberg-Markquardt algorithms. Analysis of possible responses of the network performance is made. The output of the system is a recommendation of antidote therapy in the conditions of the first and emergency aid. The system was tested on case histories of real patients, the coincidence with diagnosis after laboratory investigations amounted to 94% on the average. The diagnosis reliability went up by 3-5% as compared to results obtained in [6].

References

1. V.N.Ruchkin, V.A. Fulin. Universal Artificial Intelligence and Expert Systems. St. Petersburg- “BHV-Petersburg. 2009, 238c.
2. Duke V.A. Data Mining Technologies in Medico-biological Researches // Artificial Intelligence News. 2004, №3, pp. 15-23.
3. Timothy D. Henry, M. D. Heart Injury Due to Carbon Monoxide Poisoning. Increases Long Term Risk of Death // Journal of the American Medical Association, January 24, 2006.
4. Eichhorn L, Thudium M, Jüttner B: The diagnosis and treatment of carbon monoxide poisoning. Dtsch Arztebl Int 2018; 115: 863–70. DOI: 10.3238/ arztebl.2018.0863.
5. Committee on Acute Exposure Guideline Levels; Committee on Toxicology; National Research Council. Acute exposure guideline levels for selected airborne chemicals: volume 14
6. Jason J. Rose, Ling Wang, Qinzi Xu , Charles F. McTiernan , Sruti Shiva, Jesus Tejero, and Mark T. Gladwin. Carbon Monoxide Poisoning: Pathogenesis, Management, and Future Directions of Therapy// American Journal of Respiratory and Critical Care Medicine Volume 195 Number 5 | March 1 2017
7. CDC (2005) Unitintentional, Non ire-related, carbon monoxide exposures United States, 2001-2003. Morbidity and Mortality Weekly Report (MMWR), CDC, USA 54: 36-39.
8. Litovitz T, Benson BE, Youniss J, Metz E (2010) Determinants of U.S. poison center utilization. Clin Toxicol 48: 449-457.
9. Bell J, Bronstein A, Clower JH, Iqbal S, Yip FY, et al. (2011) Carbon Monoxide Exposures United States, 2000-2009. Morbidity and Mortality Weekly Report (MMWR), CDC, USA 60: 1014-1017.
10. Iqbal S, Clower JH, Boehmer TK, Yip FY, Garbe P (2010) Carbon monoxide-related hospitalizations in the US: evaluation of a web-based query system for public health surveillance. Public Health Rep 125: 423-432.
11. R. E. Ghosh, R. Close, L. J. McCann, H. Crabbe, et al.. Analysis of hospital admissions due to accidental non-fire-related carbon monoxide poisoning in England, between 2001 and 2010. Journal of Public Health, 2015, pp.1-8
12. G.Abdullayeva, N. Gurbanova, I.Mirzazadeh. Information Technologies in Toxicology. LAP LAMBERT Academic Publishing, 2014, Germany. 118p.
13. Abdullayeva G.G. Mirzazadeh I.Kh. Organization of monitoring for toxic poisonings/ COIA-2018. Proceedings of the 6th International Conference on Control and Optimization with Industrial Applications. Baku-Azerbaijan, 2018, vol.II, pp.20-22
14. L.A.Zadeh Fuzzy Algorithms. - Information and Control, vol.12, 1968, pp.94-102
15. S. Osovsky. Neural networks for information processing. Moscow: "Finance and Statistics", 2002, 344c.