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# Engineering of a Knowledge Management System for Relational Medical Diagnosis

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# Engineering of a Knowledge Management System for Relational Medical Diagnosis

by

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# DEDICATION

To my parents, Enrique and Lesvia, for their unconditional love; and to my sisters Martha, Milena and Monica, for the continuous motivation and enduring reminder of what is really important in life.

To my husband and best friend, Kirk William, for laughing with me, for his loving support and for being there for me through thick and thin.

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## ABSTRACT

The increasingly high costs of health care in the U.S. have led the general public to search for different medical approaches. Since the 1990's, the use of Complementary and Alternative Medicine (CAM) has radically increased in the U.S. due to its approach to treat physical, mental, and emotional causes of illness. In 2009, the National Health Statistics reported the impact of CAM in the U.S. health care economy, with population expenditures of $14.8 billion out-of-pocket on natural Medicine and $12.4 billion out-of-pocket on visits to CAM providers as a complement to Western Medicine care.

CAM interconnects human functions to reach a balanced state, whereas Western Medicine focuses on specialties and body systems. Both Western Medicine and CAM are unlimited sources of knowledge that follow different approaches but that have the common goal of improving patients' well-being. Identifying relationships between Alternative and Western Medicine can open a completely new approach for health care that can increase understanding of human medical conditions, and facilitate the development of new and more cost-effective treatments. However, the abundance and dissimilarity of CAM and Western Medicine data makes knowledge correlation and management an extremely challenging task.

The objective of this research is to design the framework for a knowledge management system to organize, store, and manage the abundant data available for Western Medicine and CAM, and to establish key relationships between the two practices for an effective exploration of ideas and possible solutions for medical

diagnosis. Three main challenges in the design of the proposed framework are addressed: data acquisition and modeling; data organization, storage and transfer; and information distribution for further generation and sharing of medical knowledge. A framework to relate the diagnosis process in Western Medicine and Traditional Chinese Medicine, as one of the various forms of CAM, is presented based on process-oriented analysis, hierarchical knowledge representation, relational database, and interactive interface for system utilization. The research is demonstrated using a case study on chronic prostatitis, and can be scalable to other medical conditions.

The presented system for knowledge management is not intended to provide a definite solution for medical diagnosis, but to enable the exploration and discovery of knowledge for relational medical diagnosis. The results of this research will positively impact information distribution and knowledge generation via interactive medical knowledge systems, development of new skills for diagnosis and treatment, and a broader understanding of medical diseases and treatments.

# CHAPTER 1

# INTRODUCTION

This chapter introduces the research motivation and current challenges for relating Complementary and Alternative Medicine (CAM) and Western Medicine. The proposed research objectives and contributions are also presented, followed by the dissertation outline.

## 1.1 Motivation

The U.S. health care system is facing critical challenges in delivering cost-effective and high quality service. In the U.S., adults receive less than 55% of recommended care due to lack of access to medical knowledge [1]. Providing access to medical knowledge is complex due to the abundant volume of knowledge and information available, and their fragmentation across different systems and disciplines. State of the art research on medical information management is limited to specific pathologies, e.g., cancer diseases [2] and rheumatoid arthritis [3]. The major drawback of these applications is that they do not consider the human body as a fully-interconnected-system. As a result, these applications isolate medical knowledge of particular disorders and severely limit the exploration of potential causes for disorders that originate from different body areas.

In the pursuit of better health care, adults in the U.S. have increasingly used Alternative Medicine to complement conventional medical care. According to the 2007

U.S. National Health Interview Survey, approximately 38% of adults use Complementary and Alternative Medicine (CAM) as a complementary approach for treating not only physical manifestations of illness, but also for treating mental and emotional causes through a mind-body approach. This trend is also observed in medical education, where there is an increasing number of health-related educational programs that are recently introducing CAM into medical education. In the U.S., 42 medical schools taught Alternative Medicine in 1995 increasing to 98 schools by 2003 [4], [5].

Some forms of Alternative Medicine are Traditional Chinese Medicine, naturopathy, chiropractic Medicine, biofeedback and acupuncture. These alternative healing practices are generally comprised of historical or cultural traditions instead of scientific basis, and provide an ancient, relational knowledge that considers the human body as a whole, fully-interconnected system. Other observations supporting the increased popularity of CAM are the effectiveness and lower cost of natural treatments that lead to fewer side effects, customized therapies sensitive to the patient's background and lifestyle, and a close patient-doctor communication [6].

Currently, Western Medicine has accepted the presence of Alternative Medicine more as an optional resource and not as a collaborative partner to care for the patient's well-being. The main resistance of Western Medicine towards Alternative Medicine resides in the lack of scientific methods, clinical trials, laboratory tests, and evidence-based publications on the effectiveness of alternative practices. Nevertheless, the growing demand for CAM has led to a major need for its scientific understanding and the need for care providers to learn more about it. In the U.S., the National Institutes of Health (NIH) established the National Center for Complementary and Alternative Medicine (NCCAM) in 1998 for scientific research and training on Alternative Medicine.

The major challenge for achieving collaborative work between CAM and Western Medicine is the enormous difference between the two medical approaches. CAM interconnects human functions to reach a balanced state, whereas Western Medicine focuses on specialties and body systems. Both CAM and Western Medicine are unlimited sources of knowledge that follow different approaches but that have the common goal of improving the patients' well-being. Identifying relationships between CAM and Western Medicine can open a completely new approach for health care that can increase understanding of human medical conditions, and facilitate the development of new and more cost-effective treatments. However, the abundance and dissimilarity of CAM and Western Medicine data makes data management, learning process, and knowledge creation and sharing extremely challenging tasks. Tools that support data mining and knowledge management for collaborative Medicine are needed to bridge the current gap between CAM and Western Medicine knowledge.

This dissertation presents a framework for a relational medical knowledge management system to acquire, organize, store, and transfer the abundant data available for CAM and Western Medicine, and to establish key relationships between the two practices for the effective exploration of ideas and possible solutions for medical diagnosis, and further creation of new medical knowledge. This work focuses on Traditional Chinese Medicine (TCM), one of the various forms of CAM. TCM practices a full-body systematic and relational diagnosis process to maintain patients in a healthy mind and body state, and to identify potential origins and causes of diseases. On the other hand, Western Medicine identifies particular body diseases' and addresses specific treatment plans based on advanced technology. Relating the alternate views of the human body by current Traditional Chinese and Western practices can lead to a

complementary and fully-interconnected health care. This can potentially improve medical diagnosis and treatment while enhancing patients' well-being.

### 1.1.1 Western Medicine and Complementary and Alternative Medicine for Health Care

Approaching the human body as a fully-interconnected system for medical diagnosis requires the identification of relational medical data while organizing and accessing it accordingly. From Western Medicine, the blood and circulatory systems in Figure 1.1(a) are fundamental concepts to explain how minerals and nutrients are transported to muscle, bones, tissues, organs and other components in the human body. With blood and nutrients in it, the human body maintains the normal functioning of its material side.

From TCM, the main channels system in Figure 1.1(b) is presented as a fundamental concept to explain how energy flows in the human body. With this energy flowing naturally, the unit functions that interconnect organs and body parts directly and indirectly are kept balanced and reflect the patient's balanced health and quality of life. TCM is considered to have a structured approach and organization of the knowledge of the human body. TCM can be considered as a relational knowledge base practiced for over 5,000 years that can serve as the foundation of a knowledge management system for medical applications.

The alternate views of the human body by current TCM and Western Medicine practices provide a research opportunity to identify key relationships between both practices that can establish a completely new approach for complementary and fully-interconnected health care, as shown in Figure 1.1(c).

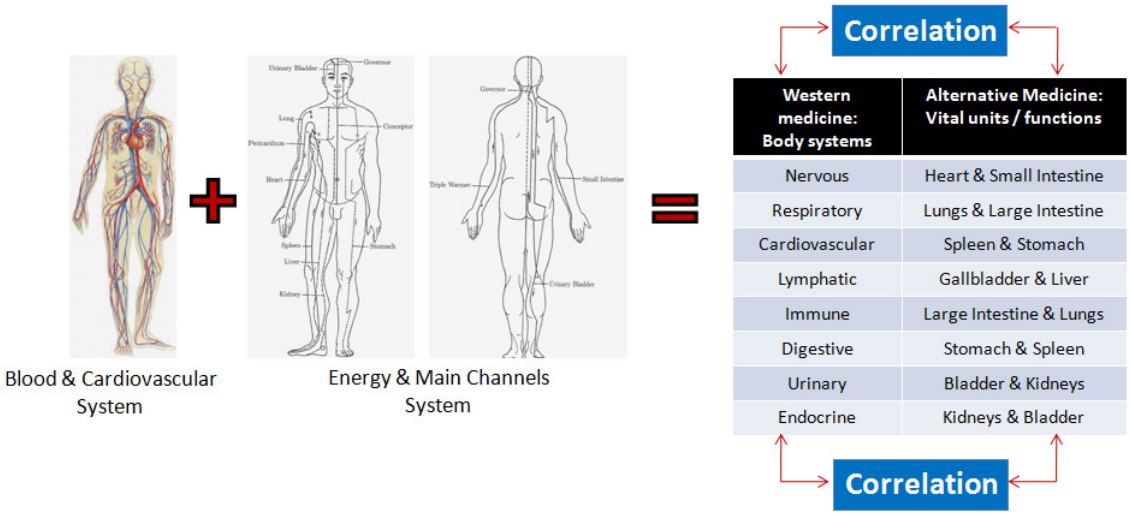



Figure 1.1. The human body seen from a) Western Medicine, b) TCM and c) Correlations between body systems in Western Medicine and body vital functions in TCM.

Western Medicine has scientific and evidence-based understanding of symptoms and syndromes detection and treatment. Clinical trials and published reports facilitate an open discussion and acceptance of conventional medical practices. In case of life threatening emergencies, the advanced developments in technology and drug design are useful for treating patients' health conditions in a timely manner. Medical specialties, such as Neurology, Cardiology, Dentistry, Ophthalmology, and Orthopedist and their correspondent clinical laboratory procedures, allow practitioners to focus on particular areas of the human body increasing their level of expertise for differential diagnosis and treatment of medical conditions. However, these isolated medical practices and the undesired drug side effects limit the discovery of the root cause of particular dysfunctions. The mentioned isolation also limits the knowledge of how different parts of the human body are correlated and could be impacted.

On the other hand, healing practices in CAM are generally based on historical or cultural traditions, instead of scientific basis. Besides TCM, CAM also includes practices such as naturopathy, chiropractic Medicine, biofeedback and acupuncture. In CAM, the patient's health is treated in a preventive manner, maintaining a balanced state of the human vital units and functions. When disorders occur, physical symptoms are analyzed along with lifestyle, nutritional habits, and emotional and mental factors making the diagnosis and treatment processes customized to every single patient. Herbs, natural compounds and therapies are part of the approaches to treat health disorders, and are preferred by the general public for their low probability of causing side effects. Nevertheless, these treatments are efficient in the long term but not suitable for emergencies or life threatening conditions.

### 1.1.2 Western Medicine and Complementary and Alternative Medicine in the U.S. Health Care Systems

The growing demand for Alternative Medicine has led to a major need for its scientific understanding and the need for care providers to learn more about it. In the U.S., the number of annual visits to CAM practitioners increased between 1990 and 1997, and between 2002 and 2007, as reported by the U.S. Department of Health and Human Services [6] and by Eisenberg et al. [7] (see Figures 1.2 and 1.3). The NCCAM in the U.S. promotes evidence-based practices of TCM and other forms of CAM that are scientifically compatible with Western Medicine, to objectively compare diagnosis approaches, prescriptions, and treatment effects [8], [9]. As a result of these efforts, Western Medicine has accepted the presence of CAM as an optional resource, but not officially as a collaborative partner to care for the patient's well-being.

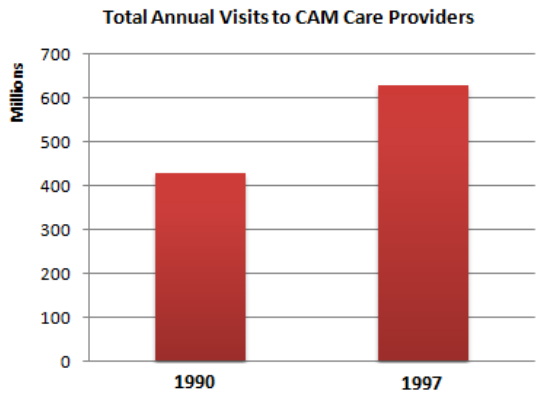



Figure 1.2. Comparison of general public visits to CAM providers between 1990 and 1997. Source: [7]

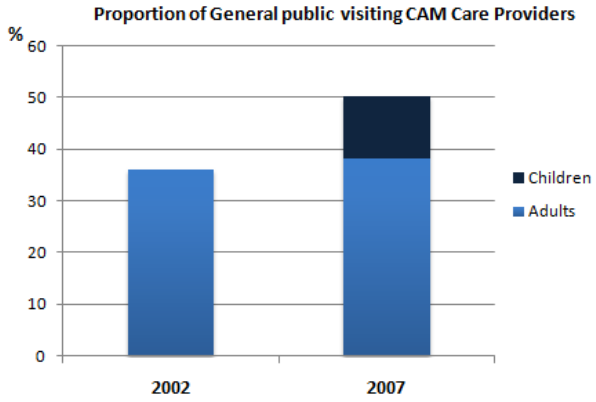



Figure 1.3. Comparison of general public visits to CAM providers between 2002 and 2007. Source: [6]

The major challenge for integrating Western Medicine and CAM is the difference in educational and cultural background between the two medical approaches. Western Medicine characterizes syndromes based on similar symptoms found in groups of patients under similar and identified conditions such as age, ethnic background, and geographic location. It then applies similar treatment based on the syndrome description, independently of each patient and his/her particular medical condition and personal circumstances.

In contrast, CAM customizes the diagnosis process for each patient by making observations of the symptoms experienced by the patient, based not only on physical signs, but also making count of the emotional and mental states. By gathering information regarding the patient's lifestyle and nutritional habits along with the patient's behavior, the CAM practitioner gets a whole view of the body functions and a global perspective of the potential root causes of disorders in the human body as a fully-interconnected system.

When acknowledging each other's medical knowledge and working together in a collaborative way, CAM and Western Medicine complement each other by practicing the systematic and relational diagnosis process of CAM, followed by the expertise and advanced technology of Western Medicine. Integrated, CAM and Western Medicine can maintain healthy patients in mind and body, identify potential origins and causes of diseases, measure and differentiate symptoms objectively, and address better-informed treatment plans.

## 1.2 Research Novelty and Objectives

Given the growing demand for CAM care to complement Western Medicine treatments, the diversity of medical information, and the lack of methodology for integrating knowledge management, there is an urgent need for new tools to support data mining, exploration, learning and creation of new knowledge for collaborative Medicine.

This dissertation presents the design of a framework for a knowledge management system to enable the management of abundant data available for Western Medicine and TCM, and to establish key relationships between the two practices for exploration of the

solution space for medical diagnosis. Three main challenges in the design of the proposed framework are addressed, as presented in Figure 1.4: Data acquisition and modeling, data organization, storage and transfer and information distribution for further generation and sharing of medical knowledge. A framework to relate the diagnosis process in Western Medicine and TCM is presented based on process-oriented analysis, hierarchical knowledge representation, relational database, and interactive interface for system utilization.

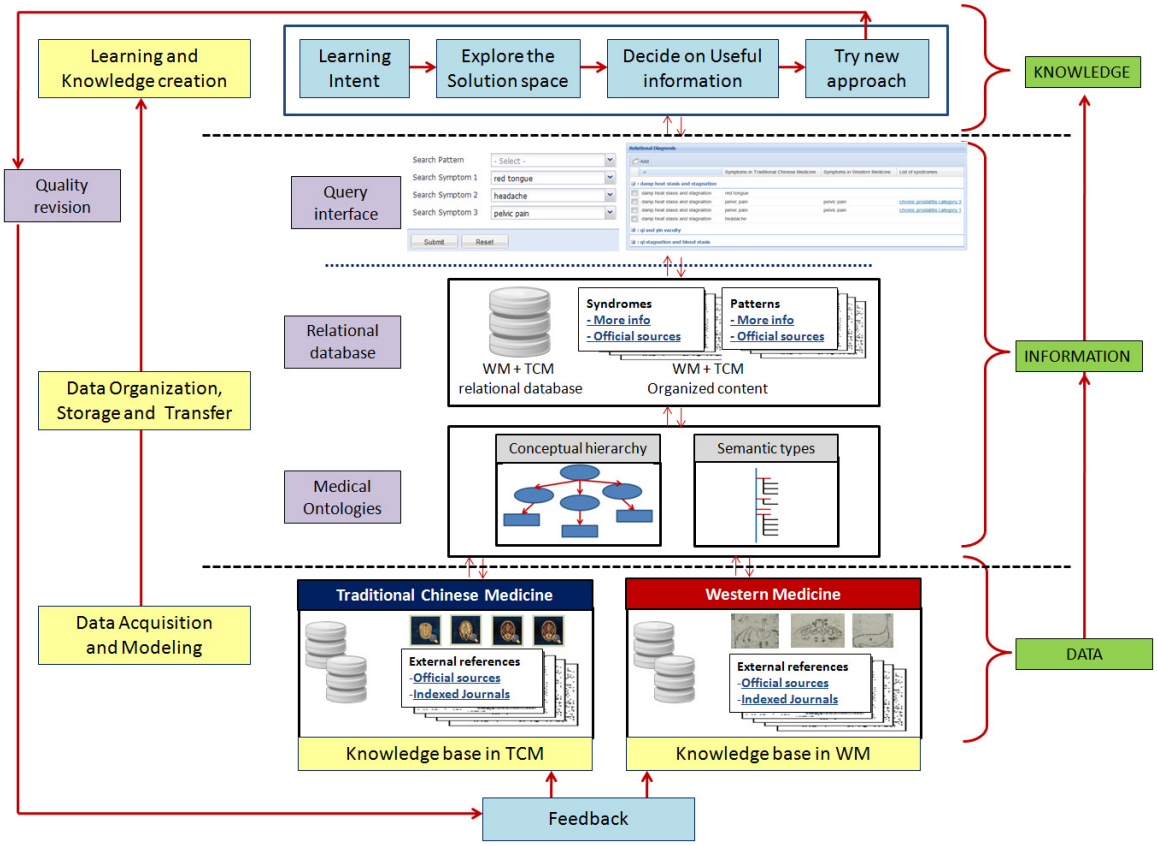



Figure 1.4. Proposed framework for a knowledge management system for medical diagnosis.

The main novelty of the proposed framework is that it establishes relationships between TCM and Western Medicine based on common symptoms for better understanding of medical knowledge, and for a broader consideration of symptoms and causes of disease. By finding key relationships, the proposed framework connects the two different medical approaches to provide a tool for the creation and sharing of medical knowledge.

### 1.2.1 Dissertation Objectives

The overall research goal in this dissertation is to design a framework for a knowledge management system to methodically organize and manage the abundant data available for Western Medicine and TCM, and to establish key relationships between the two practices for an effective exploration of ideas and possible solutions for medical diagnosis. The research objectives are:

1: To integrate TCM and Western Medicine diagnosis practices via data acquisition using hierarchical modeling and process-oriented analysis

2: To organize, store, and transfer medical data via standard conceptual hierarchies, semantic types, and relationships.

3: To design and implement the interface for learning and knowledge creation, via information exploration and sharing capabilities.

The proposed system aims to present an interactive approach for linking knowledge from TCM and Western Medicine for a better understanding of Medicine integration, and for a broader consideration of symptoms and causes of disease. Potential target users for the relational knowledge management system are TCM and Western Medicine care providers, medical students, and patients. Our system presents the organized and

stored data to users in an informative way, brought to a common ground so that it is easy to understand for a patient, but still objective and scientific enough for a care provider.

### 1.2.2 Dissertation Scope and Broader Impact

This research covers the design and implementation of a framework for relational medical diagnosis as a prototype to verify the validity of the research idea. The prototype investigates the viability of approaches used to deal with data acquisition and modeling, data organization, storage and transfer, and information distribution for learning and knowledge creation.

Without loss of generality, the system prototype is demonstrated through a case study on chronic prostatitis to describe the functionality of the knowledge management system for medical diagnosis. Chronic prostatitis is the most common but least understood form of prostatitis, and relates to the chronic inflammation of the prostate gland. This syndrome affects an estimated 30-50% of males of fertile age in the United States, and could be of bacterial or nonbacterial origin, presenting a relapsing urinary tract infection due to the same pathogen found in the prostatic secretions [10]. Medical information has been collected from specialized and reliable Traditional Chinese and Western medical literature as in [1]-[15], and the selected data has been organized with the help of medical collaborators. The prototype has been designed to be expanded for other syndromes (Western Medicine) and pattern disorders (CAM).

The scope of the dissertation does not cover full integration of all syndromes as scientifically recognized by Western Medicine, full coverage of all patterns per disorder as presented by TCM, connections with commercial or public medical databases, and

research outcomes of the National Science Foundation or National Institutes of Health. This work does not intend to present the user with specific medication and/or procedures to treat syndromes or patterns. All these bounds are considered beyond the scope of this research, and will be addressed in future research work to expand the knowledge integration and management from Western Medicine and TCM.

The broader impact of this dissertation is the framework for a novel system to disseminate the benefits of the integration of TCM and Western medical knowledge for medical diagnosis. To the society, the proposed framework for a knowledge management system represents a platform for TCM and Western medical students and practitioners to develop crossed skills and better understanding of medical conditions. Their collaboration will lead to the creation of new treatments, improved patient-TCM-Western practitioner communication and increased patient participation in the healing processes. This is relevant to plan diagnosis, treat and educate patients accurately, and potentially reduce the high costs of the U.S. health care system.

### 1.2.3 Dissertation Outline

The remainder of this dissertation is organized as follows. Previous work on management of medical knowledge is introduced in Chapter 2. The gathering of medical data and knowledge, data requirements, system boundaries, and the knowledge modeling for the integration of TCM and Western medical diagnosis processes is presented in Chapter 3. The data organization, identification of key relationships in TCM and Western Medicine, and the data storage and transfer is presented in Chapter 4. The design of the interface for learning and knowledge creation and sharing is presented in Chapter 5. Chapter 6 presents the prototype of the proposed framework, illustrated with

a case study on chronic prostatitis from both, TCM and Western Medicine perspectives. Finally, conclusions and discussions for future work are presented in Chapter 7.

# CHAPTER 2

# LITERATURE REVIEW

This chapter presents an introduction to knowledge management, overview of previous works on knowledge management in Traditional Chinese and Western Medicine, and information and knowledge distribution for medical applications. Major drawbacks and limitations in the literature are also presented.

## 2.1 Knowledge Management Systems

Knowledge-based systems are becoming increasingly popular in areas where knowledge is predominant rather than data, and requires logic in reasoning to facilitate knowledge exploration and discovery. As for knowledge management, its main goal is to facilitate effective and efficient knowledge-sharing among the system's users. Liao [16] reviewed general techniques for knowledge management, listing seven different categories: Knowledge management framework, knowledge-based systems, data mining, information and communication technology, artificial intelligence, database technology and modeling, along with their applications for different research and problem domains. Boose [17] suggested knowledge type as causal knowledge and example cases. Knowledge representation is suggested in the form of cognitive maps, concepts, correlations and tables. Knowledge modeling is suggested in the form of causal models, cognitive models, conceptual models and task-level models. On

computational techniques for knowledge-based information systems, the survey by Rubenstein-Montano [18] presents artificial neural network, fuzzy logic, classifier system and rule-based reasoning as some of the approaches taken in research and practice.

## 2.2 Knowledge Management for Medical Applications

Research on medical knowledge management tries to capture the essential knowledge of experts in a knowledge-based system. The medical knowledge and experience are directly related, and are hard to represent through explicit mathematical models due to uncertainty. This makes it a difficult task to develop computerized medical systems.

Biomedical data acquisition and analysis are shown to be increasingly important in healthcare given the abundance and diversity of biomedical data, the constant creation of biomedical knowledge sources, and the ever increasing processing power available for knowledge discovery [19]-[21]. Zhang et al. [22], Zhou et al. [23], and Koutkias et al. [24] designed and implemented efficient data acquisition mechanisms to effectively manage the large volume of medical information available during practitioner-patient sessions. Medical information includes patient information gathering and syndrome differentiation, the practitioner's notes and experience, results of subsidiary tests and annotations for future references. These tools have greatly increased knowledge of healthy and diseased subjects for medical research, becoming a critical component in diagnosis and treatment planning, as presented by Pham et al. [25].

On data analysis, the increasing availability of high-powered computers has opened up the possibility for handling abundant heterogeneous data to accurately perform reasoning in Medicine. Subbaraj and Ravi [26] used computer tomography slices and

performed a geometric analysis of reconstructed volumetric data to generate internal thickness mapping, useful for pre-operative planning and custom implant design. Zhou et al. [27] present a model for integrative mining approach to uncover functional relationships, for which relation weight computing methods, name entity, relation extraction and online analytical processing (OLAP) capabilities were used. On data storage, Jones et al. [28] analyzed and stored data in frameworks using data mining and optimization techniques, rules for inferential reasoning, and machine learning to extract meaningful knowledge from the available data, which can be shared with other information systems, such as [29]- [36].

Efforts in data mining are facilitated by networking and storage technologies, used to develop massive temporal databases. As an example, Taylor et al. [37] designed a clinical dynamic database to query, process and display clinical data, capable of adapting the internal table structure for data accommodation.

For knowledge creation, ontology and rule languages were used by O'Connor et al. [38] for knowledge-data integration and temporal reasoning in clinical trial systems. Wei et al. [39], and Lifshits and Lifshits [40] presented applications of knowledge management systems in Medicine intended to model, design and evaluate knowledge in automated diagnosis and treatment processes. Searchable information sources available for medical applications are commonly found as commercial and public databases, as presented in the Foundational Model of Anatomy [41].

### 2.2.1 Knowledge Management Systems in Western Medicine

Western Medicine is considered a very high-volume domain for information exploring, requiring adaptation for generating new knowledge and making proper decisions. Knowledge management is becoming increasingly popular for more general medical applications, providing support and expert advice in a solution space of data collection, data storage, information extraction, interpretation and medical action. Regarding the progress of engineering of knowledge generation and management in Western Medicine, some knowledge-based support systems have been developed for assisting applications in Medicine, trying to capture the essential knowledge of experts in a knowledge-based system.

On decision support systems for medical diagnosis, Haug et al. [42] and Zhang et al. [43] used data mining technologies, methods and logistic regression for disease prediction. Koutkias et al. [44] used knowledge-sharing mechanisms to detect important cases for chronic disease management. Horn [45] presented a methodology to develop intelligent molecular biomarkers via data mining, as a medical application for prostate cancer diagnosis.

On the creation of knowledge bases, Taylor et al. [46] and Cao et al. [47] presented clinical dynamic databases designed to process, display, query, and adapt the internal table structure to accommodate clinical data. Floares et al. [48] proposed a complement to background knowledge for medical applications, for which intensive data and knowledge bases were created to enhance the performance of decision support systems.

On knowledge creation, the data approach with soft computing methods is used to identify the relevant features and discover their relationships with clinical outcomes.

Goncalves et al. [49] presented a knowledge management system for studying the quality of life in head and neck cancer patients. By systematically retrieving the information about the quality of life of the patient, the results were typified and customized to decide on the best therapeutic strategy for a particular patient. Barret et al. [50] used nonlinear mixed effect models, Bayesian forecasting algorithms coupled with data summary and visualization tools to create drug-specific decision support system that utilize individualized patient data from the electronic medical record system. This contribution addressed the need of facilitating pharmacotherapeutic decision making in pediatrics, given the often limited data available to guide dosing and manage patient response.

Despite of the evident progress and continuous efforts to efficiently support the exploration of medical information and knowledge creation in Western Medicine, it is recognized that many projects on data acquisition, modeling, organization, storage and transfer have experienced difficulties using general medical knowledge for tasks beyond statistics. The interaction between user and information for knowledge creation should be intuitive, for which accurate relationships between medical concepts are lacking. Data representation, taxonomies and ontologies all play a role in the health and public health areas in Western Medicine. Lack of background knowledge is one of the major challenges, remarking the need to acquire abundant knowledge from medical experts, and then make it available for decision support to the less experienced.

### 2.2.2 Knowledge Management in Traditional Chinese Medicine

Countless medical practices and theoretical researches in TCM have accumulated a great deal of data and knowledge in the form of ancient books and literatures. With a history of several thousand years of studying human diseases and practicing diagnosis and treatments, TCM provides an organized and systematic approach to view human life.

In an effort to group, analyze and understand the huge amounts of data in TCM, previous work has been done in the areas of data mining and computational methods for data processing and knowledge discovery. A survey of approaches and resources for data mining in TCM are presented by Lukman et al. [51] and Zhou et al. [52]. The survey presented by Lukman et al. [51] focuses on computational methods for TCM classifications, types of databases and mining tools. The survey by Zhou et al. [52] focuses on publications that are concerned with data mining techniques for the processing of TCM data, searching in full-text databases in Chinese, bibliographic databases such as PubMed and popular textbooks and up-to-date international publications.

For knowledge discovery, Feng et al. [53] presented four main fields: Knowledge discovery in databases (KDD) for Chinese medical formula, KDD for Chinese herbal Medicine, KDD for TCM syndrome research, and KDD for TCM clinical diagnosis. ZhuGe [54] presented an analysis of the knowledge structure between the concepts and practice in Traditional Chinese Medicine diagnosis.

For diagnosis in TCM, Wang et al. [55] presented a novel self-learning expert system which facilitates knowledge in terms of causal diagrams, association rules and reasoning rules. In this case, the data-driven nature distinguished the system from those

existing in TCM based on if-then rules to address the knowledge generation. Zhang et al. [56] approached the syndrome differentiation problem in TCM via machine learning techniques, developing a new clustering method in the form of latent tree models towards and objective diagnosis process.

Templeman and Robinson [57] presented models of integrative Medicine in contemporary health care settings, analyzing the factors affecting the success of Integrative Medicine in terms of the collaboration between Western Medicine and CAM. Rehberg [58], Wong et al. [59], Tsuei [60] and Sun et al. [61] presented multimodal/multidisciplinary approaches based on the similarity of pain management models between TCM and other types of Medicine. As a conceptual analysis between TCM and Western Medicine, the knowledge between the two is compared, not judging nor favoring either background, but simply analyzing the differences of advices given to patients in terms of lifestyle related to hypertension and cardiovascular diseases.

### 2.2.3 Information and Knowledge Distribution for Medical Applications

In general, knowledge management systems in Medicine frequently deploy advanced information using Semantic web and Knowledge integration for searching, processing and managing biomedical information. Semantic web ontology and rule languages are used for knowledge-data integration in clinical trial systems, as presented by Downing et al. [62] and Fuentes-Lorenzo et al. [63]. Web-based knowledge management systems collect patients' data and allow physicians to collaborate on a timely manner over the Internet, which simplifies physician reporting, improves the management of the results and supports treatment decisions, as presented by Lu et al [8], Timpka et al. [64] and Li et al. [65]. Public searchable information sources available

for medical diagnosis applications are commonly found in the form of web-based applications. Some sources are in the form of medical databases [66]-[70] , medical on-line portals [71]-[74], research centers and official medical information sources [75]-[82], indexed and international journals [83]-[89], and repositories for medical images [90]-[94].

Summarizing, the state of research contributions on knowledge-based systems for medical applications have influenced the rapid growth of research work and development in information management and decision support systems. There is great interest on knowledge-based management for biomedical applications to assist medical diagnosis and treatment. Given the growing demand for complementary practices, there is a need for knowledge-based systems that integrate Western Medicine and TCM.

## 2.3 Current Major Drawbacks and Limitations

In Western Medicine, the major drawback of current knowledge management systems is that they do not consider the human body as a fully-interconnected unit for diagnosis purposes. In CAM and in TCM particularly, current knowledge management systems organize and store data to be retrieved for medical information and knowledge generation, but do not relate its medical knowledge to Western Medicine. As a result, these systems isolate medical knowledge of particular disorders, severely limiting the exploration of potential causes for disorders that originate from different body areas, and the exploration of new treatments for health maintenance and for life-threatening conditions.

The mapping of Western and TCM medical knowledge has the potential to greatly impact the diagnosis and treatment planning processes. However, challenges remain on various fundamental issues, such as lack of support for medical data collection, organization and storage, and for medical information sharing, weak management of new knowledge, integration of different medical backgrounds, diversity of medical information, and lack of methodologies for data correlation and management for knowledge generation.

# CHAPTER 3

# MODEL FOR INTEGRATED MEDICAL DIAGNOSIS PROCESS

This chapter presents the research work for data acquisition from Western Medicine and TCM, and the modeling and process-oriented analysis of an integrated medical diagnosis. Medical data and information from Western Medicine and TCM comes from various sources and in various forms. The challenge addressed in this chapter is the understanding, documentation and representation of the diagnosis process for both TCM and Western Medicine, the outline of information requirements, and the outline of the framework for knowledge management.

## 3.1 Medical Data Acquisition

Medical data and descriptive information of medical diagnosis were gathered via literature review of textbooks [12]-[14], medical journals [74]-[89], and via personal interviews with medical practitioners. Observed signs and present symptoms, physical examination, assessment and treatment are identified as the relevant activities for both TCM and Western Medicine diagnosis processes. Figure 3.1 illustrates the integration of the TCM (left) and Western Medicine (right) diagnosis processes. Each approach follows a particular protocol to identify signs and symptoms, perform the physical examination, conclude a diagnosis and formulate the necessary treatment. Although the

protocols are conceptually similar, the ways they are conducted are significantly different.

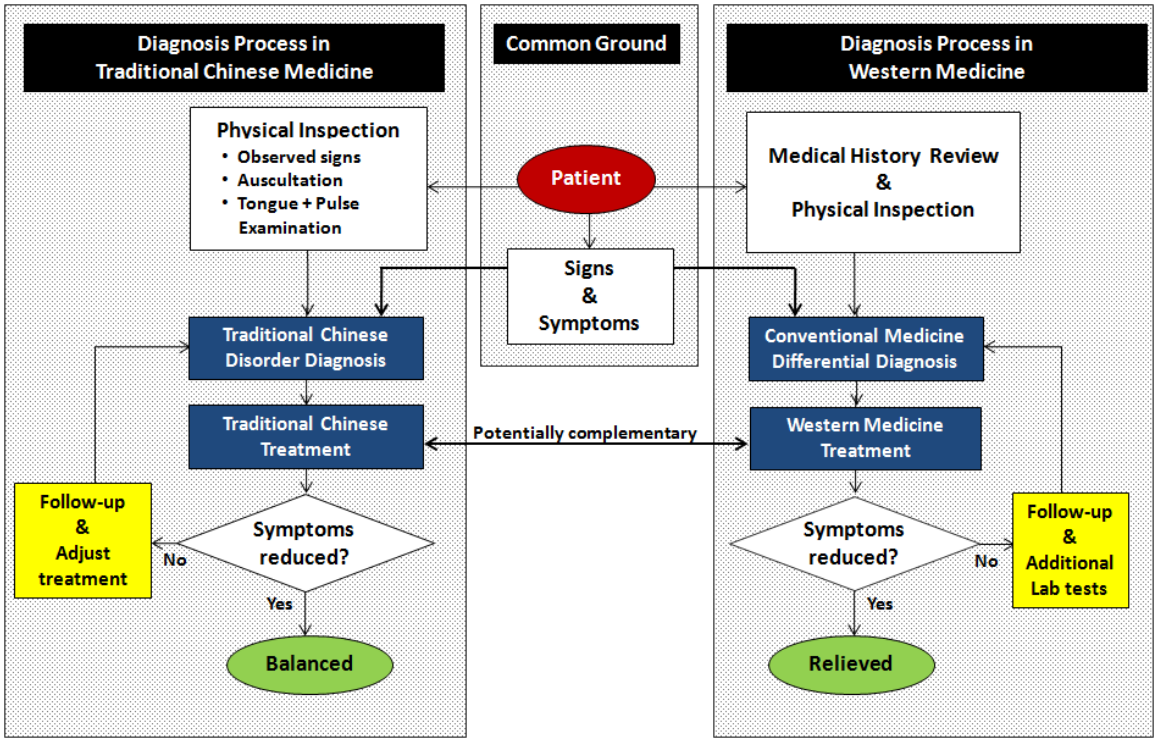



Figure 3.1. Integration of the Traditional Chinese (left) and Western Medicine (right) diagnosis processes

As seen in Figure 3.1 (left), the diagnosis process in TCM is based on information obtained from physical inspection and direct observation of external features for each patient, auscultation, and olfaction in some cases, direct questions to the patient for better understanding of his or her experience, palpation, pulse detection and tongue inspection. TCM then establishes the potential disorder diagnosis and the priorities for medical treatment, and formulates herbal prescriptions and other therapeutic resources. The patient's evolution health-wise determines if the initial treatment covered all the important dysfunctions towards a balanced-health state. Otherwise, the prescription, treatment and ordered therapies are to be adjusted. Finally, following-up the patient's

evolution determines the formulation of a specific herbal prescription, and this iterative process is continued until the patient's health is properly balanced.

On the other hand, Figure 3.1 (right) presents the diagnosis process in Western Medicine. Besides physical inspection of the human body, the patient's medical history is reviewed to consider the chances for the patient to experience a particular disease, either by predisposition after experiencing other diseases, exposure to specific conditions, or by genetic tendency given the ethnic or family background. Western Medicine proposes potential disease diagnosis based on pathological examination of isolated organ dysfunctions. Differential diagnosis is achieved through laboratory tests and other medical procedures to conclude the dysfunction to treat. For example, if the patient experiences health improvements in terms of relieved symptoms, correction of an organ defect or dysfunction, or tumor hysterectomy, the treatment is said to be successful. Otherwise, additional laboratory tests and support medical procedures are ordered to determine the reinforcement to the initial treatment, or if definitely a new treatment is needed due to lack of positive results or to side effects.

The symptom-based connection in Figure 3.1 (center) was established by analyzing clinical information for selected syndromes in Western Medicine, and information on medical assessment and diagnosis for selected patterns in TCM. By comparing the set of symptoms in Western syndromes to the set of signs and symptoms in TCM, there is a subset of symptoms commonly recognized by both TCM and Western Medicine. Therefore, symptoms in general were identified as the main bridge connecting TCM and Western Medicine knowledge.

Considering Figure 3.1 as a whole, the process for TCM and Western Medicine diagnosis occurs differently, even if starting from a common list of signs and symptoms. For a mapped medical diagnosis, TCM could reveal to Western Medicine potential causes of illness originated in different locations in the human body, besides the affected area and/or the isolated organ dysfunction. Western Medicine could contribute TCM by prioritizing objectively the syndromes that need to be targeted from the initial list of potential diagnosis. Advanced clinical technology, medical procedures and medical specialties for differential diagnosis in Western Medicine are significantly useful to TCM practitioners. When the difference between patterns for TCM diagnosis seems unclear, the list of patterns could be mapped to syndromes in Western Medicine for an objective, clear understanding of the illness. Therefore, a more informed diagnosis could be achieved, and a better treatment plan could be identified for better results.

## 3.2 Process-Oriented Analysis to Relate Western and Traditional Chinese Medical Diagnosis

As part of our knowledge integration approach, a framework to relate the diagnosis process in Western Medicine and TCM is presented based on process-oriented analysis. The knowledge modeling was done via the Integrated Definition for Function Modeling methodology, level 0 (IDEF0). IDEF0 was used to create the hierarchical models representing the medical knowledge in the form of decisions, actions and activities behind the diagnosis process. This facilitates the information sharing process for model evaluation and improvements.

The elements that generally compose the function-based model are illustrated in Figure 3.2. Boxes represent the function (main process), its principal activities and any other action necessary to transform and add value to the inputs for each activity. Arrows entering the boxes are inputs as any material or information that is required to complete each step in the process, and mechanisms as people and/or computational resources to complete activities. Arrows leaving the box are controls such as regulations, policies and procedures dictating how to complete the activity, and outputs as inputs that have been transformed and added value to make it a significant result.

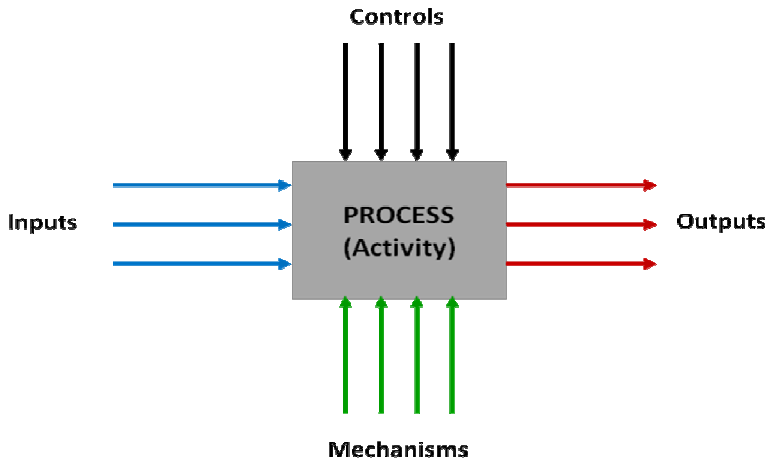



Figure 3.2. Main elements of the IDEF0 model: Inputs, outputs, mechanisms and controls.

For the integrated medical diagnosis process, the elements for the IDEF0 function model are identified as follows:

- Inputs: Patient, medical history, preliminary diagnosis, clinical laboratory results, and treatment plan and prescription.
- Mechanisms: Medical care provider, medical information system, laboratory technician, and our framework for relational knowledge management system.

- Controls: Medical diagnosis procedure, laboratory testing procedure, medical symptom description, TCM pattern definition, Western Medicine syndrome definition.
- Outputs: Preliminary diagnosis, updated medical history, clinical laboratory results, treatment plan, treated patient and creation of new knowledge to share.

The collected medical data has been organized in main concepts characterizing the background in both TCM and Western Medicine, as follows:

- Vital organ: Internal organs responsible for the balanced status of the emotional, mental and physical body system in CAM, illustrated in Figure 3.3
- Channel: In TCM, refers to the path inside the human body governed by each one of the vital organs, shown in Figure 3.3. Also known as meridians, channels distribute various forms of energy within the human body, reflected in the normal functioning of the physical, emotional and mental bodies in a human being. Channels interconnect directly or indirectly to different body parts, for which one particular health disorder may have more than one origin in the body. It is also possible that, once the disorder starts and it is not well treated, it will affect gradually the normal functioning of associated body parts covered within the affected channel.
- Microsystem: Body parts and areas representative of the vital organs and functions in CAM, indicated in Figure 3.3
- Signs: Characteristic physical manifestation of a particular illness, observed equally in Western Medicine as well as in TCM in any of the CAM microsystems, as an indicator of a potential dysfunctions related to any of the vital organs.

- Symptoms: Thoughts, emotions and physical pain or discomfort, experienced by each patient and that may be common for both, CAM and Western Medicine
- Syndrome: In Western Medicine, refers to the clinical definition of a disease, specifying the correspondent set of symptoms to assess.
- Pattern: In TCM, a pattern is the set of signs and symptoms that a patient may experience as a manifestation of an energetic dysfunction of one or more of the vital units. For each vital unit, several combinations of symptoms result into several types of patterns. Therefore, a TCM practitioner may consider as many patterns as necessary in order to identify the set of symptoms that better reflects the patient's health disorder.
- Clinical diagnosis: Refers to the differential evaluation of symptoms, clinical laboratory tests and advanced assessment technology for the objective measurement of a particular health condition.
- Pattern differentiation: In TCM, refers to the differential evaluation of signs to determine and prioritize the pattern(s) to treat. It is possible to differentiate patterns presenting similar symptoms by assessing the tongue and the pulse. By observing shapes, marks, colors and coating on the tongue, combined with the speed and depth of the pulse, it is possible for a TCM practitioner to differentiate aliased patterns.
- Treatment: Therapies, herbs and natural compounds in TCM, and pharmaceutical drugs, therapies and surgical options developed in Western Medicine.

- External references for knowledge augmentation: Official clinical trials, medical journals and other online resources suggested for information exploration and knowledge augmentation.

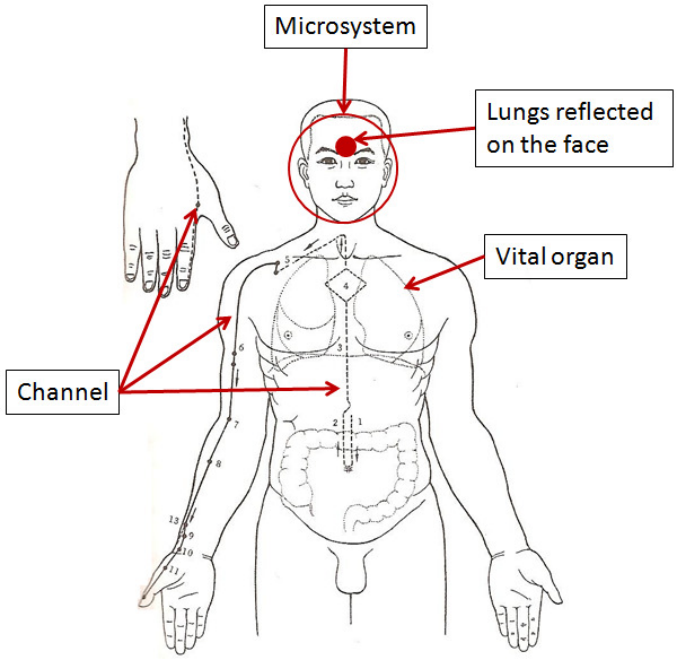



Figure 3.3. The Lung Channel. Source: Piegl [95]

Figure 3.4 presents the IDEF0 model of the diagnosis function for the relational medical diagnosis process, and each main activity is detailed in Appendices A1 - A4. In terms of an engineering process, Figure 3.4 presents the main activities of Physical inspection, Diagnosis, Treatment and Follow-up. The patient in need of medical care enters the process when visiting the TCM or Western care provider. Complementary patient information such as medical history is considered another type of input to gather specific information that the patient may have not communicated during the consultation such as previous medical conditions or current treatments, herbs and/or prescriptions in use. The medical history is carried and updated along the process. Clinical definition of syndromes and Traditional Chinese information of patterns are used to globally and

locally frame the patient's medical condition, differentiate health disorders and reach a final diagnosis.

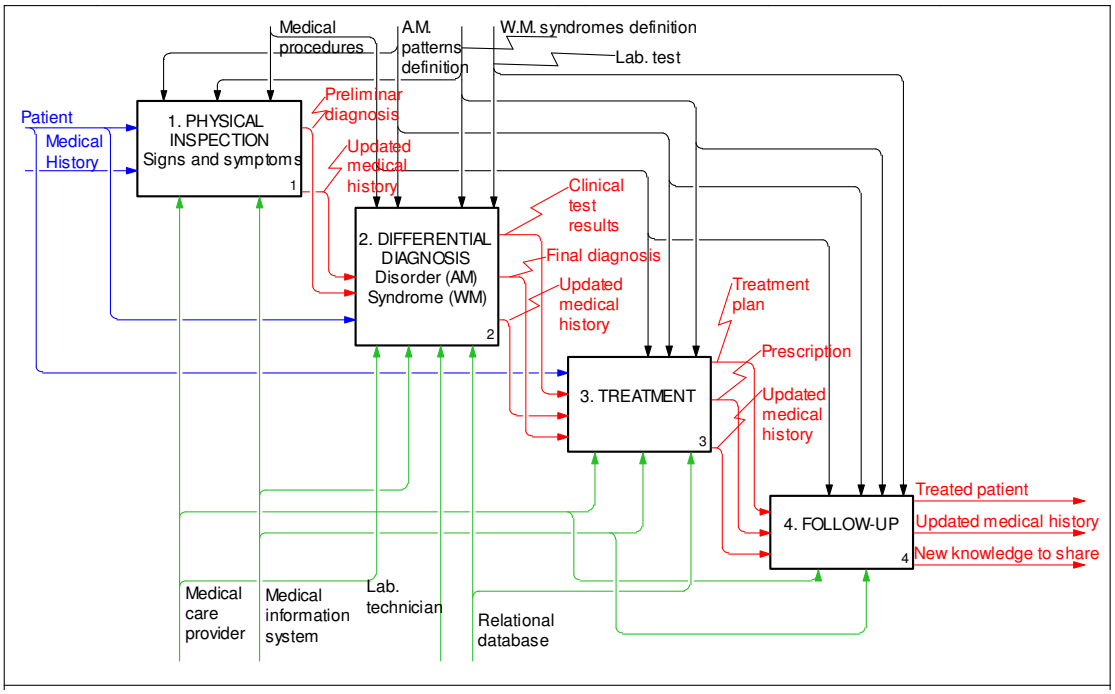



Figure 3.4. IDEF0 model - Diagnosis function for the integrated medical diagnosis process

The proposed framework for a knowledge management system supports the diagnosis process. As an assistant tool, our system is used for an organized and effective exploration of ideas and possible solutions for medical diagnosis, and for further medical knowledge generation. The care provider uses our system to narrow down treatment options, and interacts with the system to learn and update available medical content. Another way of interacting with the system is by running symptom, syndrome and/or pattern-based searches into the relational database. These searches allow the user to navigate between Traditional Chinese and Western medical data, explore the organized and stored medical data and understand the relationships between syndromes and patterns via the interconnection of symptoms. Common

symptoms to Traditional Chinese and Western Medicine are mapped and presented in terms that the care provider is conceptually familiarized with, indistinctive of the medical approach. As a tool for knowledge sharing, the system provides the user with a form view to add new data for syndromes, new data for patterns and new relationships between syndromes and patterns, as it may be the case. Once submitted, the new data is stored and reviewed prior to publication for future searches.

Besides the care provider's background, our knowledge management system offers the user with ways of accessing complementary information sources, promoting further knowledge exploration and discovery. The care provider uses the information sources as proper for deciding on better combinations of treatments, prescriptions, therapies and following-up procedures, among the options available in Traditional Chinese and Western Medicine official institutes, public reports and literature in general.

# CHAPTER 4

# ESTABLISHING KEY RELATIONSHIPS BETWEEN TRADITIONAL CHINESE MEDICINE AND WESTERN MEDICINE FOR MEDICAL DIAGNOSIS

This chapter presents the research work for the design and creation of the relational database to extract interconnected medical knowledge. After acquiring medical data, this phase focuses on the revision and selection of medical ontologies and the research challenge of data organization, storage and transfer for relational medical diagnosis.

## 4.1 Background

For organization, storage and transfer of medical data, Figure 4.1 illustrates the architecture of the proposed knowledge management system to retrieve integrated medical knowledge. As a proof of concept, the data was acquired from sources such as textbooks in Medicine, NCCAM, journals, public medical databases, textbooks and journals recognized and well-respected among Traditional Chinese and Western Medicine communities. Nevertheless, our framework for relational knowledge management system has been designed to be expanded; that is, to be populated with abundant medical data as available. It is open to be merged with external databases and computer-based applications in Medicine, so that the data acquisition could be automated.

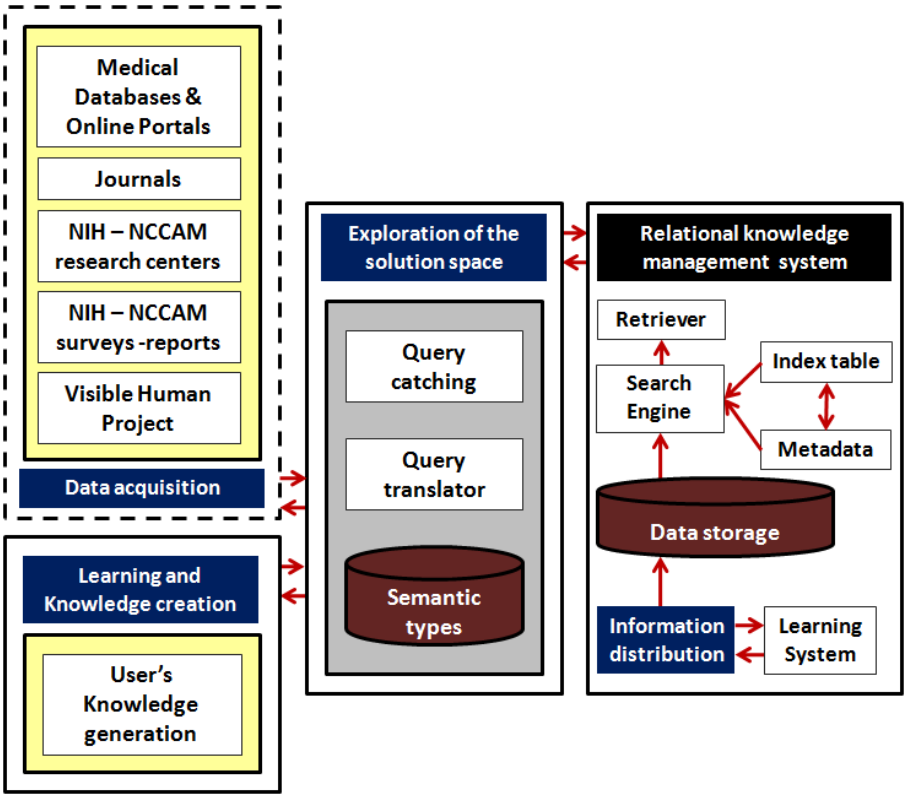



Figure 4.1. System architecture and boundaries for the organization, storage and transfer of integrated medical knowledge

For data organization, storage and transfer, standard medical ontologies were used to organize hierarchical concepts and to establish the relationships and semantic types. This organization approach made it helpful to create the conceptual structure of the relational database, where entity-relationship key connections were established for medical diagnosis. By organizing, storing and relating medical data from Western Medicine and TCM, the data is translated into meaningful information to the user via the query interface, when exploring ideas and potential solutions for medical diagnosis. For content-based searches, a search engine is used to retrieve descriptive medical information stored in the system. With the use of an index table and metadata, the search engine locates descriptive medical content and related references from official

agencies, to augment the information distribution for user learning and creation of new knowledge.

As a tool for exploration of medical information for learning, the framework is designed for users with different levels of privileges to interact with the system. After new knowledge is created, the system is open to receive feedback in the form of new data, either from exploration of potential solutions or from personal expertise after learning. The new data is submitted by the user via add form and logic variables, to ensure that the data is stored under the hierarchy of medical concepts without replacing existing values. The added data is received into the system, but only published after being reviewed by knowledgeable editors, mainly to ensure the accuracy of the data to be used for further knowledge. The interface facilitates the interaction with the knowledge-based system, complements descriptive information, improves user learning, and enables the submission of new knowledge.

## 4.2 Conceptual Correlation between Knowledge from Western and Traditional Chinese Medicine

As presented in Figure 3.1 (center), symptoms are found to be the main connection between the diagnosis processes of TCM and Western Medicine, as they may be equally experienced by patients from both backgrounds. Figure 4.2 illustrates the conceptual design of the relational database for integrating Western Medicine and TCM, as a symptom-based relational medical diagnosis. Initially, a list of syndromes in Western Medicine has been selected for research purposes, as well as a list of patterns in Traditional Chinese Medicine that could be treating a health disorder considered similar at first glance. The main intention was to analyze and compare the list of

symptoms that clinically identify and define a syndrome in Western Medicine, and analyze and compare the list of signs and symptoms that define a pattern in Traditional Chinese Medicine. By comparing the set of symptoms in Western syndromes to the set of signs and symptoms in Traditional Chinese patterns, there is a subset of symptoms commonly recognized by both Traditional Chinese and Western Medicine. Therefore, symptoms in general were identified as the main bridge connecting Traditional Chinese and Western Medicine knowledge.

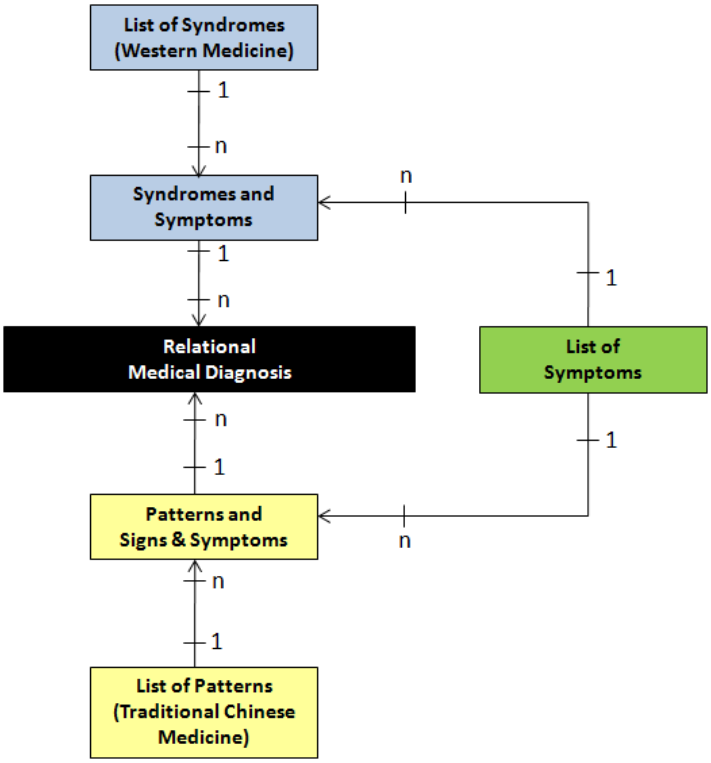



Figure 4.2. Conceptual connection between the diagnosis processes of TCM and Western Medicine

## 4.3 Ontologies in Western and Traditional Chinese Medicine

The heterogeneous nature of data, information and knowledge in Medicine, makes data extraction and knowledge creation challenging tasks. Among other issues, the large amount of medical concepts and vocabulary poses a challenge for searching and deciding on useful information in different medical resources.

The semantic web approach, based on ontologies, represents a feasible way to approach the challenge of organizing and storing medical data. When related properly, the initial data can be processed into meaningful information for learning and knowledge creation. Therefore, ontologies facilitate a shared understanding of some domain of interest, and can be used as a unifying resource to close the gap between different terms and backgrounds from TCM and Western Medicine. It can also facilitate further knowledge creation, sharing and management. Figure 4.3 presents a simplified model of ontology functions and dimensions.

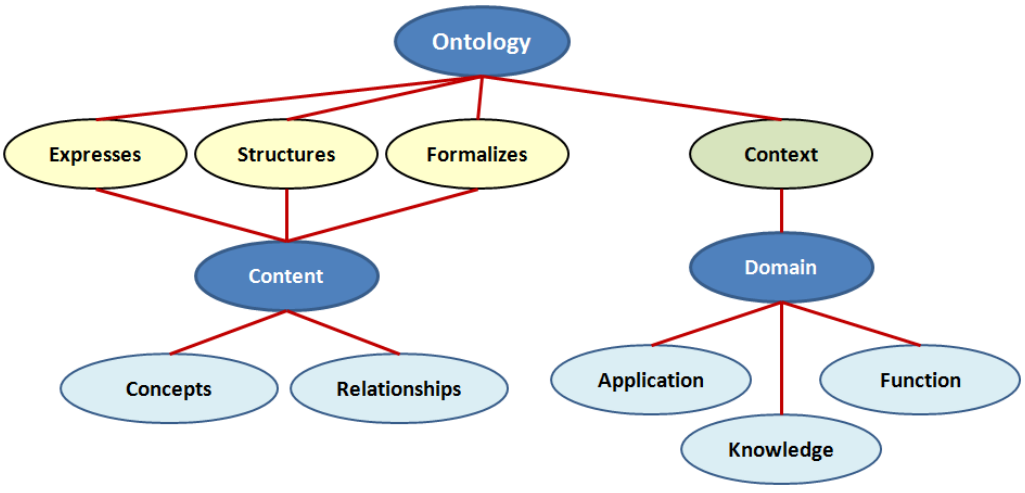



Figure 4.3. Ontology functions and dimensions. Modified from [96]

The U.S National Library of Medicine has developed the Unified Medical Language System (UMLS) [97], ontologies in the semantic web used to reduce the barriers when using and developing computer applications in Medicine. Semantic types and semantic relationships were created to define entities, events and the relationships connecting them accordingly. Figure 4.4 presents a simplified model of the UMLS semantic system. Although the UMLS was initially created for computer-based applications in Western Medicine, it later inspired the creation of the Unified Traditional Chinese Medicine Language Medicine project (UTCMLS), creating with it a standard to structure TCM for medical applications.

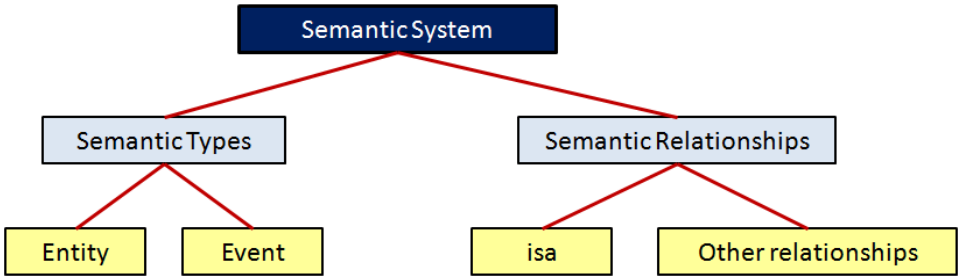



Figure 4.4. Simplified model of the UMLS semantic system.

## 4.4 Definition of Entities, Key Relationships and Attributes to Correlate Western and Traditional Chinese Medicine

The Integrated Definition for Function Modeling methodology, level 1X (IDEF1X) was used to create the table structure of the database, with table names (entities), fields (attributes), and key attributes. Figure 4.5 presents the simplified semantic data model for correlation of medical data for syndromes (Western Medicine) and patterns (TCM).

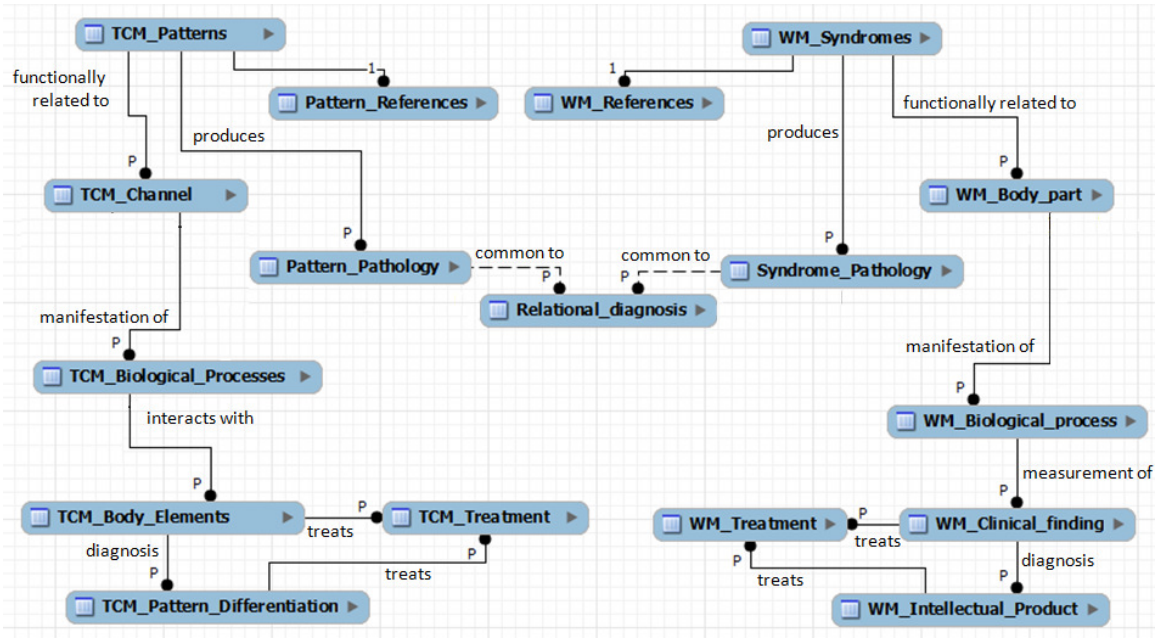



Figure 4.5 Simplified IDEF1X model - Entity-relationship key connections between syndromes, patterns and symptoms for relational diagnosis.

The model presented in Figure 4.5 represents the simplified structure and semantics for medical data correlation (Appendix B.1 presents the complete model). Among the medical data to correlate, there is data for Western Medicine syndromes and the correspondent symptoms, and data for TCM patterns and the correspondent signs and symptoms. The collected medical data has been organized and stored in tables for both TCM and Western Medicine. In Western Medicine:

- WM_Syndrome: List of syndromes
- WM_Body_parts: Affected body part(s) per syndrome, and the associated body system it is part of.
- WM_Pathology: For each syndrome, any physical pain or discomfort commonly experienced by patients.
- WM_Biological_process: Physiology of the body part(s) related to a particular syndrome.

- WM_Clinical_finding: Laboratory tests, expected results and other clinical procedures for assessing the severity of a syndrome.
- WM_Intellectual_product: Clinical classification per syndrome.
- WM_Treatment: Common prescriptions, therapies or surgical procedures associated to a particular syndrome.
- WM_References: Content in Western Medicine syndromes, including a list of external references such as official agencies and medical journals for knowledge augmentation.

In TCM:

- TCM_Pattern: Potential health dysfunctions, defined based on clusters of signs & symptoms observed in the whole human body.
- TCM_Channel: Vital unit, corresponding channel and associated patterns.
- TCM_Biological_processes: Physiology and psychology of the vital unit in the human body as a system.
- TCM_Body_elements: List of body parts, interconnected to each other via the channel concept.
- Pattern_pathology: Signs and symptoms per pattern.
- TCM_Pattern_differentiation: Tongue and pulse combined conditions per pattern.
- TCM_Treatment: Therapy, natural remedies, life style and diet and herbal compounds recommended per pattern. Also, treatments suggested to compensate the underactivity, overactivity or balancing of vital units.
- Pattern_References: Content in TCM pattern, including a list of external references such as official agencies and medical journals for knowledge augmentation.

The model relates medical diagnosis based on symptoms that are particular to Western syndromes and TCM, also mapping symptoms that are commonly treated in Western and TCM. For diagnosis purposes, one or more signs and symptoms may correspond to one or more pattern disorders, and one or more symptoms may correspond to one or more syndromes at the time.

## 4.5 Normalization Level for the Data Model

Treatment of medical data for the design of our relational knowledge support system faced challenges such as data redundancy and normalization. Data redundancy impacts the data integrity when stored records are subject to user actions such as insert, delete and update. Normalization is the process of controlling data redundancies, using unique identifiers so that there are no multiple entries overlapping or eliminating records that should be kept. For this dissertation, a certain level of redundancy is actually desired given the nature of the medical data. It is necessary to allow multiple entries, as it is the case of data related to symptoms: Each symptom may be related to one or more syndrome (Western Medicine), and could also be related to one or more patterns (Traditional Chinese Medicine).

Three different types of forms are commonly used for system normalization. The 1st Normal Form prevents a single field from containing more than one value from its column's domain. The system is in the 2nd Normal Form if and only if all its non-prime attributes are functionally dependent on the whole of every candidate key. Finally, the system is in the 3rd Normal Form if for the 2nd Normal Form every non-prime attribute is not directly dependent on every candidate key. Based on this consideration, the system is in its 3rd Normal Form, so that a syndrome and a pattern can contain more than one

symptom, a symptom can be related to more than one syndrome and/or pattern, and new additions and relationships can be submitted by the user via insertion without compromising data integrity.

In case of record deletion, the system will allow only few editor profiles with capabilities to delete records. If a record is to be deleted, the system in its 3rd Normal Form will control that only the selected record is deleted, not carrying along any other record that may be related.

## 4.6 Design of the Forms for Symptom, Syndrome and Pattern-Based Searching for Relational Medical Diagnosis

The design of the form for relational medical diagnosis is focused on two main purposes. The first purpose is for the user to be able to use key terms for a search based on symptoms, syndromes and patters. New data could be entered in the system after learning and creating new knowledge, either in the form of more symptoms for a particular syndrome or pattern, or new relationships to interconnect syndrome and patterns based on symptoms.

The second purpose is for the user to be able to query the relational database and retrieve results in the form of a report, starting the search either from the Western Medicine or TCM side. The primary search reports mapped syndromes (Western Medicine) and patterns (TCM) based on symptoms, and a second report is created for detailed information about the medical diagnosis for a selected syndrome or pattern. The connection among tables to retrieve data for relational medical diagnosis is explained in section 4.6.1, and the views for the form and report views are presented in section 4.6.2.

### 4.6.1 Tables and Connections in MySQL for Relational Medical Diagnosis

For a user to query the relational database, it is necessary to interconnect more than two tables in many cases. Interconnecting tables implies not only selecting tables and the correspondent columns to call and display data from within. It also implies to determine the condition(s) that the query must fulfill to process the data, and then to present the user with meaningful information for learning and deciding on potential medical diagnosis. In the case of queries for relational diagnosis in TCM, Figure 4.6 presents a simplified example of the syntaxes for selecting the columns containing the data from the search fields, the type of connection relating them, the sub-query to display a second record with the medical diagnosis for a particular syndrome or pattern, and the conditions to retrieve the data.

Likewise, in the case of queries for relational diagnosis in Western Medicine, Figure 4.7 presents a simplified example of the syntaxes for selecting the columns containing the inputs from the search fields, the type of connection relating them, the sub-query to display a second record with the diagnosis for a particular pattern in TCM, and the conditionals to process the data and retrieve the correspondent information.

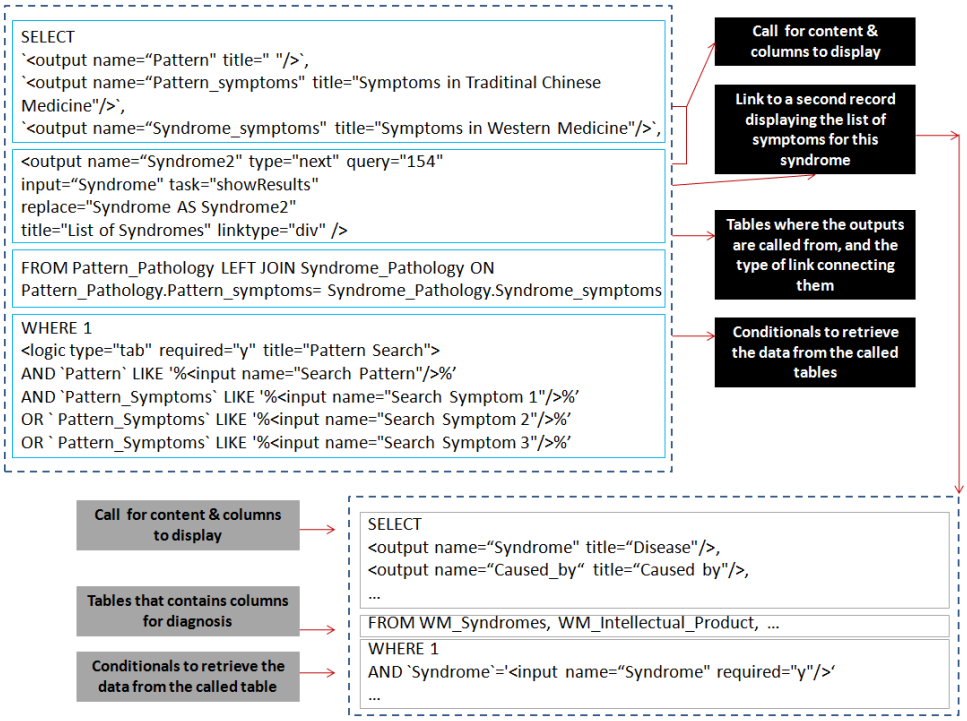



Figure 4.6. Simplified query in MySQL for relational medical diagnosis, from TCM to Western Medicine.

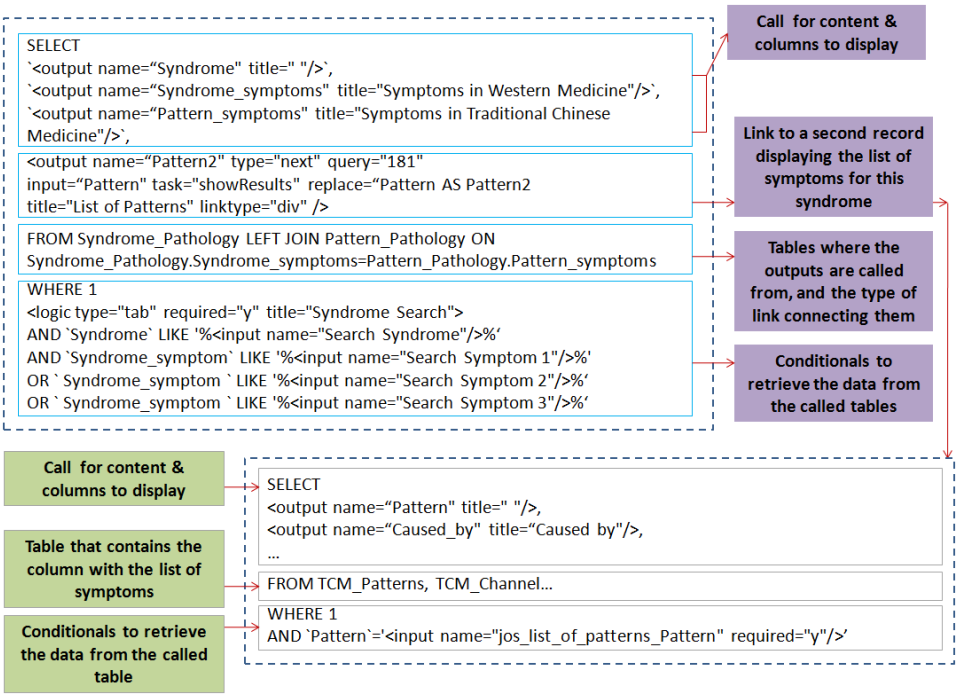



Figure 4.7. Simplified query in MySQL for relational medical diagnosis, from Western Medicine to TCM.

### 4.6.2 User Views for Search and Add Forms, and Result Reports

To start querying the system, the first form offered to the user is a search form. Based on user's requirements, it is necessary for the form to allow searches based on keywords for syndromes, patterns or symptoms, or combination of syndromes and symptoms (Western Medicine) or patterns and symptoms (TCM).

For the case of a user starting the relational medical diagnosis from the Western Medicine side, Figure 4.8 presents the symptom-based search form for relational medical diagnosis. Figure 4.9 presents the initial result report based on the searched terms while Figure 4.10 shows the secondary report listing the diagnosis for a selected, previously mapped pattern (TCM). Figure 4.11 shows the form offered to the user for adding more data, either for more symptoms for a particular syndrome, or more relationships connecting the syndrome with a pattern based on symptoms. The quality and accuracy of these data are verified by an authorized editor, and then the data is published to make it available for future searches.

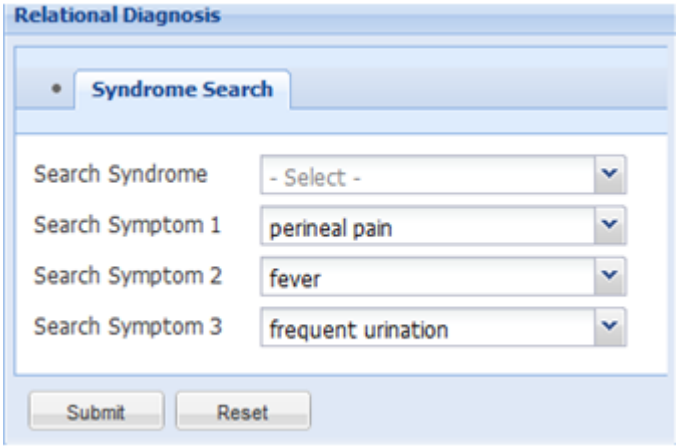
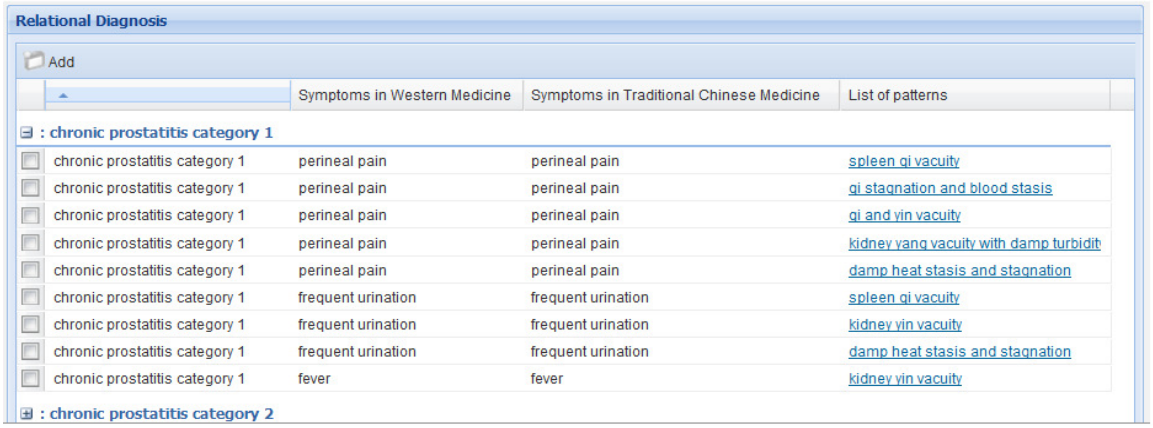



Figure 4.8. Search form for relational medical diagnosis from Western Medicine

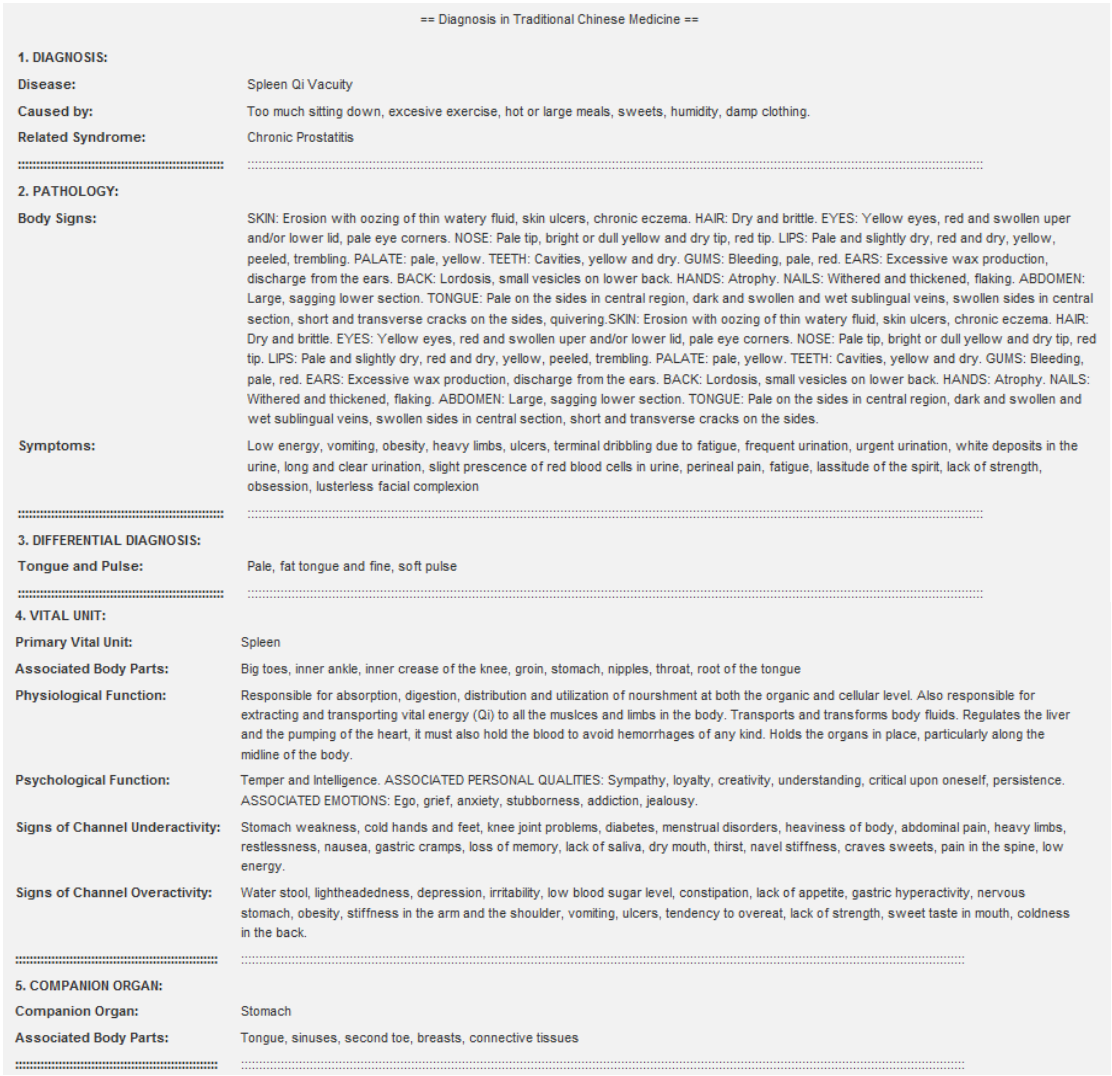


**Relational Diagnosis**

Add

| | Symptoms in Western Medicine | Symptoms in Traditional Chinese Medicine | List of patterns |
|---|---|---|---|
| **: chronic prostatitis category 1** | | | |
| chronic prostatitis category 1 | perineal pain | perineal pain | spleen qi vacuity |
| chronic prostatitis category 1 | perineal pain | perineal pain | qi stagnation and blood stasis |
| chronic prostatitis category 1 | perineal pain | perineal pain | qi and yin vacuity |
| chronic prostatitis category 1 | perineal pain | perineal pain | kidney yang vacuity with damp turbidit |
| chronic prostatitis category 1 | perineal pain | perineal pain | damp heat stasis and stagnation |
| chronic prostatitis category 1 | frequent urination | frequent urination | spleen qi vacuity |
| chronic prostatitis category 1 | frequent urination | frequent urination | kidney yin vacuity |
| chronic prostatitis category 1 | frequent urination | frequent urination | damp heat stasis and stagnation |
| chronic prostatitis category 1 | fever | fever | kidney yin vacuity |
| **: chronic prostatitis category 2** | | | |

Figure 4.9. Initial report based on the searched symptoms in Western Medicine, mapped into TCM.



== Diagnosis in Traditional Chinese Medicine ==

**1. DIAGNOSIS:**

**Disease:** Spleen Qi Vacuity

**Caused by:** Too much sitting down, excesive exercise, hot or large meals, sweets, humidity, damp clothing.

**Related Syndrome:** Chronic Prostatitis

**2. PATHOLOGY:**

**Body Signs:** SKIN: Erosion with oozing of thin watery fluid, skin ulcers, chronic eczema. HAIR: Dry and brittle. EYES: Yellow eyes, red and swollen uper and/or lower lid, pale eye corners. NOSE: Pale tip, bright or dull yellow and dry tip, red tip. LIPS: Pale and slightly dry, red and dry, yellow, peeled, trembling. PALATE: pale, yellow. TEETH: Cavities, yellow and dry. GUMS: Bleeding, pale, red. EARS: Excessive wax production, discharge from the ears. BACK: Lordosis, small vesicles on lower back. HANDS: Atrophy. NAILS: Withered and thickened, flaking. ABDOMEN: Large, sagging lower section. TONGUE: Pale on the sides in central region, dark and swollen and wet sublingual veins, swollen sides in central section, short and transverse cracks on the sides, quivering.SKIN: Erosion with oozing of thin watery fluid, skin ulcers, chronic eczema. HAIR: Dry and brittle. EYES: Yellow eyes, red and swollen uper and/or lower lid, pale eye corners. NOSE: Pale tip, bright or dull yellow and dry tip, red tip. LIPS: Pale and slightly dry, red and dry, yellow, peeled, trembling. PALATE: pale, yellow. TEETH: Cavities, yellow and dry. GUMS: Bleeding, pale, red. EARS: Excessive wax production, discharge from the ears. BACK: Lordosis, small vesicles on lower back. HANDS: Atrophy. NAILS: Withered and thickened, flaking. ABDOMEN: Large, sagging lower section. TONGUE: Pale on the sides in central region, dark and swollen and wet sublingual veins, swollen sides in central section, short and transverse cracks on the sides.

**Symptoms:** Low energy, vomiting, obesity, heavy limbs, ulcers, terminal dribbling due to fatigue, frequent urination, urgent urination, white deposits in the urine, long and clear urination, slight prescence of red blood cells in urine, perineal pain, fatigue, lassitude of the spirit, lack of strength, obsession, lusterless facial complexion

**3. DIFFERENTIAL DIAGNOSIS:**

**Tongue and Pulse:** Pale, fat tongue and fine, soft pulse

**4. VITAL UNIT:**

**Primary Vital Unit:** Spleen

**Associated Body Parts:** Big toes, inner ankle, inner crease of the knee, groin, stomach, nipples, throat, root of the tongue

**Physiological Function:** Responsible for absorption, digestion, distribution and utilization of nourshment at both the organic and cellular level. Also responsible for extracting and transporting vital energy (Qi) to all the muslces and limbs in the body. Transports and transforms body fluids. Regulates the liver and the pumping of the heart, it must also hold the blood to avoid hemorrhages of any kind. Holds the organs in place, particularly along the midline of the body.

**Psychological Function:** Temper and Intelligence. ASSOCIATED PERSONAL QUALITIES: Sympathy, loyalty, creativity, understanding, critical upon oneself, persistence. ASSOCIATED EMOTIONS: Ego, grief, anxiety, stubborness, addiction, jealousy.

**Signs of Channel Underactivity:** Stomach weakness, cold hands and feet, knee joint problems, diabetes, menstrual disorders, heaviness of body, abdominal pain, heavy limbs, restlessness, nausea, gastric cramps, loss of memory, lack of saliva, dry mouth, thirst, navel stiffness, craves sweets, pain in the spine, low energy.

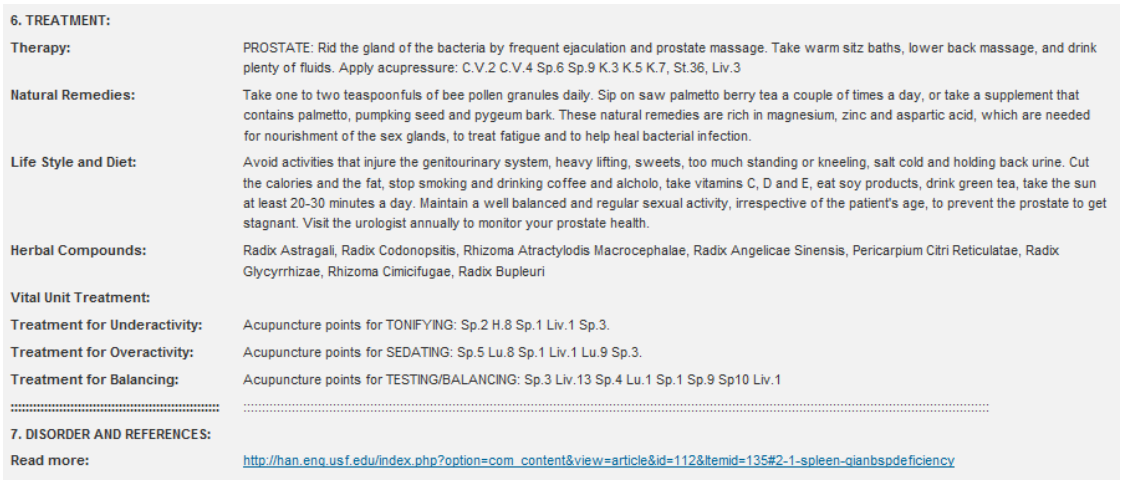
**Signs of Channel Overactivity:** Water stool, lightheadedness, depression, irritability, low blood sugar level, constipation, lack of appetite, gastric hyperactivity, nervous stomach, obesity, stiffness in the arm and the shoulder, vomiting, ulcers, tendency to overeat, lack of strength, sweet taste in mouth, coldness in the back.

**5. COMPANION ORGAN:**

**Companion Organ:** Stomach

**Associated Body Parts:** Tongue, sinuses, second toe, breasts, connective tissues

Figure 4.10. Diagnosis report with detailed information for a selected pattern



| | |
|---|---|
| **6. TREATMENT:** | |
| **Therapy:** | PROSTATE: Rid the gland of the bacteria by frequent ejaculation and prostate massage. Take warm sitz baths, lower back massage, and drink plenty of fluids. Apply acupressure: C.V.2 C.V.4 Sp.6 Sp.9 K.3 K.5 K.7, St.36, Liv.3 |
| **Natural Remedies:** | Take one to two teaspoonfuls of bee pollen granules daily. Sip on saw palmetto berry tea a couple of times a day, or take a supplement that contains palmetto, pumpking seed and pygeum bark. These natural remedies are rich in magnesium, zinc and aspartic acid, which are needed for nourishment of the sex glands, to treat fatigue and to help heal bacterial infection. |
| **Life Style and Diet:** | Avoid activities that injure the genitourinary system, heavy lifting, sweets, too much standing or kneeling, salt cold and holding back urine. Cut the calories and the fat, stop smoking and drinking coffee and alcholo, take vitamins C, D and E, eat soy products, drink green tea, take the sun at least 20-30 minutes a day. Maintain a well balanced and regular sexual activity, irrespective of the patient's age, to prevent the prostate to get stagnant. Visit the urologist annually to monitor your prostate health. |
| **Herbal Compounds:** | Radix Astragali, Radix Codonopsitis, Rhizoma Atractylodis Macrocephalae, Radix Angelicae Sinensis, Pericarpium Citri Reticulatae, Radix Glycyrrhizae, Rhizoma Cimicifugae, Radix Bupleuri |
| **Vital Unit Treatment:** | |
| **Treatment for Underactivity:** | Acupuncture points for TONIFYING: Sp.2 H.8 Sp.1 Liv.1 Sp.3. |
| **Treatment for Overactivity:** | Acupuncture points for SEDATING: Sp.5 Lu.8 Sp.1 Liv.1 Lu.9 Sp.3. |
| **Treatment for Balancing:** | Acupuncture points for TESTING/BALANCING: Sp.3 Liv.13 Sp.4 Lu.1 Sp.1 Sp.9 Sp10 Liv.1 |
| **7. DISORDER AND REFERENCES:** | |
| **Read more:** | http://han.eng.usf.edu/index.php?option=com_content&view=article&id=112&Itemid=135#2-1-spleen-qianbspdeficiency |

Figure 4.10. (Continued)

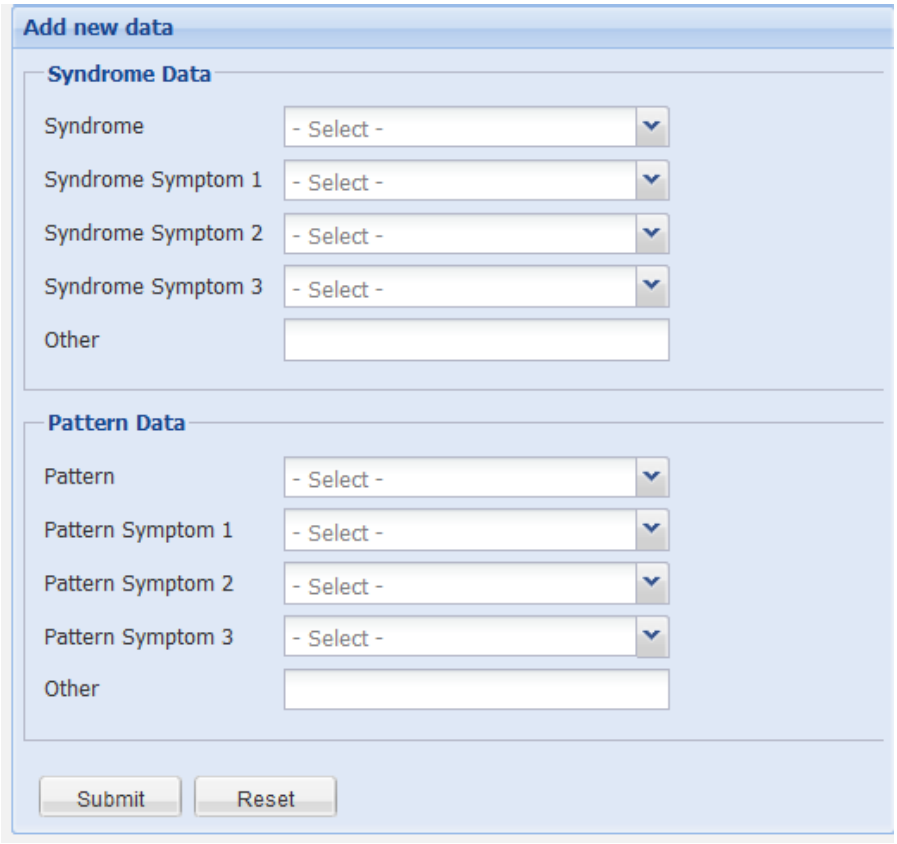



Figure 4.11. Form for adding new relationships between syndrome (Western Medicine) and pattern (TCM)

Likewise, for the case of a user starting the relational medical diagnosis from the TCM side, Figure 4.12 presents the symptom-based search form for relational medical diagnosis. Figure 4.13 presents the initial report based on the searched symptoms, and Figure 4.14 shows the diagnosis for a selected, previously mapped syndrome (Western Medicine). Figure 4.15 shows the form offered to the user for adding more data, either for more symptoms for a particular syndrome, or for more relationships connecting the syndrome with a pattern based on symptoms.

The intention of offering both search forms is for the user's convenience. Coming from different medical backgrounds, TCM or Western Medicine followers can start querying the system using terms such as syndromes, patterns, or symptoms, to learn of potential diagnosis.

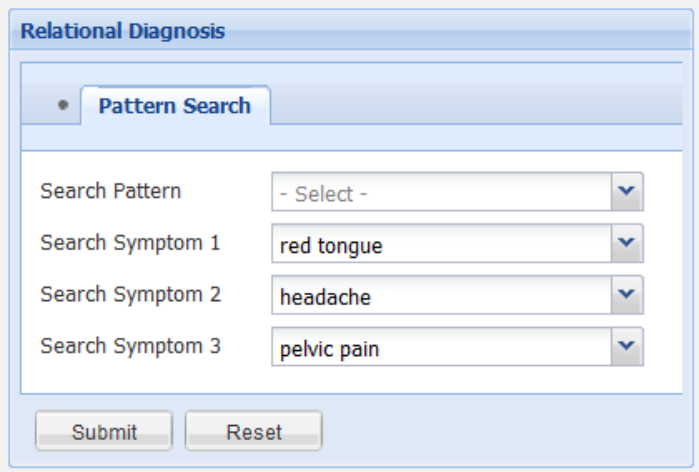



Figure 4.12. Search form for relational medical diagnosis starting from TCM

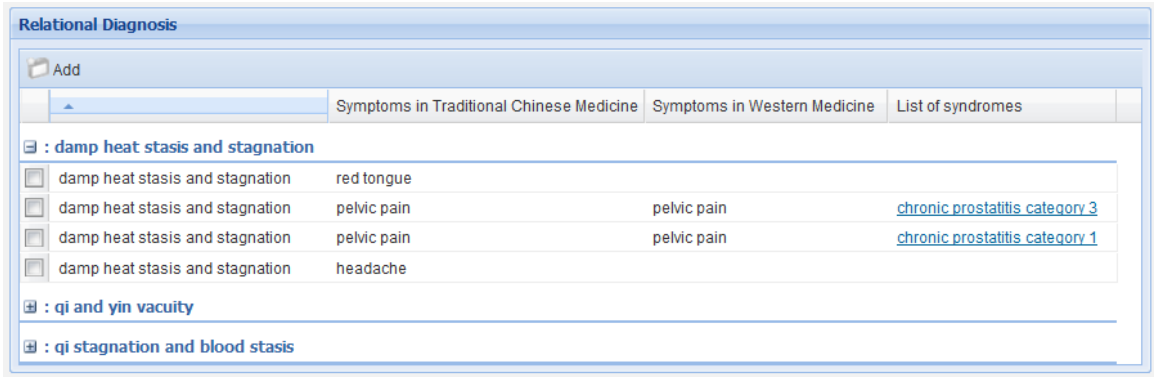



Figure 4.13. Initial report based on the searched symptoms in TCM, mapped into Western Medicine.

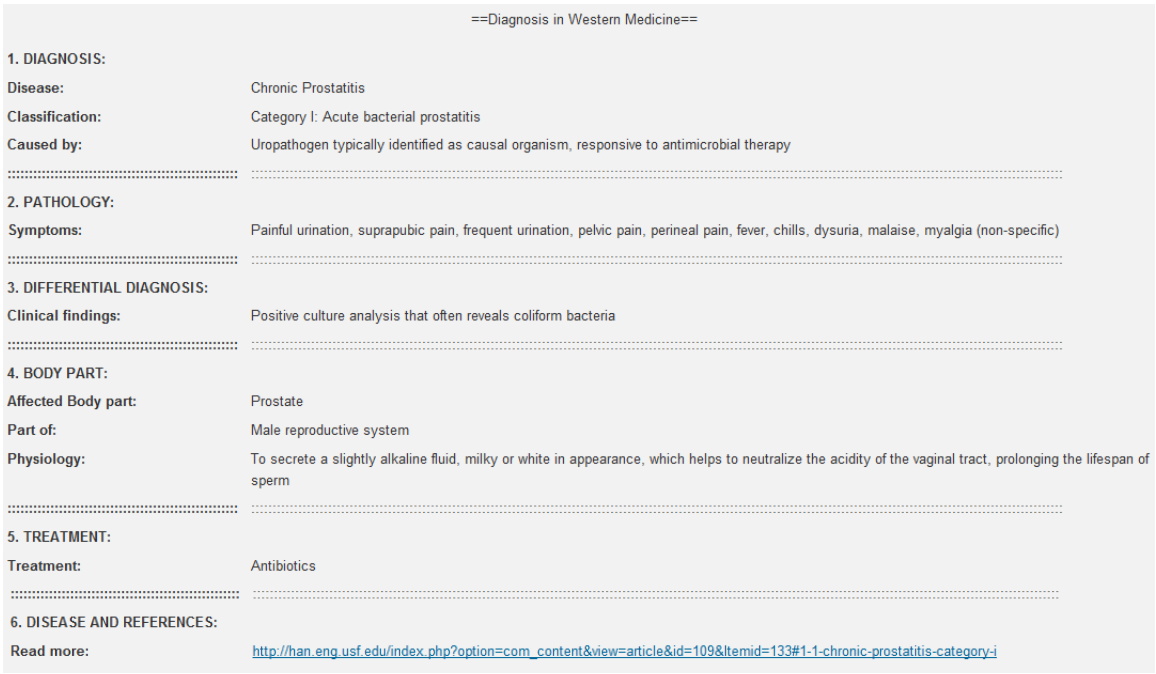



Figure 4.14. Diagnosis report with detailed information for a selected syndrome

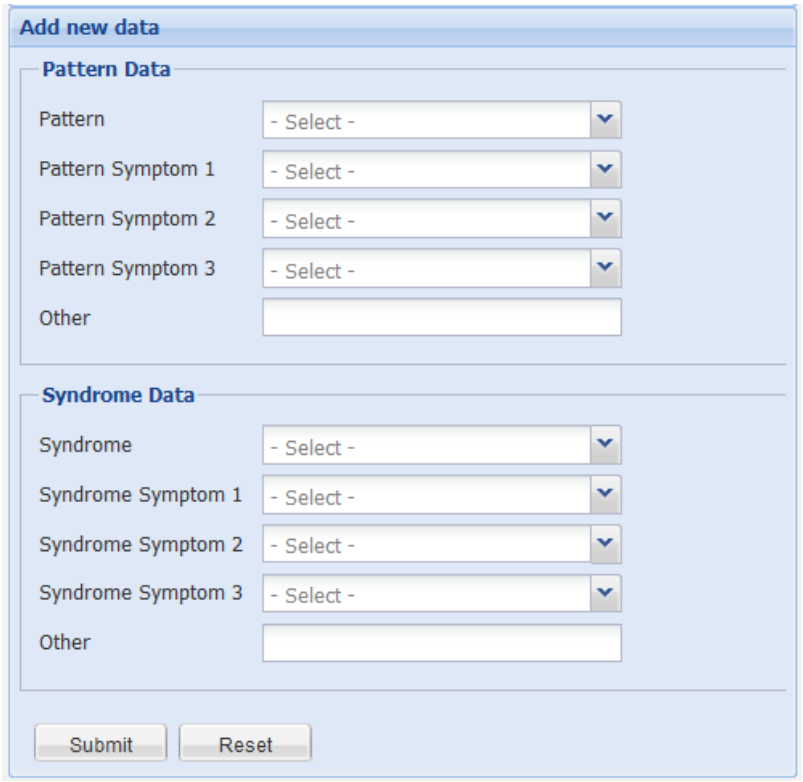



Figure 4.15. Form for adding new relationships between pattern (TCM) and syndrome (Western Medicine)

# CHAPTER 5

# INTERFACE FOR KNOWLEDGE EXPLORATION AND DISCOVERY

This chapter presents the design and development of an interface via web-based design techniques to facilitate the exploration of potential solutions available for medical diagnosis, learning, creation and sharing of new knowledge.

## 5.1 Background

Data are retrieved from the database as medical information to facilitate users to understand keyword-based searches for symptoms, pattern and syndrome for relational medical diagnosis. The system not only allows regular users to view and explore the stored content, but also provides links to external information sources with complementary information.

From the Front End, authorized users are allowed to access the system and submit created knowledge, in the form of new data derived either after exploration of the solution space or from personal expertise. The submitted data is reviewed prior to being published by knowledgeable editors collaborating with the knowledge system. The interface facilitates the interaction with the knowledge-based system, complements descriptive information, improves user learning, and enables the submission of new knowledge.

The challenge addressed in this chapter is the creation of an interactive interface, by means of a web application framework and object-oriented programming, to facilitate information exploration and further knowledge creation.

## 5.2 Definition of the Functional and Informational Architecture

Potential users of the relational knowledge management system such as medical practitioners have been interviewed to gather information regarding their needs for Western and TCM medical knowledge access. The basic user requirements were expressed as:

- Ease of use and access
- Display the information in no more than three windows
- Complement anatomical data with links to related histological data.

As a medical community, users consider it important to be able to insert new data and have system users responsible for editing existing data. As for the initial data to upload, preferred sources are practitioner's new knowledge, indexed medical journals, official agencies, national libraries and research centers for both, Western and TCM medical data.

Gathered previously, some of the user expressed requirements to consider are the system capabilities for user registration and levels of user access to the information. Figure 5.1 illustrates the user management for the knowledge management system. For different user profiles interacting with the system through the interface, general users can only view and browse the published content, authorized users can submit new content to be published after revision, quality verification and approval, administrator users can have access for revising submitted content, and webmasters have higher

permit level for accessing the database to modify the content-based management system in general.

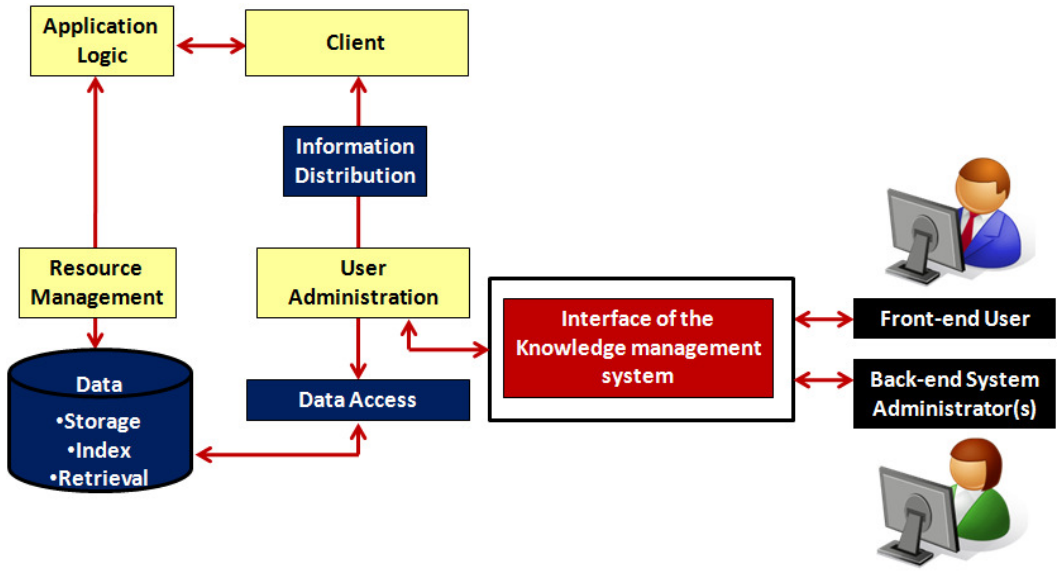



Figure 5.1. User administration for the knowledge management system for exploration and knowledge sharing.

As part of the functional architecture, inserting new records into the database tables occurs based on two actions: 1) For descriptive content, the authorized user logs in the system, creates the article and submits it for revision and further publication. This is, the content does not get to be published without being revised and approved. 2) For symptoms, syndromes and patterns for relational diagnosis, the creation of new records occurs once an authorized user completes the add form and submits the data to populate each one of the correspondent fields.

Regarding the delete category, webmaster users are allowed to make any required changes to the web application and to the records in the database tables from the back end. Updating content is for authorized users and for editors to create new content in an

existing article. As for changing the value of an attribute in a particular table, just the super-administrator is allowed to do this accessing the database from the back end.

Finally, the read only category applies to users that are allowed to access the information for viewing and exploration purposes, not allowed to post nor make any changes. This would be a typical profile for common users like medical students or patients, who are just consulting or exploring the relational knowledge-based management system for learning.

## 5.3 Definition of the Screen Design for User View

Examples of information gathered from the users include:

- Requirements for exploring the knowledge management system
- Form view of user interface to enable medical users to access knowledge to improve their diagnosis and treatment procedures
- Preferred sources and format for the information to be retrieved and displayed from the database using searching methods.

Considering the screen as the electronic document the user will interact with, the form approach is the desired one in this research. Using the computer screen, the form design will allow users to view data and, depending on his/her user profile, may be able to use the same screen (front end) to change or add data. Unlike the form design, a report as an electronic document will not serve user needs, as the report retrieves information from the database and formats it for presentation. However, it does not allow the user to update or make changes to the stored data.

Regarding how knowledge discovery is facilitated to the user, Figure 5.2 illustrates how the web-based application framework presents the user with content-based, descriptive information. The interface and the framework guide the user towards the relationship between the vital organs in Western Medicine and vital functions in TCM either by navigating through images or text.

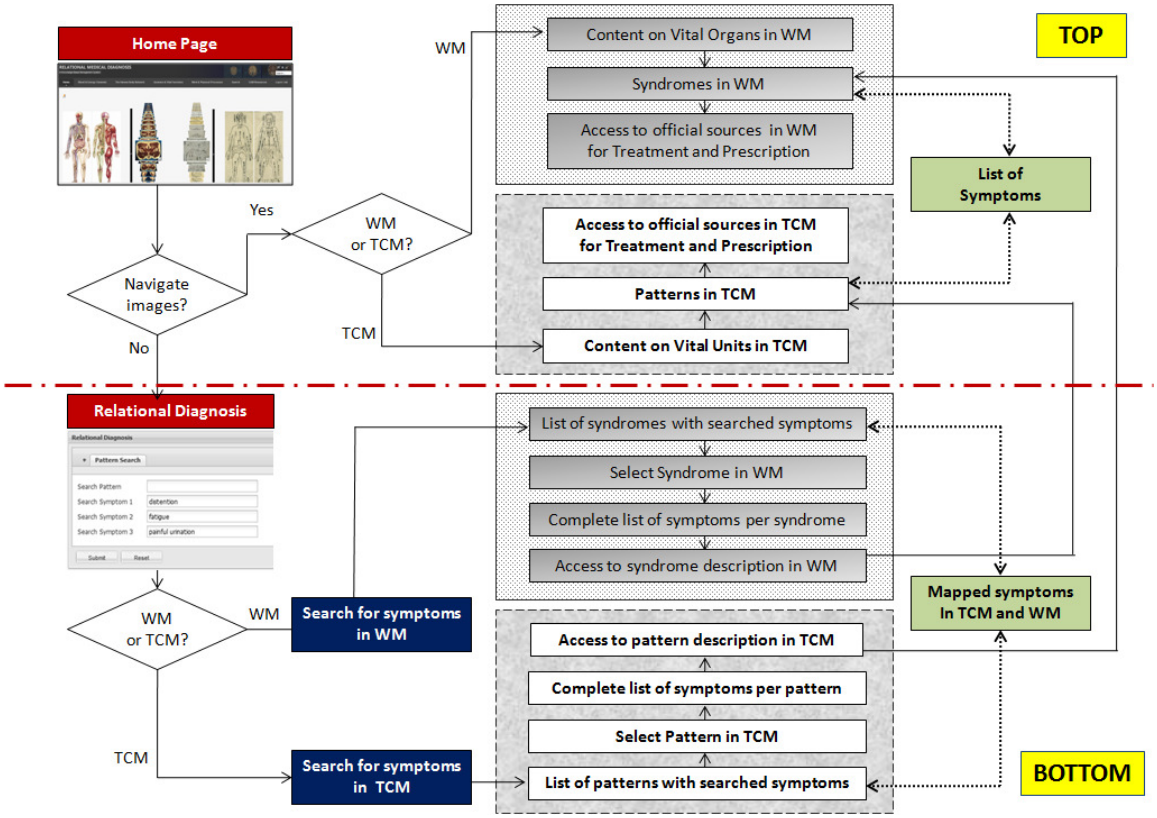



Figure 5.2. Conceptual model – Design of interface for the knowledge management system for relational medical diagnosis

From Figure 5.2 (top), the user navigates the system through images of anatomical representations of organs in Western Medicine or vital functions in TCM. The descriptive information is intended to present basic concepts of vital organs and vital units, clinical definition of syndromes in Western Medicine and TCM information of patterns, and facilitate access to official sources for treatment and prescriptions. Figures 5.3 and 5.4

present the access from the home page in the user interface. The descriptive information is intended to present basic concepts of vital organs and vital units, clinical definition of syndromes in Western Medicine and Traditional Chinese information of patterns, and facilitate access to official sources for treatment and prescriptions. Besides medical observations when inspecting the patient's physical body, the practitioner consults medical knowledge stored in our knowledge-based system for better assessment of any particular signs of either mental, emotional or physical medical condition, and are necessary to evaluate the body as a fully interconnected system. Figure 5.5 details our interactive interface for image and content-based navigation of our knowledge based system for relational diagnosis.

With cascade menus and headlines of the content stored in the database along with the menu options, the images correspond to the human body as seen in Western Medicine (left) and Traditional Chinese Medicine (right). The slide bars allow the user to visually navigate the system by identifying a representative image of the human body at a particular level. If flipped, the images present brief descriptive information, and a link to pages with correspondent and detailed content. In this case, the images link to the pages for kidneys and bladder as vital organs (Western Medicine) and vital functions (Traditional Chinese Medicine). From here, the user can access and map content on related syndromes in Western Medicine and related patterns (Traditional Chinese Medicine) based on symptoms.

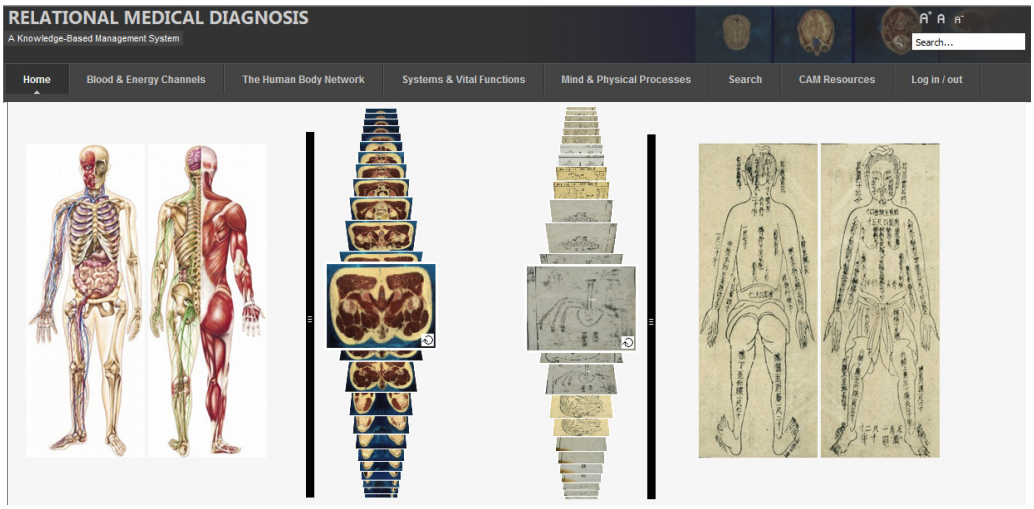



Figure 5.3. Access to the knowledge management system from the home page

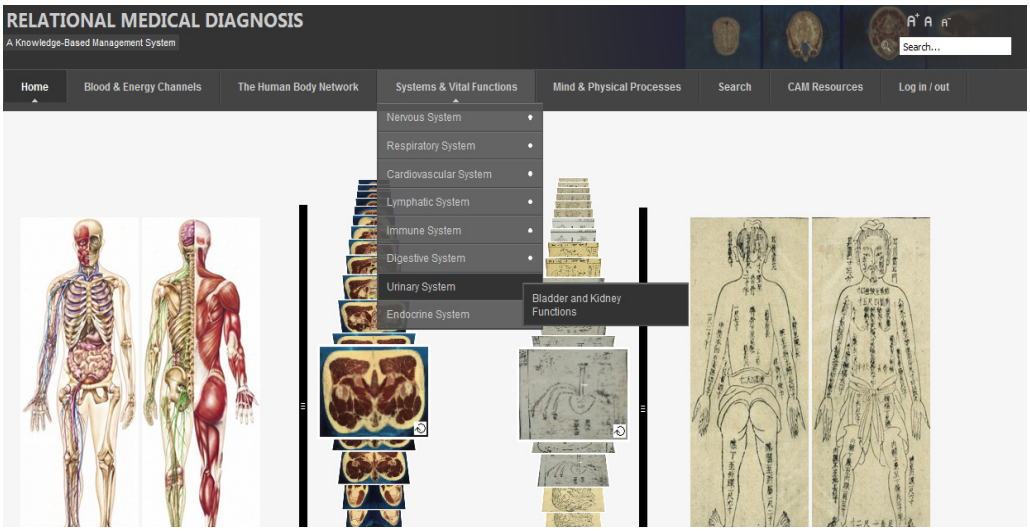



Figure 5.4. Cascade menu navigation matching Western Medicine body systems with TCM body vital functions.

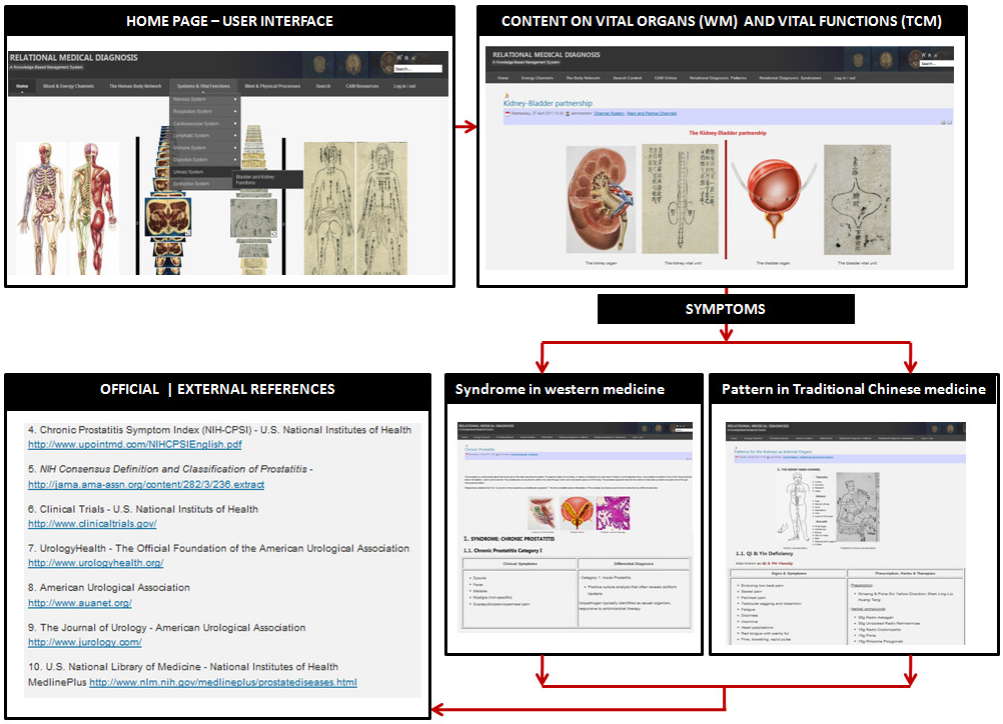



Figure 5.5. Image and content-based navigation of our knowledge management system, from Figure 5.2 (top).

From the query interface in Figure 5.2 (bottom), the user runs symptom, syndrome and/or pattern-based text searches into the relational database, as detailed in Figure 5.6. Common symptoms to TCM and Western Medicine are mapped and presented to the care provider. These searches allow the user to navigate between TCM and Western medical data, explore the stored knowledge and understand the relationships between syndromes and patterns via the interconnection of symptoms.

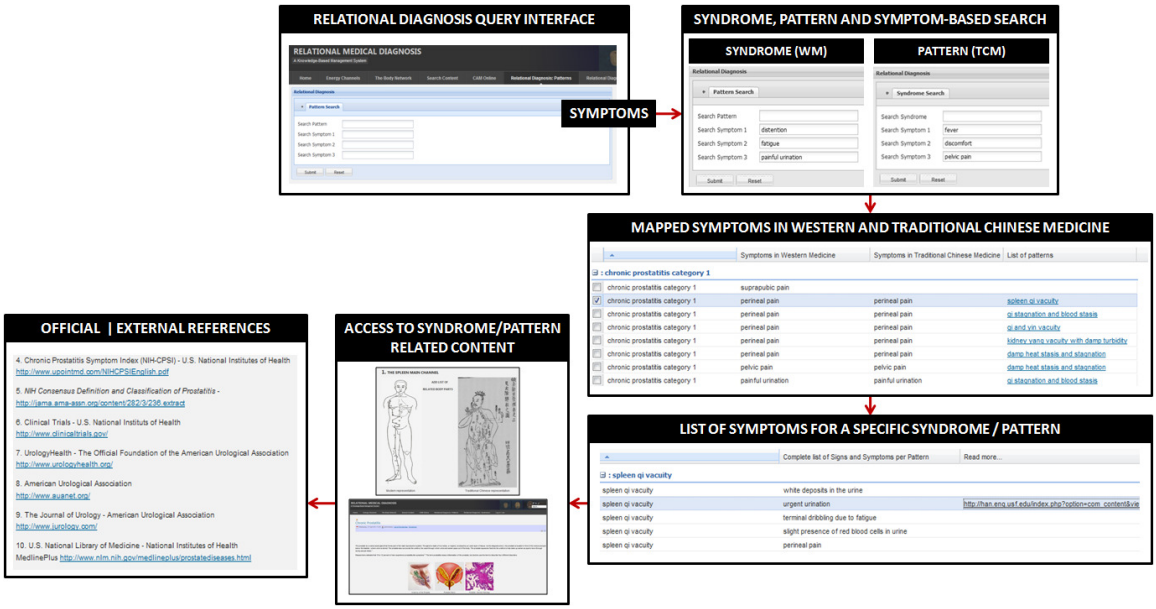



Figure 5.6. Symptom, syndrome and pattern search-based interface for relational medical diagnosis in Western Medicine and TCM, from Figure 5.2 (bottom).

The advantage of having these two navigation approaches is that it increases the interaction possibilities between the system and the user, for an organized and effective exploration of ideas and better informed medical diagnosis. For care providers, the interaction with the knowledge management system facilitates their learning of unknown relationships between Western Medicine and TCM, for better assessment of any particular signs of either mental, emotional of physical medical condition, and are necessary to evaluate the body as a fully interconnected system.

## 5.4 Definition of the Form Specification

In general, the screen design allows users to operate and execute functions for knowledge exploration, discovery and sharing with the simplest and easiest access to the information, so that the user needs previously listed are met (Figures 5.3 -5.4). Users interact with the web application framework through knowledge mining techniques,

successfully used to retrieve information from databases based on the user interaction. Further work will extend the query criteria options in the knowledge-based system to validate the functionality of keyword-based search and query-based knowledge mining approaches in retrieving information from the database. A keyword-based framework for dynamic content has been built to effectively search and access medical textual data with related images stored in our database (Figures 5.7 – 5.8).

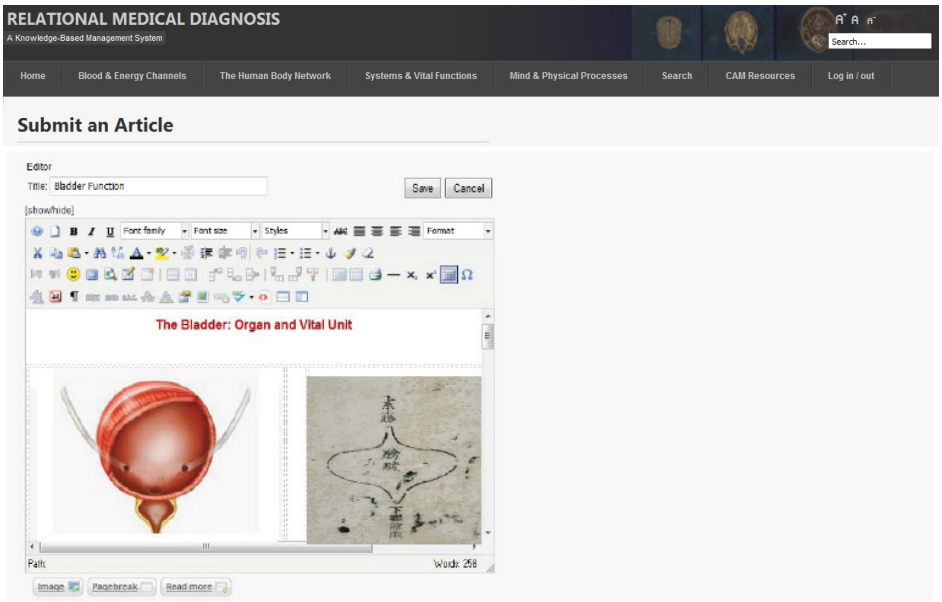
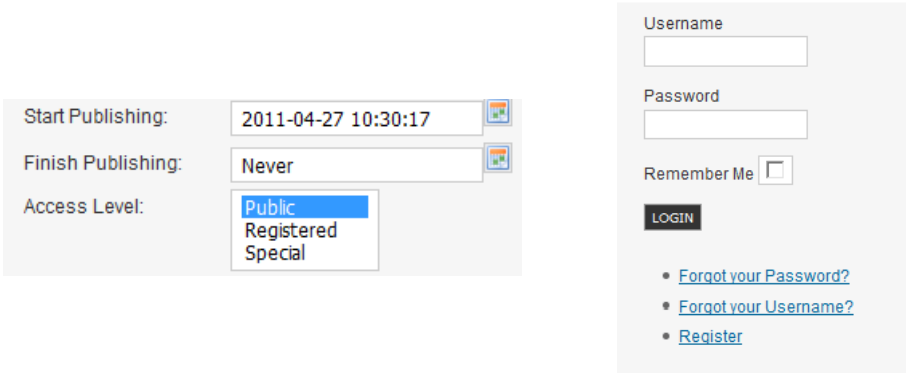



Figure 5.7. User capability for knowledge sharing.




a) b)

Figure 5.8. User capability to a) determine access level and b) register and log in/out

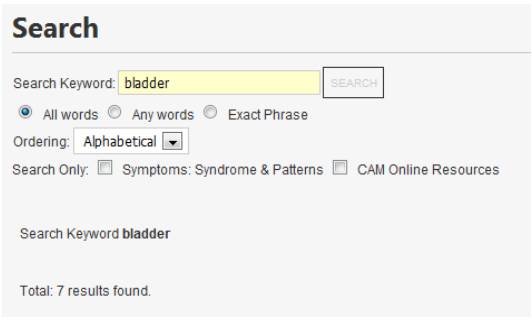



Figure 5.9. User capability for keyword-based search.

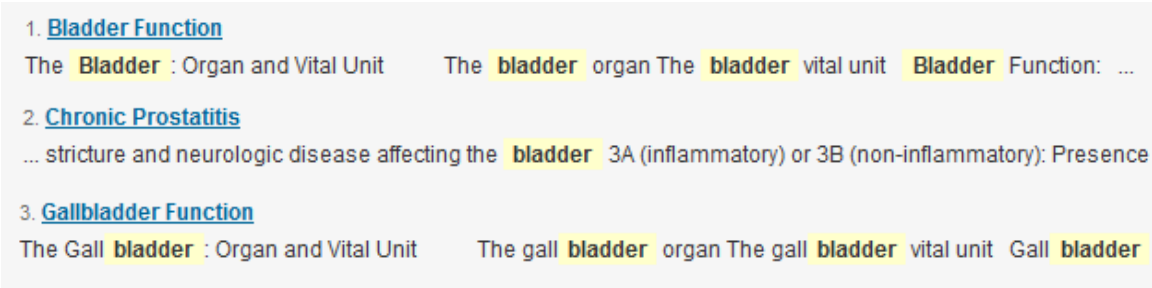



Figure 5.10. List of results for the keyword-based search.

Other user requirements for the system were expressed as: a) easy to explore, b) balanced usage of visual and textual data to describe and illustrate medical information, c) navigation through menu options or directly from displayed content, d) no more than three levels in the navigation tree to get to the required user view, e) keyword-based browsing option to retrieve specific information, and query-based search to tailor the knowledge discovery.

As the screen design has been decided to be a form instead of a report, a proper form must allow users to operate and execute functions for knowledge exploration, discovery and sharing with the simplest and easiest access to the information, so that the user needs previously listed are met.

Layout, data integrity requirements, form navigation and user interaction are the issues to address when determining the form specification. When presenting the information on the screen, the layout for this research will not reference the layout on any existing physical document in current use for relational medical diagnosis in Complementary Medicine. However, it is of interest to keep the layout as simple and clean as possible. This will help the user find navigation options, and explore the knowledge in the database in a simple manner. As for data integrity requirements, the current process for entering data is basically manual, and always subject to the administrator's revisions to assure that the data is being loaded properly. The system is currently using medical knowledge from textbooks and interviewed practitioner's experience, so the closest to a control for data entry is the publication of a set of instructions to be read always that an authorized user decides to create a new content, or when editor publishes the content after revision and validation.

Finally, form navigation in this system presents forms that have multiple pages, reason to keep navigation commands (tabs) on the upper section of the screen so that the user can directly display cascade menus and select the option that may take him/her to a new content of interest. These tabs are located on the same position on the screen; independently of how advanced the navigation is relative to the home page.

The prototype and its functionality demonstrate the effectiveness of interactive over functionality-oriented design. Based on this feedback, the interactive web-based interface was designed to effectively present module areas, graphic and word-based methods for interface navigation. Also, the query and keyword-based search module has been successfully integrated.

# CHAPTER 6

# CASE STUDY: USE OF THE PROPOSED KNOWLEDGE MANAGEMENT SYSTEM FOR THE RELATIONAL DIAGNOSIS OF CHRONIC PROSTATITIS

This chapter demonstrates the capabilities of the proposed framework through a case study on chronic prostatitis, and can be scalable to other medical conditions. By mapping different medical and cultural backgrounds and establishing connections between knowledge from TCM and Western Medicine, the information is distributed for broader consideration of physical, mental and emotional signs, symptoms and causes of disease for a complementary medical diagnosis.

## 6.1 Data Acquisition for Chronic Prostatitis in Traditional Chinese and Western Medicine

Medical data for the diagnosis of chronic prostatitis was acquired from well-known textbooks, medical journals, interviews with medical practitioners and access to public information from official agencies. In TCM, the data acquisition about signs, symptoms, patterns, therapies, herbal compounds and prescription for treatments was based on references in literature such as Flaws and Finney [12], Flaws and Sionneau [13], Maciocia [14] and Piegl [95]. Open-access sources were used, such as the databases Acupuncture.com.au [68], Dictionary of Chinese Herbs [69], Plants for a future [70], the MD Anderson Center [75] and Clinical Trials in CAM [76].

In Western Medicine, data acquisition about symptoms, differential diagnosis, laboratory tests, prescriptions and treatments was based on references such as the Campbell-Welch Urology Review Manual [1], the International Classification of Diseases [71], NIH drug information portal [72], Mayo Clinic [73], NIH MedlinePlus [74], the National Kidney & Urologic Diseases Information Clearinghouse (NKUDIC) [80] and NIH PubMed [89].

## 6.2 Data Organization, Storage and Transfer

Consider the use of key relationships between TCM and Western Medicine in the diagnosis of chronic prostatitis. When there is prostate inflammation, most patients experience symptoms such as low back and perineal pain, urinary urgency, urinary frequency and painful urination. These are some of the symptoms considered common knowledge to both TCM and Western Medicine. However, the definition of prostatitis-related syndromes in Western Medicine differs from the definition of prostate dysfunction patterns in TCM.

As presented in Figure 3.4 (on page 31), the care provider will start the diagnosis process by physically examining the patient. For diagnosis purposes, the care provider uses our relational system to list potential syndromes or patterns containing the listed symptoms. Not only this action is useful to confirm the initial impression for a particular syndrome or pattern, but also allows the practitioner to explore and create new knowledge, to find mappings and relationships between syndromes and patterns through the set of common symptoms.

Consider first a TCM practitioner as the system user. Fatigue and painful urination are some of the symptoms experienced by a particular patient, and these and other set

of symptoms facilitate classification and diagnosis of the chronic prostatitis disease in TCM patterns. From Figure 6.1, based on the result of a symptom-based search, the care provider learns that there are more than two potential patterns that could be considered for diagnosis and treatment.

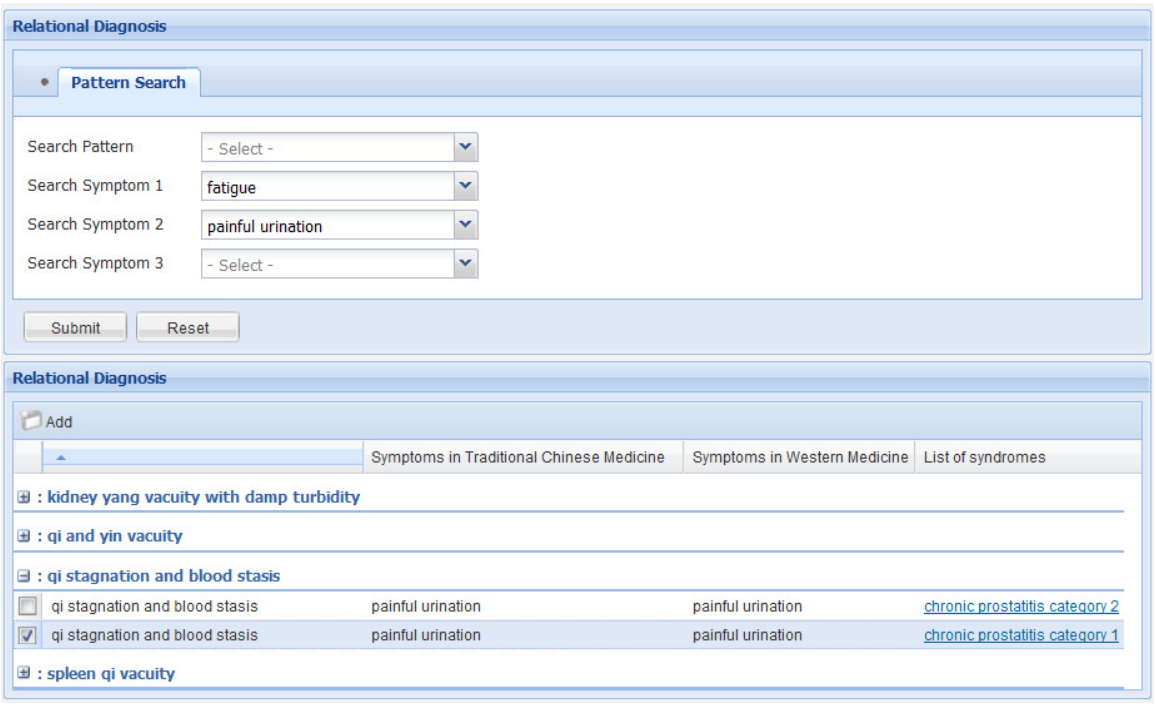



Figure 6.1. Relational diagnosis: List of potential patterns as the result of a symptom-based search

For each symptom included in the search, the system maps the searched symptoms in Western Medicine, and reports the syndromes that are associated to the mapped symptoms. In the case of the result Qi stagnation and blood stasis, the care provider realizes that painful urination is a symptom also treated in Western Medicine, for both Chronic prostatitis category 1 and Chronic prostatitis category 2 syndromes. Assuming that the care provider is interested in learning more about the symptoms treated in

Chronic prostatitis category 1, the diagnosis in Western Medicine for this syndrome is reported as shown in Figure 6.2.

==Diagnosis in Western Medicine==

| | |
|---|---|
| **1. DIAGNOSIS:** | |
| **Disease:** | Chronic Prostatitis |
| **Classification:** | Category I: Acute bacterial prostatitis |
| **Caused by:** | Uropathogen typically identified as causal organism, responsive to antimicrobial therapy |
| **2. PATHOLOGY:** | |
| **Symptoms:** | Painful urination, suprapubic pain, frequent urination, pelvic pain, perineal pain, fever, chills, dysuria, malaise, myalgia (non-specific) |
| **3. DIFFERENTIAL DIAGNOSIS:** | |
| **Clinical findings:** | Positive culture analysis that often reveals coliform bacteria |
| **4. BODY PART:** | |
| **Affected Body part:** | Prostate |
| **Part of:** | Male reproductive system |
| **Physiology:** | To secrete a slightly alkaline fluid, milky or white in appearance, which helps to neutralize the acidity of the vaginal tract, prolonging the lifespan of sperm |
| **5. TREATMENT:** | |
| **Treatment:** | Antibiotics |
| **6. DISEASE AND REFERENCES:** | |
| **Read more:** | http://han.eng.usf.edu/index.php?option=com_content&view=article&id=109&Itemid=133#1-1-chronic-prostatitis-category-i |

Figure 6.2. Relational diagnosis: Mapped syndrome and its complete list of symptoms, from Figure 6.1

After exploring ideas and learning potential solutions for diagnosis and treatment, the care provider can share the created knowledge. The new data to add could refer to either more symptoms, or to new relationships interconnecting the same pattern in TCM with a different syndrome in Western Medicine. For example, painful urination, frequent urination and pelvic pain are symptoms not only presented in chronic prostatitis category I, but are also associated with cystitis. Therefore, after updating the knowledge in TCM as presented in Figure 6.3, and after quality verification by an authorized editor prior to publishing, future searches will present chronic prostatitis and cystitis as syndromes in

Western Medicine related to the Qi stagnation and blood stasis pattern in TCM, augmenting the field of ideas and possible solutions for medical diagnosis.

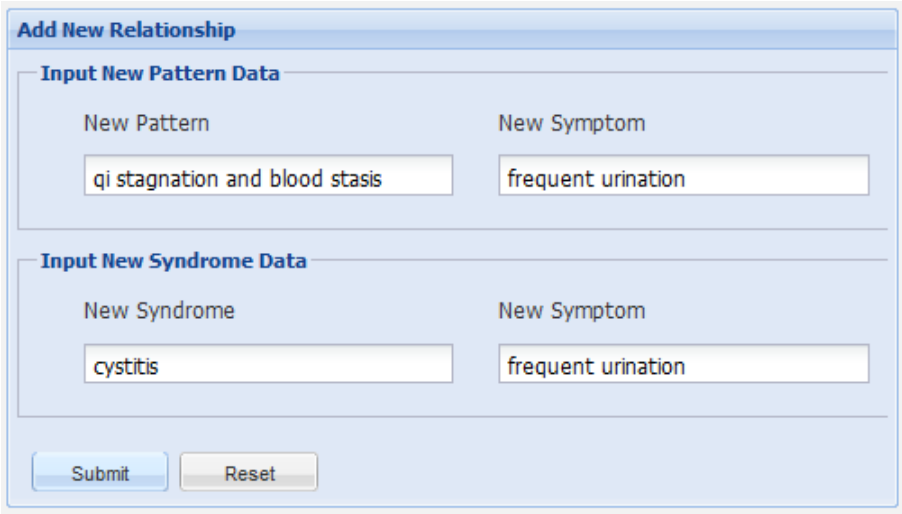



Figure 6.3. Sharing new knowledge in TCM by adding new data to relate an existent pattern with a new syndrome, based on common symptoms.

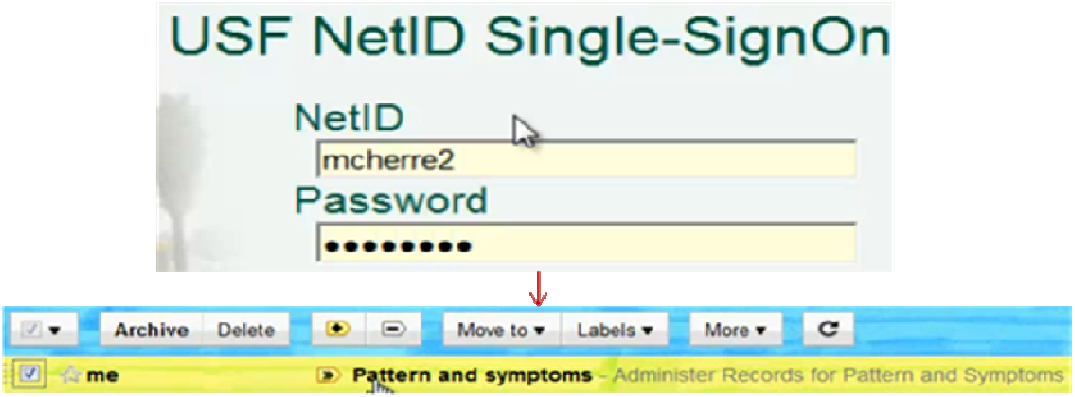



Figure 6.4. E-mail notification for editor to review new content.

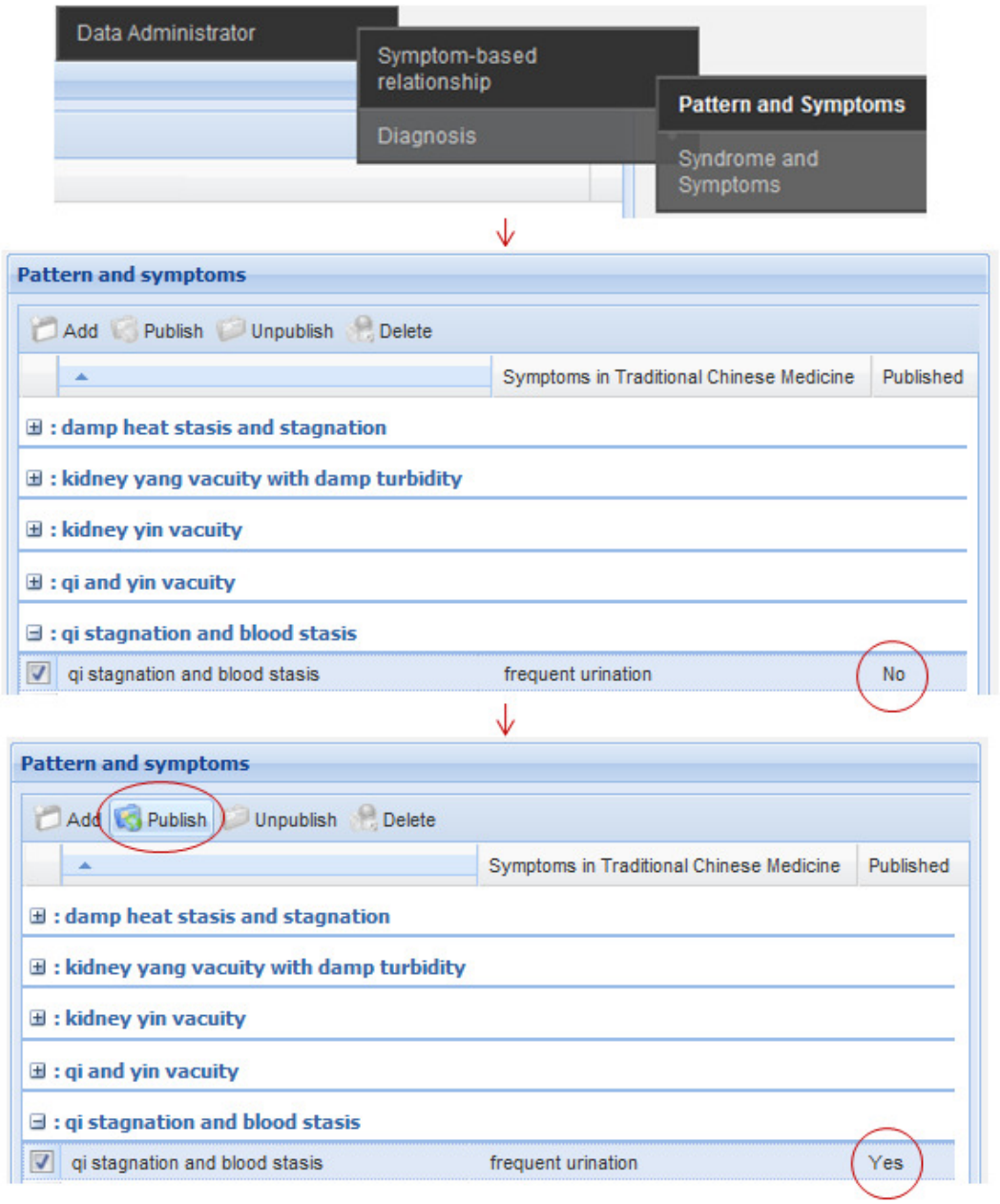



Figure 6.5. Data administrator view for quality verification and publishing of new data.

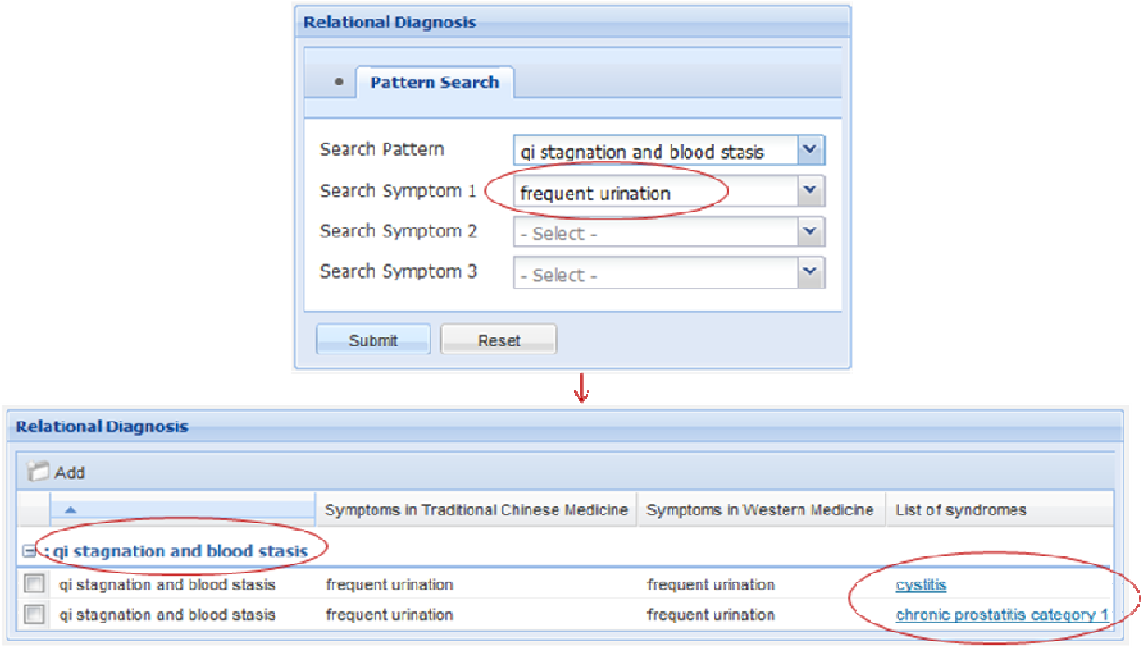



Figure 6.6. Verified and published new data is included in future searches.

Now consider a care provider in Western Medicine as the system user, and the same patient with similar symptoms. Chronic inflammation of the prostate gland could be of bacterial or nonbacterial origin, and implies a relapsing urinary tract infection due to the same pathogen found in the prostatic secretions [12]-[14]. The diagnosis process in Western Medicine differentiates medical conditions based on history, experienced symptoms and clinical laboratory results. From Figure 6.7, the care provider could consider several potential types of chronic prostatitis for diagnosis and treatment. For a symptom-based search including fever, and pelvic pain, our system provides the care provider with three potential syndromes to consider for diagnosis. In the case of Chronic prostatitis category 1, the system provides the user with information that pelvic pain and fever are symptoms also treated in Traditional Chinese Medicine, for Damp heat stasis and stagnation and for Kidney yin vacuity patterns, respectively. Assuming that the user is interested in learning more about the symptoms treated in Kidney yin vacuity, the

pattern and its complete diagnosis in Traditional Chinese Medicine as shown in Figure 6.8.

After exploring ideas and learning potential solutions for diagnosis and treatment, the new knowledge to share can be also added to the system either in the form of more symptoms, or as new symptom-based mapping of the same syndrome in Western Medicine with a different pattern in TCM. For example, cystitis could not only be related to the Qi stagnation and blood stasis pattern in TCM based on common symptoms such as painful urination, frequent urination and pelvic pain. Cystitis could also be related to the kidney yin vacuity pattern, based on common symptoms such as fever and dark urine. After updating the knowledge in Western Medicine as presented in Figure 6.9, and after revising the accuracy and quality of the new data prior to publishing, future searches will present cystitis in Western Medicine related to both Qi stagnation and blood stasis and Kidney yin vacuity patterns in TCM, augmenting the field of ideas and medical knowledge available for a better informed medical diagnosis.

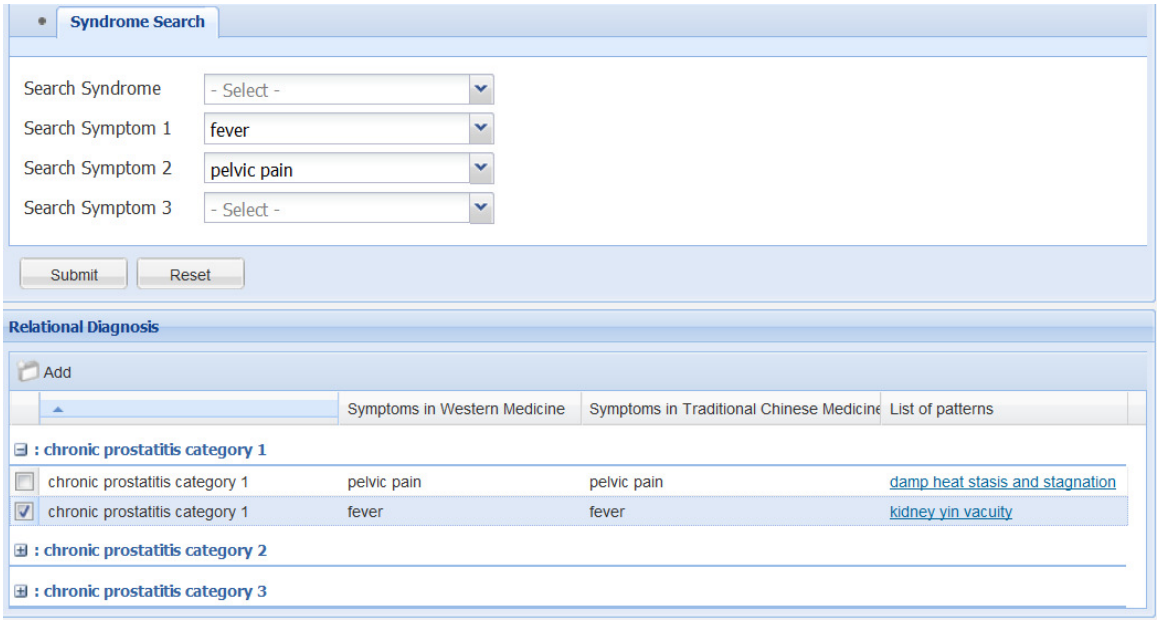



Figure 6.7. Relational diagnosis: List of potential syndromes as the result of a symptom-based search

== Diagnosis in Traditional Chinese Medicine ==

| | |
|---|---|
| **1. DIAGNOSIS:** | |
| **Disease:** | Kidney Yin Vacuity |
| **Caused by:** | Too much standing or kneeling, salt, excess liquid, hot clothing, sweets, excess of sexual activity, heavy lifting. |
| **Related Syndrome:** | Chronic Prostatitis |
| **2. PATHOLOGY:** | |
| **Body Signs:** | SKIN: Dry. HAIR: Falling out, dry and brittle, premature greying. EYES: Dark eye lids, worsen eye streaming when tired, pale eye corners. NOSE: Dark and dry tip, swollen nose. LIPS: Red and swollen, red and dry. TEETH: Cavities, loose teeth, plaque, dry and dull, yellow and dry, grey, ash-like grey, upper teeth moist and lower teeth dry. GUMS: Bleeding, receding, slightly red without swelling. EARS: Dry and contracted helix, greenish-dark helix, red helix, redness and swelling of the concha, excessive wax production, discharge from the ears. THROAT: Pale red pharynx, sore throat. BACK: Spine bent forward, scoliosis, kyphosis, pustules on lower back. HEARTBEAT: Displaced to the sixth intercostal space. HANDS: Atrophy. NAILS: Thin and brittle, withered and brittle, cracked, flaking. CHEST: Sunken chest, protruding sternum. SKIN: Dry skin, skin ulcer. TONGUE: Dark, swollen and wet sublingual venis, deep midline crack with other cracks stemming from it, lack of coating all over, red body. |
| **Symptoms:** | Lower back pain, hair loss, sexual problems, painful joints, high blood pressure, knee problems, discharge of clear thin fluid from urethra, frequent urination, frequent nocturia, yellow urine, dizziness, tinnitus, sexual impotence, seminal emission, insomnia, night sweats, vexatious heat in the five hearts, fever, constipation, rapid pulse, sacral soreness. |
| **3. DIFFERENTIAL DIAGNOSIS:** | |
| **Tongue and Pulse:** | Red tongue with scanty fluids and a fine, rapid pulse |
| **4. VITAL UNIT:** | |
| **Primary Vital Unit:** | Kidneys |
| **Associated Body Parts:** | Ring finger, middle toe, bones, hair on head, ears, reproductive organs, knees, small toe, inner ank |
| **Physiological Function:** | Resposible for proper functioning of the endocrine system and the neurohormonal system. Filter the body's fluid and move the waste to the urinary bladder for evacuation as urine. Responsible for the watery part of the blood, for the development of the hair on the head and the development of bones and the skeletal structure. All ear functions are also related to the kidneys. Sexual drive is closely related to the kidneys and sexually transmitted diseases have their roots in the kidneys. The |
| **Psychological Function:** | Willingness of the person. ASSOCIATED EMOTIONS: Fear, sexual climax, guilt, depression, awe, lack of will power, no zest for life. PERSONAL QUALITIES: Libido, humility, restraint, will power, ideas, fire of life. |
| **Signs of Channel Underactivity:** | Cold feet, urination disorders, bad memory, incontinence of urine, low resistance, fear, aversion to cold, chills, joint diseases, lack of sexual desire, ulcers, anxiety, lack of patience, physical and emotional fatigue, cracks in the nails, stiffness below the navel, dry and puffy skin. |
| **Signs of Channel Overactivity:** | High blood pressure, hot feet, dry mouth, excess mucus, painful joints, inner restlesness, fever, dark urine, impatience, lack of determination, vomiting, blood in slaiva, fainting, heaviness of head, thirst, poor hearing, stiff back, ringing in the ear, bad breath, proneness to inflammation. |
| **5. COMPANION ORGAN:** | |
| **Companion Organ:** | Urinary Bladder |
| **Associated Body Parts:** | Little toe, nervous system, ureters, sexual organs, knees, rectum |

Figure 6.8. Relational diagnosis: Mapped pattern and its complete diagnosis in TCM, from Figure 6.7

| | |
|---|---|
| **6. TREATMENT:** | |
| **Therapy:** | PROSTATE: Rid the gland of the bacteria by frequent ejaculation and prostate massage. Take warm sitz baths, lower back massage, and drink plenty of fluids. Apply acupressure: C.V.2 C.V.4 Sp.6 Sp.9 K.3 K.5 K.7, St.36, Liv.3 |
| **Natural Remedies:** | Take one to two teaspoonfuls of bee pollen granules daily. Sip on saw palmetto berry tea a couple of times a day, or take a supplement that contains palmetto, pumpking seed and pygeum bark. These natural remedies are rich in magnesium, zinc and aspartic acid, which are needed for nourishment of the sex glands, to treat fatigue and to help heal bacterial infection. |
| **Life Style and Diet:** | Avoid activities that injure the genitourinary system, heavy lifting, sweets, too much standing or kneeling, salt cold and holding back urine. Cut the calories and the fat, stop smoking and drinking coffee and alcholo, take vitamins C, D and E, eat soy products, drink green tea, take the sun at least 20-30 minutes a day. Maintain a well balanced and regular sexual activity, irrespective of the patient's age, to prevent the prostate to get stagnant. Visit the urologist annually to monitor your prostate health. |
| **Herbal Compounds:** | Uncooked Radix Rehmanniae, Cooked Radix Rehmanniae, Radix Dioscoreae, Poria, Rhizoma Alismatis, Fructus Corni, Cortex Moutan, Fructus Ligustri Lucidi, Herba Ecliptae, Rhizoma Smilacis Glabrae, Rhizoma |
| **Vital Unit Treatment:** | |
| **Treatment for Underactivity:** | Acupuncture for TONIFYING: K.7 Lu.8 Sp.3 K.5 K.9 Lu.9. |
| **Treatment for Overactivity:** | Acupuncture for SEDATING: K.1 Liv.1 Sp.3 K.5 Lu.5 Liv.3 Sp.1. |
| **Treatment for Balancing:** | Acupuncture for TESTING/BALANCING: K.5 G.B.25 Sp.6 K.7 K.1 Sp.3 Sp.9 K.3 |
| **7. DISORDER AND REFERENCES:** | |
| **Read more:** | http://han.eng.usf.edu/index.php?option=com_content&view=article&id=111&Itemid=134#3-1-kidney-yin-deficiency |

Figure 6.8. (Continued)

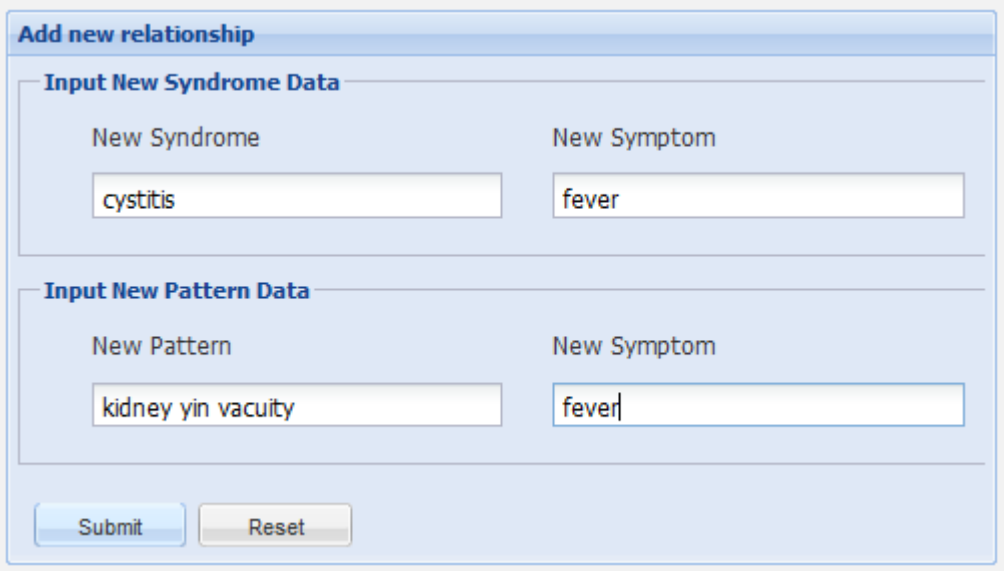



Figure 6.9. Updating new knowledge in Western Medicine by adding new data to relate an existent syndrome with a new pattern, based on common symptoms.

## 6.3 Learning and Knowledge Creation for Relational Diagnosis in Traditional Chinese and Western Medicine

By using our knowledge management system, the practitioner learns the correspondence between patterns and syndromes through common symptoms. The practitioner also accesses complementary information to learn that there are clinical ways in Western Medicine to evaluate objectively the nature and severity of the condition. Overall, the TCM practitioner explores and learns potential solutions and learns that there is similar medical knowledge in Western Medicine based on the common symptoms to describe the same chronic prostatitis syndrome. The relationships between syndromes and patterns help TCM providers to learn Western clinical ways to analyze and evaluate the severity of the disease, make informed decisions for pattern diagnosis, and for a complete treatment plan.

For a care provider in Western Medicine, external sources for information on treatments and prescriptions on Kidney-related patterns are provided to the user through the listed link. The relational system provides the care provider with knowledge on the way TCM creates direct relationships between the prostate gland and other organs and body parts, signs and symptoms such as red eyes, weakness, yellow tongue coating and headache behind the eyes. The relational system also provides indirect relationships between the prostate and the TCM vital units of the Spleen and Kidney. These relationships provide the practitioner with a broader vision of the human body as a fully-interconnected system. It also helps the practitioner to consider other body areas as potential disease origins, different from the initial cause dictated by the Western medical knowledge.

## 6.4 Conclusions of the Case Study

This case study shows that the proposed system establishes connections between knowledge from TCM and Western Medicine for broader consideration of physical, mental and emotional signs, symptoms and causes of disease for a complementary medical diagnosis. The system also provides access to information from official sources for available treatments in TCM and Western Medicine to facilitate the design of more efficient therapies and prescriptions.

Summarizing, our framework for a knowledge management system for medical diagnosis can benefit both TCM and Western Medicine care providers. TCM practitioners can learn from our system how to assess clinically the severity of the medical condition and restore in short time the patient's health if life-threatening medical conditions occur. Western Medicine benefits from the relational diagnosis approach by learning ways to interconnect the human body and evaluate signs, symptoms and treatments, and the relationships with other organs and body parts. The relational medical diagnosis presents a unique opportunity for knowledge discovery on clinical trials and evidence-based research on treatment methods, access to complementary medical practices such as journals, official reports and available sources online. Equally important, the relational medical diagnosis presents a special opportunity to improve the patient-care provider interaction and to engage patients in their self-healing process.

The relational system provides the care provider with knowledge on the way TCM creates direct relationships between the prostate gland and other organs and body parts, signs and symptoms such as red eyes, weakness, yellow tongue coating and headache behind the eyes. The relational system also provides indirect relationships between the prostate and the TCM vital units of the Spleen and Kidney. These relationships provide

the practitioner with a broader vision of the human body as a fully-interconnected system. It also helps the practitioner to consider other body areas as potential disease origins, different from the initial cause dictated by the Western medical knowledge.

# CHAPTER 7

# CONCLUSIONS, DISCUSSIONS AND FUTURE WORK

This dissertation presented the design of a framework for a knowledge management system that maps the diagnosis processes in TCM and Western Medicine for organized exploration of potential solutions and for further generation of medical knowledge. The relational medical system enables the organization, storage, access and sharing of the abundant data available for both TCM and Western Medicine, while establishing key relationships between the two practices based on common symptoms.

The integrated medical diagnosis process has been modeled and the knowledge management system has been demonstrated through a case study on chronic prostatitis. The case study shows that the proposed framework maps different medical and cultural backgrounds, establishing connections between knowledge from TCM and Western Medicine for broader consideration of physical, mental and emotional signs, symptoms and causes of disease for a complementary medical diagnosis. The framework also provides access to information from official sources for available treatments in TCM and Western Medicine to facilitate the design of more efficient therapies and prescriptions.

The presented framework for a knowledge management system sets the foundation for future research on TCM and Western Medicine integration and management. It aims to disseminate the benefits of the integration of these two medical practices for better understanding of health conditions, creation of new treatments, and improvement of patient-practitioner communication.

Future work includes improvements on medical data acquisition. The framework for relational knowledge management system has been designed to be expanded; this is, to be populated with abundant medical data as available. It is open to be merged with external databases and computer-based applications in Medicine, such as the Foundational Model of Anatomy and the standards for medical ontologies (UMLS) in Western Medicine. With some collaborative work with the institutions that create these potential databases, the data acquisition could be automated, and also could be set up to receive the updates at the same time partner systems are updated. In TCM, the existent databases are commonly for herb-based prescription with scientific citations. Therefore, it is necessary to build a database in TCM under a similar structure compared to the mentioned ones in Western Medicine, so that both can be connected using the proposed system.

At the same time the acquired data increases in volume, there is future work for organization, storage and transfer. The performance of the system could be improved by automating rules for management. This will minimize the need for manual handling and processing of the acquired data, and will increase the accuracy of the relational approach for medical diagnosis. The current input of medical information is a limited trial, and more detailed information is expected to be included with the systematic use of this tool. The user interaction with the system could be enhanced by improving the system's interface. By merging the relational database in MySQL with frames such as Protégé, it could make it easier for the user to explore ideas for medical diagnosis.

Summarizing, knowledge management for medical applications continues to advance along with computers, their enhanced data processing capabilities and the improved human-machine interaction. For medical diagnosis, relating the alternate views of the human body by current practices in TCM and Western Medicine can lead to

a complementary and fully-interconnected health care. This can significantly improve medical diagnosis and treatment while enhancing patients' well-being.

# REFERENCES


[1] McGlynn, EA., Asch SM, Adams J. The quality of health care delivered to adults in the U.S. New England Journal of Medicine 348:2635-2645. 2003.

[2] Ferrizzi AC, Jardini LR, Colombo J, Mauad EC, Kerr LM, Hidalgo GS, Rahal P and Valencio CR. A clinical decision support system for cancer diseases. EATIS Proceedings of the 2008 Euro American Conference on Telematics and Information Systems. ISBN: 978-1-59593-988-3. 2008.

[3] Li LC, Adam P, Townsend AF, Stacey D, Lacaille D, Cox S, McGowan J, Tugwell P, Sinclair G, Ho K, Backman K. Improving healthcare consumer effectiveness: An Animated, Self-serve, Web-based Research Tool (ANSWER) for people with early rheumatoid arthritis. BMC Medical Informatics and Decision Making. 9:40. 2009.

[4] Wetzel MS, Kaptchuk TJ, Haramati A, Eisenberg DM. Complementary and alternative medical therapies: Implications for medical education. Ann Intern Med 138(3): 191-196. 2003.

[5] Barzansky B, Etzel SI. Educational programs in US medical schools, 2002-2003. JAMA 209(9):1190-1196.

[6] HHS, U.S. Department of Health and Human Services. 2009. “Costs of Complementary and Alternative Medicine (CAM) and Frequency of visits to CAM Practitioners: United States, 2007”. National Health Statistics Report. No. 18 – July 30, 2009.

[7] Eisenberg, D.M., Davis, R.B., Ettner, S.L., Appel, S., Wilkey, S., Van Rompay, M., KESSLER, R.C. 1998. “Trends in Alternative Medicine Use in the United States, 1990 – 1997”. Journal of American Medical Association. November 11, 1998. Vol. 280, No. 18. Pg 1569 – 1575.

[8] Lu A, Jiang M, Zhang C, Chan K. An integrative approach of linking Traditional Chinese Medicine pattern classification and bioMedicine diagnosis. Journal of Ethnopharmacology. doi:10.1016/j.jep.2011.08.045. 2011.

[9] National Institutes of Health – National Center for Complementary and Alternative Medicine. http://nccam.nih.gov/ Retrieved: March, 2011.

[10] National Institutes of Health – National Center for Complementary and Alternative Medicine. http://nccam.nih.gov/ Retrieved: July, 2011.

[11] Wein AJ, Kavoussi LR, Novick AC, Partin AW, Peters CA. Campbell-Welch Urology Review Manual. 3rd edition. Saunders, ISBN: 978-1-4160-3155-0. 2007.

[12] Flaws B, Finney D. A Compendium of TCM Patterns & Treatments. Blue Poppy Press, ISBN-13 9780936185705, R601.F574 1996eb. 1996.

[13] Flaws B, Sionneau P. The treatment of modern Western diseases with Chinese Medicine. Blue Poppy Press. ISBN 1-891845-20-9. R601.F583. 2001.

[14] Maciocia G. Diagnosis in Chinese Medicine: A Comprehensive Guide". Churchill Livingstone; 1 edition. ISBN-10: 0443064482. ISBN-13: 978-0443064487. 2004.

[15] Tsuei JJ. Eastern and Western approaches to Medicine. Western Journal of Medicine. 128:551-557. 1978.

[16] Liao Sh. Review: Knowledge management technologies and applications – Literature review from 1998 to 2002. Expert Systems with Applications 25 155 – 164. doi: 10.1016/S0957-4174(03)00043-5. 2003.

[17] Boose, JH. A survey of knowledge acquisition techniques and tools. Knowledge Acquisition 1, 3-37. Academic Press Limited, 1042-8143/89/010003. 1989.

[18] Rubenstein-Montano B. A survey of knowledge-based information systems for urban planning: Moving towards knowledge management. Computers, Environment and Urban Systems 24 155-172. PII: S0198-9715(99)00055-1. 2000.

[19] Pandey B, Mishra RB. Knowledge and intelligent computing system in Medicine. Computers in Biology and Medicine 39 215-230. 2009.

[20] Bach PB, Jett JR, Pastorino U, Tockman MS, Swensen SJ, Begg C. Computed Tomography Screening and Lung Cancer Outcomes. JAMA. 297(9):953-961. doi: 10.1001/jama.297.9.953. 2007.

[21] Yu H., Davis M, Wilson C, Cole F. Object-relational data modeling for informetric databases. Journal of Informetrics. 2, 240-251. doi: 10.1016/j.joi.2008.06.001. 2008.

[22] Zhang NL, Yuan S, Chen T, Wang Y. Latent tree models and diagnosis in Traditional Chinese Medicine. Artificial Intelligence in Medicine 42, 229-245. doi:10.1016/j.artmed.2007.10.004. 2008.

[23] Zhou X, Chen Sh, Liu B, Zhang R, Wang Y, Li P, Guo Y, Zhang H, Gao Z, Yan X. Development of Traditional Chinese Medicine clinical data warehouse for medical knowledge discovery and decision support. Artificial Intelligence in Medicine 48. 139-152. doi: 10.1016. 2010.

[24] Koutkias V, Chouvarda I, Maglaveras N. A Multiagent System Enhancing Home-Care Health Services for Chronic Disease Management. IEEE Transactions on Information Technology in BioMedicine. Vol. 9, No. 4. 2005.

[25] Pham DL, Xu C, Prince JL. Current Methods in Medical Image Segmentation. Annual Rev. Biomedical Engineering. 2:315-337. 2000.

[26] Subbaraj K, Ravi B. High Resolution Medical Models and Geometric Reasoning starting from CT/MR Images. IEEE. Indian Institute of Technology (Bombay, Mumbay – India). 2007.

[27] Zhou Z, Liu B, Wu Z, Feng Y. Integrative mining of Traditional Chinese Medicine literature and Medline for functional gene networks. Artificial Intelligence in Medicine 41, 87-104. doi: 10.1016/j.artmed.2007.07.007.

[28] Jones MB, Berkley Ch, Bojilova J, Schildhauer M. Managing Scientific Metadata. IEEE Internet Computing. September-October 2001. http://computer.org/internet/

[29] Saeed M, Lieu C, Raber G, Mark RG. MIMIC 11: A Massive Temporal ICU Patient Database to Support Research in Intelligent Patient Monitoring. Computers in Cardiology 29:641-644. 2002.

[30] Eom, S.B. Mapping the intellectual structure of research in decision support systems through author co-citation analysis (1971-1993). Decision Support Systems 16, 315-338. 0167-9236(95)00026-7. 2006.

[31] Wang X, Qu H, Liu P, Cheng Y. A self-learning expert system for diagnosis in Traditional Chinese Medicine. Expert Systems with Applications 26, 557-566. doi: 10.1016/j.eswa.2003.10.004.

[32] Kazemzadeh RS, Kamran S. Interoperability of data and knowledge in distributed health care systems. Proceedings of the 13th IEEE International Workshop on Software Technology and Engineering Practice STEP. 2005.

[33] Tsipouras MG, Exarchos TP, Fotiadis DI, Kotsia AP, Vakalis KV, Naka KK, Michalis LK. Automated Diagnosis of Coronary Artery Disease Based on Data Mining and Fuzzy Modeling. IEEE Transactions on Information Technology in BioMedicine. Vol. 12, No 4. 2008.

[34] Colantonio S, Massimo M, Moroni D, Salvetti O, Chiarugi F, Emmanouilidou D. A Decision Support System for Aiding Heart Failure Management. IEEE Computer Society. Ninth International Conference on Intelligent Systems Design and Applications. 2009.

[35] Constanzo D. Biomedical Data Acquisition and Processing in the Decision Support Services of HEARTFAID Platform. IEEE International Workshop on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications. 2009.

[36] Chao S, Wong F. Knowledge Acquisition in Supporting Diagnosis for e-Healthcare Infrastructure. Software Engineering and Data Mining (SEDM), 2nd International Conference. 322 – 327. 2010.

[37] Taylor D, Naguib RNG, Boulton S. A Dynamic Clinical Dental Relational Database. IEEE Transactions on Information Technology in BioMedicine. Vol. 8. No. 3. 2004.

[38] O'Connor MJ, Shankar RD, Parrish DB, Das AK. Knowledge-data integration for temporal reasoning in a clinical trial system. International Journal of Medical Informatics 78S. S77-S85. 2009.

[39] Wei C, Hu J, Liu Sheng OR. A Knowledge-Based System for Patient Image Pre-Fetching in Heterogeneous Database Environment – Modeling, Design and Evaluation. IEEE Transactions of Information Technology in BioMedicine, vol. 5, No. 1, S 1089-7771(01)01714-9.

[40] Lifshits G, Lifshits Y. System and Method for Automated Diagnostics and Medical Treatment Development for Oriental Medicine. United States Patent Application Publication – US 2010/0023351 A1.

[41] Foundational Model of Anatomy. Structural Informatics Group, University of Washington. ©1996-2003. http://fme.biostr.washington.edu:8089/FME/index.html Retrieved: April, 2010.

[42] Haug, P.J., Rocha, B.H.S.C., Evans R.S. "Decision support in Medicine: Lessons from the HELP system". International Journal of Medical Informatics 69. 273 – 284. 2002.

[43] Zhang, S., Tjortjis, C., Zeng, X., Qiao, H., Buchan, I. and Keane, J. "Comparing data mining methods with logistic regression in childhood obesity prediction". Information Systems Frontiers. 1387-3326 (Print), 1572-9419 (Online). DOI 10.1007/s10796-009-9157-0. 2009.

[44] Koutkias V, Chouvarda I, Maglaveras N. A Multiagent System Enhancing Home-Care Health Services for Chronic Disease Management. IEEE Transactions on Information Technology in BioMedicine. Vol. 9, No. 4. 2005.

[45] Horn, W. AI in Medicine on its way from knowledge-intensive to data-intensive systems. Artificial Intelligence in Medicine 23 5-12. 2001.

[46] Taylor, D., Naguib, R.N.G. and Boulton, S. "A Dynamic Clinical Dental Relational Database". IEEE Transactions on Information Technology in BioMedicine. Vol. 8. No. 3. 2004.

[47] Cao C, Leong, TY, Leong APK, Seow, FC. Dynamic decision analysis in Medicine: A data-driven approach. International Journal of Medical Informatics 51 13-28. 1998.

[48] Floares A, Balacescu O, Floares C. Mining Knowledge and Data to Discover Intelligent Molecular Biomarkers: Prostate Cancer i-Biomarkers. IEEE 4th International Workshop on Soft Computing Applications. 2010.

[49] Goncalves J, Silveira A, Rocha A. A Knowledge Management System for study of quality of life in head and neck cancer patients. Information Systems and Technologies (CISTI), 5th Iberian Conference. 2010.

[50] Barret J.S, Mondick J.T, Narayan M, Vijayakumar K and Vijayakumar S. Integration of modeling and simulation into hospital-based decision support systems guiding pediatric pharmacotherapy. BioMed Central - BMC Medical Informatics and Decision Making. 2008.

[51] Lukman S, He Y, Hui S. Computational methods for Traditional Chinese Medicine: A survey. Computer Methods and Programs in BioMedicine 88, 283-294. doi: 10.1016/j.cmpb.2007.09.008.

[52] Zhou X, Peng Y, Liu B. Methodological Review: Text mining for traditional Chinese medical knowledge discovery: A survey. Journal of Biomedical Informatics 43, 650-660. doi: 10.1016/j.jbi.2010.01.002.

[53] Feng, Y., WU, Z., Zhou, X., Zhou, Z., Fan, W. "Knowledge discovery in Traditional Chinese Medicine: State of the art and perspectives". Artificial Intelligence in Medicine 38, 219-236. doi: 10.1016/j.artmed.2006.07.005. 2006.

[54] ZhuGe, J. "Diagnosis of Traditional Chinese Medicine based on the Structural Model of Knowledge Discovery Technology". Third International Symposium on Intelligent Information Technology Application, IEEE Computer Society. 2009.

[55] Wang X, Qu H, Liu P, Cheng Y. A self-learning expert system for diagnosis in Traditional Chinese Medicine. Expert Systems with Applications 26, 557-566. Elsevier. 2004.

[56] Zhang N.L, Yuan Sh, Chen T, Wang Y. Latent Tree models and diagnosis in Traditional Chinese Medicine. Artificial Intelligence in Medicine 42, 229-245. Elsevier. 2008.

[57] Templeman, K, Robinson, A. Integrative Medicine models in contemporary primary health care. Complementary therapies in Medicine 19, 84-92. 2011.

[58] Rehberg, B. Evidence-based integrative pain Medicine. European Journal of Integrative Medicine. 2, 109-113. 2010.

[59] Wong, A.K.S., Chan, L.W.C and Liu, Y. Automating object-oriented integration and visualization of multidisciplinary biomedical data in radiology workflow: Compartmental PACS model. Inf Syst Front (2009) 11:369–379. DOI 10.1007/s10796-009-9150-7. 2009.

[60] Tsuei JJ. Eastern and Western approaches to Medicine. Western Journal of Medicine. 128:551-557. 1978.

[61] Sun WY, Chena WW, Chenb L, Wang G. Difference of lifestyle advice between traditional Chinese medical doctors (TCMDs) and Western-style medical doctors (WSMDs) in People's Republic of China. Patient Education and Counseling. Elsevier. Volume 25, Issue 3. 311-316. 1995.

[62] Downing GJ, Boyle, SN, Brinner, KM, Osheroff, JA. Information management to enable personalized Medicine: Steakholder roles in building clinical decision support. BMC Medical informatics and Decision Making. 9:44. 2009.

[63] Fuentes-Lorenzo, D., Morato, J. and Gomez, J.M. "Knowledge management in biomedical libraries: A semantic web approach". Inf Syst Front (2009) 11:471–480. DOI 10.1007/s10796-009-9159-y. 2009.

[64] Timpka T, Eriksson H, Ludvigsson J, Ekberg J, Nordfeldt S, Hanberger L. Web 2.0 systems supporting childhood chronic disease management: a pattern language representation of a general architecture. BMC Medical Informatics and Decision Making. 8:54. 2008.

[65] Li K, Ray P, Merrell R and Kwankam Y. Improving the Health Care and Public Health Critical Infrastructure. Managing Knowledge through Interoperability. IEEE Engineering in Medicine and Biology. 2008.

[66] London Medical Databases, UK, http://www.lmdatabases.com. Retrieved: April, 2010

[67] Foundational Model Explorer. Structural Informatics Group, University of Washington. ©1996-2003. http://fme.biostr.washington.edu:8089/FME/index.html Retrieved: April, 2010

[68] Acupuncture.com.au. Classification of TCM formulations based on their actions. http://www.acupuncture.com.au/education/herbs/herbs.html. Retrieved: April, 2010

[69] Dictionary of Chinese Herbs. Disease-specific TCM formulations, toxicity and side effects. http://alternativehealing.org/chinese_herbs_dictionary.htm. Retrieved: April, 2010

[70] Plants for a future. TCM herbs with their potential side effects, physical characteristics and medicinal usages substantiated by relevant scientific citations. http://www.pfaf.org. Retrieved: April, 2010

[71] The International Classification of Diseases, 9th Revision, Clinical Modification" (ICD-9-CM), Sixth Edition, issued for use beginning October 1, 2008 for federal fiscal year 2009 (FY09). http://icd9cm.chrisendres.com/. Retrieved: April, 2010

[72] Drug Information Portal – National Library of Medicine, National Institutes of Health. http://druginfo.nlm.nih.gov/drugportal/drugportal.jsp. Retrieved, April, 2010

[73] Symptom Checker – Mayo Clinic, US. http://www.mayoclinic.com/health/ Retrieved: April, 2010

[74] MedlinePlus - National Library of Medicine, National Institutes of Health. http://www.nlm.nih.gov/medlineplus/. Retrieved: April, 2010

[75] Complementary/Integrative Medicine Education Resources - MD Anderson Center, The University of Texas. http://www.mdanderson.org/education-and-research/resources-for-professionals/clinical-tools-and-resources/cimer/index.html Retrieved: August, 2011

[76] Clinical Trials in Complementary and Alternative Medicine - National Center for Complementary and Alternative Medicine, NCCAM. National Institutes of Health. http://nccam.nih.gov/research/clinicaltrials/ Retrieved: August, 2011

[77] Research in Complementary and Integrative Medical Therapies - Harvard Medical School, Osher Research Center. http://www.osher.hms.harvard.edu/ Retrieved: August, 2011

[78] Research in Acupuncture - Centre for Complementary Medicine, university of Western Sydney. http://www.uws.edu.au/complemed/complementary_Medicine/research_projects Retrieved: August, 2011

[79] Canadian Interdisciplinary Network for Complementary & Alternative Medicine Research - IN-CAM. http://www.incamresearch.ca/index.php?id=26,27,0,0,1,0 Retrieved: August, 2011

[80] U.S. Department of Health and Human Services - National Kidney & Urologic Diseases Information Clearinghouse (NKUDIC) http://kidney.niddk.nih.gov/index.aspx Retrieved: August, 2011

[81] Clinical Trials - U.S. National Institutes of Health http://www.clinicaltrials.gov/ Retrieved: August, 2011

[82] National Cancer Institute - U.S. National Institutes of Health http://www.nia.nih.gov/healthinformation/publications/prostate.htm Retrieved: September, 2011

[83] The New England Journal of Medicine. http://www.nejm.org. Retrieved: April, 2010

[84] The Journal of American Medical Association http://jama.ama-assn.org. Retrieved: April, 2010

[85] Annals of Internal Medicine http://www.annals.org/. Retrieved: April, 2010

[86] The Medical Journal of Australia http://www.mja.com.au. Retrieved: April, 2010

[87] Canadian Medical Association Journal http://www.cmaj.ca/. Retrieved: April, 2010

[88] Health Information Resource Database. National Health Information Center (NHIC). http://www.health.gov/nhic/AlphaKeyword.htm. Retrieved: April, 2010

[89] PubMed. U.S. National Library of Medicine and the National Institutes of Health. http://www.ncbi.nlm.nih.gov/pubmed. Retrieved: April, 2010

[90] Digitally Reproduced Embryonic Morphology (DREM) project. Computer Imaging Laboratory - LSU Health Sciences Center, New Orleans. Human Developmental Anatomy Center – National Museum of Health and Medicine, Washington DC. http://virtualhumanembryo.lsuhsc.edu/DREM/DREM_home.htm. Retrieved: April, 2010

[91] Visible Human Project. United States National Library of Medicine – National Institutes of Health. http://www.nlm.nih.gov/research/visible/visible_human.html: Retrieved: April, 2010

[92] Hardin MD medical and disease pictures http://www.lib.uiowa.edu/hardin/md. Retrieved: April, 2010

[93] Public Health and Image Library – Center for Disease Control and Prevention, US. http://www.cdc.gov/. Retrieved: April, 2010

[94] The Whole Brain Atlas – Harvard Medical School, US. http://www.med.harvard.edu/AANLIB/home.html. Retrieved: April, 2010

[95] Piegl L. The KI Book. CAD Solutions. ISBN 974-93008-3-1. 2005.

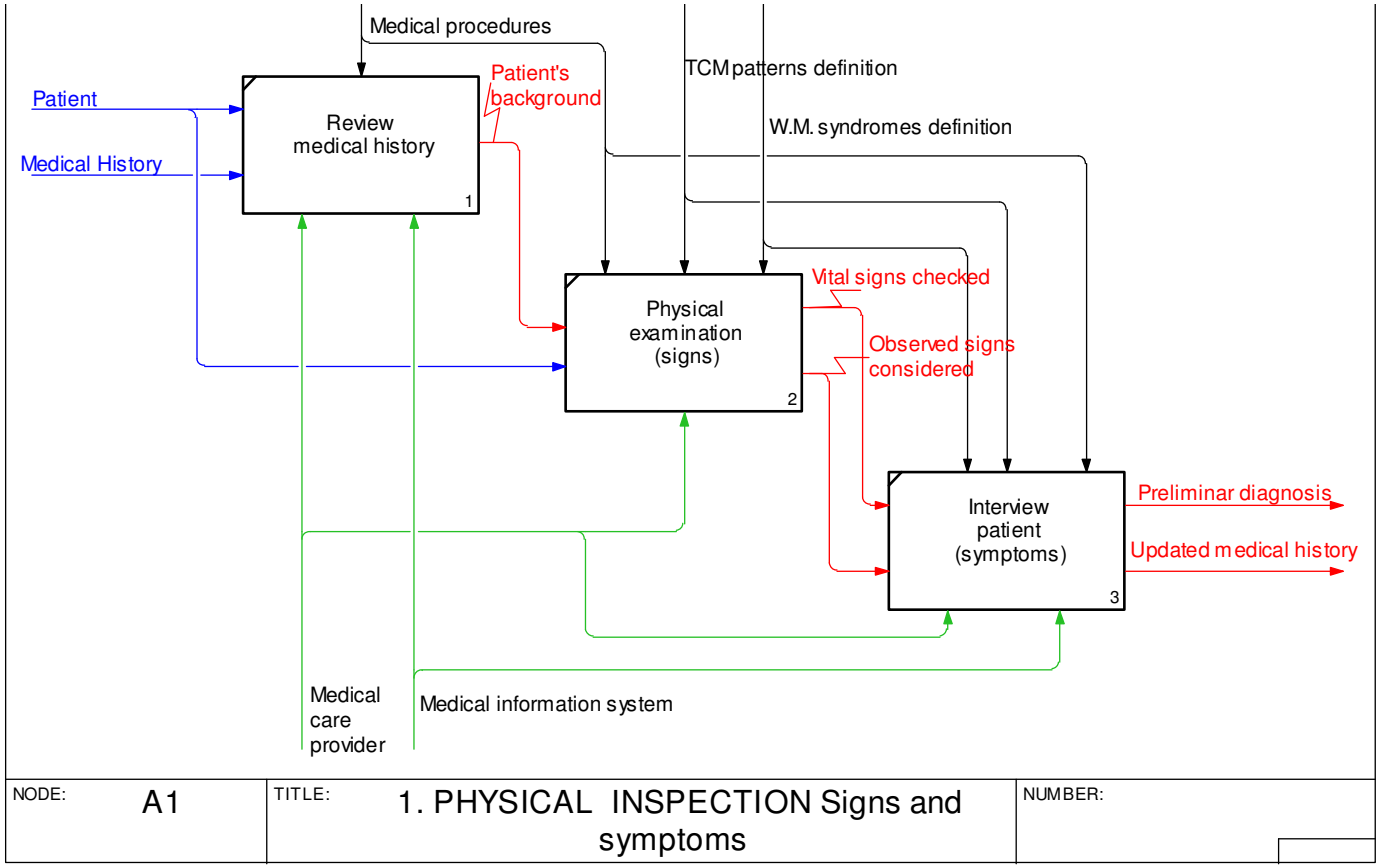
[96] Jokiniemi, J. Ontologies and Computational Methods for Traditional Chinese Medicine. Aalto University – School of Science and Technology. Faculty of Electronics, Communications and Automation. Department of Telecommunications. Master's Thesis. 2010.

[97] Unified Medical Language System – UMLS National Library of Medicine. http://www.nlm.nih.gov/research/umls/META3_current_relations.html Retrieved: October, 2011

# APPENDICES

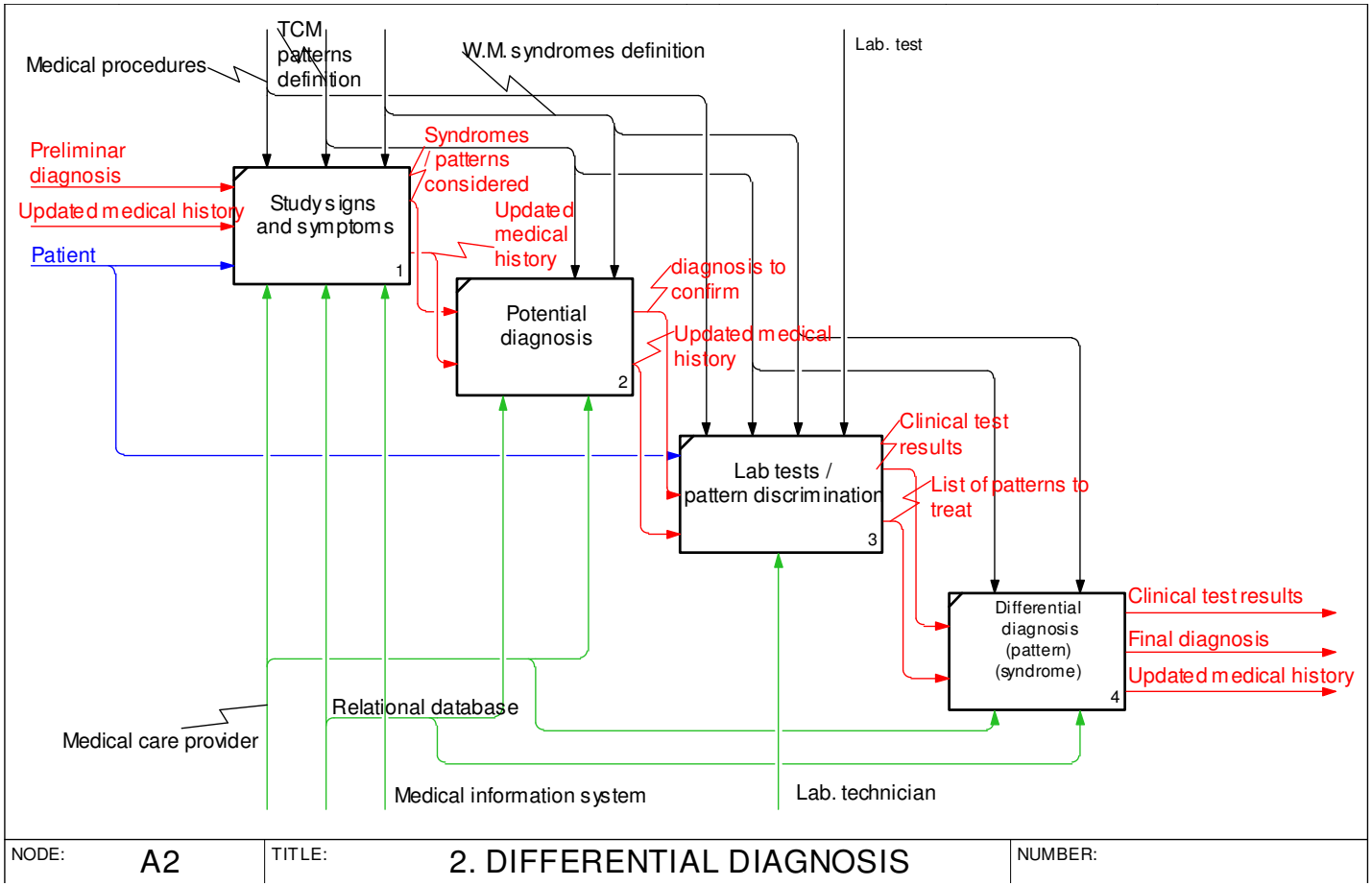
Appendix A: IDEF0 Detailed Model for the Integrated Medical Diagnosis Function

## A.1 A1 Node: Sub-Activities for Activity 1: Inspection of Signs and Symptoms



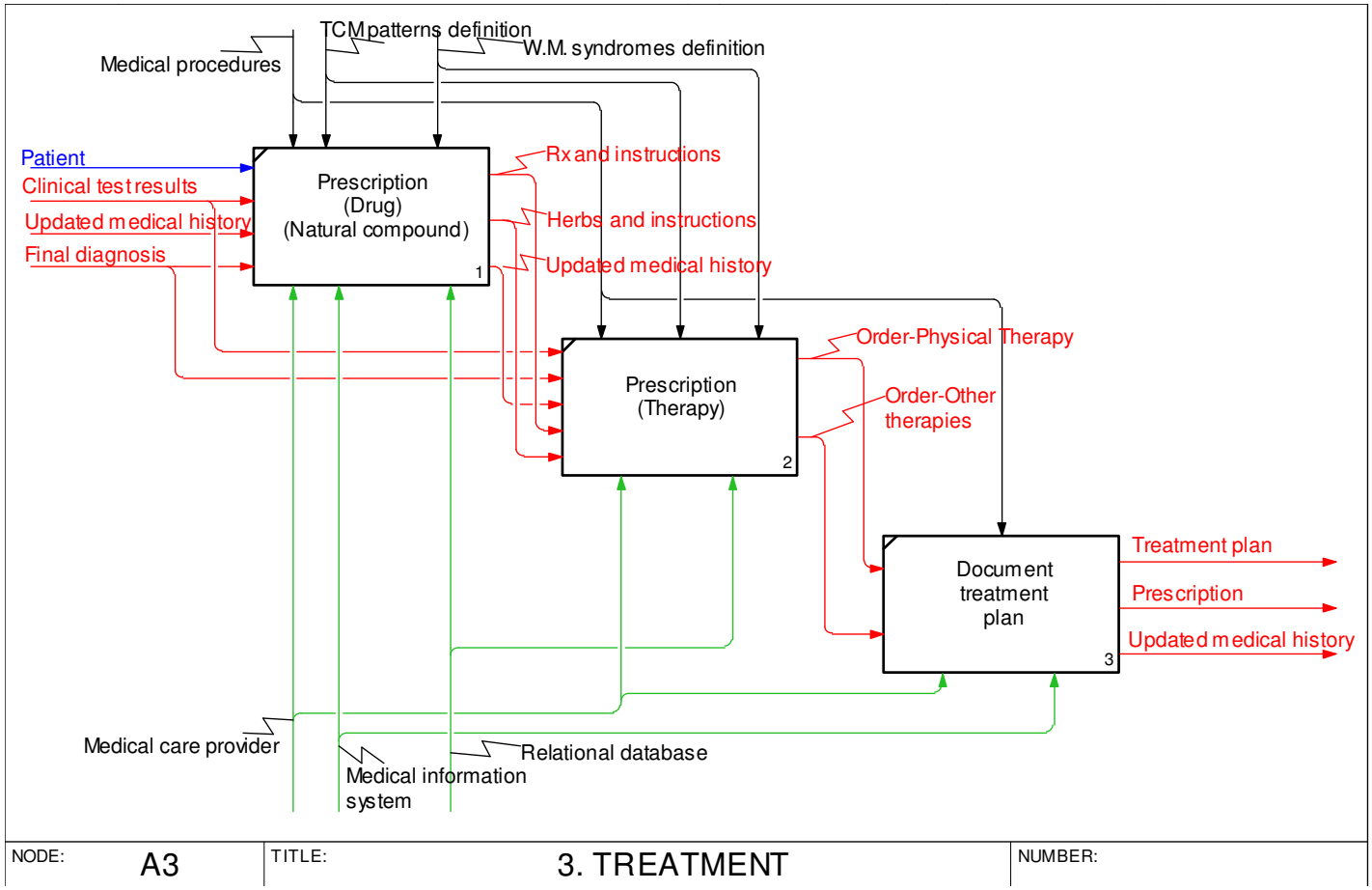
Appendix A (Continued)

A.2 A2 Node: Sub-Activities for Activity 2: Differential Diagnosis of Pattern Disorders (Traditional Chinese Medicine) and Syndromes (Western Medicine)



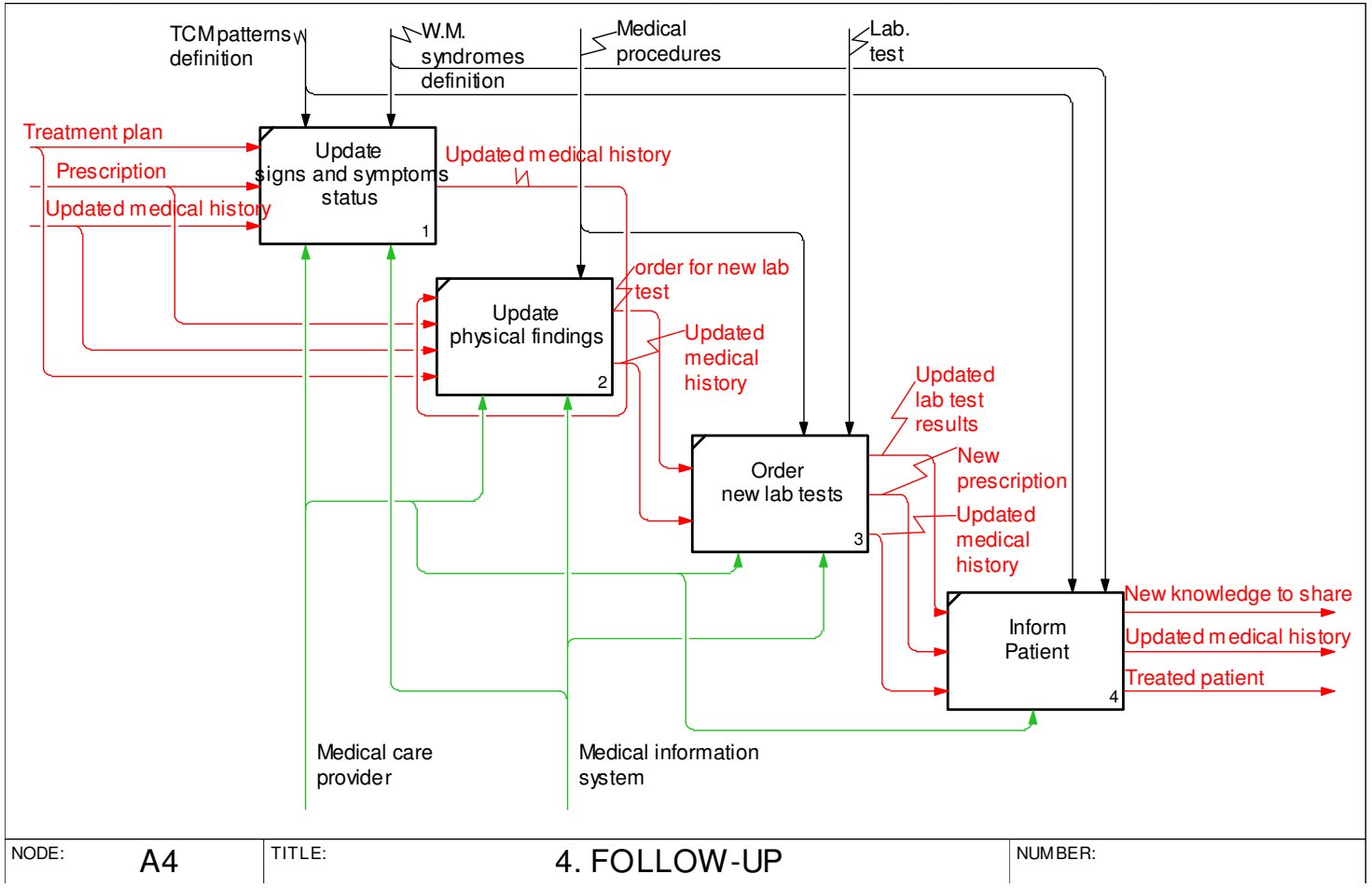
Appendix A (Continued)

A.3 A3 Node: Sub-Activities for Activity 3: Treatment, Prescription and Therapies Targeting Pattern Disorders (Traditional Chinese Medicine) and Syndromes (Western Medicine)



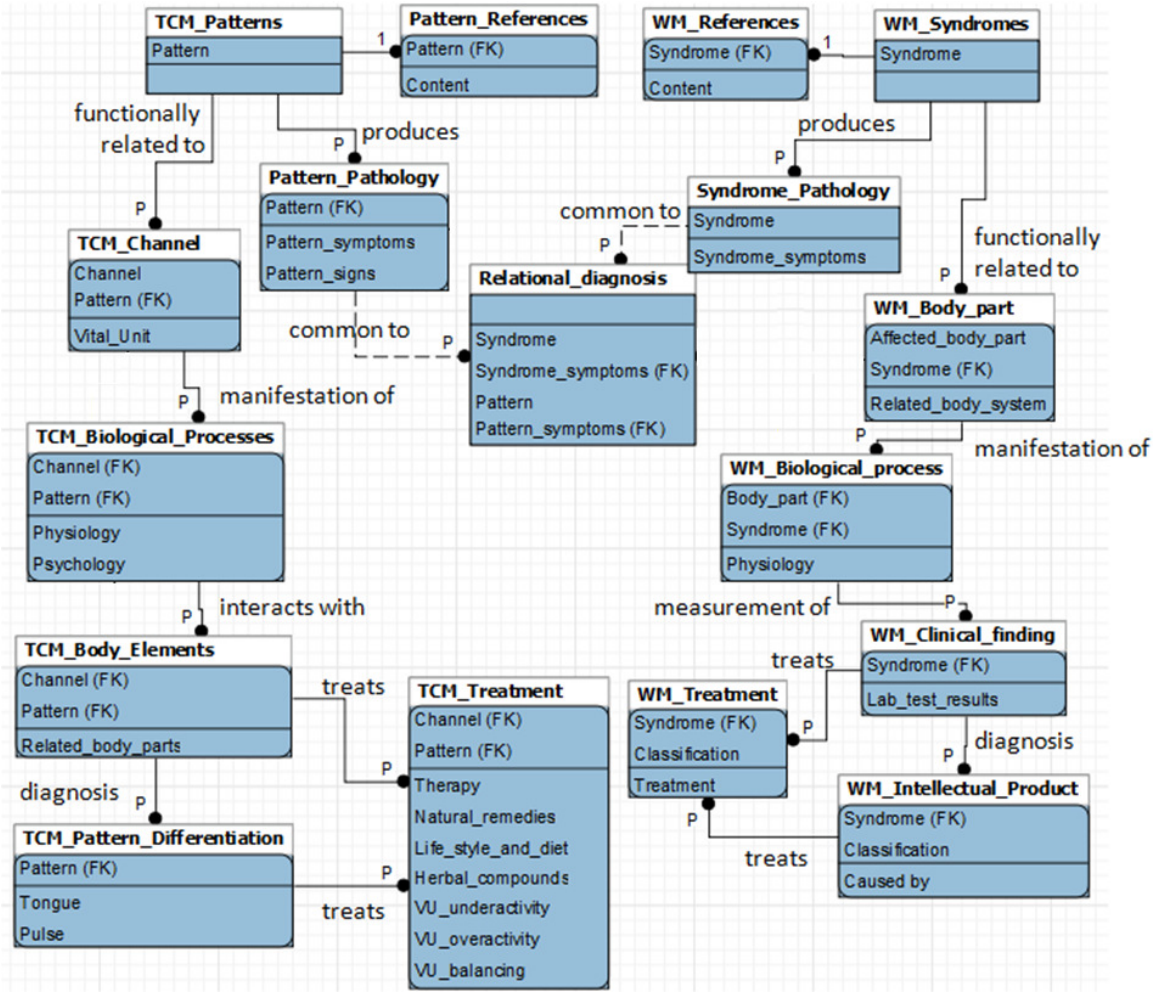
Appendix A (Continued)

## A.4 A4 Node: Sub-Activities for Activity 4: Follow-Up



Appendix B: Complete IDEF1X Model

B.1 Entity-relationship Key Connections between Syndromes, Patterns and Symptoms for Relational Diagnosis



# ABOUT THE AUTHOR

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