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## Digital Transformation in Healthcare – the case of a Chinese Medicine Inquiring System

CATHERINE HAN LIN, DAVID PHILLIPS &  
NILMINI WICKRAMASINGHE

**Abstract** The unique philosophy, diagnosis, and treatment methods of Chinese Medicine (CM) suggest that Health Informatics developments in this domain could benefit by adopting a more suitable synthesis, specifically, incorporating Hegelian and Kantian inquiring systems with the support from Singerian, Lockean, and Leibnizian inquiring systems, and key concepts of Knowledge Management.

Directed by qualitative methodology with Case Study and Design Science methods, the specific CM inquiring system, a Patient Management System (PMS) prototype, was constructed. It is anticipated that this experiment provides suggestions and reference to Health Informatics implementations in CM. This paper focuses on the design and building of the PMS.

**Keywords:** • Health Informatics • Chinese Medicine • Patient Management System • Inquiring System •

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## 1 Introduction

Managing hospital and clinical information in the 21st century has moved away from using paper-based systems to incorporating Health Informatics (Lin *et al.*, 2015b; Wickramasinghe & Schaffer, 2010). Many system applications, solutions and research projects have been developed, and brought great benefits to the healthcare sector (Buntin *et al.*, 2011; Groves *et al.*, 2016; Wager *et al.*, 2017). For example, Electronic Health Record (EHR) implementations are widespread and used in many hospitals globally (Alharthi *et al.*, 2014; King *et al.*, 2014; Nguyen *et al.*, 2014). Jha *et al.* (2008) reported that like the United Kingdom, nearly 90% of General Practitioners (GP) in Australia and New Zealand use EHR (Jha *et al.*, 2008). Hence, it is more important than ever that patient medical information is kept up-to-date and made available for all healthcare workers and providers. This understanding is also supported by the Chinese Medicine Board of Australia (CMBA), who has stated that patient health records are expected to be accurate, legible, clear, and contain sufficient detail so that another practitioner can take over the care of the patient if necessary. Moreover, the Guidelines of Patient Health Records have also stated that patient records must be kept in accordance with the requirements of Australian laws relating to health records information management (CMBA, 2016b). Therefore, Chinese medicine (CM) patient records must support the HealthConnect<sup>1</sup> Personally Controlled EHR requirements, if required (CMBA, 2016b).

Besides EHR, clinical management systems such as Clinical Knowledge Management (CKM) and Clinical Decision Support (CDS) are also utilised in hospitals and clinics (Berner & La Lande, 2016; Büchner *et al.*, 2016; Lin *et al.*, 2015b; Varghese *et al.*, 2016; Wager *et al.*, 2017). This is because CKM and CDS, with compiled comprehensive medical knowledge, can provide assistance to various aspects of decision making. However, it has been shown that current Health Informatics developments in CM have limitations (Chan *et al.*, 2015; Lin *et al.*, 2016). There is a lack of a more suitable synthesis support due to CM's unique philosophy, diagnosis, and treatment methods (Chan *et al.*, 2015; Lin *et al.*, 2015b; Yang *et al.*, 2009). Based on Churchman's Inquiring System, Lin *et al.* proposed that the CM Inquiring System suggests that CM Health Informatics are more Hegelian and Kantian inquiring systems with support from Singerian, Lockean, and Leibnizian inquiring systems, combining with key concepts of Knowledge Management (KM) (Lin *et al.*, 2015a; Lin *et al.*, 2015b).

## 2 Problem Definition

How can Information Systems/Information Technology (IS/IT) be used to support the delivery of CM? This research examined the potential of using IS/IT tools and techniques in CM clinics, therefore enhancing the delivery of CM practices. Analysing Churchman's Inquiring Systems and KM concepts has led to the proposal of the CM Inquiring system. Constructing the Patient Management System (PMS) became the vehicle for utilising IS/IT and supporting the delivery of CM clinical practices.

### 3 Methodology and Processes

This research adopted a qualitative methodology with Case Study and Design Science methods. Through a typical Case Study, in-depth insights and understanding of why people do things the way they do can be captured (Harding, 2013; Yin, 2013). In the current research, data were collected via various sources (including visiting case clinics and from interviewees, participants, field notes, government and organizational documentations), which helped analysing and addressing the research question (Barratt et al., 2011). Well known Case Study tools and techniques, such as interview, observation and analysis of documents, were used in assisting data collection and analysis (Barratt et al., 2011). This provided increased reliability of data and a stronger evidence base (Barratt et al., 2011; Silverman, 2016).

In selecting the case clinics, this research used a range of selection criteria which included clinic size, number of patients, number of clinic staff, types of medicine and usage, diagnosis, treatments and dispensing patterns, clinical administration, and government compliance and adherence to standards. Six clinics in Melbourne, Australia were chosen for this study. Collected data were used for studying common themes and assisted in forming the core and foundation of the PMS prototype, which was proposed to answer the research question using a practical approach and providing a tangible solution.

The process of building this prototype was guided by Design Science guidelines and principles (Hevner & Chatterjee, 2010). Design Science is regarded as an important and legitimate IS research paradigm, and has its roots in the field of engineering and science artefacts (Gregor & Hevner, 2013; Hevner & Chatterjee, 2010). Further, March & Smith outlined four Design Science outputs, specifically constructs, models, methods, and instantiations (March & Smith, 1995). The construction is related to a problem/solution, which typically involves problem awareness and specification as well as solution proposal (Peffer et al., 2007; Vaishnavi & Kuechler, 2015; Wieringa, 2014). Models as problem and solution statements express the relationships between construction processes such as problem awareness (this can include the research question, synthesis and/or solution proposal) (Peffer et al., 2007; Vaishnavi & Kuechler, 2015). Methods are sets of algorithms or guidelines used to direct the developments of the proposed solution (Peffer et al., 2007; Vaishnavi & Kuechler, 2015). Instantiation is the operationalisation of constructs, models, and methods (Vaishnavi & Kuechler, 2015). Following these principles, Vaishnavi and Kuechler (2015) provide a general model describing a cycle of process steps, as: 1) awareness of the problem (construction), an initial proposal depicting the existence of a problem that needs to be solved; 2) suggestion and/or solution statements (models and methods), a phase where the formulated proposal is tested if it can be transferred into a tentative design (Vaishnavi & Kuechler, 2015); 3) development (instantiation), or the building process of the artefact; 4) evaluation, where once the artefact is developed, it is evaluated accordingly to the criteria; and 5) conclusion, where the research final results are consolidated and summarised. These processes are repetitive in the sense that each step can lead to refinement and improvement of prior steps through the knowledge flows (Gregor & Hevner, 2013; Vaishnavi & Kuechler, 2015; Wieringa,

2014). It is through this cycle of evaluations, refinement, and better understanding that new knowledge is produced (Gregor & Hevner, 2013; Vaishnavi & Kuechler, 2015; Wieringa, 2014). Based on these processes, PMS development is elaborated in the following sub sections.

### 3.1 Problem Awareness and Verification

The awareness and verification of the problem in this research came from a literature review and case study. First, the traditional, manual form of clinical management is increasingly out-dated, where new computerised systems can facilitate superior practice (Lin *et al.*, 2014; Yang *et al.*, 2009). Second, incorporating new and/or updated international and national CM practice standards, regulations, and registrations (AHPRA, 2014; CMBA, 2012a, 2012b, 2016b; WHO, 2013) can be better achieved through IS/IT (Hu *et al.*, 2013; Lin *et al.*, 2016). Third, because most of the current IS/IT system solutions utilised in CM have been created in China or Asia, there is limited employment and research in this domain in western countries such as Australia (Lin *et al.*, 2014; Lin *et al.*, 2016; Lukman *et al.*, 2007). The case clinics then verified the existence of these problems.

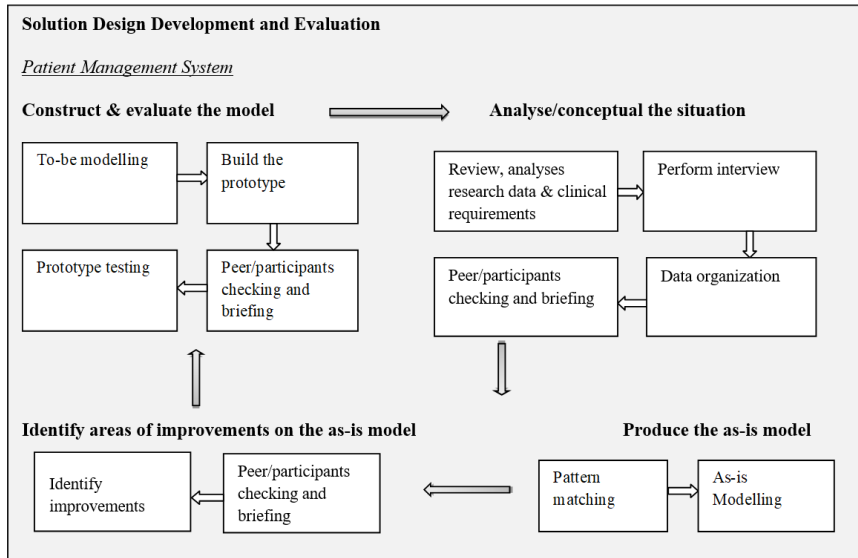
### 3.2 Solution Design and Development

In this process, a solution framework and structure were designed for the research problem tailored to the current CM clinic practices. It is important to “identify and conceptualize current (as-is) business processes and future (to-be) processes” (Rosemann & vom Brocke, 2015) in any Business Process Management design and modelling. Therefore, in this research analysis was performed at two major phases. First, the existing clinical situation (as-is) was modelled, described, and analysed. Second, areas of improvements were identified for the proposed PMS system structure. The new (to-be) system was also analysed, explained, and modelled. A range of IT tools and techniques were used in designing the system solution. For example, a UML<sup>2</sup> Activity Diagram was used to illustrate the CM clinic’s daily operations and processes (Rosemann & vom Brocke, 2015), hence giving important information about functionalities, boundaries, and guidelines for the construction. ERD<sup>3</sup> was created presenting the interconnection and management of the PMS system data (Murphy *et al.*, 2016). WAMP<sup>4</sup>, a Window based, open-source web development tool containing a web server with Apache, PHP, and MYSQL were installed, and a sitemap (See Appendix 2 – PMS Website Map) was designed to guide the navigation within the PMS.

### 3.3 Evaluation

The evaluation phase ensures rigour (Rosemann & vom Brocke, 2015), where the modules of the proposed system are evaluated, and refined by research participants with specification, expectation, and precise scope. For example, a Patient Entry Form (a feature/function of PMS) was tested by entering and retrieving testing data. Changes were made after the testing with participants’ feedback. The research went through at least one

Design Science evaluation cycle and validated the research prototype in terms of functionality, usability, and completeness.



**Figure 1: Solution design, development, and evaluation for the PMS.**

At the completion of the above processes, research findings and results are summarised. Research contributions, limitations and future studies/approaches are identified and have been documented in a research thesis and publications.

#### 4 PMS Design and Development

The PMS prototype had the purpose of assisting CM clinics patient management via various system methods, tool, and techniques. Hence, it was necessary to identify and analyse the major activities/processes. Figure 2 illustrates these activities (Appendix 3 lists and explains the symbols that were used in the activity diagrams).

To achieve the idea of user flexibility, multi devices, real-time and fast access of patients' information, the PMS is a web application which allows multi device access (including Desktop or laptop computer, tablet, and mobile phones).

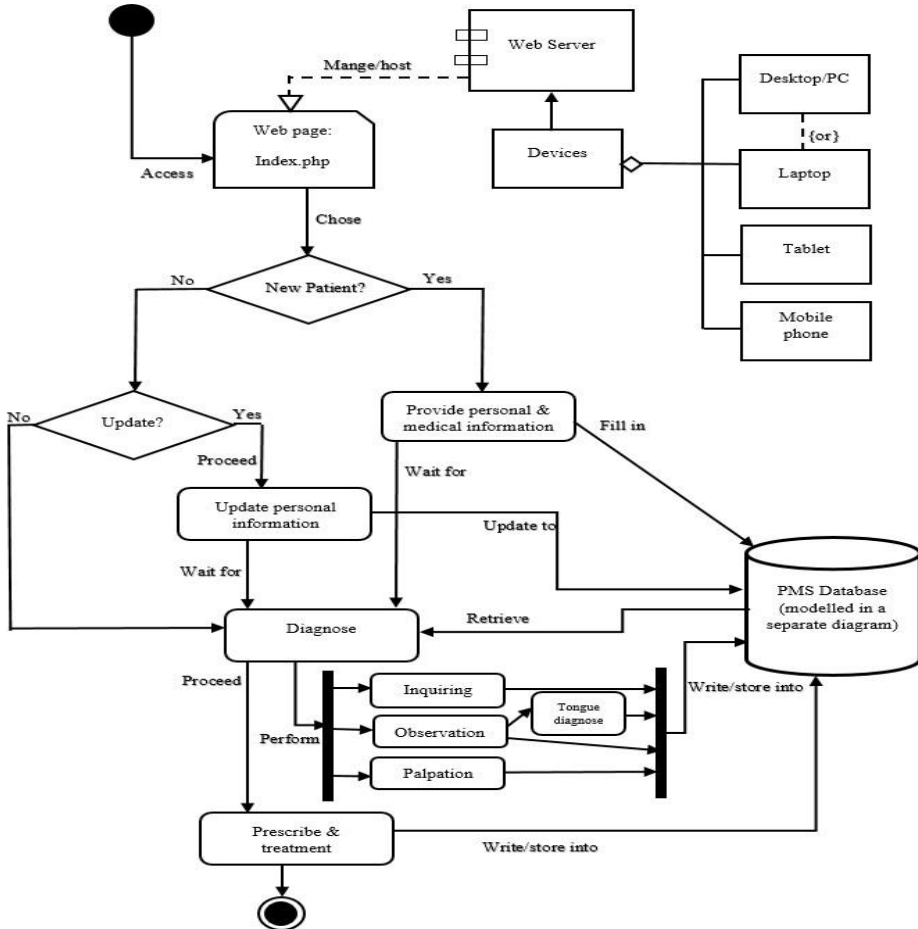


Figure 2: Activity diagram of the proposed PMS design with computerised components.

#### 4.1 PMS Database

Tracing through the PMS functions and activities design, information required for each activity was identified. As a result, twelve tables were created (via running SQL<sup>5</sup> statements). For example, the User table contains physician and administrator details; therefore, it includes table fields of: UserId, Title, UserFirstName, UserLastName, Sex, DateOfBirth, Password, UserLevel, UserPosition, MaritalStatus, Address, Suburb, PostCode, Mobile, HomePhone, WorkPhone, and Email. UserId was created as the Primary Key<sup>6</sup> to ensure that every physician and/or administrator has a unique identification number to avoid duplicate records (for example, one patient's record is saved more than once in the same table), confusing and incorrect information (such as a

different person with the same name). This Primary Key was used as the Foreign Key<sup>7</sup> to link/relate the other tables of `doctor_patient` (UserId was renamed as `doctorId` in this table), `doctor_note` (UserId was renamed as `doctorId` in this table), `drag_drop_info`, `tongue_diagnosis` (UserId was renamed as `doctorId` in this table), and `treatment`. This linkage/relationship is an essential requirement and concept in Relational Database Design (Coronel & Morris, 2016), which enables the actions of selecting (for example, search for a particular patient with key words), inserting (for instance, add new physician or patient into the User or Patient table), updating (such as update patient's new mobile phone number) and queries that had been identified in the activity diagrams (for example, update and storing existing patient's personal information in the PMS database).

The `tongue_diagnosis` table stores the patient's tongue image, with a test image incorporated in the PMS prototype. A real patient's tongue image, however, can be uploaded and used in the future. Further, a portion (left tip of the tongue) of the test image was used to test the PMS tongue diagnosis. This portion image, as a canvas, was subdivided into many mini-parts to obtain accurate and exact location and symptoms of the patient's disorder conditions represented on the tongue image. Each tongue diagnosis on the tongue image is saved into this table for records and retrievals.

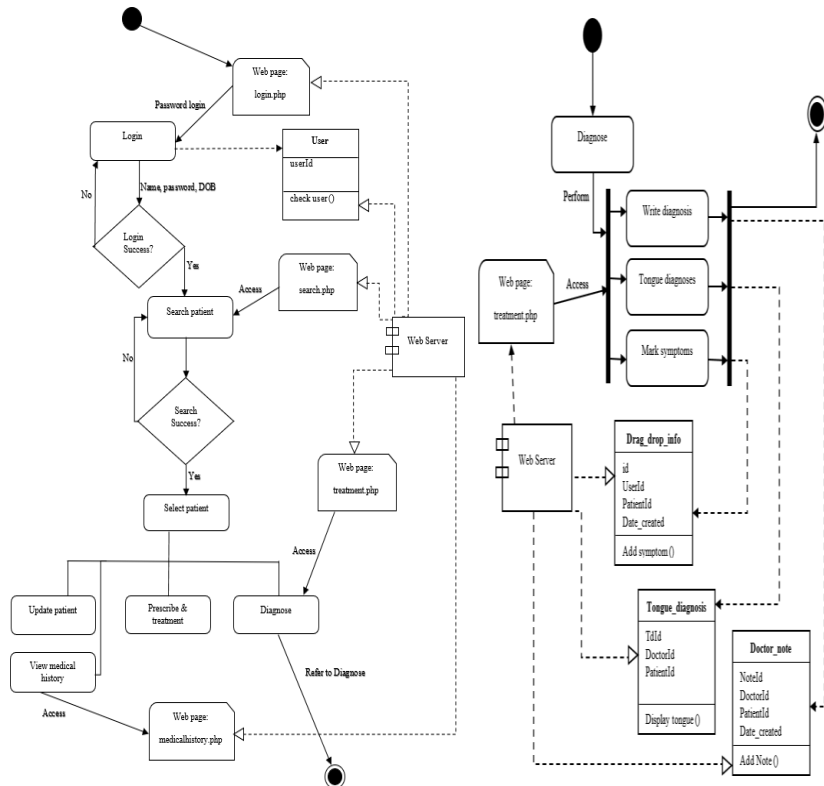
The `drag_drop_info` table stores the symbol combination of the patient's tongue diagnosis. For example, a patient may have a red spot (represented by the symbol X) or all (O, |, and ~) symptoms at the same tongue location (see Appendix 4 for description of each symbol).

The medication table contains the CM herbs provided by the CMBA recommended CM medication list (CMBA, 2016a). This table supports the search function at the prescription generation stage. The `comments_table` stores CM physician's diagnosis notes of each patient's visit. Finally, the PMS database contains twelve tables, which are: `user`, `patient`, `doctor_patient`, `patient_history`, `tongue_diagnosis`, `drag_drop_info`, `doctor_note`, `medication`, `clinic`, `patient_clinic`, `treatment`, and `comments_table` (see Appendix 1 – ERD of PMS Database Tables and Relationships).

## 4.2 PMS Diagnose, Prescription and Treatment

In the PMS, diagnosis is conducted by the CM physicians, as they have the knowledge, expertise, and responsibility. Therefore, this process/activity should be restricted to CM physicians only; hence, authorisation must be implemented. Figure 3 shows that at the login webpage, CM physicians can login with a username and password which were created by the system administrator in advance and stored in the PMS database User table. Then they were retrieved for verification to eliminate false logins. Upon a successful login, the patient details can be searched. The CM physician can update the patient's details if necessary, view the patient's medical histories, start the diagnosis and prescribe treatments. All diagnosis information is then added to the PMS database tables (e.g. `doctor_note`, `tongue_diagnosis`, and `drag_drop_info`) which is hosted by the web server.





**Figure 3: Activity diagram of the PMS physician login and diagnosis functions.**

The PMS system diagnosis processes/activities include write diagnosis notes, tongue diagnoses, and mark symptoms. The treatment webpage provides menu links for the CM physicians to write diagnosis notes, diagnose and mark tongue symptoms directly on the graphic interface on the webpage (see Appendix 4 – PMS Tongue Diagnosis). This information and symptoms are then saved into the PMS database tables. When performing tongue diagnosis, the patient's tongue image is displayed on the screen, allowing the physician to mark the symptoms on the exact location on the image using the tool of drag-and-drop with built-in symbols (for example, X indicate red dots, O indicate purple dots, | indicate cracks, and ~ indicate teeth mark). This graphic and/or image user interaction design offers the following advantages comparing to the traditional writing (on paper or electronic notes) method: 1) Visual aid. A picture/image can contain many visual r and it can suddenly give the viewer (whoever has the authority to access the image) a clear, whole, focused, visual, and vivid memories of the patient's health problem. 2) Accurate indication. The image is a visual confirmation of the patient's condition that complements the recorded notes. The problem/illness is indicated and located at the exact and accurate location supported with colour, texture, shape, and size. 3) Supporting

efficiency. This saves time for the physicians and avoids having to write lengthy descriptions of the patient's illness and diagnosis. It is easier for other health workers and the patient to understand their health problem. 4) Provide selection of methods, tools, and techniques for diagnosis, hence supporting the CM Inquiring System that CM Health Informatics is more a Hegelian and Kantian inquiring system (Lin *et al.*, 2015a). This proposal suggests that duality (tacit and explicit, Yin and Yang) and multiplicity (on perspectives, models and techniques, interpretations and explanations) are key components.

In addition to the graphic/image tongue diagnosis, the PMS offers different devices and input methods (keyboard and/or touch screen).

CM prescription and treatments commonly contain herbal medications (Kaptchuk, 2014; Maciocia, 2015). In the PMS herbal medicine prescription and treatments design (Appendix 5 – PMS CM Prescription and Treatment), experienced CM physicians who have mastered the medicine names can write/input the herbal medicine name (in both English and Chinese) in the prescription notes (stored in the `comments_table`) without assistance. Otherwise, a search of a specific CM herb name can be achieved via the search option with a letter or key word as the parameter to search the CM medication table. According to CMBA's guideline, it is compulsory that all prescriptive CM medicine names are recorded in English (CMBA, 2016b), with Chinese names (either PinYin<sup>8</sup> or character) being optional and to be added after the English name (CMBA, 2016a). Based on this, the PMS was designed primarily in English. Once the right herb is selected, then it can be written into the prescription notes. It is also common that many herbs are listed and put together as a compound in a single prescription.

The medication table in the PMS database was created with guidance from CMBA's recommended CM medication list (CMBA, 2016a). The PDF list file was downloaded from the official CMBA website, converted to a text file, and imported into the PMS database.

The 'Medical Treatment' link opens the 'Patient Treatment Notes' screen (see Appendix 5), where prescription and treatments can be entered directly via keyboard-entry. Both English (mandatory) and Chinese (optional) names can be used here. A physician can search for a CM herb by clicking the 'Search Medicine details' button. This opens the lower panel screen for medicine search. A list of herb names will appear after a letter is typed in the 'Search' box and the 'Go' button clicked. An herb can be selected at the left side under the 'Matched Medicine Details' list table. The 'Details' link at the right side of the table leads to the displaying of the herb details including: English Name, Scientific Name, Pharmaceutical Name, Authorised PinYin Name, Simplified Chinese Characters, Simplified Character Keystrokes, Traditional Chinese Characters, and Chinese Species Name. The patient's herbal prescription is saved once the 'Submit' button is clicked. To view a patient's prescription history, physicians can select the 'Treatment History' link, then select the date under the 'Medical Notes Visit Dates'.

### 4.3 Other Key PMS Modules

In addition to the Diagnosis, Prescription, and Treatment models, the PMS contains the following extra modules.

- **New Patient Personal and Medical Information Management.** In this implementation, a patient is encouraged to answer if they are a new patient to the clinic, and a new patient must provide their personal information and medical history to the clinic. In PMS this can be done while the patient is waiting for a consultation via different devices through the clinic's web address. Some information is important and required by both the clinics and CMBA standards, therefore these fields (such as patient names, date-of-birth, and gender) must be filled before the webpage is processed. Here security checks are performed at the webpage and web server, if any required fields are not filled, the patient is asked to re-enter the missing fields. A new patient is also asked to provide medical history information, by proceeding to the next webpage (reason webpage) and filling in all additional required fields. The same type of security check is performed on required fields for medical history before all the input data are added/written into the PMS database. The patient and patient\_history tables then store the new patient's personal and medical history.
- **Updating Existing Patient Personal Information.** Existing patient information is stored and managed by the PMS database. At the times when this information must be updated/changed due to various reasons (such as change of phone number or address), a patient can do this update via devices accessing the clinic web address. By giving the correct patient's first and last names as well as the date-of-birth, existing patient's information can be searched and retrieved from the PMS database. On the details webpage, update links to each specific patient information (such as update mobile phone number) can be selected, then new/changed information is updated into the PMS database patient table. This process can also be done by the clinical physician and administrator on behalf of the patient, so this feature provides additional efficiency and flexibility to the system.
- **Clinic patients and physicians online list.** A link is provided to display the list of all patients and/or physicians in the PMS database. This function is available for both the clinic administrator and physician.
- **A physician can update their own personal details.** The logic behind this activity is identical to the patient's personal information update. However, the only difference is that changed information is updated to different tables.
- **Adding a patient link is available for both the administrator and/or physician.** This is because at times, new patients may not be able to add themselves to the clinic system for various reasons, such as a disability and/or difficulty in reading and writing. This function/activity is very similar to managing a patient's personal and medical history information.
- **Clinic administrators are not permitted to perform diagnosis, prescription, and treatments;** therefore, they do not see/access these links and menu options in the PMS. They can, however, add a new physician/doctor into the PMS database.

#### 4.4 PMS Evaluation

The PMS was carefully designed to meet all the requirements after comprehensive analysis of the research domain, scope, and proposed theory. Using different analytical tools and methods, the final designs of the PMS were very thorough, clear, modular, and instructional. Hence, they were easier to build. Despite this, the PMS went through the Design Science evaluation cycle as explained below.

At the design stage, the ‘Diagnose’ module took several attempts, and the conclusion was that it needed to be broken into further sub-segments to fully embrace all necessary components. This analysis resulted in the modular workflows as shown in Figure 3.

It was decided that a generic tongue image would be useful for documenting tongue diagnosis. During development, it was realised that taking a portion of the tongue image as a smaller sample to work on would be much easier and quicker to implement all the identified functions and features. As from the system performance point of view, the tongue image is a canvas on the webpage, once a portion of a tongue diagnosis is working as desired without any problem, then the concept and technique can be extended and applied to all areas of a tongue. However, targeting and working on a smaller tongue image reduces PMS database capacity, especially tables (such as `tongue_diagnosis`, `drag_drop_info`). This in return promotes faster process time at the run time, reduce coding complexity, and downgrade system errors. As a proof-of-concept, it was decided to use the right tip of a tongue image for the tongue diagnosis module in the PMS prototype.

Initial development was made on a local computer with the agreed development tools. After many tests (for each individual module and all combinations), the developed PMS was ready to be released to the research clinic participants and other researchers for further testing. This meant that the PMS had to be hosted on a remote web server where all participants could gain access. For this reason, a webhost service was purchased. Following the same format, all PMS files, modules, and structure were recreated and transferred to the new web server (<http://catherinehanlin.net/pms/index.php>). During this process, various configuration problems and incompatibilities occurred. For example, database location, connections, and queries were modified with the new web server details and rules. After a number of further testing and development, all problems were rectified, and the prototype were tested again. Furthermore, the researcher created a unique account with user names and password for each participant. Operation instructions and a user menu were sent to all the participants.

After several weeks of participant testing, feedback was received and gathered. Most of the comments and suggestions were very positive. For example, all participants agreed that the design of using real-time, flexible multi-device on entering patient’s personal and medical history was very good, as it saved clinic physicians and/or administrators time. The built-in security control (with user login requirements) on PMS was well designed and developed. All participants liked the graphic tongue diagnose module and suggested that it can be used as an excellent resource in teaching trainee CM practitioners.

The participants suggested that testing was hampered by just following the written instructions. On that basis, three YouTube videos for assistance to new users were developed:

1. New patient module (to enter a new patient personal and medical history on PMS): <https://www.youtube.com/watch?v=kbzwGOQx3uA>
2. Existing patient checking and updating personal information (this can be done by the patient themselves after user name and date-of-birth verification and confirmation): <https://www.youtube.com/watch?v=tdWrZ8awq8I>.  
These two modules above can be operated via any devices - mobile, tablet, laptop, and desktop.
3. The tongue diagnosis module:  
<https://www.youtube.com/watch?v=4GTDDA0JfmM>

## 5 Conclusions and Future Development

This paper has presented the rationale for embracing a CM inquiring system grounded in the incorporation of Hegelian and Kantian as well as support from Singerian, Lockean and Leibnizian perspectives. To illustrate, the presented PMS prototype was designed drawing from a Design Science methodology. The PMS prototype is an endeavour created by following the proposed CM Inquiring System theory which extends Churchman's Inquiring System concept to the CM clinical system domain. The PMS was built to incorporate and accommodate multiple methods, tools, technologies, viewpoints and interpretations, knowledge and language duality, and contributions to the research domain. As an initial step, the PMS has its limitations and can be further developed as suggested below.

- The limitation of typical Australian CM case clinics can be extended by studying more case clinics nationally and internationally to accommodate new requirements and updates.
- This research is limited to the development of a patient management solution, with other areas such as Acupuncture Information Management, Finance management, Material/medicine Order and Management to be considered in future iterations.
- The PMS can be further refined with a more sophisticated visual/graphical interface, and security configurations which are tailored to individual healthcare institutes.

This research has many contributions to theory with the development of the inquiring system and practice with the potential of the PMS to digitally transform practice patterns and workflows in the context of Chinese medicine clinics. Future developments will include more specific tailoring of the solution to particular clinics' needs as well as expanding the functionality of the various aspects within the solution. In closing, we note that the paper highlights an opportunity for digital transformation in what has been historically a very traditional domain grounded in ancient practices.

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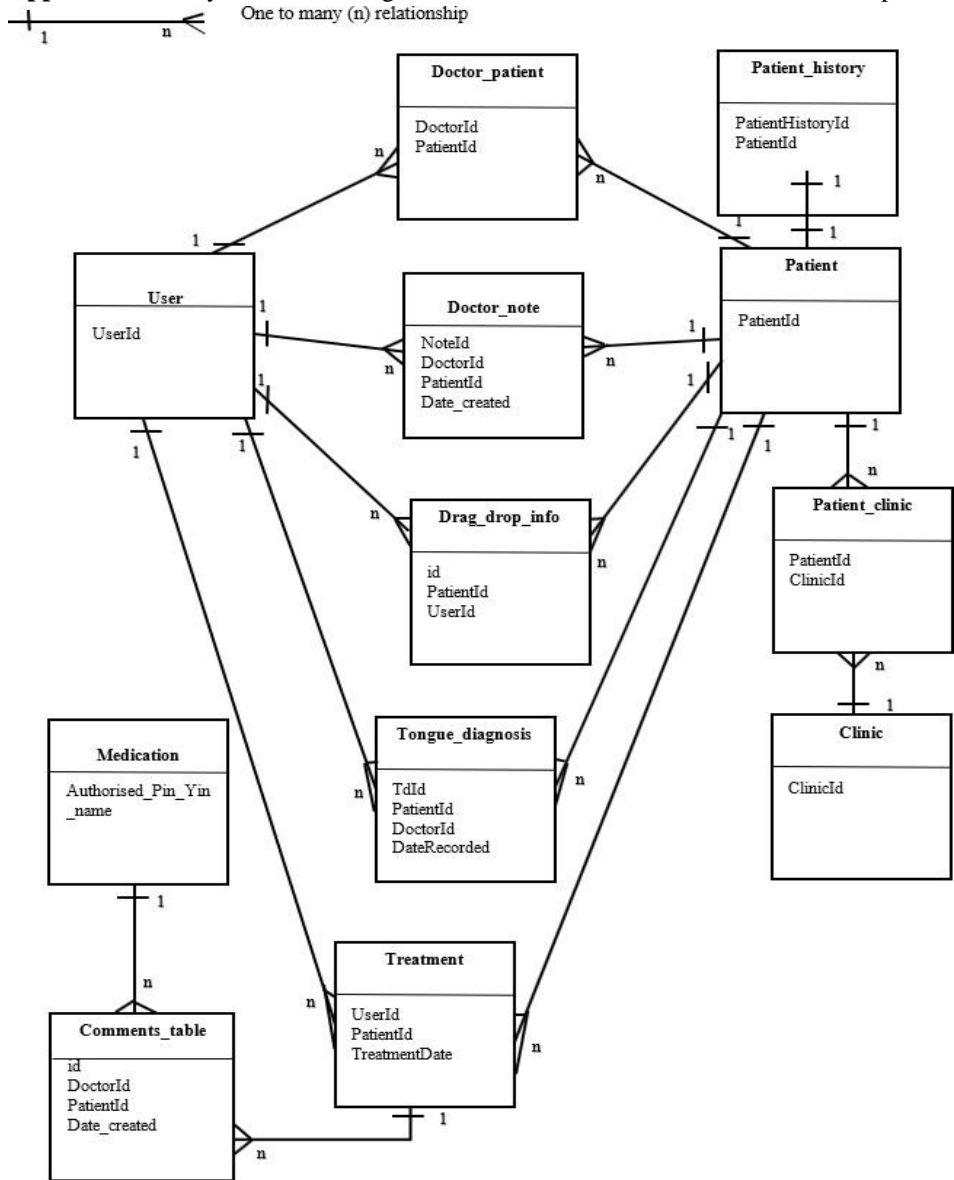
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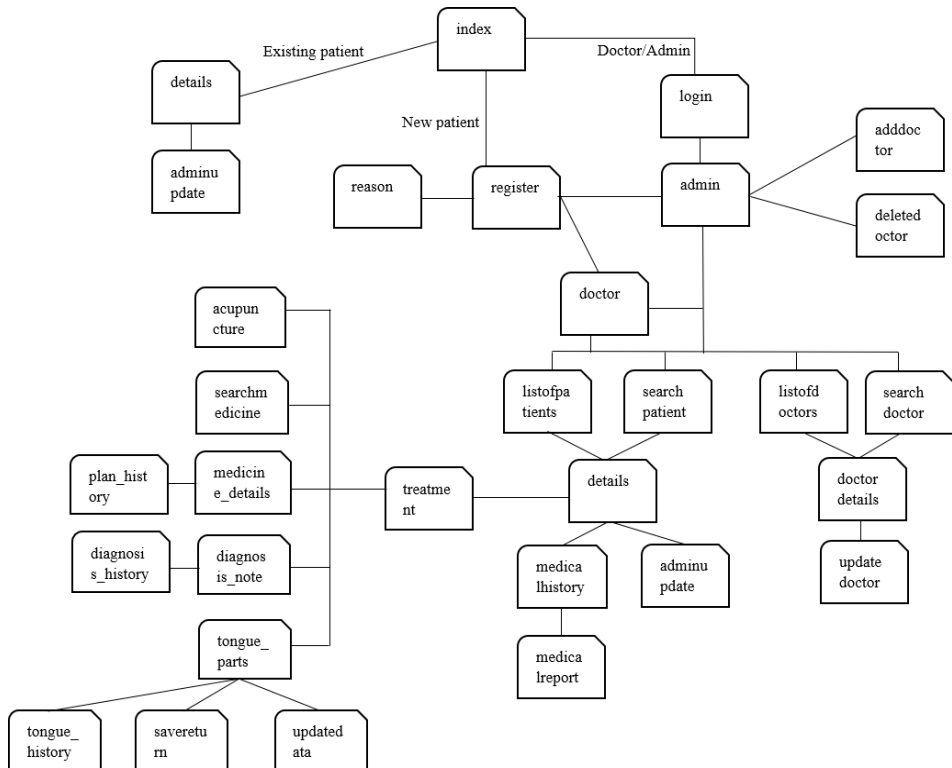
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**Appendix 1: Entity Relational Diagram of PMS Database Tables and Relationships**

















## Appendix 2: PMS Website Map



At the first (index) webpage, an existing patient can view and update his/her personal details with correct first and last Names and date-of-birth. If the patient is new, these personal details as well as the patient's medical history are collected via the register and 'reason' pages. Physicians and clinic administrators must provide a valid login to enter the PMS system to access functions/features that are have restricted access. An administrator can add a new physician into the PMS database as well as deleting a physician who no longer works at the clinic, these two functions are restricted to administrators who have the correct login details. Like physicians, the administrators can also search a patient and/or physician, see the list of patients and/or physicians, view and update their details. An administrator cannot perform diagnosis, prescription, and treatment. These core PMS functions belong to physicians only, where tongue diagnosis with graphical image of patient's tongue is analysed and examined. Diagnosis note and prescription details are recorded into the PMS database tables.

### Appendix 3: Symbols Used in the Activity Diagrams

Symbols	Description
	Solid circle represents the start.
	Bull's eye indicates the endpoint.
	Solid line with a solid arrowhead is a symbol for a transition.
	Round-corner rectangle represents an activity.
	A diamond indicates a selection or decision.
	Solid bold lines show the separate transitions/activities into concurrent paths (first solid bold line indicates the beginning of the split; the second solid bold line signifies the merge).
	Transition occurs from an activity is presented by a broken line with solid arrowhead.
	A broken line with empty arrowhead represents transitions outside of activities.
	An empty small diamond with links indicates instances of the same object.
	A sharp corner rectangle indicates hardware such as electronic devices.
	A rectangle with left top round corner and snapped right top corner represents a webpage.
	A sharp corner rectangle with two mini sharp corner rectangles at left indicates a server.
	A sharp corner rectangle with two separation lines represents a database table/ entity. Table name is written at the top, table columns/attribute names are listed next, and the activities/functions are stated at the bottom separation.
	A cylinder represents a database.

## Appendix 4: PMS Tongue Diagnosis.

Tongue observation is an important part of CM diagnosis. CM physicians often indicate the colours of the tongue body and tongue coating, for example, tongue body: red, pale, purple; tongue coating: thin or thick, dry or moisture, or simply no coating. Hence, the PMS provides the option of entering tongue diagnosis note, where these notes can then be reviewed through the ‘Tongue History’ link (circled in red below). To be consistent, a list of symbols was used to signify different conditions. It is important to point out that these conditions can appear at multiple tongue areas (e.g. left, right, centre), so that one symbol can be used (drag and place) multiple times.

Symbol	Significance
x	Indicate red dots on the tongue
o	Indicate purple dots on the tongue
	Indicate the cracks on the tongue
~~	Indicate teeth marks at the sides of the tongue

The figure displays four screenshots of the Patient Management System (PMS) interface, illustrating the tongue diagnosis process. The top row shows the main interface with a tongue image and various toolbars. The bottom row shows a 'Successfully Entered' dialog box and a 'Tongue History' link circled in red.

The screenshots show the following elements:

- Top Left:** Patient Management System interface showing patient details (Miss Watermelon Pumpkin) and a tongue image with various symbols (x, o, |, ~) overlaid.
- Top Right:** Patient Management System interface showing patient details (Miss Watermelon Pumpkin) and a tongue image with various symbols (x, o, |, ~) overlaid.
- Bottom Left:** Patient Management System interface showing a 'Successfully Entered' dialog box (circled in red) and a 'Tongue History' link (circled in red).
- Bottom Right:** Patient Management System interface showing a 'Tongue History' link (circled in red) and a 'Doctor Notes' section with the text 'Tongue coating: no coating, Tongue body: red'.

## Appendix 5: PMS Prescription and Treatment

The screenshots illustrate the user interface for entering medication details in the Patient Management System. The left screenshot shows the 'Matched Medication Details' table with the following data:

English Name	Scientific Name	Pharmaceutical Name	Details
Alum	I. Potassium aluminum sulfate	Alumen	Details

The right screenshot shows the 'Successfully Entered' confirmation screen with the 'Submit' button circled in red.

To view patient's prescription history, select the 'Treatment History' link (circled in red), select the date under the 'Medical Notes Visit Dates' (circled in red).

The screenshots illustrate the user interface for viewing a patient's prescription history in the Patient Management System. The left screenshot shows the 'Medical Notes Visit Dates' table with the following data:

Medical Notes Visit Dates
2017-10-29

The right screenshot shows the 'Medical Notes' table with the following data:

Medical Notes
Herbs: BaiShu 5mg, DangSheng 10mg, FuLing 10mg, Alum 10g, 5mg