AUTHOR QUERY FORM

ELSEVIER	**Journal:** COMM **Article Number:** 3133	**Please e-mail or fax your responses and any corrections to:** **E-mail:** corrections.esch@elsevier.thomsondigital.com **Fax:** +353 6170 9272

Dear Author,

Please check your proof carefully and mark all corrections at the appropriate place in the proof (e.g., by using on-screen annotation in the PDF file) or compile them in a separate list.

For correction or revision of any artwork, please consult http://www.elsevier.com/artworkinstructions.

Any queries or remarks that have arisen during the processing of your manuscript are listed below and highlighted by flags in the proof. Click on the 'Q' link to go to the location in the proof.

Location in article	Query / Remark: click on the Q link to go Please insert your reply or correction at the corresponding line in the proof
Q1	Please check whether the author names and affiliations are correct.
Q2	The country name has been inserted for the third author's affiliation. Please check, and correct if necessary.
Q3	Please supply the year of publication for Refs. [2,14,20,23].

Thank you for your assistance.

COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE XXX (2010) XXX–XXX

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer

Hsueh-Chun Lin[a,*], *Hsi-Chin Wu*[b,1], *Chih-Hung Chang*[c,2], *Tsai-Chuan Li*[d,3], *Wen-Miin Liang*[e,4], *Chung-Yi Wang*[f,5]

[a] *Department of Health Risk Management, China Medical University, 91 Hsueh-Shi Road, Taichung 40402, Taiwan*
[b] *School of Medicine, China Medical University, 91 Hsueh-Shi Road, Taichung 40402, Taiwan*
[c] *Department of Psychology, Rush Medical College, Feinberg School of Medicine, Northwestern University, 750 North Lake Shore Drive, Suite 601, Chicago, IL 60611, United States*
[d] *Institute of Biostatistics & Biostatistics Center, China Medical University, 91 Hsueh-Shi Road, Taichung 40402, Taiwan*
[e] *Institute of Biostatistics & Institute of Environmental Health, China Medical University, 91 Hsueh-Shi Road, Taichung 40402, Taiwan*
[f] *Department of Health Services Administration, School of Public Health, China Medical University, 91 Hsueh-Shi Road, Taichung 40402, Taiwan*

ARTICLE INFO

Article history:
Received 5 April 2009
Received in revised form
25 September 2010
Accepted 5 October 2010

Keywords:
Clinical infometrics
Modelized architecture
Patient-oriented interface
Object relation mapping
Quality of life

ABSTRACT

Objective: The aim of this study was to establish a real time online health and decision support system with the novel information technology integrating modelized architecture and Web services for clinical infometrics on patient reported outcome (PRO) and quality of life (QOL) for prostate cancer patients.

Methods: The patient-oriented interface was practiced with object relation mapping (ORM) and clinical data warehouse to collaborate QOL measurement and medical informatics through internet by incorporating a variety of hospital information systems. The conceptual infrastructure was designed by five primary layers to organize the data flow of online assessment and clinical data for real-time decision support.

Results: A preliminary knowledge bank was formed by feedback of expert opinions to provide online guidance for decision references. Observation and assessment of prostate cancer patients' QOL and clinical markers were immediately tracked with automatic computation algorithm to improve health care quality in the treatment cycle.

Conclusions: The established Web-based system can help clinicians concurrently collect and analyze real-time PROs and QOL for enhancing communication with patients and improving the quality of care.

* *Corresponding author*. Tel.: +886 4 22070429.
E-mail addresses: snowlin@mail.cmu.edu.tw, snowcmu.lin@gmail.com (H.-C. Lin), wuhc@mail.cmu.edu.tw (H.-C. Wu), chchang@northwestern.edu (C.-H. Chang), tcli@mail.cmu.edu.tw (T.-C. Li), wmliangkimo@yahoo.com.tw (W.-M. Liang), ericwang@mail.cmu.edu.tw (C.-Y. Wang).
[1] Tel.: +886 4 22053764.
[2] Tel.: +1 312 503 5868.
[3] Tel.: +886 4 22078539.
[4] Tel.: +886 4 22078539.
[5] Tel.: +886 4 4 22031108.

0169-2607/$ – see front matter © 2010 Published by Elsevier Ireland Ltd.
doi:10.1016/j.cmpb.2010.10.003

1. Introduction

Rather than a single therapy for a cancer treatment, the cures with compound therapies by medical progress became new tendency in the past years. The major cancer therapies for destroying tumors usually bring side effects that could cause vomit, asthenia, and hair loss in addition to mental suffering. Therefore, patients' quality of life (QOL) was deeply impacted by their unsafe and anxious feelings for uncertainty and after-effect due to treatments of the oncology clinic. It is worthwhile to design an automatic system with flexible functionalities for immediately responding QOL assessments with clinical markers beyond the hospital information system (HIS). Insufficiently, the quality of clinical care may be diminished when clinicians explain clinical markers to their patients without presenting analytical data and visualized diagrams. Sometimes, patients are embarrassed to answer private questions as watched by health care people and probably even hide the actual conditions to lead incorrect judgments. Bridges et al. [1] formulated a vision of how a patient-based health technology assessment could be used to promote patient empowerment and patient-centered care. Based on the professional book [2] of biomedical informatics for discussing computer applications in health care, an electronic healthcare information with clinical decision support system (CDSS) is quite important for clinicians to efficiently obtain instant and reliable patient report outcomes (PROs), e.g. QOL, as well as patient clinical records (PCRs) to improve the quality of medical care in clinic. As comparing the documentation quality by electronic and paper-based medical records, the past study indicated that high workloads, shortage of bedside hardware and lack of software features were prominent influential factors [3]. Many studies reviewed a variety of computer-based CDSSs and concluded that clinical performance and patient outcome could be enhanced for active medical care and other aspects of healthcares [4,5]. To provide efficient facilities for physicians, for example, many studies developed decision aid tools or specific information systems to improve quality of care in hospitals with limited financial resources [6–8]. Obviously, it is not easy to create a universal HIS for satisfying varied clinical requirements. However, it would be possible and helpful to generate an expandable platform with flexible components for specified clinical purpose beyond a generalized framework. Therefore, the Web-based information system with customized components for health care becomes a solution to incorporate PROs and the CDSS to adapt the existing HIS according to different requirements of hospitals.

Recently, Chang [9,10] established an interactive assessment and management system, which is called clinical infometrics by technologies of information and psychometrics for measurement, statistical modeling, informatics and practice, to improve clinical assessment with computerized procedure in palliative care. The system contains informatics, predictive models, PRO item bank, computerized adaptive testing, clinical practice guidelines and practices for obtaining better treatment effects. Applied for measurement and management of PROs, infometrics technique can help clinicians precisely recognize actual feeling and response from patients and improve the quality of care with instant process as well as data statistics for real time outcomes and online clinical decision. Clinicians can further convince patients by comparing their instant outcome with others in clinic visits.

In this study, we proposed an integration platform of Web-based infometrics system, which combines CDSS and health care information, for clinical infometrics of prostate cancer treatment by involving components of novel information technology, health care assessment, and evidence-based medicine. The methods for developing the system upon the modelized architecture were detailed to incorporate heterogeneous databases with Web services according to patient's convenience and clinical requirement. In advance, the assessment of QOL was practiced for real time online clinical decision support. Finally, the proposed system was approved by the institutional review board (IRB) and was implemented in the Hospital of China Medical University (CMUH) in Taiwan to deliver the functions of multi-disciplinary, patient-centered, evidence-based, methodology-derived, database-driven, and technology-assisted characteristics.

2. Methods

In this section, the Web-based models of the conceptual architecture are described for constructing the infometrics system by novel information technology to collate PCRs and PROs data with online QOL assessment of prostate cancer patients.

2.1. *Infometrics of quality of life*

When the superior standard of medical environment is served, the higher criteria for quality of health care must be enhanced. Compared to importance of survival evaluation, QOL hence becomes another significant index of health care.

The World Healthy Organization (WHO) defines the QOL as individuals' perceptions of their position in life in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards, and concerns. European Organization for Research and Treatment of Cancer (EORTC) creates series of QOL assessments in cancer clinical trials to provide a more accurate evaluation of the well-being of individuals or groups of patients and of the benefits and side-effects that may result from medical intervention. The reliability, validity and sensitivity of assessment are acceptable since questionnaires have been translated and validated into a variety of languages and are used in more than 3000 studies worldwide. Thus the quality of life questionnaire (QLQ) C30 can assess the QOL of cancer patients while several other modules are running for specified cancers such as breast, lung, etc., and PR25 is one of the modules designed for prostate cancer patients.

In this study, a web-based platform of real time online assessment was developed for infometrics system to serve prostate cancer patients. The core measurement of QLQ C30 with prostate cancer module PR25 were selected in the system as well as connected to PCR database. The QLQ-C30 incorporates nine multi-item scales: five functional scales (physical, role, cognitive, emotional, and social); three symptom scales (fatigue, pain, and nausea and vomiting); and a global health and quality-of-life scale. Several single-item

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003

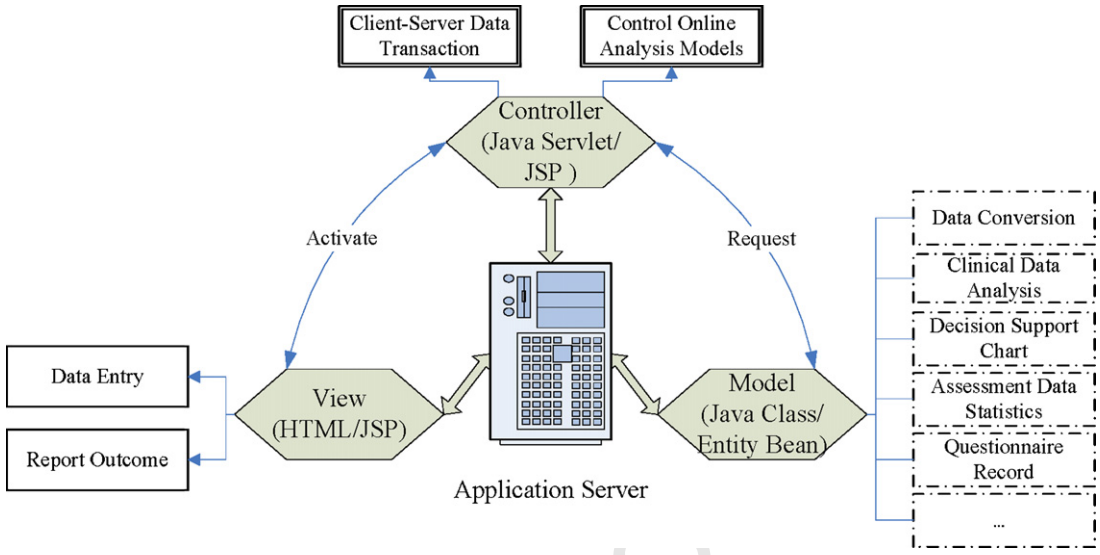


Fig. 1 – Model-View-Controller components.

symptom measures are also included [11]. The PR25 is a 25-item questionnaire designed for use among patients with localized and metastatic prostate cancer. It includes sub-scales assessing urinary symptoms (9 items), bowel symptoms (4 items), treatment-related symptoms (6 items) and sexual functioning (6 items).

All questionnaires with enlarged font and selection buttons were displayed on a touch screen by patient-oriented design for an accessibility interface. Besides, an optional functionality of multimedia was available for patients who cannot read. Patients were arranged to complete questionnaires easily in a private space as waiting for outpatient service, and then clinicians can evaluate instant assessment results with online analysis report by practicing automatic process of computation and statistical modeling.

2.2. *Modelized architecture*

To acquire QOL data of patients from the Web-based infometrics system and adapt to the legacy HIS, a concept of modelized architecture would be implemented as the foundation. The base of this architecture reflects the model-view-controller (MVC) design pattern, which was established in 1970s by including several design patterns to describe proven strategies for building reliable object-oriented (OO) software system [12]. The concept was first made available by Gamma et al. [13] to introduce 23 patterns related to creational, structural and behavioral models for software design to progress recurrent elements. The MVC theoretically divides system responsibilities into 3 parts: the model, which maintains program data and logic; the view, which provides a visual presentation of the model; the controller, which processes user input and makes modifications to the model [14]. In the other word, the system based upon the modelized architecture may be imagined as a human being who has organs (model) to create physiological functionalities; has eyes, ears, or limbs (view) to sense or behave responses; and has a brain (controller) with the neural system to structure persistent communications throughout the whole body. Hence the MVC-based framework uses its input control to solve the problems on consuming computation resources when the user is not interacting with the interface and avoid unnecessary performance loss [15].

According to the architecture, the approach of online QOL infometrics would be constructed on the Web-based platform with the open source framework. The framework is required to support less services but it is much less intrusive than enterprise modules; and the driving force behind this shift is the need for greater productivity and reduced complexity in web

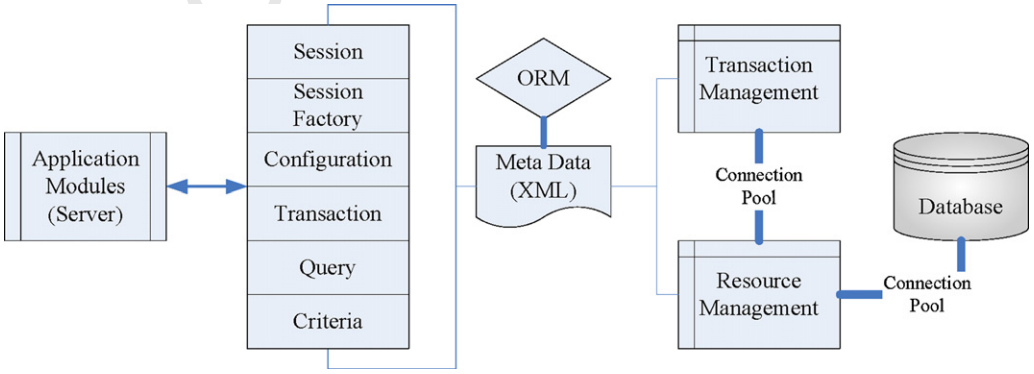


Fig. 2 – Data flow in object relational mapping.

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003

application development and implementation [16]. Herein, the system must request assessment components with flexible functionality and patient-oriented interface. The conceptual frame is outlined in Fig. 1, and main components are organized by three parts containing the model, view and controller, which provide individual modules but support one another due to system requirements such as QOL assessment, decision support, and so on.

2.3. *Object relation mapping mechanism*

Object-relational mapping (ORM) is a programming technique for converting data between incompatible type systems in relational databases and OO programming languages. It uses metadata that describes the mapping between the objects and the database to relate the automated and transparent persistence of application objects to the tables within database. The ORM, in essence, works through reversibly transforming data from one representation to another [17]. Therefore, we coordinate the infometrics and clinical data flow on the conceptual interface of ORM, shown as Fig. 2, to convert persistent objects and manage data transaction and resource prior to database. Based upon the mechanism, the session interface conducts lightweight instances of application in safe as the necessary data are requested on the web tier all the time; the application obtains session instances from a session factory to share many application modules and cache scripted database transaction and other mapping metadata at runtime for data conversion. Then, the configuration interface configures the location of mapping documents and specific properties for data retrieval; thus a transaction interface can be optionally selected to keep applications portable between different execution environments. Furthermore, the query interface performs instances to control data queries against the database, while the criteria interface executes OO criteria queries.

Herein, the assessment of QOL questionnaires and integrity of Web services for online analysis are implemented by the ORM modules to concurrently process and share light weight data over the Web-based system through rearranging storage, organization, and retrieval of structured data. By using XML-based configuration, metadata with mapping information and necessary parameters can be generated to synchronize application request from interfaces and database. Therefore, the framework exposes a configuration-time-meta model that declares the information in XML mapping documents for extension by user-written code.

2.4. *Clinical data warehouse*

To incorporate infometrix data with existing PCRs for online analysis, a clinical data warehouse was planned and practiced in this study. The data warehouse is an integrated, subject-oriented, time-variant and non-volatile database that provides support for decision making, and used to build up an integral database for historical data repository with lack of systematic arrangement by information technique [18,19]. It allows complex queries and analyses on the information without slowing down the operating system. The raw clinical data would be rigorously unified by the extract-transform-load (ETL) procedure, shown as Fig. 3, into database through extraction, consolidation, filtering, transformation, cleansing, conversion and aggregation [20]. As planning the data warehouse, the fact tables and related cube dimensions are key elements while classifying several schemas in different dimension models; i.e., the fact table contains facts that are linked through their dimensions, which qualify characteristics that provide additional perspectives to the given facts. In this study, we created the clinical and infometrix data warehouse in which the fact table represents data of QOL and PCRs while cube dimensions present advanced statistical information. Herein, we developed the control modules by inducing three primary database functions to build up the data warehouse: dynamic view, stored procedure and trigger. They were programmed by prestored database transaction scripts to generate dimensional cubes and enable the automatic processes while integrating diverse data in the data warehouse.

2.5. *Web services and online analysis*

Web services represent an interface for describing a collection of operations that are network accessible through standardized XML messaging [21]. The W3C defines a Web service as "a software system designed to support interoperable machine to machine interaction over a network." The key components within the infrastructure follow the standards of SOAP (simple object access protocol), WSDL (Web service definition language), UDDI (universal description, discovery, and integration) to interact heterogeneous service data with standard, formal XML notation; i.e., the services take the form of XML documents to translate metadata depicted by WSDL definition, transport data communicated through SOAP framework, and search information registered in UDDI mechanism. In our design, the historical data of QOL assessment stored in database were queried with statistical estimation and yielded the reference indexes to avoid laggardly processing upon large data; moreover, the computation model would retrieve decision criteria from unified document to create online statistical diagrams through Web services.

The technique of online analytical processing (OLAP) has been functional to decision support for an enterprise system since early period of network boom-up era [22]. It provides efficient functionalities on the backbone of data warehouse to explore historical data. To manage and analyze infometrix and clinical data in the study, we extended the OLAP over the Web server and database as online computation models of the CDSS. The QOL assessment and PCR query were integrated with heterogeneous database while accessing the server. This progress kept complex query behind data mining for knowledge bank but left simple data transaction through dynamic views in data warehouse.

3. System developments

3.1. *Requirement analysis*

With the limitation for security manners of hospital management, the architecture of proposed clinical and infometrics system was requested to integrate two individual networks which concurrently worked with the legacy HIS for PCRs

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003

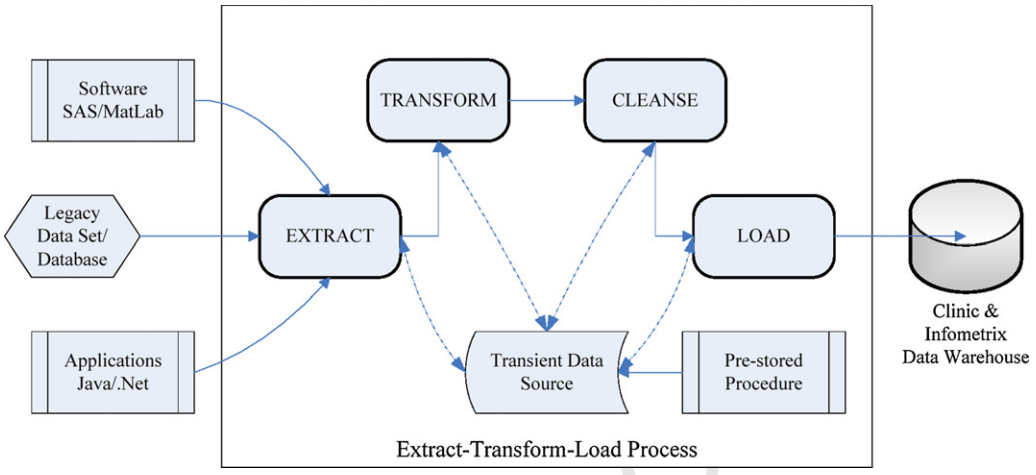


Fig. 3 – ETL process for clinic and infometrix data warehouse.

and clinical diagnostic interface. The initial development was planted on prostate cancer treatments in urology clinic for reflecting relationship between QOL and pretreatment parameters such as prostate-specific antigen (PSA), clinical classification stage, and Gleason score, etc. Referring the literature [23], prostate cancer rarely causes symptoms early in the course of the disease because the majority of adenocarcinomas arise in the periphery of the gland distant from the urethra. Growth of prostate cancer into the urethra or bladder neck can result in obstructive and irritative voiding symptoms. Local invasion of prostate cancer can involve the trigone of the bladder and lead to ureteral obstruction that, if bilateral, can cause renal failure. Through urologic treatments such as transurethral resection, radical prostatectomy, hormone therapy, etc., prostate cancer has greatly benefited from the discovery of tumor markers.

Hence analytical fundamentals of the system with automatic computation algorithm should be required by following scopes: (A) instantaneous observation of QOL assessment, (B) online clinical markers tracked in the treatment cycle, (C) immediate comparison with overall patients' OQL, and (D) real time cross-evaluation of QOL and clinical markers.

3.2. *Integration design*

From right to left in Fig. 4, the system was designed for collaborating database, analysis, management, presentation, and acquisition layers, upon the modelized architecture by implementing previous methodology.

1. The database layer founds the system base for building clinical and infometrix data warehouse. Fig. 5 illustrates the primary object relationship diagram and related schema, where the field attributes denote correlation between QOL domains and treatment effects. The designed schema combines two sets of fact tables for infometrix and clinical records so that "Answer_Full" and "Answer_Domain" tables store assessment data and transform to QOL domain scores, respectively, while "Patient_Info" and "Prostate_Cancer" tables retrieve data from PCR including essential information and clinical biomarkers. The index table "Answer_Index" is the bridge to join both of fact table sets, "Answer" and "Question" tables which request and arrange assessment data, and derives cube dimensions of PSA, treatment, clinical stages and Gleason scores.
2. The analysis layer assists researchers in analyzing data and feeding back statistical results as resources of knowledge bank. In this study, several formats for converting data files were defined in advance to satisfy different database progresses that analysis tools could support. The layer incorporates both database and Web servers through remote computation or offline data mining and feeds back expert opinions into the knowledge bank of CDSS.
3. The management layer plays the role of control center for managing data flow within entire system. A management interface was designed for enhancing capability of data access functions to catch online charts, identify single sign-on, process data conversion, administrate user privilege, and acquire QOL assessment. All modules were created for sharing functionality but secured with privilege roles of health care people, clinicians and researchers.
4. The presentation layer yields the platform of real time decision support to provide communication interface between patients and clinicians. The visualized design can present coincident statistical information by expert opinions after automatically updating assessment database and knowledge bank. Herein, for prostate cancer infometrics, it simultaneously performed the real time QOL evaluation corresponding to the mean value of other patients with similar age, initial PSA, Gleason score, treatment stage, etc. Clinicians hence were able to improve efficiency of communication by indicating online treatment indexes through the graphical interface for advanced decision support.
5. The acquisition layer becomes the data receiver of system to react online QLQ behind accessibility interface design. Perhaps most of patients felt uncomfortable, either in physical or mental status, while answering assessment questions by hand-written paper in person. For this design, the touch screen was installed for patients who are not familiar with operating computer by mouse; large font was

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003

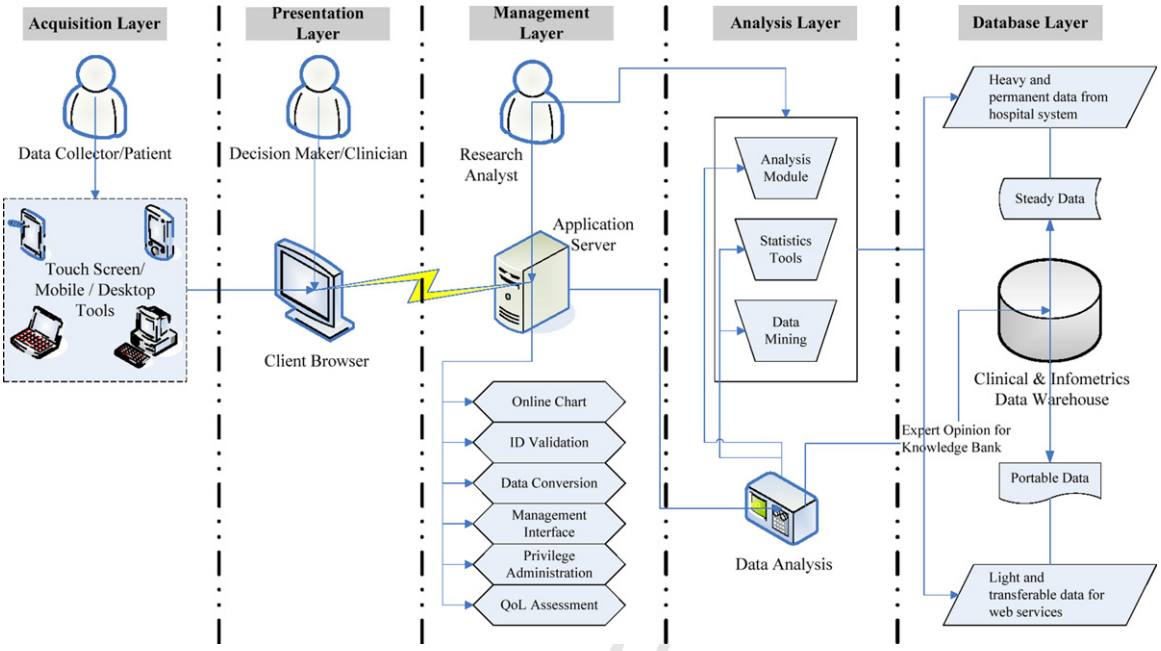


Fig. 4 – Five-layer development of CDSS infrastructure.

designed for senior patients who do not have good eyesight; audio–video media playing with ear or head phones were considered for low education level patients who could not recognize lettered questions.

Based on the system design, clinicians and researchers were able to access infometrix data after patients finished assessments through patient-oriented interface. For improving work efficiency and balancing dataflow loads of Internet data transportation, the Web server requests infometrix diagrams for decision support by processing lightweight data, thus the database server provides statistical analyses with querying heavy data. Furthermore, the technique of remote backup and disaster recovery in database was practiced in the proposed system to ensure the integrity of clinical data warehouse. The procedure can remotely track the state of a primary system and take over data transaction processes when disaster hits the primary site [24]. In order to secure the privacy of patients, the PCRs must be forbidden from internet users except of particular clinical people; therefore, the primary database server for instant infometrix becomes the data center at the clinic site; meanwhile, a backup database server at the research site is allowed to routinely restore data through specified protocol.

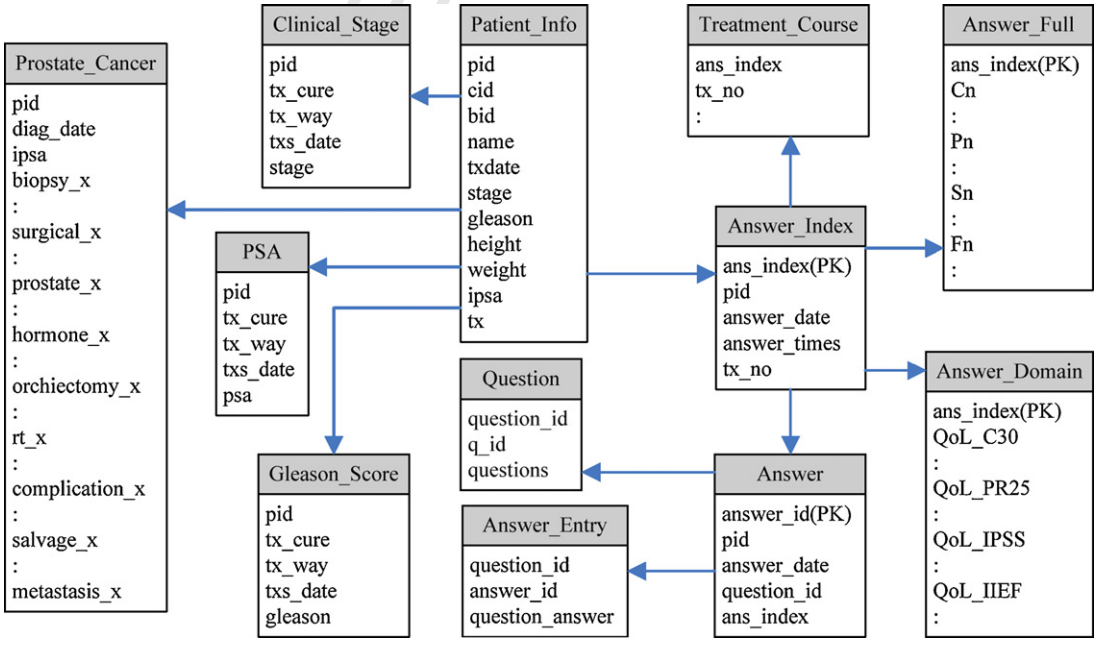


Fig. 5 – Object relationship diagram and schema.

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003

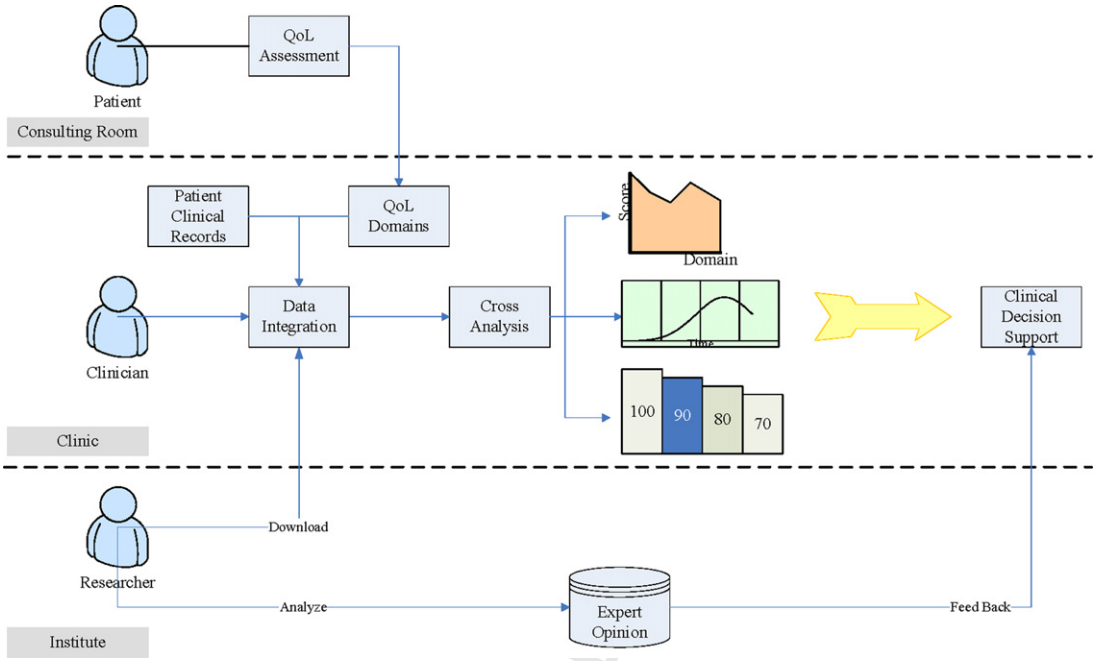


Fig. 6 – Clinic progress practiced with clinical infometrics system.

4. Results and discussions

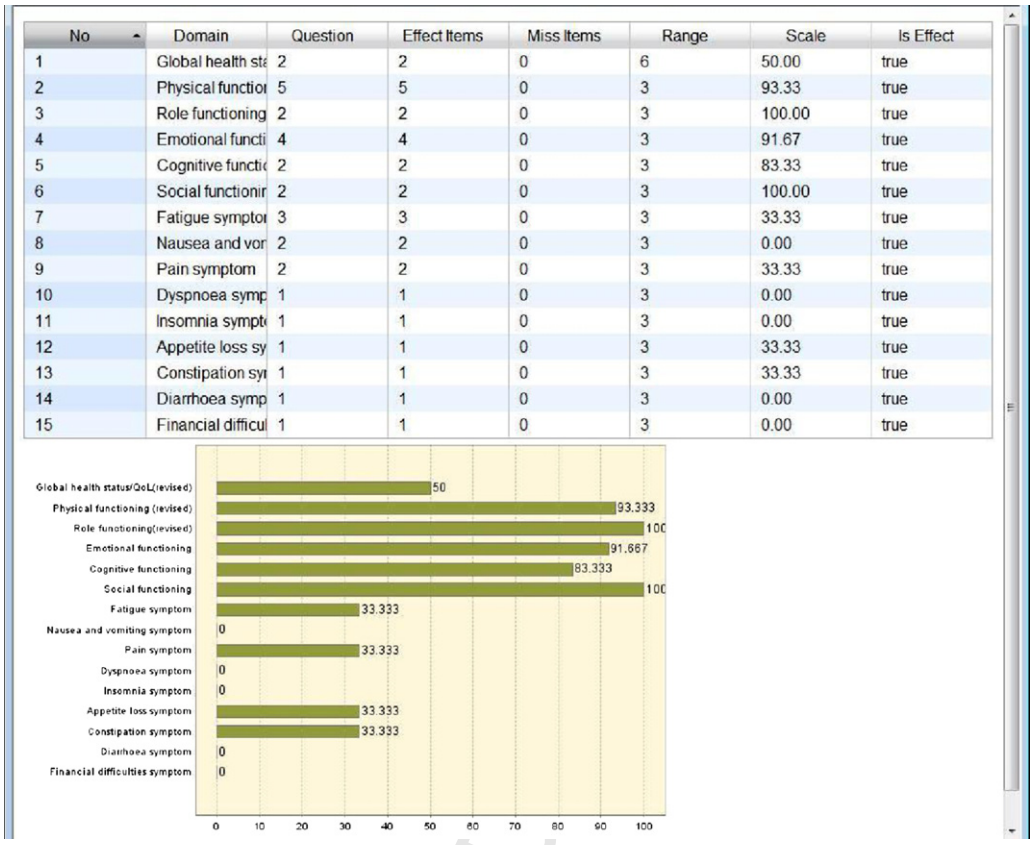
4.1. *Results*

A pilot study of the proposed system was employed on the department of urological cancer of CMUH. Before the system development, hundreds of prostate cancer patients were tracked by handwriting QOL assessment for six times per cycle during cure period but lacks of the automatic electronic progress. Because of physical or mental suffering, patients used to complete paper works through conversation with health care people. Meanwhile, doctors took many efforts to explain patient outcomes at clinic visits by printing out PCRs for advices. Therefore, the designed system was established by practical user requirements of each layer to increase interaction with patients to consolidate relationship as well as reduce official burden of health care people.

The patients were scheduled in a consulting room for online assessment as waiting for the clinic time. In the practice, the patient read the introduction page and login with personal ID to start the QOL assessment. There is only one question per browser page and the patient can adjust suitable font size on the touch screen in addition to consider the voice control button for assistance. On the other hand, the clinician was able to compare patient's record with others who match similar markers and evaluate assessment results by figures or charts for advanced consultation. Fig. 6 performs the operating procedure in which the clinician can reciprocally compare overall cure information and quality of patient's life during the treatment cycle. The expert opinion can be feed back by researchers after analyzing data. Patients are able to discuss and learn information with the doctor during clinic time since all online diagrams are immediately updated once the QOL assessments are finished. The result charts for clinical infometrix matching the requirement analysis are highlighted below.

A. *Assessment amendment*: The tablet denotes all answered items for final modification that reminds the patient or health care assistants to make double-check if there are unexpected missing items occurred by careless manipulation. In the pilot study, some patients were not familiar with operation on the touch screen so that several questions could be lost. The health care people were able to help patients make up mistakes.
B. *Statistics of QOL domains*: The chart in Fig. 7 details the final assessment results involving the questionnaire, range and scale in each domain, effect and missing items while answering questions. All domains reflect patient's functions and symptoms regarding the physical or mental conditions during the treatment cycle. The clinician can assist the patient to recognize how many questions, including the effect and missing items, have been answered for each domain, and what scale for each domain is scored. For this example, the patient gets a 50% scale of the global health status/QOL domain which contains 2 questions ranged in 6, it means each question grades the QOL level from 1 (very poor) to 7 (very good) points and the patient obtains 50% of total 14 points, thus the assessment is effective since no required item is missed. Due to the brief bar chart, the patient can conveniently realize the better QOL circumstance by the higher function scale and lower symptom scale, and vice versa.
C. *Cross-comparison*: The chart supports the clinician and patient a platform to take an overview on assessment records for discussing the variation of QOL compared with the mean value of other patients in similar conditions. The presented case shown in Fig. 8 indicates that the patient

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003



No	Domain	Question	Effect Items	Miss Items	Range	Scale	Is Effect
1	Global health sta	2	2	0	6	50.00	true
2	Physical functior	5	5	0	3	93.33	true
3	Role functioning	2	2	0	3	100.00	true
4	Emotional functi	4	4	0	3	91.67	true
5	Cognitive functic	2	2	0	3	83.33	true
6	Social functionir	2	2	0	3	100.00	true
7	Fatigue symptor	3	3	0	3	33.33	true
8	Nausea and vor	2	2	0	3	0.00	true
9	Pain symptom	2	2	0	3	33.33	true
10	Dyspnoea symp	1	1	0	3	0.00	true
11	Insomnia sympt	1	1	0	3	0.00	true
12	Appetite loss sy	1	1	0	3	33.33	true
13	Constipation syr	1	1	0	3	33.33	true
14	Diarrhoea symp	1	1	0	3	0.00	true
15	Financial difficul	1	1	0	3	0.00	true

Fig. 7 – Statistics of QOL domains.

performed 50 points of global QOL with respect to 30 points in average for the similar age range. It enhanced the patient with confidence to follow doctor's comments for advanced treatment. In the pilot study, the patients reflected eager motivation with more interaction to clinicians as recognizing QOL history with clinical markers.

D. *Overall evaluation*: The charts provide optional choices on the domain scale of all historical assessments that patients

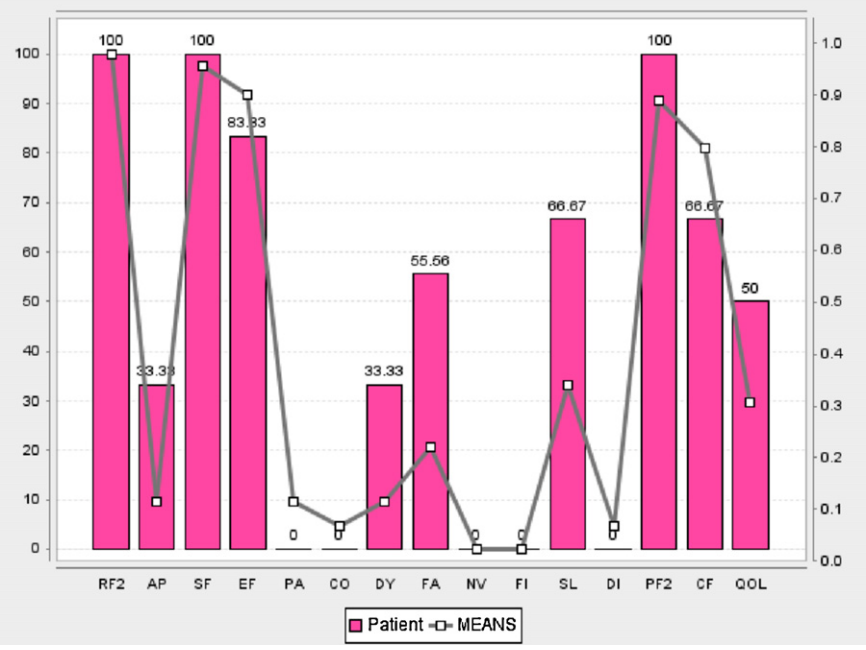


Fig. 8 – Cross comparison after assessment.

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003

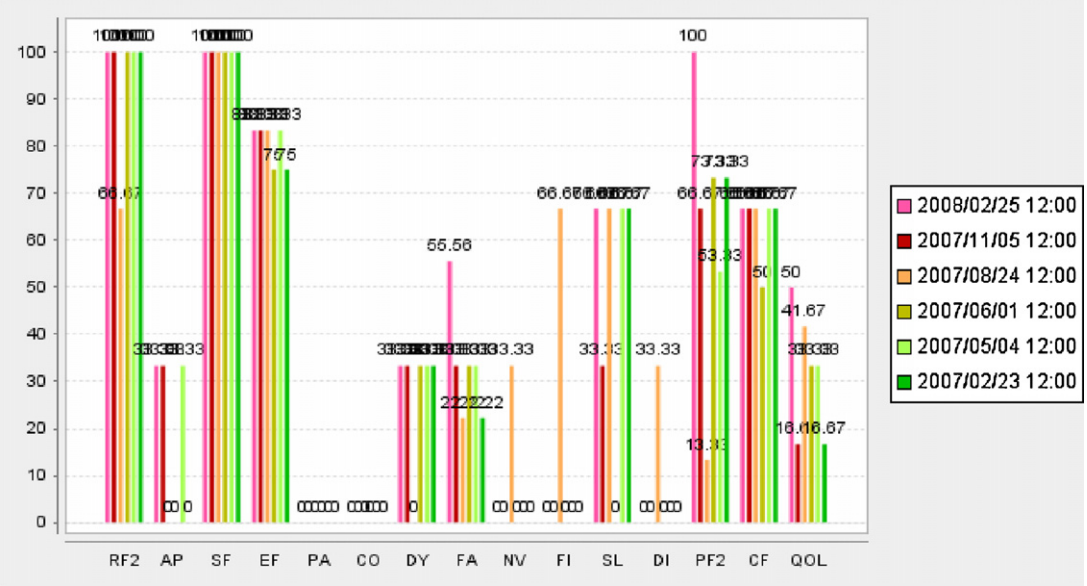


Fig. 9 – Overall evaluations with historical records.

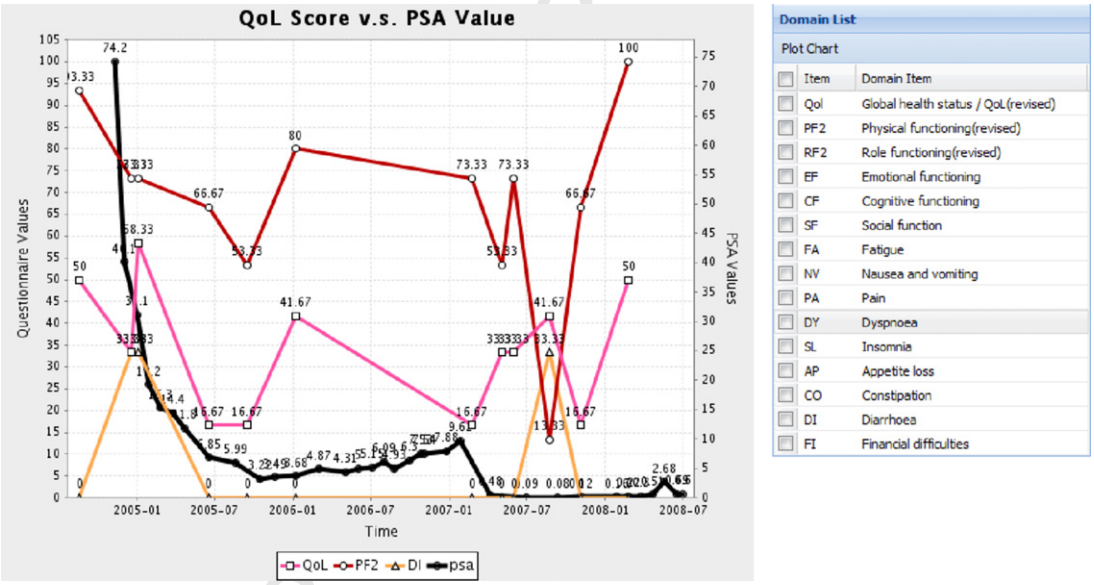


Fig. 10 – QOL vs. PSA history of a specified patient.

had experienced to make detailed evaluation and judgment. These functions also imply the decision support model that works for the system architecture shown in Fig. 1 because the diagrams may remind the clinician to make decisions by the visualized reference data. The specified case in Fig. 9 displays the change of QOL, which became better after some particular time because of the successful prostate surgery. Referring the PSA history compared with selected QOL domains in Fig. 10, the patient accepted surgery operation in early-2007 and improved the PSA value. It explains the reason of the better QOL assessment result. However, a suspected point was observed in the period around July in 2007 under stable PSA baseline, the patient felt uncomfortable since the physical function was suddenly getting worse (73.33–13.33) while the diarrhoea symptom became significant (0–33.33). Meanwhile, the corresponding global QOL score did not reflect it but at next point. It assisted the clinician in recognizing whether the problem was caused by the prostate disease.

4.2. *Discussions*

In this study, clinicians indicated that they use the system mainly for functional assessment as well as for highlighting patients' most bothersome symptoms. The most common benefits would include enhancing communication with patients, identifying under-reported symptoms for clinicians and increasing efficiency in clinics. To assess the

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003

advantage of the developed system for users, some problems are discussed below.

A. *Real time informetrix categories for patients*: The best practice of the developed system should be applied for patients whose disease can be chronically and periodically tracked by specified clinical markers. Therefore the design of real time infometrix for prostate cancer patients displays their PSA values associated with QOL domains to provide categories of physical, role, cognitive, emotional, and social functions in addition to that of fatigue, pain, nausea and vomiting symptoms. Particularly, it reflects urinary, bowel, treatment-related symptoms and male-related sexual functioning. Patients are able to recognize personal health conditions immediately with respect to others through the instant graphical chart in the clinic.
B. *Users' experiences on system operation*: The participant doctors began to explain the disease conditions to patients by the overall evidence-based diagrams like Fig. 10. A satisfaction survey for 100 users' experiences on system operation shows that 92% of users felt easy to operate the functionality through the system, and 97% of them sensed friendly for the designed interface. When patients answered the questionnaires, 10% and 24% of them thought that the font is too small and the content is too much, respectively. With overall statistics, 92% of users approved the innovative setup and new technical design. The investigation data certainly encourage the advanced study in the future.
C. *Information security for risk avoidance*: As generating the infometrix system, patients' assessment data were secured by both of questioning environment and electronic software. Patients were led to a consulting room to answer the questionnaires so that they could finish the assessment with full privacy. Moreover, all personal data were encrypted as being written into the database to avoid being falsified and stolen. Hence the risk avoidance for the security problem is approved and patients have enough confidence to comply with clinicians' guidance.
D. *Improvement in clinician–patients relationships*: Several studies in chronic diseases suggested that feedback of health status data may facilitate communication between patients and clinicians and enhance patients' care [25][26]. Accordingly, incorporating standardized QOL assessments in routine clinical oncology practices can heighten physicians' awareness of their patients' [27]. Correspondingly, herein, the developed system obviously assists clinicians in discovering reliable QOL information of prostate cancer patients since they would like to confess more factual illness status. Therefore, data quality is ensured by the automatic transportation procedure with no manual mistakes. It confirms that the web-based individual QOL assessment through the real time clinical infometrix system with immediate outcomes to improve clinician-patients relationships is possible and feasible.

5. Conclusions

This study revealed the progression of the clinical infometrics system with the novel information technology to establish fundamentals of real time online analysis and decision support on the modelized architecture. The proposed system incorporated the methodologies including Web services, online analysis, database warehouse, and object relation mapping. The infrastructure consists of five layers with flexibility to develop expandable modules and provides accessible functions to reach requirements of prostate cancer in clinic applications. A patient-oriented interface designed with the touch screen was considered as a major subject to assist patients in fulfilling QOL assessment. In a variety of heterogeneous database systems distributed in hospital, clinic and campus networks were integrated for an expert bank with remote data backup and disaster recovery. In advance, the patient outcome was available to offer instant statistical charts for decision making as well as improved communication and relationship between clinicians and patients.

Acknowledgement

The author would like to thank the research support from China Medical University with project number CMU96-228, CMU97-321 and CMU96-153.

REFERENCES

[1] J.F.P. Bridges, C. Jones, Patient-based health technology assessment: a vision of the future, Int. J. Technol. Assess. Health Care 23 (1) (2007) 30–35.
[2] E.H. Shortliffe, J.J. Cimino, Biomedical Informatics Computer Applications in Health Care and Biomedicine. 3rd ed., Springer.
[3] F. Pourasghara, H. Malekafzalia, S. Kocha, U. Forsa, Factors influencing the quality of medical documentation when a paper-based medical records system is replaced with an electronic medical records system: an Iranian case study, Int. J. Technol. Assess. Health Care 24 (2008) 445–451.
[4] M.E. Johnston, K.B. Langton, R.B. Haynes, A. Mathieu, Effects of computer-based clinical decision support systems on clinician performance and patient outcome: a critical appraisal of research, J. Internal Med. 120 (1994) 135–142.
[5] D.L. Hunt, R.B. Haynes, S.E. Hanna, K. Smith, Effects of computer-based clinical decision support systems on physician performance and patient outcomes, JAMA 280 (1998) 1339–1346.
[6] T.Y. Yu, H.H. Ho, The design and development of a physician-oriented PACS for the enhancement of e-hospital facilities, Int. J. Med. Inform. 77 (2008) 836–847.
[7] A.A. Elie, B.J.B. Grant, G.H. Guyatt, V.M. Montori, H.J. Schünemann, A decision aid for COPD patients considering inhaled steroid therapy: development and before and after pilot testing, BMC Med. Inform. Decis. Mak. 7 (12(online)) (2007).
[8] J.A. Blaya, S.S. Shin, M.J. Yagui, G. Yale, C.Z. Suarez, L.L. Asencios, J.P. Cegielski, H.S. Fraser, A web-based laboratory information system to improve quality of care of tuberculosis patients in Peru: functional requirements, implementation and usage statistics, BMC Med. Inform. Decis. Mak. 7 (33(online)) (2007).
[9] C. Chang, A. Boni-Saenz, R. Durazo-Arvizu, S. DesHarnais, D. Lau, L. Emanuel, A System for interactive assessment and management in palliative care, J. Pain Symp. Manage. 33 (2007) 745–755.

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003

[10] C. Chang, Novel pain assessment and intervention network (NoPAIN) and clinical infometrics, J. Pain 8 (2008) S72–S172.
[11] N.K. Aaronson, et al., The European organization for research and treatment of cancer QLQ-C30: a quality-of-life instrument for use in international clinical trials in oncology, J. Natl. Cancer Inst. 85 (1993) 365–376.
[12] G.E. Krasner, S.T. Pope, A cookbook for using the model-view-controller user interface paradigm in Smalltalk-80, J. Object-Oriented Program. 1 (3) (1988) 26–49.
[13] E. Gamma, R. Helm, R. Johnson, J. Vlissides, Design Patterns: Elements of Reusable Object-Oriented Software, Addison-Wesley, 1994.
[14] H.M. Deitel, P.J. Deitel, A.E. Santry, Advanced Java 2 Platform—How To Program, Ch. 3, Prentice Hall.
[15] Y.P. Shan, An event-driven model-view-controller framework for smalltalk, in: Conference Proceedings on Object-oriented Programming Systems, Languages and Applications, New Orleans, LA, United States, 1989, pp. 347–352.
[16] J. Arthur, S. Azadegan, Spring framework for rapid open source J2EE Web application development: a case study, in: Proceedings of the 6th International Conference on SNPD/SAWN, 2005, pp. 90–95.
[17] C. Bauger, G. King, Hibernate in Action, Manning Publications, 2005.
[18] W.H. Inmon, Building the Data Warehouse, 3rd ed., Wiley & Sons, 1996.
[19] B. Inmon, C. Kelley, The twelve rules of data warehouse for a client/server world, Data Management Review 4 (5) (1994) 6–16.
[20] P. Rob, C. Cornel, Database Systems: Design, Implementation and Management. Ch. 12, 6th ed., Tomson Course Technology.
[21] K. Gottschalk, S. Graham, H. Kreger, J. Snell, Introduction to web services architecture, IBM Syst. J. 41 (2 (online)) (2002).
[22] S. Chaudhuri, U. Dayal, An overview of data warehousing and OLAP technology, ACM SIGMOD Record 26 (1) (1997) 65–74.
[23] H.B. Carter, M.E. Allae, A.W. Partin, Diagnosis and Staging of Prostate Cancer, Vol. III, 9th ed., Sec. XVI, Ch. 94, Campbell-Walsh Urology.
[24] R.P. King, N. Halim, H. Garcia-Molina, C.A. Polyzois, Management of a remote backup copy for disaster recovery, ACM Trans. Database Syst. (TODS) 16 (2) (1991) 338–368.
[25] L.E. Kazis, L.F. Callahan, R.F. Meenan, T. Pincus, Health status reports in the care of patients with rheumatoid arthritis, J. Clin. Epidemiol. 43 (11) (1990) 1243–1253.
[26] A.K. Wagner, et al., Patient-based health status measurement in clinical practice: a study of its impact on epilepsy patients' care, Qual. Life Res. 6 (4) (1997) 329–341.
[27] S.B. Detmar, M.J. Muller, J.H. Schornagel, L.D.V. Wever, N.K. Aaronson, Health-related quality-of-life assessments and patient–physician communication: a randomized controlled trial, JAMA 288 (23) (2002) 3027–3034.

Please cite this article in press as: H.-C. Lin, et al., A real time online assessment system with modelized architecture on clinical infometrics for patient reported outcomes of prostate cancer, Comput. Methods Programs Biomed. (2010), doi:10.1016/j.cmpb.2010.10.003