Computer System for Diagnosis in Medicine Domain

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***Abstract* — The research has been conducted in the medical field and reflects the development of computer system. The computer system has been designed for arterial hypertension (high arterial blood pressure) differential diagnosis. It means that it is possible to determine with the computer system whether a patient has hypertension, and if it is found, then it is possible to determine the cause.**

The development of the computer system was based on the knowledge about hypertension diagnosis and treatment of cardiologists at the Research Institute of Cardiology of the University of Latvia and Pauls Stradins Clinical University Hospital.

There are two tasks assigned for the diagnostic system and there are two stages made to reach these two tasks. The first task is the selection of hypertension patients or screening, implemented at the first stage. The second task is indicative differential diagnostics, which allows differentiating hypertension from 7 symptomatic arterial hypertensions (diencefal syndrome, pheochromocytoma, Conn's syndrome, coarctation of the aorta, renal hypertension, aortic atherosclerosis and thyrotoxicosis). The second stage of the diagnostic system is made for the implementation of this task.

***Keywords* — Arterial hypertension, differential diagnostics, expert system, high blood pressure, production rule system, screening.**

I. Introduction

Artificial intelligence systems, including expert systems, are used in various sectors (industrial, logistics, business process management, medicine, etc.) nowadays.

An expert system is a knowledge-based system. It is built in the form of a computer program and it manages the expert's reasoning and decision-making simulation in a particular problem domain. Operation of an expert system is provided by the knowledge base, which consists of certain information about the problem domain – various facts, statements, attitudes among them, as well as the knowledge resulting from experiences.

This type of computer systems, thanks to their advantages, has become an important, sometimes even indispensable, part of the process of the conduct of many different industries, including medicine. Some of the advantages of expert systems in medicine are as follows:

- knowledge base combines large-scale systems of multi-expert knowledge that strongly complement each other;
- the doctor is able to make sure that the diagnosis is correct in cases of doubt, and in the absence of sufficient knowledge of disease symptoms that are rare;
- expert system can make a large number of complex tasks in a short time period.

This paper deals with the general expert system complying with the requirements of software systems in the medical field – arterial hypertension (high arterial blood pressure) differential diagnosis.

II. Knowledge Base and Decision-making Technology

There is a knowledge base created pursuant to the first and second phase for the establishment and functioning of the computer system. The knowledge base is developed in the form of production rules, and their creation is based on:

- 25 diagnostic symptoms;
- linear discriminant functions with threshold values;
- decision trees.

A. The First Stage

Out of 25 diagnostic symptoms, only 6 symptoms are used at the first stage. They are chosen by experts and they form the linear discriminant function [5]:

$$LDF_1(x) = 6x_1 + 6x_2 + 7x_3 + 2x_4 + 2x_5 + 2x_6, \quad (1)$$

where $LDF_1(x)$ – the linear discriminant function;
x_n – symptoms;
coefficient on the x values – diagnostic parameters.

For each x of LDF_1 there is one specific symptom. For example, x_1 corresponds to a symptom of "high blood pressure during the examination" (Table I).

TABLE I
Symptoms of LDF_1

Name (x_n)	Symptom
x_1	high blood pressure during the examination
x_2	high blood pressure for the last 2 weeks or a month
x_3	high blood pressure for several years
x_4	currently blood pressure is normalized
x_5	blood relatives have a history of high blood pressure
x_6	complaints of headache or dizziness

To be able to come to a conclusion at the first stage, the user (in this case the doctor) must enter an affirmative (yes) or negative (no) response for each symptom presence of the patient. Communication between the computer system and the

user is organized in a question-and-answer form, which is accustomed to humans and easy to understand (e.g., "Does the patient have high blood pressure during the examination?"). There are generated corresponding values in a computer system according to given answers. "Yes" is equal to "1" and "no" – to "0". Depending on the given answers, the computer system for each x of LDF_1 assigns a value of "0" or "1".

Aggregation of all parameters of LDF1 gives a numerical value, which has to be compared with the threshold values. Table II shows all possible decision-making results of the first stage – screening.

For making knowledge shown in Table II understandable, the computer system arranged it in the form of production rules with the form of "IF ... THEN ...":

1. IF $LDF_1 < 3$, THEN arterial hypertension has not been established.
2. IF $LDF_1 \geq 6$, THEN arterial hypertension is diagnosed.
3. IF $LDF_1 \geq 3$ and $LDF_1 < 6$, THEN for setting the hypertension diagnosis, further investigation is necessary.

TABLE II

DECISION-MAKING RESULTS OF THE FIRST STAGE

Value of LDF_1	**Screening process, the result obtained**
$LDF_1 < 3$	Arterial hypertension has not been established.
$LDF_1 \geq 6$	Arterial hypertension is diagnosed.
$6 > LDF_1 \geq 3$	For setting the hypertension diagnosis, further investigation is necessary.

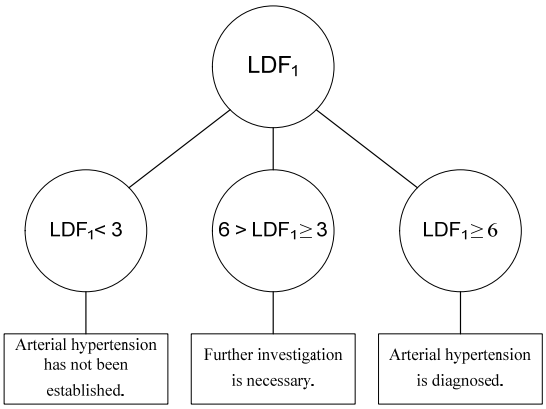

Fig. 1. Decision tree for the LDF_1.

Depending on the decision of the first stage, the system can stop working or move to the next stage. Moving to the second stage occurs in two cases:

- if arterial hypertension is diagnosed;
- for setting the hypertension diagnosis, further investigation is necessary (Fig. 1).

B. The Second Stage

The second stage includes 19 symptoms, which are selected by experts and make it possible to determine whether the patient has hypertension or high blood pressure appears as a symptom of another disease (diencefal syndrome, pheochromocytoma, Conn's syndrome, coarctation of the aorta, renal hypertension, aortic atherosclerosis and thyrotoxicosis). Experts choose the symptoms that characterize diseases from which hypertensive disease has to be differentiated.

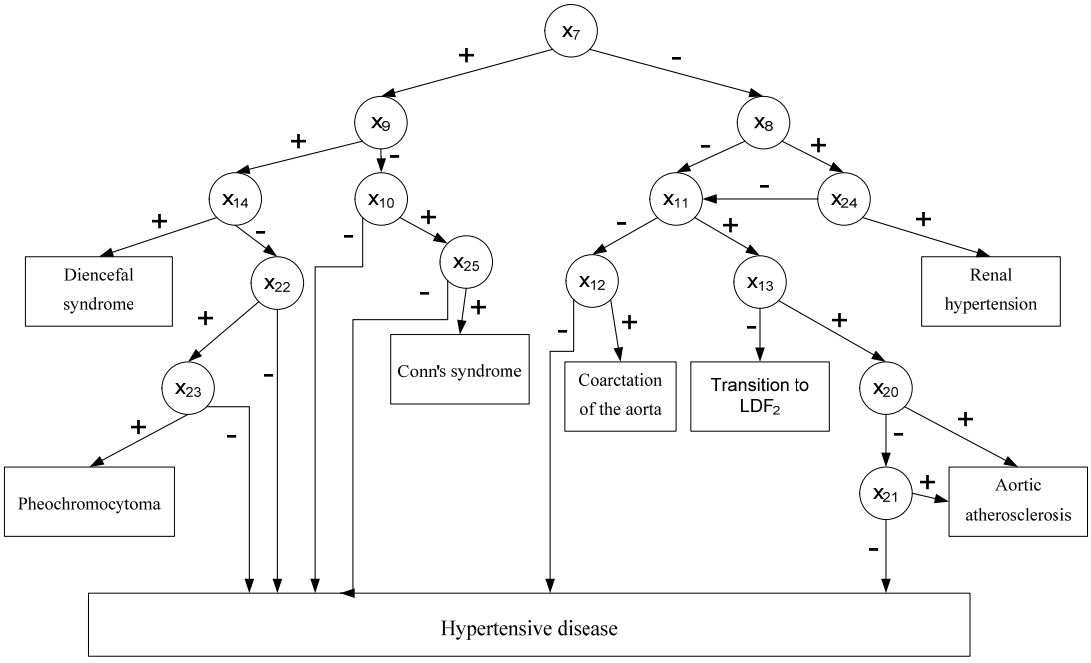

Fig. 2. Decision tree for the second stage

Decision-making is organized with the help of a decision tree [8], [16]. For the specific task the decision tree is created, which is shown in Fig. 2, with x symptoms are marked (Table III). The symbol "+" corresponds to the user to respond "yes", while "-" represents the answer "no" for the presence of symptoms of the patient. Tree peaks in a deadlock differentiate disease names.

TABLE III
SYMPTOMS OF THE SECOND STAGE

Name (x_n)	Symptom
x_7	blood pressure rises fitfully
x_8	pain in the renal area
x_9	pain in the heart area or pounding attack, during high blood pressure attack
x_{10}	weakness and thirst are fitful
x_{11}	systolic arterial hypertension
x_{12}	blood pressure on a.femoralis (femoral artery) > blood pressure to a.humoralis (upper arm artery)
x_{13}	age > 50 years
x_{14}	*urina spaticae* (spontaneous urination seizures during high blood pressure attack)
x_{15}	frequent heart palpitations
x_{16}	often a feeling of warmth
x_{17}	emaciation
x_{18}	exoftalm
x_{19}	goitre
x_{20}	systolic noise on aortic valves
x_{21}	extended aortic arch
x_{22}	constant excitation, anxiety
x_{23}	unreasonably chills
x_{24}	urinary abnormalities
x_{25}	positive test for furosemide

The first question asked is a question about the symptom x_7 ("Or does the patient blood pressure rise fitfully?"). Depending on the answers given, the system goes further to one or the other decision tree branch. In this way, there is a move from one on other peaks of the entire decision tree framework. The exception is the peak, following the negative answer to the question of symptom x_{13}. In this case, the user sequentially is asked about symptoms x_{15}, x_{16}, x_{17}, x_{18}, x_{19}. In order to determine future operation of decision making, linear discriminant function with threshold values is used [5]:

$$LDF_2(x) = 2x_{15} + 2x_{16} + 3x_{17} + 3x_{18} + 4x_{19}. \quad (2)$$

At the second stage, the current LDF_2 works similarly to the first stage of the current LDF_1.

TABLE IV
POSSIBLE DIAGNOSES ACCORDING TO THE LDF_2 VALUE

Value of LDF_2	Diagnosis
$LDF_2 < 3$	Hypertensive disease
$3 \le LDF_2 < 5$	Thyrotoxicosis is possible
$LDF_2 \ge 5$	Thyrotoxicosis

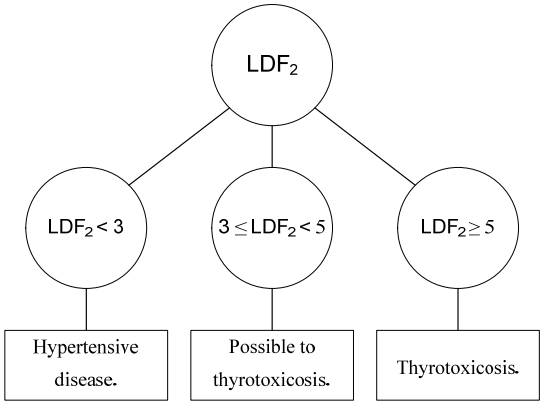

Fig. 3. Decision tree for the LDF_2.

For a computer system to implement the decision-making process, the information of entire decision tree (Fig. 2) by looking at all the possible paths is converted to products in the form of law, such as:

IF the answer to the question of symptom x_7 is „no”
AND the answer to the question of symptom x_8 is „yes”
AND the answer to the question of symptom x_{24} is „yes”
THEN diagnosis is renal hypertension.

III. CREATION OF THE DATABASE

There is a possibility to build a database in computer system, which consists of computer files containing the information obtained from patient data input time. Each file in the database contains the following information:

- identification data of patient (name, surname, personal identity number);

- data entry (patient visits) date;
- protocol, which is a result of system administration information on the presence or absence of symptoms of the patient;
- systems' diagnosis.

The developed protocol can serve as an explanation of the decision of the computer system.

It is possible to open, edit, save, and print files from the database. In addition to everything stated above, it should be noted that since the information contained in the database can be viewed and analysed, then based on the available data, the computer system can evaluate the accuracy of the decision and indicate to experts. Thereby with the help of experts, it is possible to adjust the knowledge base, thereby increasing the accuracy of the computer system.

IV. The Development of Software and User Interface

The computer system is developed by using Borland Delphi 7 [3], [4]. It is based on the open source software, which is found at the web site [17], and which has been modified and improved in accordance with a particular system needs. Borland Delphi 7 was selected because of the possibilities it offers, that is, it was possible to implement all of the requirements established by the computer system.

The knowledge base is created into files, which are formed in the form of production rules, in which information is represented by a decision tree basis (TREE-type files), according to the first and second stage. A fragment from the knowledge base is shown in Fig. 4.

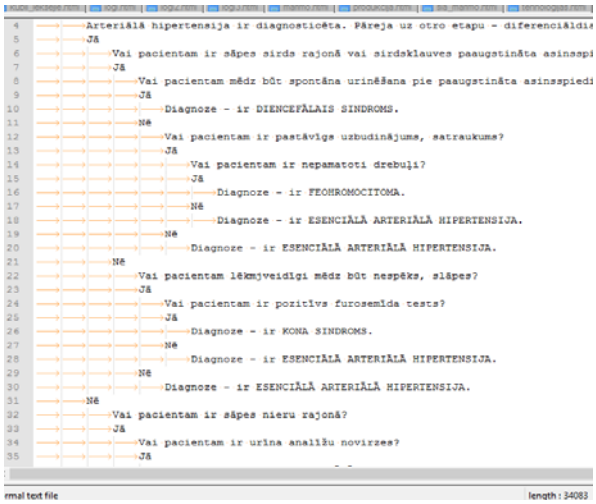

Fig. 4. Fragment from the knowledge base.

Computing system user interface consists of two windows, which are complementary to each other functions:

- an interactive dialogue window (Fig. 5);
- A data input and processing window (Fig. 6).

C. Interactive Dialogue Window

The functionality of interactive dialogue window of the diagnostic system of arterial hypertension:

- the selection of the required diagnostic systems stage from the list (Fig. 7);
- implementation of interactive survey (Fig. 8);
- with the arrow buttons (Fig. 8) it is possible to switch between the next question or to return to the previous and the correct answer;
- the result output on the screen of the first stage – screening, and the provision of guidance to follow up the user (Fig. 9):
  - arterial hypertension has not been established, work with the system may be stopped;
  - the need for additional tests, an automatic transition to the second stage;
  - arterial hypertension is detected, an automatic transition to the second stage;
- the representation of the result (diagnosis) of the second stage – differential diagnostics (Fig. 10);
- pressing the "Datu ievade" (Fig. 5), the system opens data entry and processing window.

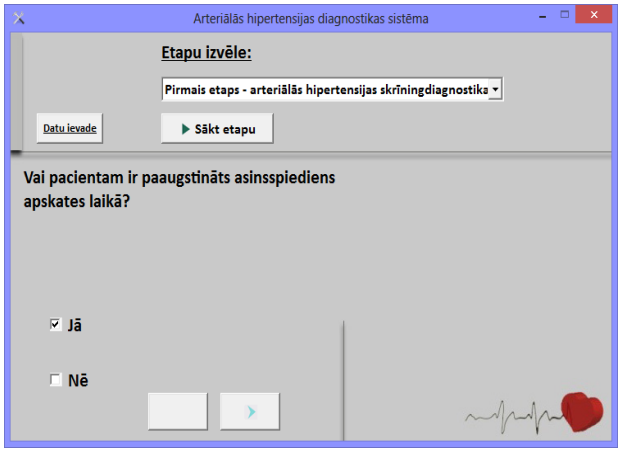

Fig. 5. Interactive dialogue window.

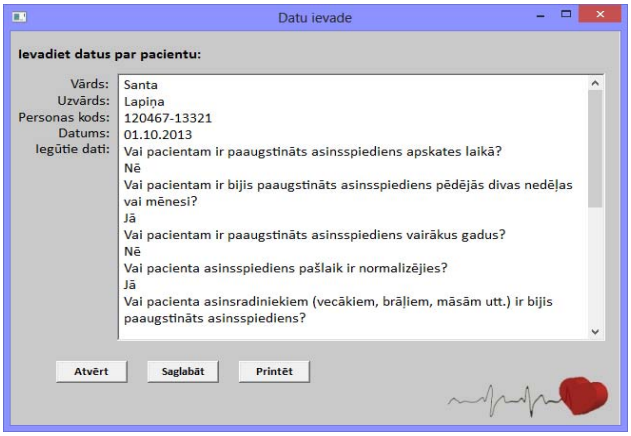

Fig.6. Data input and processing window

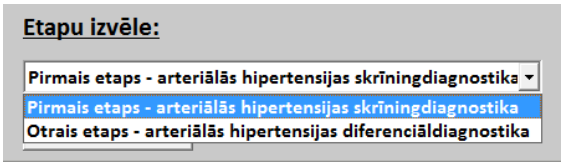

Fig. 7. Stage selection list

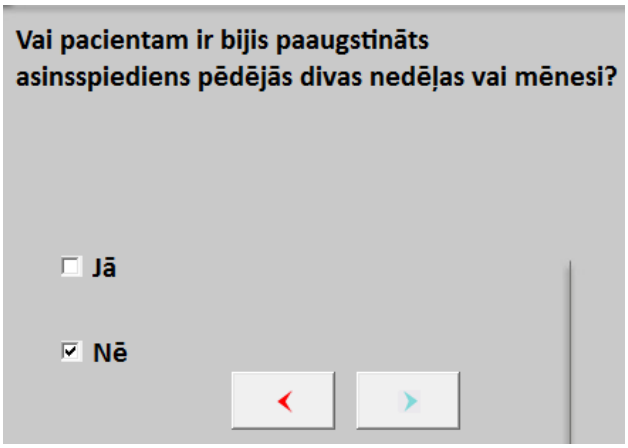

Fig. 8. The realization of interactive survey.

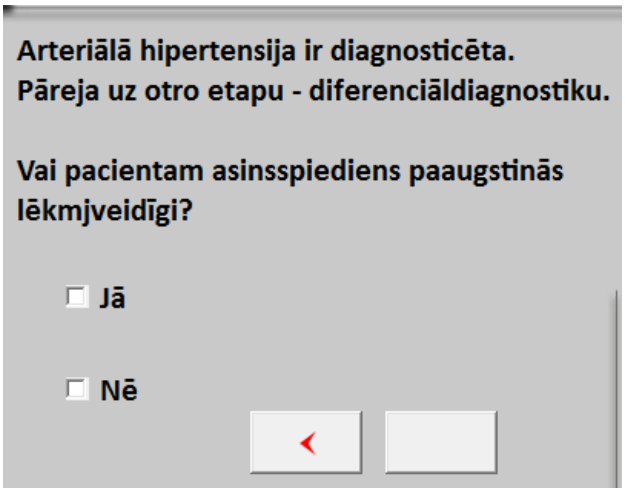

Fig. 9. Result output of the first stage.

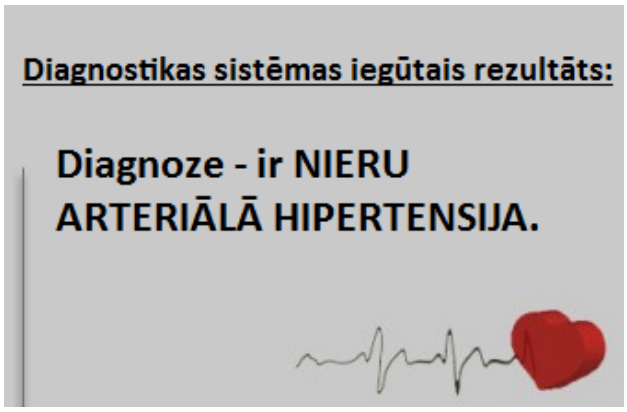

Fig. 10. Result output of the second stage.

D. Data Input and Processing Window

Functionality of data entry and processing window:

- identification data of patient (name, surname, personal identity number) and the date of completion of the survey entry (Fig. 11);

Fig. 11. Data input.

- during the data entry the window shows all asked questions and answers to them. They can be used as an argument of a computer system decision. The system also shows given diagnosis. (Fig. 12);

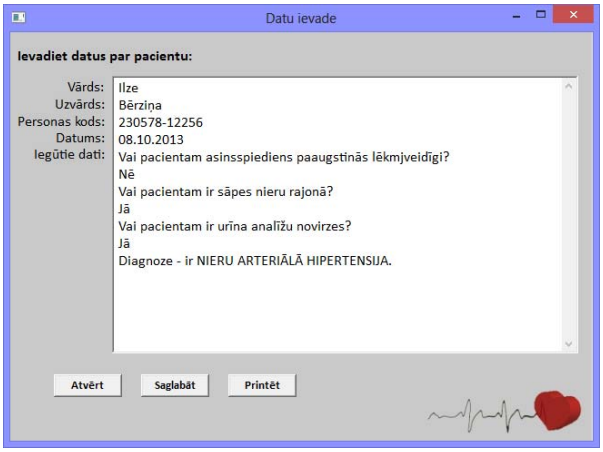

Fig. 12. Functionality of data entry and processing window.

- clicking on the "Saglabāt" button (Fig. 12), a file saving window opens, and the data are saved in .txt format, creating a diagnostic system database (Fig. 13);
- clicking on the button "Atvērt" (Fig. 12), the data appears in the opening window and can be opened as .txt format files that store the results of a previous survey (Fig. 14);
- clicking on the "Printēt" (Fig. 12), it is possible to print the data shown in the input window (Fig. 15).

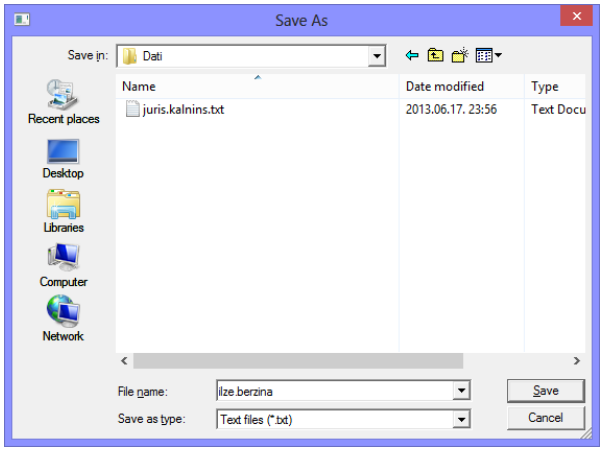

Fig. 13. File saving window.

In addition to the functionality that is provided, the user can manually open, edit, save and print files from the database.

In individual cases when before the screening performance it is already known that the patient has hypertension, for time-saving it is possible to go directly to the second stage – differential diagnostics – by selecting from the list (Fig. 7).

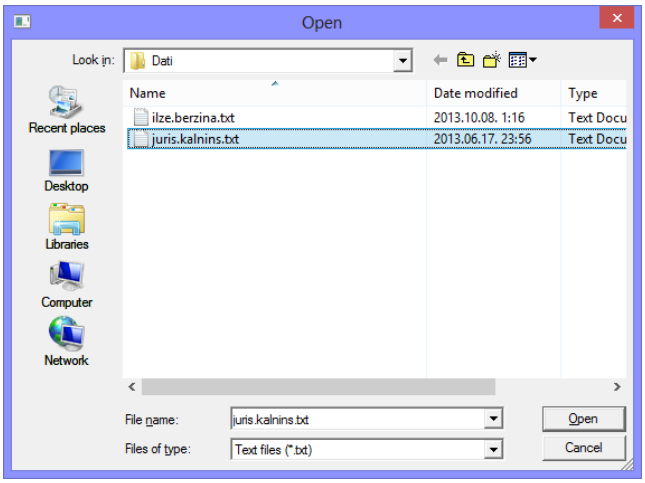

Fig. 14. File opening window.

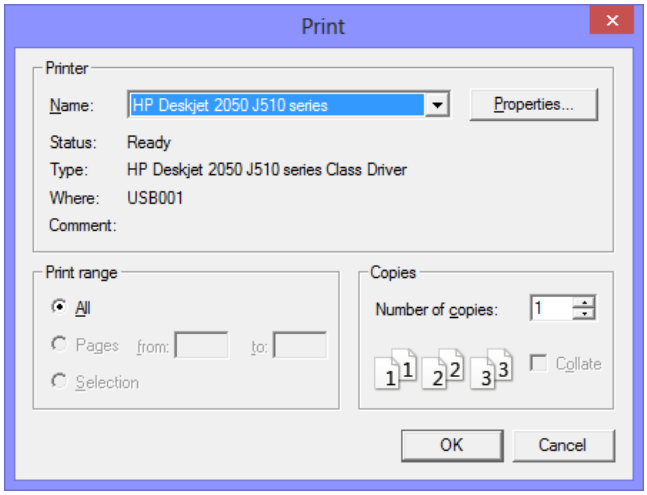

Fig. 15. Printing window.

V. System Testing

Expert system testing can be carried out based on many different criteria, so there are no certain guidelines that should be tested. For each expert system testing, special criteria are carefully selected in order to perform the analysis in the best and most accurate manner, which directly demonstrates its key features and properties.

The computer system described in the paper has been tested according to two criteria – ease of use and reliability of the results (validity). Such criteria are chosen because:

- it is important that the computer system should be easy to use;
- computer system, which is designed for the medical field – arterial hypertension (high arterial blood pressure) differential diagnosis – is as specific as possible, as shown by the results of system reliability (validity).

Ease of use has been evaluated by listening to the medical staff and student feedback. The computer system has been evaluated using a rating scale with pre-defined values from 0 to 5 (fragment is shown in Table V), as well as listening to additional comments.

TABLE V

System Ease of Use Assessment

The evaluator (No.)	Assessment					
	Totally uncomfortable	Uncomfortable	Almost uncomfortable	Almost comfortable	Comfortable	Very comfortable
	0	1	2	3	4	5
1.		x				
2.				x		
3.					x	
....						

After the user's view, ease of use of the system shows:

- easy to use and transparent user interface;
- communication between the computer system and the user is organized in a question-and-answer form, which is accustomed to humans and easy to understand data entry form;
- the results are displayed on the screen and can be printed together with explanations;
- it is possible to store data of patients and the results obtained by creating the database.

To determine the computer system reliability, the clinical data of patients with 25 symptoms (6 of the first stage – screening and 19 of the second stage – differential diagnosis) were entered into the system and clinically verified to differential diagnoses.

The number of cases was examined, in which the computer system provided the results according to clinical diagnosis verified. Test results showed that the system gave the same diagnosis in 14 out of 18 cases.

IV. Conclusions and Future Perspectives

1. The computer system has been developed for arterial hypertension (high arterial blood pressure) differential diagnosis.
2. The computer system does two tasks. The first one is screening and it allows determining whether the patient has arterial hypertension. The second task is differential diagnostics – the cause of hypertension is identified and the treatment strategy is determined.
3. The established system meets the general requirements of expert systems:
   - performance is comparable to expert performance, as evidenced by the reliability of system, but it needs to be further tested with a larger number of clinically verified cases;

- logic of the system is close to experts' logic, because the knowledge base is built in the form of production rules;
- the system justifies a decision by logical justifications – a protocol is designed, there is an opportunity to build a database;
- system knowledge base is open – it is likely to change, edit and expand the addition of the symptoms, as well as differential diagnosis;
- the system works in an interactive mode;
- work with the system does not require any special user training, as evidenced by the ease of use evaluation system;
- issues and conclusions can be formulated as a system user's language (at present, the system is implemented only in Latvian, but it is possible to add translation and provide language options).

4. The developed hypertension diagnostic system is designed for use both in the field of medical practice and in training medical students.

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Ance Kancere, Ieva Markoviča, Zigurds Markovičs. Diagnostikas datorsistēma medicīnā
Darbs izstrādāts medicīnas sfērā un atspoguļo datorsistēmas izstrādi. Datorsistēma paredzēta arteriālās hipertensijas (paaugstināta arteriālā asinsspiediena) diferenciāldiagnostikai. Tas nozīmē, ka ar datorsistēmas palīdzību ir iespējams noteikt, vai pacientam ir arteriālā hipertensija, un, ja tā ir konstatēta, tad kāds ir tās cēlonis.
Datorsistēma izstrādāta, balstoties uz Latvijas Universitātes Kardioloģijas zinātniskā institūta un P. Stradiņa Klīniskās universitātes slimnīcas kardiologu zināšanām par arteriālās hipertensijas diagnostiku un ārstēšanu.
Diagnostikas sistēmai paredzēti divi uzdevumi. Lai tos izpildītu, izveidoti divi posmi. Pirmais uzdevums ir arteriālās hipertensijas pacientu atlase jeb skrīningdiagnostika, kas realizēta pirmajā posmā. Otrais posma ir orientējoša diferenciāldiagnostika, kas ļauj diferencēt hipertonisko slimību no 7 simptomātiskajām arteriālajām hipertensijām (diencefālais sindroms, feohromocitoma, Kona sindroms, aortas koarktācija, nieru arteriālā hipertensija, aortas ateroskleroze un tireotoksikoze). Šī uzdevuma realizācijai paredzēts diagnostikas sistēmas otrais posms.

Анце Канцере, Иева Марковича, Зигурдс Маркович. Диагностическая компьютерная система в области медицины.
Работа связана с областью медицины и отражает процесс разработки компьютерной системы. Компьютерная система предназначена для дифференциальный диагностики артериальной гипертонии (высокое артериальное давления). Это значит, что при помощи данной компьютерной системы можно определить, наблюдается ли у пациента гипертензия и, если это так, тогда будет констатирована и причина.
Компьютерная система разработана в соответствии со знаниями диагностики и опытом лечения артериальной гипертонии кардиологов Клинического университета имени П. Страдыня и Научно-исследовательского института кардиологии при Латвийском университете.
Диагностическая система рассчитана на решение двух задач. Чтобы их успешно выполнить, процесс разделён на два этапа. Первой задачей является отбор пациентов, страдающих гипертонией, либо скрининг, который производится на первом этапе. Второй задачей является дифференцирование, которая позволяет дифференцировать гипертоническое заболевание из 7 симптоматических артериальных гипертензий (диенцефальный синдром, феохромоцитома, синдром Кона, коарктация аорты, почечная гипертензия, атеросклероз аорты и тиреотоксикоз). Данная задача решается во время второго этапа диагностической системы.