Principles of ostis-system of automatic diagnosis design

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***Abstract*—The work is devoted to the development of intelligent ostis-system of automatic diagnosis. This article presents analysis of well-known solutions to automation of physician's activities on handing down a medical decision problem. Article also deals with principles of knowledge base and knowledge processing machine for ostis-system of automatic diagnosis design based on semantic networks with set-theoretical interpretation.**

***Keywords*—medical diagnosis, automatisation, intelligent system**

I. Introduction

Possibility of setting and solving problems of automatic medical diagnosis without physician's participation has appeared in response to creating a new technological generation of wave diagnosis in the early part of the current century. This generation is the third after electrography technologies (gas discharge rendering) and frequency-resonant diagnosis. The new wave diagnosis was dubbed functional spectral-dynamic diagnosis (FSD-diagnosis) and honor of its creating belongs to S.M. Zakirov [9].

FSD-diagnosis can be undertaken by the following areas of activity:

1) nosological diagnosis (diagnosis of diseases);
2) system diagnosis (assessment of body systems functional status);
3) etiological diagnosis (detection of active viruses, bacteria, etc);
4) patient-specific complementary medicated products adjustment.

FSD-diagnosis is accomplished through Medical spectral-dynamic complex (MSDC). It's a computer appliance related to physical medicine solutions and designed for performing quick, delicate and quite universal (in reference to common diseases) diagnosis [4].

It's possible to mark the following FSD-diagnosis advantages:

1) simplicity of assessment procedure;
2) low assessment time (signal recording takes 35 seconds);
3) there's no necessity to process acupoints;
4) passive diagnosis mode, i.e. there's no effect on the human body;
5) instrumentation transportability;
6) accessibility for any physician;
7) diagnostic accuracy (more than 90 %);
8) MSDC marker base includes large amount of diagnostic markers (more than 8,000).

At the level of implemented by MSDC analysis, i.e. during the process of concrete processes presence recognition, three major modules are working with the patient's code including pattern recognition module, dynamics analysis module and abnormal aptitudes analysis module.

Pattern recognition module compares patient's code (pattern) with the codes (patterns) of prescribed diagnostic markers set and calculates the recognition probability metric (in %) for each marker.

Dynamics analysis module puts diagnostic markers in order of corresponding processes activity.

Abnormal aptitudes analysis module evaluates the level of abnormal aptitudes between spectral-dynamic codes of markers and patient on ordinal scale from 1 to 6.

The methodological basis for creating the automatic FSD-diagnosis systems, including telemedicine, is the combination of the passive mode of this diagnosis and its high informational content (diagnostic markers multitude). [3], [9].

II. Problem domain definition

At the physician level, the doctor uses dozens of markers (and sometimes hundreds) to perform the FSD-diagnosis of a particular disease and analyzes three quotients for each marker, including the similarity quotient (marker recognition probability in %), the process activity index (position in the list of the specific body system markers) and an indicator of the level of abnormal aptitudes (on the ordinal scale).

Consequently, physician has to manually process quotients values for markers multitude available from assessment to hand down a decision. This lead to substantial increase in duration of single patient diagnosis and to slowdown in physician's work efficiency due to fatigue cumulation through samely repeating actions performing and hence lead to risk of handing down a wrong decision increase.

At present, there is no such diagnosis automation tool that could integratedly assess (on the strength of all the informative parameters) the acute patient conditions in the express-analysis mode and would help the specialist to establish the definite diagnosis [7].

Based on the above, it follows that it's necessary to automate the pack of physician's measures in furtherance of handing down a diagnostic decision as soon as such opportunity exists in principle.

The existing diagnosis process automation tools require considerable costs to commissioning as well as to training of qualified professionals capable of maintaining such system and manipulating it at first hand [7].

III. Common approaches analysis

Medical diagnosis tasks are nothing more than recognition tasks with unfixed set of recognition objects.

Such knowledge representation languages as rule-based language (by using CLIPS and OPS) and first-order predicate logic (by using Prolog) are available for representation knowledge from medical diagnosis domain. Nevertheless, there are series of restrictions that are imposed upon the models listed above. These restrictions are hindering the designing of flexible and multifunctional system.

The production model has the disadvantage that when a fairly large number of productions (of the order of several hundred) is accumulated, they begin to contradict each other, in which case adding a new rule to the system causes difficulties for the developer and the expert. In addition, there is principal difficulties emerge during the system work validation due to inherent to the system nondeterminacy (ambiguous selection of executing production from the activated productions scope) [11].

One of the logical model disadvantages is that it is impossible to determine the truth or falsity of a sentence using rules specifying the language syntax. The sentence may be syntactically valid, but it could occur completely pointless. Another disadvantage is that most intelligent tasks are exemplified by completeness lack, deficiency and ill-posedness, that hinders their formalising based on sentential calculus [1], [8].

IV. Proposed approach

It's proposed to use Open Semantic Technology for Intelligent Systems (OSTIS) for automatic diagnosis system design [10].

Graph-dynamic models of special form – semantic models of representation and processing of knowledge based on semantic networks with set-theoretical interpretation – are used within the mentioned Technology as a formal basis for the designing intelligent systems.

Technology inherits all the fundamental advantages of semantic networks, and knowledge representation in the form of semantic networks enables to essentially simplify the knowledge integration procedure and to reduce this procedure to determining and merging synonymic elements of integrable semantic networks.

Approach based on semantic networks with set-theoretical interpretation has the following advantages in medical diagnosis domain:

1) knowledge representation by applying semantic networks is easier to understand and easier to see;
2) semantic networks enable to work not only with numeric parameters and characteristics values but with any nominal and order objects;
3) it's easier to follow and refine decisional process in semantic model of knowledge processing, i. e. it's enough to modify few infence rules or add some new ones for modification the decisional process without affecting the entire infence machine in case of making wrong decision or appearing a necessity of expanding the method;
4) system built upon semantic networks can explain the way it made one or another decision at any time, by user request.

The way of internal knowledge representation within OSTIS Technology is called SC-code (Semantic Code). Signs included into SC-code texts are called sc-elements [10]. Nodes of semantic network represented by SC-code are called sc-nodes and connections between them are called sc-connectors. Oriented connections are called sc-arcs, non-oriented ones are called sc-edges.

Semantic knowledge processing (problem solving) model within Technology represents an abstract multi-agent system consists of abstract semantic memory storing semantic networks and set of agents oriented on processing the semantic networks stored in mentioned semantic memory.

Practicability of automatic diagnosis intelligent system design applying OSTIS Technology relies on lack of sufficient tools of physician's activities on handing down a medical decision automation and predominance of approach based on semantic networks with set-theoretical interpretation over other knowledge representation models within medical diagnosis domain.

Systems designed by OSTIS Technology are called ostis-systems. Every ostis-system includes the following architectural components:

1) knowledge base;
2) knowledge processing machine;
3) user interface.

Consider next principles of ostis-system of automatic diagnosis design and composition of components it includes.

V. Principles of ostis-system of automatic diagnosis design

Proposed automatic diagnosis system has to solve the following key diagnosis problems:

- functional diagnostics (diagnosis of functional organism systems states);
- prenosological diagnostics (diagnosis of exposures to diseases);
- prednosological diagnostics (diagnosis of latent diseases);
- nosological diagnostics (diagnosis of symptomatic diseases);
- differential diagnostics diseases and other states.

The set of concrete states or diseases estimated probabilities is an input data for designed system.

The estimation of each state probability is making on the following order scale: very low, low, small, high, very high. Prior and post-hoc significances for each state are determined at some context. Interim decisions hierarchy with ranking will be generated in terms of those significances. Also it's determined which estimate scale values will be taken as crucial or near crucial values for each state.

Interim decisions in considered system are handing down in terms of patterns predefined within the scope of estimates subset designated for analysis per each state.

An end-point decision based on analysis and union of all interim decisions made for each assessed state is an output data for designed system.

Operation principle of proposed ostis-system of automatic diagnosis can be submitted in a form of scheme displayed on Figure 1.

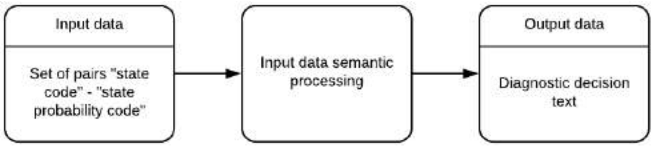

Figure 1. Operation scheme of ostis-system of automatic diagnosis

Consider some indications on described above scheme:

- state code – unique numeric identifier of state stored in ostis-system of automatic diagnosis knowledge base;
- state probability code – one of the following numeric values coding mentioned above state estimation scale: 1 - very low, 2 - low, 3 - small, 4 - high, 5 - very high;
- input data semantic processing – forming the diagnosis decision text based on semantic connections between states existing in knowledge base.

The algorithm of handing down a diagnosis decision appears as follows:

1) to sort the input estimates set in order of predefined priorities;
2) if it's enough data for handing down a decision, then make an interim decision for each estimate by using corresponding patterns;
3) if it's enough data for handing down a decision, then:
   a) to request additional data;
   b) if additional data is received, then return to step 2);
   c) if it's impossible to receive additional data, then hand down a decision of additional assessment requirement for current estimate;
4) to hand down an end-point decision (functional, prenosological, prednosological, nosological, permitting, limitative or prohibitive) or a decision of additional assessment requirement based on obtained interim decisions.

Consider the operation of ostis-system of automatic diagnosis on the following example. The estimates of two states are given as input data: Hepatitis C (state code - 1) and hepatoprotectors requirement state (state code - 2).

Some possible estimates of each state and based on them decisions are presented further on SCg language [2].

Memory state for small probability of both macroorganism states case is presented on Figure 2.

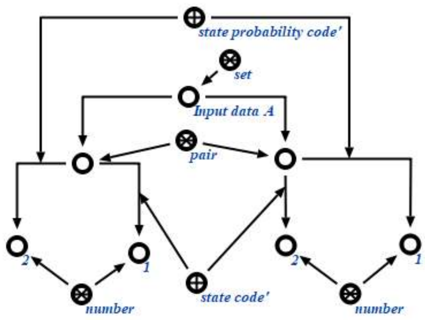

Figure 2. Input data for small probability of both states case

Decision of Hepatitis C clearance is handing down as the first state estimate is lower than high. The forming decision result is shown on Figure 3.

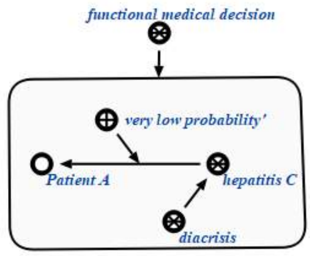

Figure 3. Output data for small probability of both states case

Input data for high probability of the first macroorganism state and small probability of the second macroorganism state case is presented on Figure 4.

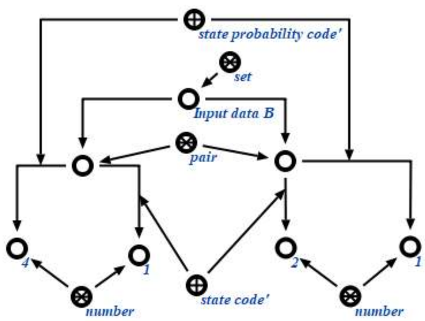

Figure 4. Input data for high probability of the first state and small probability of the second state case

Hepatoprotectors requirement estimate verifying is performing as Hepatitis C estimate is high. The second state estimate is lower than high in this way decision of Hepatitis C risk state is forming. Memory state as result of forming decision is shown on Figure 5.

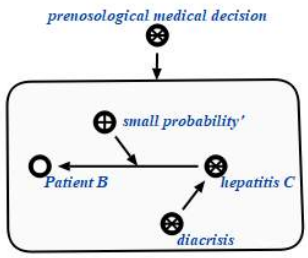

Figure 5. Output data for high probability of the first state and small probability of the second state case

High probability of the Hepatitis C and very high probability of the Hepatoprotectors requirement state case is presented on Figure 6.

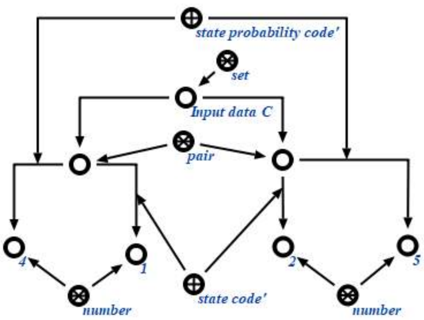

Figure 6. Input data for high probability of the first state and very high probability of the second state case

Hepatoprotectors requirement estimate verifying is performing as Hepatitis C estimate is high. The second state estimate is very high, consequently decision of Hepatitis C latency stage is forming. Result of forming described decision is shown on Figure 7.

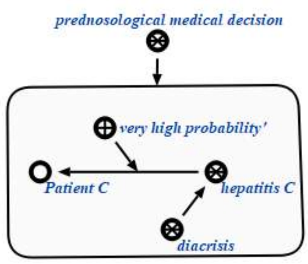

Figure 7. Output data for high probability of the first state and very high probability of the second state case

VI. Structure of ostis-system of automatic diagnosis knowledge base

Each ostis-system knowledge base is characterised by some highest level subject domain decomposition on more partial subject domains. As such, it's necessary to divide all knowledge presented in particular domain to thematic subject domain for designing a knowledge base of concrete ostis-system. Besides, it's necessary to determine the maximum class of researched objects, not maximum class of researched objects and researching relations set for each subject domain (if there are any). Maximum class of researched objects is a class of such entities described within subject domain that can't be outlined by means of more general entities on the scope of this subject domain. Subsequently, classes of entities that can't be subsumed as maximum classes of researched objects should be labeled as not maximum classes of researched objects [6].

A. Subject domains of ostis-system of automatic diagnosis knowledge base hierarchy

Subject domains determined within the medical diagnosis domain and their connections with subject domains from IMS knowledge base [2] are presented further on SCn language [2]:

1) Subject domain of medical diagnosis (medical diagnosis is considered as activity field in this case).

Subject domain of medical diagnosis
<= *particular subject domain**:
  Subject domain of actions and tasks
∋ *maximum class of researched objects'*:
  medical diagnosis
∋ *not maximum class of researched objects'*:
  diacrisis
∈ *subject domain*
∈ *structure*

2) Subject domain of macroorganism states.

Subject domain of macroorganism states
<= *particular subject domain**:
  Subject domain of temporal entities
∋ *maximum class of researched objects'*:
  macroorganism state
∋ *not maximum class of researched objects'*:
- *urogenital system state*
- *organism system state*
- *parasitic system state*
- *cardiovascular system state*
- *excitatory system state*
- *bronchopulmonary system state*
- *osteoarticular system state*
- *fungal system state*
- *immune system state*
- *detoxification system state*
- *endoecological system state*
- *virous system state*
- *digestive system state*

• *bacteritic system state*
• *ENT-system state*
∈ *subject domain*
∈ *structure*

It should be noted that each organism system can has a set of states (among them are diseases) and a set of diagnostic decisions corresponding to them. It's possible to hand down a set of diagnostic decisions relating to each endoecological system, among them are decisions relevant to causation of concrete disease.

3) Subject domain of medical decisions.

Subject domain of medical decisions
<= *particular subject domain**:
Subject domain of temporal entities
∋ *maximum class of researched objects'*:
medical decision
∋ *not maximum class of researched objects'*:
• *prohibitive medical decision*
• *functional medical decision*
• *limitative medical decision*
• *nosological medical decision*
• *permitting medical decision*
• *prenosological medical decision*
• *endoecological medical decision*
• *differential medical decision*
• *etiological medical decision*
• *prednosological medical decision*
∈ *subject domain*
∈ *structure*

B. Family of ostis-system of automatic diagnosis knowledge base ontologies

The system of ontologies, i. e. system of subject domain concepts properties and interconnections descriptions, was designed for Subject domain of macroorganism states on the authority of approach to knowledge bases designing described in OSTIS Technology [6]. Mentioned system of ontologies includes the following ontologies kinds:

1) structural specification;
2) set-theoretical ontology;
3) terminological ontology;
4) ontology of tasks classes and solution methods;
5) logical ontology;
6) integrated ontology [6].

Consider some of determined ontologies kinds for ostis-system of automatic diagnosis knowledge base.

Structural specification is an ontology that describes the roles of concepts included into subject domain and connections between described subject domain and other subject domains.

Set-theoretical ontology is an ontology that describes the set-theoretical connections between concepts of described subject domain.

Fragment of Subject domain of macroorganism states structural specification is presented on Figure 8.

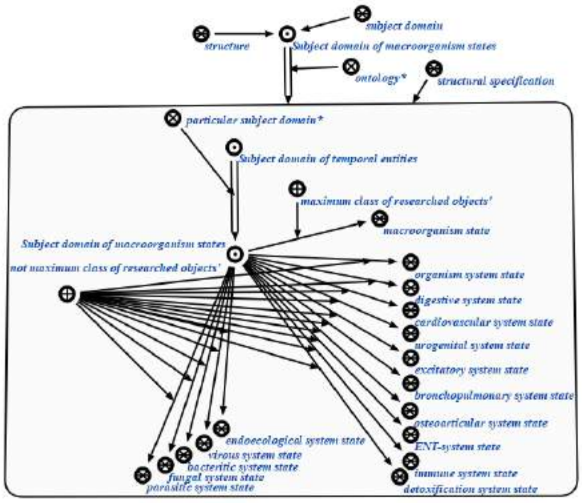

Figure 8. Fragment of Subject domain of macroorganism states structural specification

Fragment of Subject domain of macroorganism states set-theoretical ontology is shown on Figure 9.

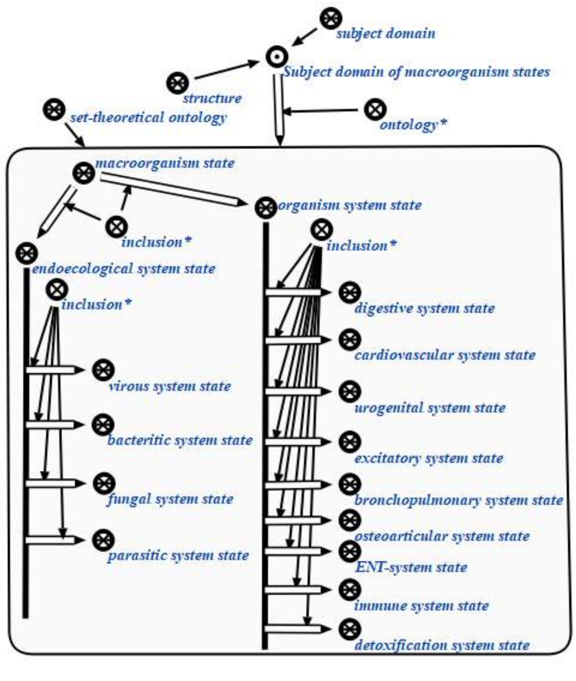

Figure 9. Fragment of Subject domain of macroorganism states set-theoretical ontology

VII. Structure of ostis-system of automatic diagnosis knowledge processing machine

Problem solving process in each ostis-system reduces to decomposition some common action to subactions which performing will lead to problem solving. Knowledge processing machine of each ostis-system represents collective of sc-agents aimed to performing the actions, which signs appear in unified semantic memory during the system work [5].

Hierarchy of sc-agents, which collective activity is aimed on end-point medical decision forming based on input set of states estimates analysis, was designed in terms of described above algorithm of handing down a diagnosis decision. Determined sc-agents hierarchy is presented further on SCn language.

Knowledge processing machine of ostis-system of automatic diagnosis
<= *abstract sc-agent decomposition**:
{
- *Abstract sc-agent of task for handing down a medical decision forming*
- *Astract sc-agent of input estimates set sorting*
- *Abstract sc-agent of input data sufficiency for handing down a decision checking*
- *Abstract sc-agent of interim decision forming*
- *Abstract sc-agent of task for additional data request forming*
- *Abstract sc-agent of additional data receiving*
- *Abstract sc-agent of end-point decision forming*

}

VIII. Conclusion

Principles of ostis-system of automatic diagnosis design by using OSTIS Technology are described in the work. Handing down medical decisions by solving different types of medical diagnosis problems is the purpose of proposed system. In future, it's possible to expand the capabilities of this system by not only considering a macroorganism as diagnosis object but any system that can be amenable to diagnosis whether it be a biological or technological system. Operating principles of the system, knowledge base structure top-levels and algorithms of forming decisions will stay the same on that assumption yet the application field of the system will significantly extend.

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ПРИНЦИПЫ ПОСТРОЕНИЯ OSTIS-СИСТЕМЫ АВТОМАТИЧЕСКОЙ ДИАГНОСТИКИ

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Работа посвящена разработке интеллектуальной ostis-системы автоматической диагностики. В статье проанализированы известные подходы к решению задачи автоматизации деятельности врача по вынесению медицинского заключения, а также рассмотрены принципы построения базы знаний и машины обработки знаний для ostis-системы автоматической диагностики на основе семантических сетей с теоретико-множественной интерпретацией.