

Decision Making in Mobile Telemedicine Complex

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Abstract — Research is dedicated to computer-based decision-making technology intended for screening diagnostics and its basic principle implementation in the Mobile Telemedicine Screening Complex (MTSC).

The decision-making logic is based on two main information flows. One is the main stream, including objective measurement results from MTSC hardware, and, the other – the subjective patient interactive questionnaire, including complaints, feelings, risk factors and conformation of existing chronic diseases.

The paper provides the description of decision-making technology starting with the exploration of the flow of mutual obligations and ending with decision-making rules to produce the final decision.

Keywords — Decision making, decision-making rules, information flow, objective measurements, production rules, screening, subjective feelings.

I. INTRODUCTION

To organize and facilitate the process of screening in prevention offices and family doctors' offices, mobile telemedicine screening complex (MTSC) is designed. It includes 14 measurement modules to obtain objective data on the condition of the body systems [1], [2].

The complex also includes an interactive questionnaire on 12 body system conditions, risk factors and chronic diseases [3], [4].

The mentioned components of the complex form two main information flows, on which the computerized decision-making system is based.

II. DEVELOPMENT OF THE DECISION TECHNOLOGY

It is intended that a screening system creates a conclusion on all 12 body systems $S1 \div S12$, which are included in an interactive questionnaire. Since 9 of them also have objective measurement data from 14 measurement modules, the conclusions should be based on two types of data – questionnaire data and measurement results.

The situation is complicated by the fact that a decision on the functioning of the system abnormality may affect not only the direct response or direct measurements, but also several adjacent measurements.

For example, the state assessment of cardiovascular system $S1$ should take into account not only the answers to the questions similar to $S1$ and the measurement results of measurement module $M1$ (ECG), but also the system H (chronic diseases), $S2$ (respiratory system), $S4$ (neoplasm system), $S10$ (neurological condition) and measurement modules $M2$ (blood measurement module), $M3$ (pulse oximetry measurement module), $M4$ (digital phonendoscope measurement module) and $M5$ (cholesterol test) [5], [6]. The situation is similar to other systems, such as $S2$ (respiratory system) as described in [3].

This means that any decision-making system considers information from several sections of the questionnaire and several measurement modules. The twelve body systems at the decision dependency sections of the questionnaire and provided measurement modules are shown in Fig. 1 in oriented form of a graph [7], [8]. A similar relation of risk factors is provided in Fig. 2.

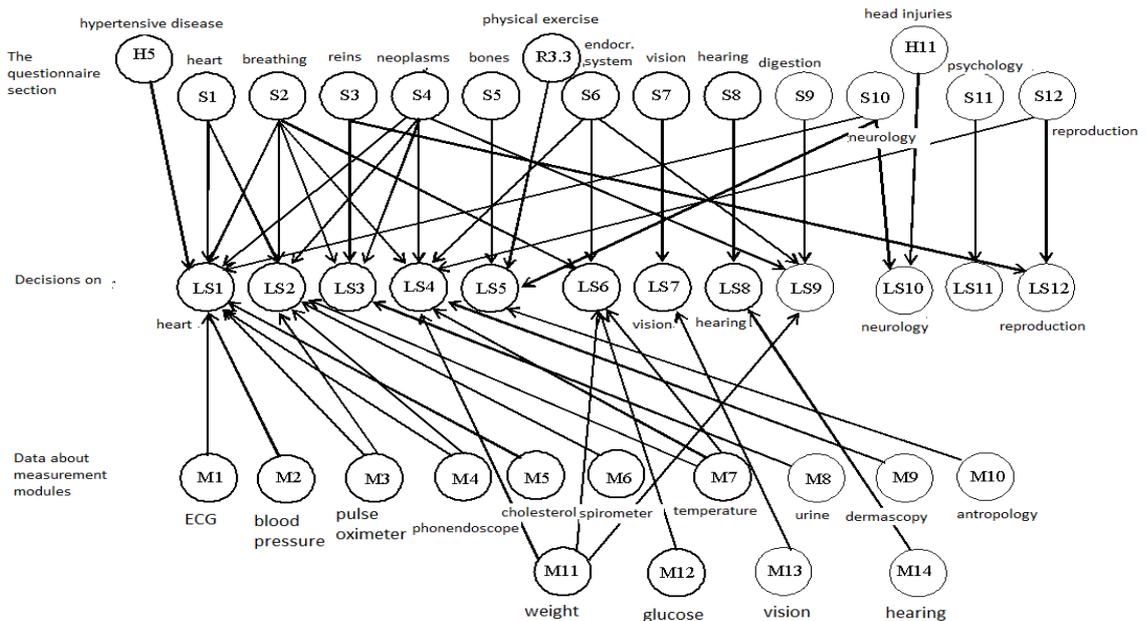


Fig. 1. Sources of information for decisions on system conditions.

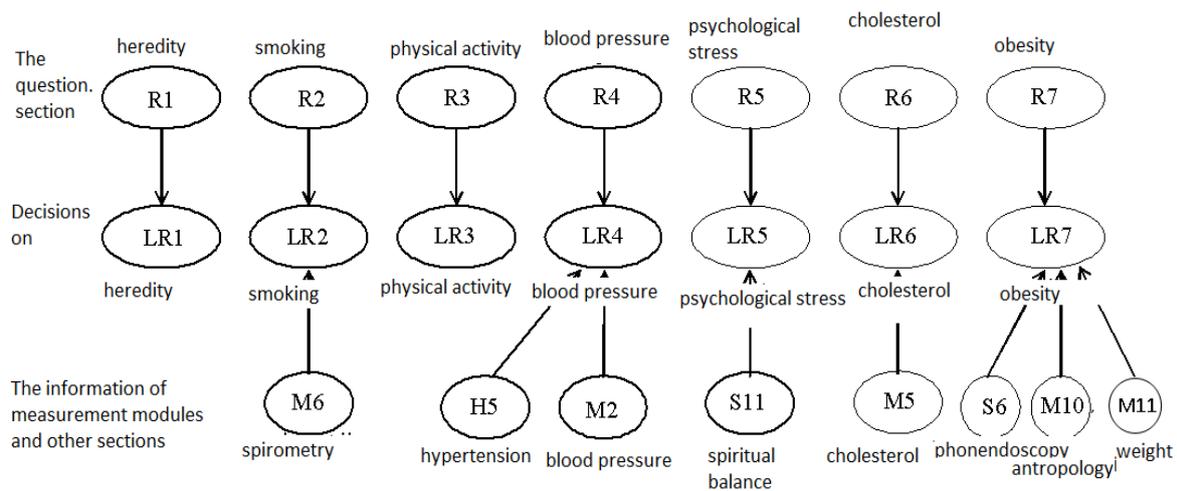


Fig. 2. Sources of information for decisions on risk factors.

Computer decision structure is aligned to:

- 1) 12 body systems included in an interactive questionnaire to S1 ÷ S12;
- 2) seven risk factors R1 ÷ R7;
- 3) decisions related to replies of section P – for the existence of regular checks;
- 4) decisions about chronic diseases in H;
- 5) additional decisions, where there are no subjective complaints, no objective deposits, but there are risk factors.

Decisions, which are made by a computer, consist of 3 parts [9], [10], [11]:

- the facts, where the reported patient's complaints and objective findings are encrypted;
- the deciding part, where there are further recommendations for action;
- part of the basis, where the patient decipheres the fields listed above in an understandable way.

For example, on a computer screen the following decisions can be lighted up:

- L S1₀ – there are NO cardiovascular abnormalities;
- L S1₁ – there ARE cardiovascular abnormalities (.....). Encrypted fields, which are indicated, are shown in parentheses.
Recommendation refers to a cardiologist.
Justification – the verbally quantified findings on which a recommendation is produced.

Decision statements should be understood as follows:

- L – decision;
- S1 – about system S1;
- 0 – there are no abnormalities;
- 1 – there are abnormalities.

II. DECISION TREES

The decision process is desirable to establish the so-called decision trees, which form the information about this or other decision that can be clearly visible in a graph [12], [13].

Figure 3 illustrates a decision tree for cardiovascular system S1, but Fig. 4 and Fig. 5 illustrate decision trees for bone and joint system S5 and neurological status S10, respectively. Similar trees have all 12 systems from S1 to S12.

Decision tree of respiratory system S2 is given in [3].

All decision trees are clearly expressed in two components (branches). Left branch of tree is characterized by a connection attribute string. All attributes are related to the conjunction AND. All attributes have 0-values that represent the situation – there is NOT deviation from the norm. Specifically, on the decision tree branch of system S1 on the left the following expressions are concentrated:

- measurement modules M1 (ECG), M2 (blood pressure), M3 (pulse oximetry), M5 (cholesterol) do not detect pathological findings (M1 = 0, M2 = 0, M3 = 0, M5 = 0);
- measurement module M4 (digital phonendoscopy) does not detect symptoms of M4.1 = 0 (heart murmur) and M4.2 = 0 (noise over large blood vessels);
- all responses from S1.1 to S1.12 sections of the cardiovascular system [4] of the questionnaire are negative;
- responses to questions S10.1, S10.2, S10.4 and S10.7 in section S10 of neurological condition [4] are negative;
- an answer to question S2.4 in the questionnaire section S2 of the respiratory system (or wakes up from shortness of breath) is negative;
- an answer to question S4.9 in the questionnaire section S4 for possible tumours (warts, etc.) is negative;
- an answer to question H5 in the questionnaire section H (or suffer from hypertension) is negative.

Only if all the mentioned measurements and the answers to the questions of questionnaire are negative, the computer decides L S1₀ – there are NO cardiovascular abnormalities in S1.

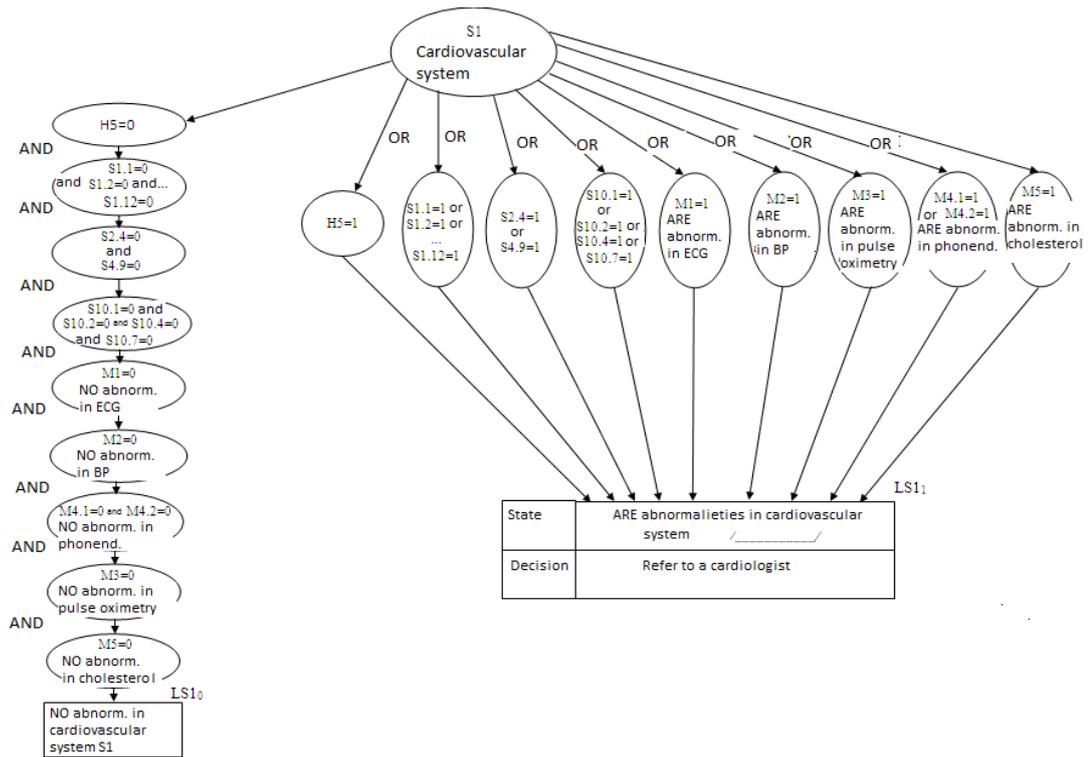


Fig. 3. Cardiovascular system.

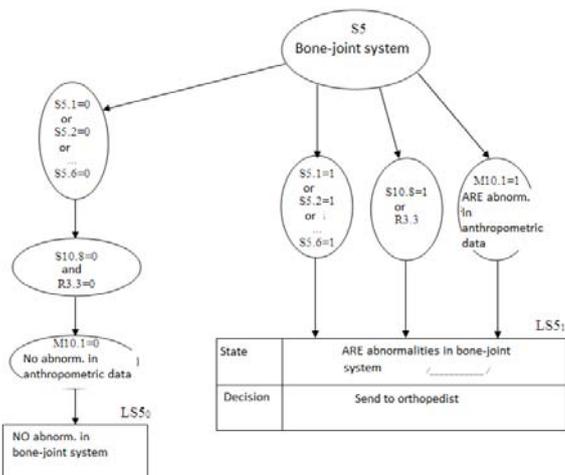


Fig. 4. Bone-joint system.

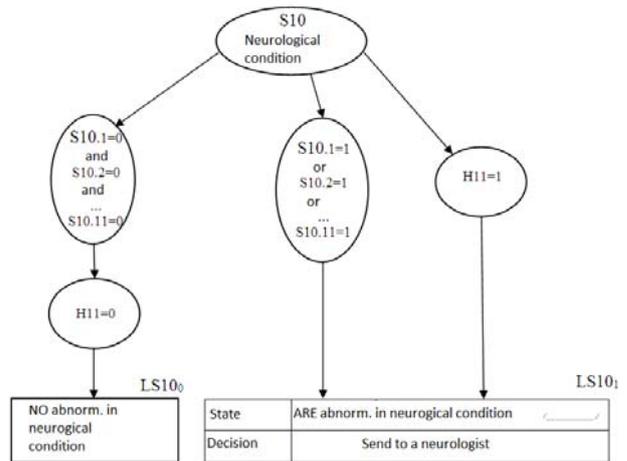


Fig. 5. Neurological condition.

Decision tree on the right-hand side contains all the same attributes as listed on the left. The difference is that:

- all attributes form a parallel structure;
- all attributes are linked by a conjunction OR;
- the symptoms of each system are mutually connected by a conjunction OR;
- the values of all the signs are equal to 1.

This means that this part of the statements focuses on the objective findings that differ from the norm of subjective complaints, according to the questionnaire. Conjunctions OR mean that it is sufficient that one of the symptoms has the value of 1 to make the final decision L S11 – there ARE

cardiovascular abnormalities, and recommendations refer to a cardiologist.

Similarly, tree S5 is analysed.

The left branch of the tree with the element string configuration reflects the decision L S50 – NO abnormalities in bone and joint system. The branch consists of replies "no" to questions S5.1÷ S5.6 directly on the bone and joint system, as well as questions S10.8 and R3.3 from other parts of the questionnaire.

Objective measurements in the tree include measurement M10.1 = 0 - abnormalities are not in anthropometric data.

All attributes of left branch have values 0 and are connected to each other by a logical "AND".

On the right side of the decision tree, the same attributes are included with the help of the element parallel configuration, but only with the values "1". It means that any subjective or objective finding, respectively, has values "yes" and "1". In this part, all attributes (as well as all the symptoms) are connected to each other by a logical conjunction "OR". Parallel configuration of attributes reflects the decision L S5₁ – there ARE abnormalities in bone and joint system.

Following formal features decision trees of risk factors (RF) are similar to the finding described above, but with a degree of specificity.

Decision tree for risk R1 (unfavourable heredity) is shown in Fig. 6 and a risk factor for R7 (overweight, obesity) – in Fig. 7.

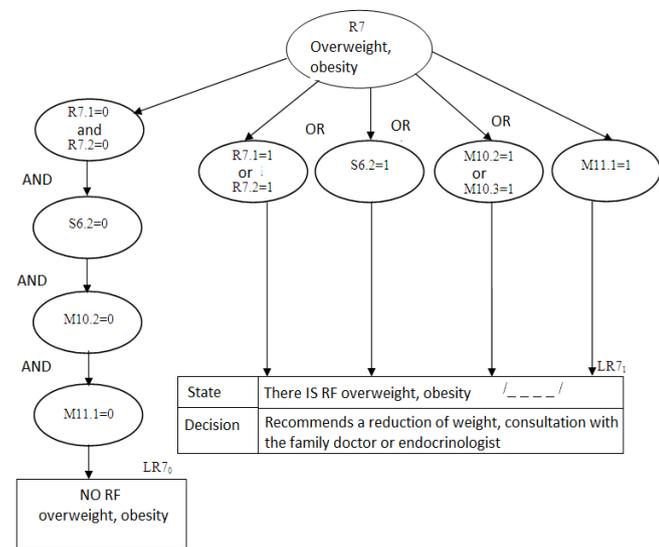


Fig. 6. Unfavourable heredity.

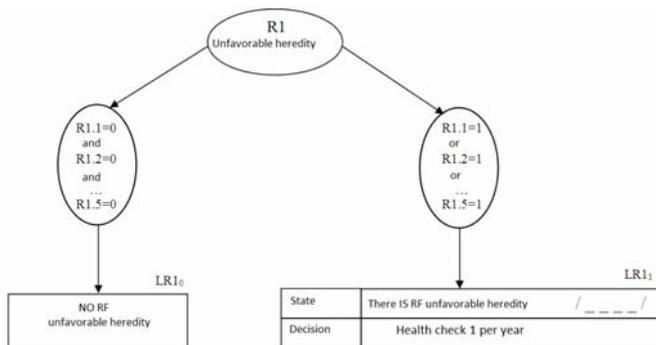


Fig. 7. Overweight, obesity.

In case of R1, a decision tree includes only the responses to questions from R1.1 to R1.5 about possible diseases of cognates [4], [5].

In case of R7, a decision tree is more complicated, because it includes:

- answers to question R7.1 – whether blood relatives are overweight and R7.2 – whether in childhood you were thicker than peers;

- answer to question S6.2 – whether you have noticed weight gain;
- objective measurement results M10.2 = 1 - increased waist circumference, M10.3 = 1 - ratio increased waist / hips, M11.1 = 1 - a higher body mass index.

The existence of any symptom mentioned above leads to a decision L R7₁ – there is risk factor R7 – overweight, obesity. Recommendation is to refer to a family doctor or endocrinologist to adequately address the weight loss procedure.

III. PRODUCTION RULES

Decision-making system has been designed with the use of elements of artificial intelligence [14], [15].

For the computer realization information contained in the decision trees can be expressed in terms of production rules in the form of "IF ... THEN" [16]. It is of practical convenience that in the condition part the format of making decision is maintained like in decision trees, in which information from different sections is separated. In the output of the laws it appears as multiple condition "IF" survival of the networking of the conjunction "OR".

For example, the output displays all of the rules of decision trees listed above:

The condition part	The concluding part L S1 ₁
IF S1.1=1 or S1.2=1 or S1.3=1 or S1.4=1 or S1.5=1 or S1.6=1 or S1.7=1 or S1.8=1 or S1.9=1 or S1.10=1 or S1.11=1 or S1.12=1	THEN there are abnormalities in cardiovascular system (.....).
IF S2.4=1 or S4.9=1 or H5=1	Send to a cardiologist.
IF S10.1=1 or S10.2=1 or S10.4=1 or S10.7=1	
IF M1=1	
IF M2=1	
IF M3=1	
IF M4.1=1 or M4.2=1	
IF M5=1	
The condition part	The concluding part L S5 ₁
IF S5.1 = 1 or S5.2 = 1 or S5.3 = 1 or S5.4 = 1 or S5.5 = 1 or S5.6 = 1	THEN there are abnormalities in bone and joint system (.....).
IF S10.8 = 1 or R3.3 = 1	Send to an orthopedist.
IF M10.1 = 1	

According to a neurological condition, production rules are:

The condition part	The concluding part L S10 ₁
IF S10.1 = 1 or S10.2 = 1 or S10.3 = 1 or S10.4 = 1 or S10.5 = 1 or S10.6 = 1 or S10.7 = 1 or S10.8 = 1 or S10.9 = 1 or S10.10 = 1 or S10.11 = 1	THEN there are abnormalities in neurological condition (.....). Send to a neurologist.
IF H11 = 1	

The condition part	The concluding part L R1 ₁
IF R1.1=1 or R1.2=1 or R1.3=1 or R1.4=1 or R1.5=1	THEN RF unfavourable heredity IS found. Recommends health check once a year.

The condition part	The concluding part L R7 ₁
IF R7.1=1 or R7.2=1 IF S6.2=1 IF M10.2=1 or M10.3=1 IF M11.1=1	THEN RF overweight, obesity IS found. Recommends a reduction of weight, consulting with the family doctor or endocrinologist.

Production rules can be easily programmed for computer realization purposes. Decision-making system has successfully passed the screening tests.

It should be noted that distribution of each production rule gives only a partial decision on the separate state of the system or the presence of RF. The final conclusion is made up of some (or all the) of partial decision compositions.

It is assumed that the partial decisions with 0-th values (there are no abnormalities) on the screen do not appear. The doctor and the patient indicate only the decisions that report the existence of the abnormalities, recommendations and guidance to final judgments, for which there are 2 options.

In the first case, the final conclusion is compiled of partial decisions, and it is only after the entire system S1 ÷ S12 inspections and all information of measurement modules M1 ÷ M14 is received. This compilation technique is the simplest one, but it has an important negation - it may be necessary to wait for the final conclusion, a relatively long period of time while dermoscopy results and supporting information come from the analysis centre.

The second version of the findings indicates the time order, once there is a computer decision on the state of the system, the patient after all the measurements would not be forced to go without any conclusion. Of course, each partial result is presented with the note that the final conclusion will be later after the approval of the analysis centre. Also, this option has a negation that appears in Fig. 1, that is, the analysis of a

particular system should be organized in some other system analysis and measurements. This complicates the decision-making software.

The choice of options is actually an issue of medical ethics. The MTSC has made the ultimate decision of the first option.

IV. CONCLUSIONS

- 1) The main input information used in the MTSC (interactive questionnaire and measurement modules) allows making a computer decision on 12 system conditions and risk factors.
- 2) Decision making in the chosen technology enables the creation of production laws and computer implementation.
- 3) The offered methodology allows creating a computer decision system with a practical application.

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Zigurds Markovičs. Lēmuma pieņemšanas algoritmi skrīninga dator sistēmā

Darbā piedāvāta datorizēta lēmumu pieņemšanas procesa tehnoloģija, kas domāta skrīninga jeb atsijājošās diagnostikas realizācijai ar mobila telemedicīnas skrīninga kompleksa MTSK palīdzību.

Lēmumu pieņemšanas loģika balstās uz divu galveno informatīvo plūsmu eksistenci. Viena no plūsmām ietver objektīvo mērījumu rezultātus, otra - pacientu subjektīvo informāciju par sūdzībām, izjūtām, riska faktoriem un hroniskām slimībām.

Darbā sniegta lemšanas tehnoloģija, sākot ar plūsmu savstarpējās saistības izpēti un beidzot ar lemšanas kārtulām produkciju likumu izskatā.

Зигурдс Маркович. Алгоритмы принятия решений для компьютерного скрининга.

В работе представлена компьютеризированная технология принятия решений, предназначенная для скрининга либо реализации atsijājošās диагностики по средствам мобильного комплекса скрининга телемедицины MTSK.

Логика принятия решений основывается на существовании двух основных потоков информации. Один из потоков включает в себя результаты объективных аппаратных данных и другой - субъективную информацию о жалобах пациента, его самочувствии, факторах риска и хронических заболеваниях.

В документе представлена технология принятия решения, начиная с изучения взаимосвязанности между потоками и заканчивая схемой принятия решений в виде производственных правил.