# Mathematical Modeling of Diagnosis and Diagnostic Information Space of Chinese Image Medicine for their Unified Representation in Information Systems for Integrative Scientific Medicine

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**Abstract**

The article is devoted to mathematical modeling of the diagnostic space of Chinese image medicine, which is an important stage in the development of an integrated onto-oriented information-analytical environment of research, professional healing and e-learning of Chinese image medicine, which is a representative of unconventional medical areas and a promising component of integrative scientific medicine. A unified model of diagnosis in Chinese image medicine has been developed, which is a function of topological and nosological ontologies, as well as ontologies of methods and ontologies of metrics and scales in Chinese image medicine.

**Keywords 1**

Mathematical modeling, diagnostic space, ontology, information system, Chinese image medicine, integrative scientific medicine.

## 1. Introduction

The modern world is characterized by rapid progress in the information-communication technologies development , which significantly affects all industries, and in particular medicine, and also becomes a determining factor in the successful formation of a promising medical field - integrative scientific medicine. Integrative medicine is developing worldwide, meeting the demand of the international community for the development of alternative and complementary medicine through the integration of the achievements of folk medical practices on an inter-complementary basis and based on the principles of evidence-based medicine [1-3]. Its prospects are due to the application of individual norms, holistic (integral) approach to the patient at the theoretical and applied levels, emphasis on prevention and rehabilitation of the body by activating its internal potential, complex substrate-energy-information nature of diagnostic and therapeutic procedures, their efficiency and economy.

In China, integrated medicine has become an integral part of the public health system, successfully combining the achievements of Western medicine and traditional Chinese medicine. In recent years, there has been a growing interest in the research of methods and tools of Chinese imaging medicine (CIM), which is a component of traditional Chinese medicine [4], has deep historical roots, is actively spreading and developing around the world (China, USA, Canada, Brazil, Switzerland, Germany, Hungary, Slovakia, Ukraine, Czech Republic, Latvia, Estonia, Russia, etc.). Beijing Kundawell Medical Research Institute (China) is a world-famous center for teaching and researching Chinese imaging medicine.

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Due to the ancient Chinese origin of CIM, most of its diagnostic and therapeutic methods are purely intuitive, empirical, and difficult to formalize; knowledge is fuzzy, poorly structured and polysemantic [5]. All this is an obstacle to the creation of a full-fledged scientific paradigm of CIM in medicine, as many theoretical and experimental aspects and patterns of this medical field of folk medicine remain unclear. To reveal the root causes and mechanisms of human diseases, unification and formalization of traditional CIM theory knowledge and the creating of its qualitative scientific theory, the Research Program of Chinese Image Medicine for 2017-2023 was developed [6]. The program is aimed at solving a problems range of theoretical, clinical, experimental and information-analytical areas. One of the current scientific and applied tasks of the Program, as well as the strategy of the World Health Organization in the field of folk medicine [7], is to create an integrated onto-oriented information-analytical environment of research, professional healing and e-learning CIM, the core of which will be an ontology of diagnostic and therapeutic methods of CIM. An important stage in the development of an integrated information environment for CIM is the creation of mathematical and software tools for a unified presentation and specification of diagnostic patient information, which is obtained by both Western scientific medicine and CIM. This work, in fact, is devoted to the creation of a mathematical model of diagnosis and diagnostic space CIM for their representation in an integrated onto-oriented information-analytical environment.

## 2. Main part

The developing purpose an information-analytical environment for CIM, the generalized architecture of which is presented in Fig.1 [8], is to ensure effective organization and coordination of existing CIM-therapists, CIM researchers, people studying CIM, as well as the formation of modern intellectualized information means and resources in the field of folk, complementary and integrative medicine at both national and international levels [9].

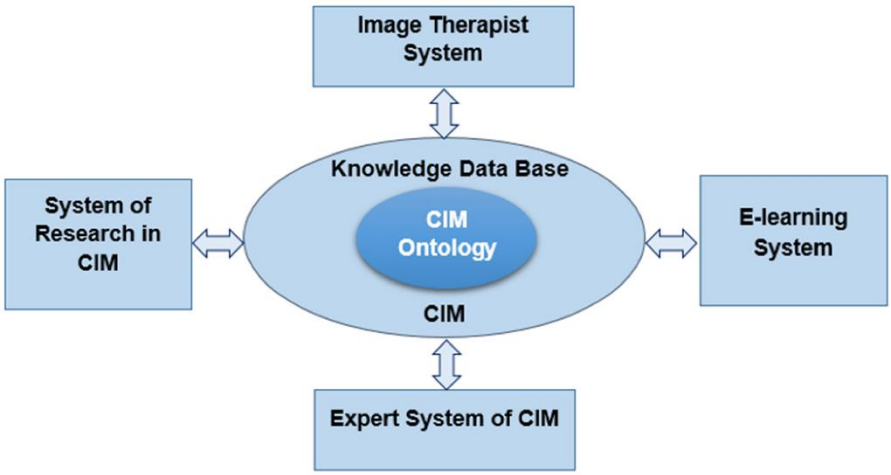


**Figure 1**: General architecture of integrated onto-oriented information analytical environment of scientific researches, professional healing activities and e-learning of Chinese image medicine

Diagnostic information about the patient in an integrated onto-oriented information-analytical environment of scientific research, professional healing and e-learning of Chinese imaging medicine is proposed to provide according to table 1.

**Table 1**
Diagnostic information types in the integrated information analytical environment for CIM

| | |
|---|---|
| Personal information (age, gender, family members, etc.) | Self-assessment information (physical and psychological condition) of the patient before and after therapy, using methods of psychological scaling |

| | |
|---|---|
| Medical information about the patient includes information obtained by methods of conventional (Western) medicine, namely, medical history and results of medical examinations (laboratory tests, results of functional diagnostics, doctor's report, etc.) | Diagnostic information obtained by TCM and CIM methods, namely, the results of diagnosis by TCM (examination, listening, palpation diagnosis results), the results of energy diagnosis by hand and (or) body, the results of internal imaging ("eye of the mind", "second heart") |

If the formation of personal information about the patient, his medical data obtained by conventional Western medicine (medical history, laboratory tests, results of functional diagnostics, etc.), the patient's self-rating information does not contain fundamental difficulties, the formation of diagnostic information by CIM methods is difficult scientific problem, the solution of which is possible by developing new mathematical models, methods and means of presenting diagnostic information obtained by CIM methods.

Creation of diagnostic space $\boldsymbol{X}$ CIM should be preceded by the development of a diagnostic ontology $\boldsymbol{O}_D$ CIM (ontology of the theory and technologies of diagnosing in CIM), which as its sub-ontology should include nosological ontology $\boldsymbol{O}_N$ CIM, topological diagnostic ontology $\boldsymbol{O}_T$ CIM, and ontology $\boldsymbol{O}_M$ methods of obtaining and specifying sensory-image diagnostic information (diagnostic methods ontology ) in CIM, as well as an ontology $\boldsymbol{O}_S$ diagnostic metrics and scales in CIM. 130 concepts of CIM were selected and used to build these ontologies.

From a formal point of view, the diagnostic ontology of CIM can be presented as such four of its sub-ontologies:

$$\boldsymbol{O}_D = \{\boldsymbol{O}_T, \boldsymbol{O}_N, \boldsymbol{O}_M, \boldsymbol{O}_S\}, \quad (1)$$

Topological diagnostic ontology $\boldsymbol{O}_T$ CIM displays information about the topological localization of diseases. Nosological ontology $\boldsymbol{O}_N$ CIM reflects knowledge of the diseases types (classes) that are accepted in the diagnostic theory of CIM.

Ontology $\boldsymbol{O}_M$ diagnosing methods in CIM reflects knowledge of obtaining methods and specifying sensory-diagnostic information in CIM. Diagnostic methods are the basis for perception and identification (characterization) of the patient's condition in terms of nosological taxonomy of CIM.

Creating such ontologies (taxonomies) is a difficult task and requires some thorough research. Some issues of ontological modeling are considered in [10].

Information on the components of the diagnostic ontology of CIM is grouped in table 2.

**Table 2**

Components of the CIM diagnostic ontology

| Components of the CIM diagnostic ontology | Components description of the diagnostic CIM ontology |
|---|---|
| NOSOLOGICAL ONTOLOGY CIM | Nosological ontology of CIM reflects knowledge about types (classes) of diseases which are accepted in the CIM diagnostic theory |
| TOPOLOGICAL DIAGNOSTIC ONTOLOGY CIM | Topological diagnostic ontology CIM reflects information on the topological localization of diseases involving the physical body, energy system (field system, Qi system) and information systems (psycho-mental-spiritual system, Shen system) of human, in particular, contains information about body parts, organs , physical body tissues , information about bioactive points and energy channels of the human energy system, information about informational, psycho-emotional, mental and spiritual topological aspects of man. |
| ONTOLOGY DIAGNOSIS METHODS OF CIM | The ontology of diagnostic methods in CIM reflects knowledge about methods (channels) of receiving and specifications of |

| | |
|---|---|
| | sensory-image diagnostic information in CIM. |
| ONTOLOGY OF DIAGNOSTIC METRICS AND SCALES IN CIM | Describes the quantitative characteristics (indicators) of the diagnostic space of CIM, which determine the disease manifestation degree and can be set to a certain numerical (for example, from 1 to 5) or non-numerical (for example, very weak, weak, medium, strong, very strong) scale. |

At the most abstract level, the diagnostic space can be represented as a set of all possible diagnoses in the CIM, and each individual diagnosis will be presented as a result of design according to a certain procedure $\boldsymbol{F}(\cdot)$ from the ontologies described above. In this case, the CIM diagnostic space is a function of the ontologies $\boldsymbol{O}_T,\ \boldsymbol{O}_N,\ \boldsymbol{O}_M,\ \boldsymbol{O}_S$, namely:

$$\boldsymbol{X} = \boldsymbol{F}\{\boldsymbol{O}_T, \boldsymbol{O}_N, \boldsymbol{O}_M, \boldsymbol{O}_S\}, \quad (2)$$

where $\boldsymbol{F}(\cdot)$ – a certain type of method (algorithm, procedure) formation of the diagnosis in CIM from the corresponding ontologies $\boldsymbol{O}_T,\ \boldsymbol{O}_N,\ \boldsymbol{O}_M,\ \boldsymbol{O}_S$.

The creation of the above ontologies and taxonomies is the first step in building a model of the diagnostic space CIM. The next research stage is to build a procedure for forming a diagnostic space for diseases ontology in CIM, topological ontology, ontology of diagnostic methods and ontology of metrics and scales in CIM.

The taxonomy can be graphically represented as an ordered root tree, the nodes of which are glossary-concept classes, and the edges will reflect the inclusion ratio. This method of graphical taxonomies representation is often used in ontology development environments. For convenience CIM diagnostic space formation from the above taxonomic trees it is necessary to carry out coding of their tops. We will use this principle of coding nodes of taxonomic trees. Each taxonomic tree is assigned a serial number $n_0$ from 1 to 4. For example, to ontology $\boldsymbol{O}_T$ is assigned number 1 ($n_0 = 1$), to ontology $\boldsymbol{O}_N$ is assigned number 2 ($n_0 = 2$), to ontology $\boldsymbol{O}_M$ is assigned number 3, and to ontology $\boldsymbol{O}_S$ is assigned number 4. The upper node (root) of the taxonomic tree will be denoted by a number equal to the ordinal number of the corresponding taxonomic tree (corresponding ontology). Each level of a taxonomic tree is encoded by an integer equal to the number of its appearance in the direction from the top (root) of the tree to its branches. In general , $k$-th level of a taxonomic tree with a serial number $n_0$ is presented as a combination of numbers separated by a period $\mathrm{n}_0.k_1., \ldots k_i$ , where the first component displays the ordinal number of the taxonomic tree, and $\boldsymbol{i}$ displays the ordinal number of the level in this taxonomic tree. For any node, the last digit indicates its sequence number at this level from its ancestor, and all previous digits indicate the ancestor node. Figure 2 shows an example of coding taxonomic tree nodes according to the above approach.

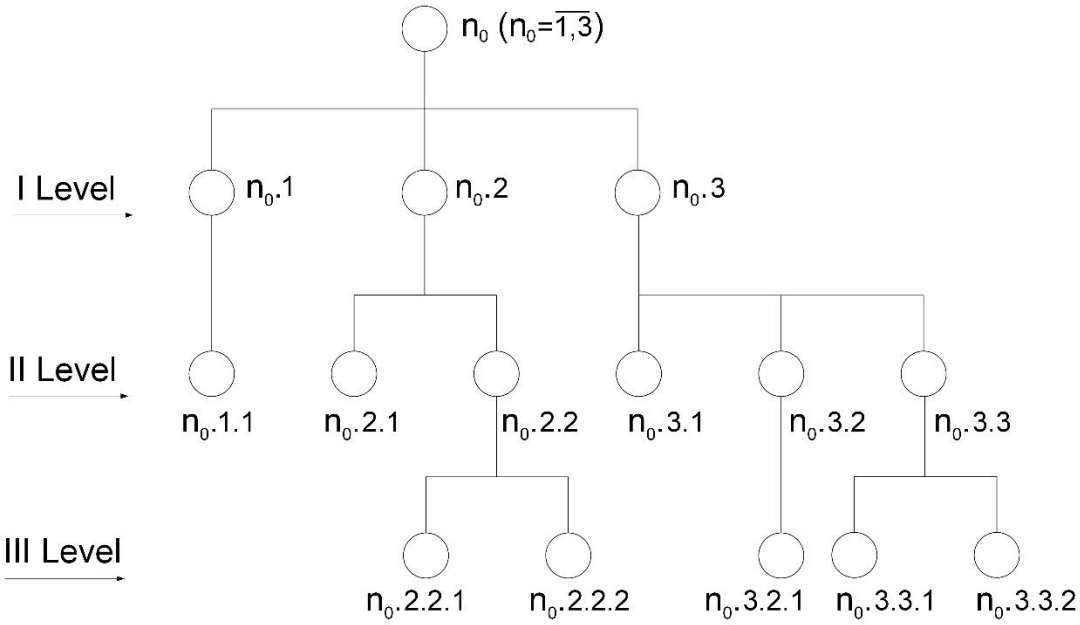


**Figure 2:** Coding example of taxonomic tree nodes for CIM

Based on the above, we create a procedure for forming a vector $X = (x_1, x_2, \dots, x_N)$ information diagnostic space $\boldsymbol{X}$ Chinese image medicine, which is a unified formalized representation of the diagnosis by CIM methods. Each $\boldsymbol{i}$ −th component $x_i$ of vector $X = (x_1, x_2, \dots, x_N)$ reflects the detected by the CIM-therapist deviation from the norm in the physical system, energy system and information system of the diagnosed patient. The total number of $N$ components of the diagnostic vector $X = (x_1, x_2, \dots, x_N)$ for each patient, in general, will be different, because it is the number of detected by the CIM-specialist deviations (diseases, pathogenic factors) in a particular patient, which are presented in terms of constructed nosological and topological taxonomies of CIM.

In general, $\boldsymbol{i}$ −th component $x_i$ of vector $X = (x_1, x_2, \dots, x_N)$ is four formal objects:

$$x_i = \langle \left(n_{O_T}.k_1., \dots\ k_j\right)_i, \left(n_{O_N}.l_1., \dots\ l_j\right)_i, \left(n_{O_M}.g_1., \dots\ g_j\right)_i, m_i \rangle, i = \overline{1,N}, \quad (3)$$

where $\boldsymbol{j}$ – ordinal number of the level of the corresponding topological taxonomic tree ($\boldsymbol{O}_T$, $\boldsymbol{O}_N$, $\boldsymbol{O}_M$, $\boldsymbol{O}_S$), and $n_{O_T}.k_1., \dots\ k_j$ – node ordinal number of the topological taxonomic tree $\boldsymbol{O}_T$; $n_{O_N}.l_1., \dots\ l_j$ – node ordinal number of the taxonomic tree $\boldsymbol{O}_N$; $n_{O_M}.g_1., \dots\ g_j$ – node ordinal number of the taxonomic tree $\boldsymbol{O}_M$; $m_i \in \overline{1,5}$ – a natural number that can take values from 1 to 5 and characterizes the manifestation degree of the disease (deviation from the norm, pathogenic factor) (in the absence of deviations from the norm number $m_i = 0$, larger value $m_i$ indicates a greater manifestation degree of the disease). You can provide the following numerical scale interpretation of the disease manifestation degree: 1 – very weak, 2 – weak, 3 – medium (moderate), 4 – strong, 5 – very strong. Figure 3 shows an example of the formation of a diagnostic vector according to the above approach.

Figure 3, for example, presents simplified fragments of ontologies $\{\boldsymbol{O}_T, \boldsymbol{O}_N, \boldsymbol{O}_M, \boldsymbol{O}_S\}$, and the dashed line connects the nodes that were selected in the diagnostic process. Thus, the vector $X = (x_1, x_2, \dots, x_N)$ information diagnostic space $\boldsymbol{X}$ Chinese image medicine for this example will be displayed as $X = (1.1, 2.2.1, 3.3, 4.1)$.

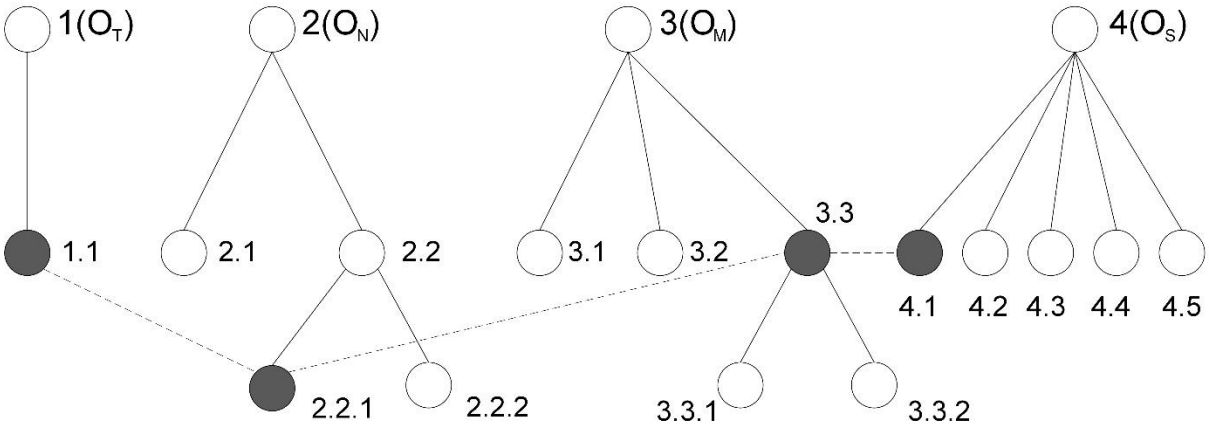


**Figure 3:** Procedure for forming a diagnostic vector for CIM

In addition to the above information, there is a field in which the CIM-specialist can provide in text format additional information that is not displayed by means of formal ontologies, or that clarifies this information.

Thus, the diagnostic space ***X*** contains both qualitative and quantitative characteristics (indicators), which in their entirety holistically characterize the patient's condition by CIM methods. Qualitative characteristics are contained in CIM ontologies, and quantitative ones determine the manifestation degree of a disease and can be set on a certain numerical (for example, from 1 to 5) or non-numerical (for example, very weak, weak, medium, strong, very strong) scale. Any vector (other than zero) from space ***X*** indicates the presence of a certain type of disease in the patient, which are detected by CIM methods.

For the convenience of forming a diagnostic vector of the patient's condition by CIM methods it is appropriate to develop an interactive visual environment based on an image model of the human body and its parts, including physical, energy, informational aspects, as well as aspects of Yin-Yang, Emptiness. Figure 4 shows one of the windows of this ontooriented system of professional healing activities "Image Therapist", the core of which is the diagnostic and therapeutic ontologies of CIM.

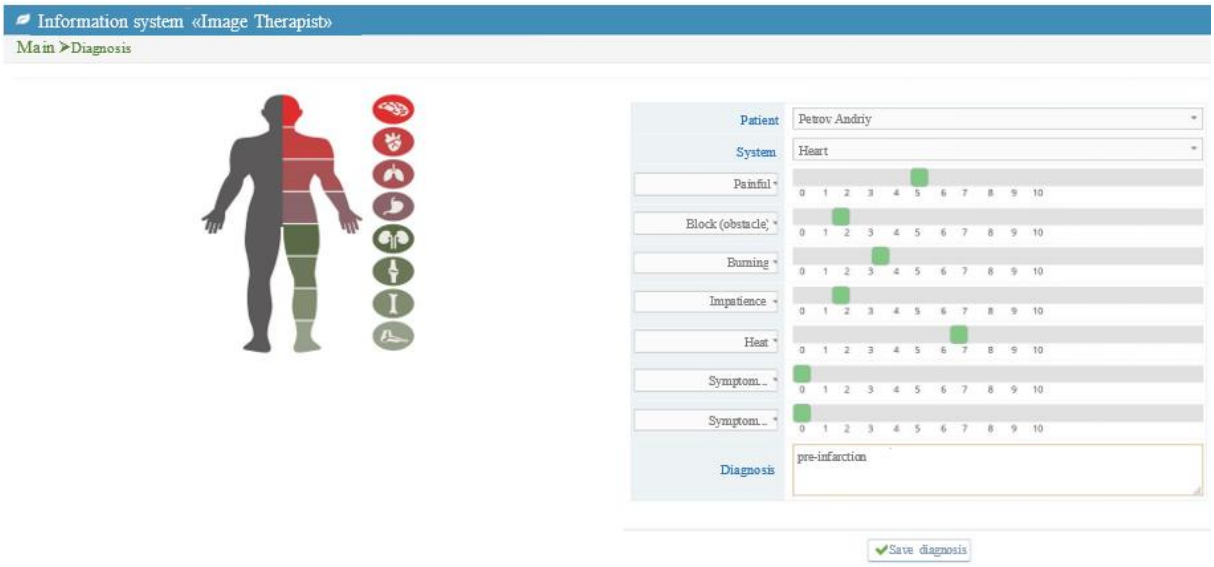


**Figure 4:** Window with CIM-diagnostic information

## 3. Conclusions

The mathematical model of diagnostic space of CIM is constructed and the unified model of the diagnosis is developed for their representation in the integrated onto-oriented information-analytical environment. This mathematical model of diagnostic space contains both qualitative and quantitative characteristics, which in their entirety holistically characterize the patient's condition by CIM methods. A prototype of the Image Therapist system is described, in which are partially implemented the described approaches about the diagnostic space and the model of diagnosis in CIM.

The developed model allows, along with the input of diagnostic information obtained by methods of Western (official) medicine, to enter diagnostic information into the information system obtained by CIM methods, which opens new possibilities for automated comparative analysis of different diagnostic approaches in integrative scientific medicine.

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