ICT Framework for an Online Medical System

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Abstract

Although many healthcare back office functions and support services are now available to both medical practitioners and patients, the field is yet to embark upon any significant medical online system that facilitates the remote diagnosis and treatment of patients via an on-line system. This paper proposes an online medical system that will enable patients to interact with medical practitioners in medical consultation, diagnosis, and treatment. The medical system provides a virtual environment for patients, practitioners and medical staff to interact. We outline the functional components of the medical system and describe the technologies applied to support an interactive experience. Several patient scenarios are used to describe how this system functions including general practitioner consultation, a medical system are also contrasted with several existing medical expert systems. Given the growth and use of on-line systems and recent trends to deploy high bandwidth communication infrastructure (such as the National Broadband Network), the opportunity exists to deploy new medical systems that provide healthcare to all people in both local and remote communities.

Keywords: Telemedicine; Expert Systems; Health Care Systems; Clinical Decision Support Systems

1 Introduction

Although there is a significant trend toward moving personal and business activities on-line for most patients who seek medical consultation, this still requires visits to a general practitioner. Although there is good reason for patient-doctor interaction, the recent advances in high bandwidth broadband technology together with the emergence of collaboration tools present the opportunity for the medical field to pursue further advances in applying these tools in remote medical consultation. As observed by the world health organization (WHO), advances in information and communication technologies have potential for impact to health services and have raised expectations [5].

The on-line world now provides users with a number of social and media tools that can provide a very personal and interactive experience in medical consultation. Although there are remote doctor services available, sel-

dom do these medical consultation services make full use of the present day broadband technologies and the range of remote healthcare monitoring and support devices now available in the market. This provides the motivation for applying these recent advances in information technology in a way to provide an interactive on-line medical service.

The application of information technology and internetworking impacts health outcomes and is able to improve the sharing of resources between patients and healthcare workers [1]. The most common form of eHealth services applied are medical expert system and practitioner recommendation systems that facilitate the contemporary model of patient visitations with the healthcare provider. We seek to expand upon the use of these eHealth services by transforming the patient contact and consultation service into a virtual on-line experience for patient and doctor. Furthermore we seek to apply these technologies in a way that allow both the

The electronic Journal of Health Informatics (ISSN:1446-4381) is dedicated to the advancement of Health Informatics and information technology in health care. eJHI is an international Open Access journal committed to scholarly excellence and has a global readership in all health professions and at all levels. © Copyright of articles originally published in www.eJHI.net under the Creative Commons Attribution 3.0 License is retained by the authors. doctor and patient to engage in a full life-cycle of medical services from initial consultation, medical testing, diagnosis, treatment, and follow-up consultations, without the need for face-to-face visit. We view this work as fostering the move towards the advanced medical home, where a key principle is use of "evidence-based medicine and clinical decision support tools to guide decision" [2].

In this paper we propose an online medical system that enables patients to seek medical consultation, diagnosis and treatment. The proposed system establishes the foundation for an online medical system that may be expanded upon to incorporate evidence based medicine that integrates medical research, findings, and clinical presentations. The medical system makes full use of internet technologies and high bandwidth networks, to provide users with an immersive patient-doctor experience online. The solution embodies all the properties of the conventional medical experience and seeks to minimize the need for travel, restricting this for the conduct of medical tests from registered laboratories. More specifically, this paper presents the following.

- 1. Review the requirements of an on-line medical consultation service;
- 2. Present a solution design and framework for an eHealth system for conducting medical services between patient and doctor online; and
- 3. Compare and contrast the proposed online medical system with contemporary eHealth and medical experts systems.

We now describe the remainder of this paper. In the next section the related literature on eHealth and medical expert systems are presented. Then in section 3 the requirements of a medical online system are presented. This is followed in section 4 with the detailed explanation of the online medical expert system, its components, and several case scenarios demonstrating how the system may be applied. In section 5 we compare and contrast the proposed system with contemporary medical expert systems and discuss the implications of this. Finally, in section 6 we present the conclusions and outline several areas of further work.

2 Related Work

We first review the literature related to medical systems that may be used to support clinical practice and those that provide an online medical capability. In [19], a medical expert system based on 3-tier client server technology is outlined. The authors' note that weaknesses

exist in medical knowledge acquisition and management and propose an internet based medical knowledge acquisition system to provide that capability. There is further work that examines physician acceptance of online medical systems where the results of a survey are presented [20]. The paper also observes the need to manage medical knowledge with the survey focused on the potential use of an online disability evaluation system for generating medical reports. The findings note a general pattern of support for these systems but noted several influencing factors including attitude, organization, and work system factors.

A web based medical expert system is presented in [21], that has the novel capability for self training which adapts the system to health issues that are prevalent in the field of use. Mitrea and Deak propose a web based design for an e-health system that enables certain common ailments to be managed by the patients themselves [22]. The online system takes the patient through a symptom oriented set of questions, medical history, and using a medical rules-engine determine if self-care or medical consultation is most appropriate. There is also further work on the application of mobile technology for medical monitoring scenarios [23]. The design of the system is presented and several mobile monitoring scenarios presented, including blood pressure measurement, use of spirometer for lung pressure, and flexilog in pH measurement.

There are a number of medical systems in use by clinical practices that support medical diagnosis and treatment including CADIAG, 5GL Doctor, ILIAD, and MetaNet [6, 10, 13, 14]; these are intended for use locally within the practitioners' office. In addition, there are further systems that provide an online capability such as DiagnosisPRO, Gideon, and Prodigy [9, 11, 16]. These medical expert systems are discussed further in section 5.0, where the online medical system proposed in this paper is compared with these existing implementations.

3 On-line Medical System Requirements

In order to propose an on-line medical system we first explore the requirements that such a system needs to support. This provides the foundations for the scope and design of the proposed system in order that the needs of medical practitioners, patients, and support personal are addressed. Three broad categories of requirements are identified. These are based upon the user groups that will access the on-line system, the treatment protocols that the system is to support, and the advanced internet technologies that may be applied.

3.1 Medical User Groups

In order to move to an on-line medical experience for patient and medical practitioner and number of additional parties require access during the consultation services provided. We now identify and clarify those user groups and the interactions required. In addition to the medical services this includes support functions such as accounting, appointments scheduling, and medical insurance processing.

Patient: The patient seeks medical services from a medical practitioner to address an ailment. The patient will provide input during the initial consultation such as symptoms and history including the patients interpretation of what is occurring, the 'patient quote'. The patient may be requested to seek further services from specialists and may require detailed medical tests to be conducted. An underlying foundation of the on-line system is to establish a relationship not only with the medical practitioner, but also other support personal involved in the medical service provided as required.

General Practitioner (GP): The general practitioner is the primary care provider who is the first point of contact for a patient seeking medical assistance. The GP provides the initial medical consultation and conducts a preliminary medical assessment of the condition. Based upon the initial assessment the GP may decide to continue medical care or may refer the patient to a medical specialist. Where the GP continues to provide medical care a diagnosis and treatment plan may be determined based upon the presenting symptoms and preliminary medical evidence. The GP may order further medical tests and provide on-going medical consultation during treatment.

Medical Specialists: Medical Specialists may be consulted by the patient as more evidence emerges as to the specific nature of the patients' condition. A referral may be immediately given by the GP, or some initial medical tests may be conducted and assessed by the GP prior to referral. The specialist is likely to also conduct an initial consultation based upon the preliminary medical evidence presented and may order further tests for the patient so that a conclusive diagnosis may be attained with a suitable treatment plan. There is also the need for on-going consultation during treatment.

Laboratory Technician: The Laboratory Technician performs specific medical tests as requested by the GP or specialists. The patient is required to attend a lab to undergo medical testing. In some cases the medical tests may also be conducted remotely at home with the patient providing test samples to the laboratory

when carried out.

Administration Services: Administration services schedule the appointments and manage accounts payable between patient, medical practices, and external providers. Further services are provided in supplying information to assist patients in following the medical procedures and treatment plans outlined.

Physicians/Researchers: During the course of consultation, diagnosis, and treatment a catalogue of data will be accrued that may be used by medical researchers and other physicians to assist in refining future diagnosis and treatment plans. The researcher or physician may be able to access this data in a way that does not compromise the privacy of the patient.

Emergency Crew: Emergency crews deal with remote medical incidents. These crews remotely provide first aid and guidance to those involved in a emergency situation until medical crews are able to physically arrive at the scene of an incident.

3.2 Consultation and Treatment Scenarios

In order to replicate and improve upon the medical experience that patients undergo we now assess the diagnostic procedures and protocols and assess what aspects may be applied on-line and those aspects that require tailoring. These treatment protocols may be classified as a number of scenarios that are to be addressed by the on-line medical system.

Initial Consultation: During the initial consultation the patient makes an appointment at the general practitioners medical centre. Depending upon severity of condition and availability of medical practitioners the patient may schedule an appointment in a relatively close timeframe (usually same day or within days). Once the appointment is booked the patient will then arrive at the medical centre, register at the medical counter and then take a seat in the waiting room. When the appointed doctor is available to see the patient an initial medical consultation is then held. During this consultation the general practitioner may access the patients' previous medical records and gather further information on presenting symptoms of the patient.

Conduct Medical Tests: During the medical examination conducted by a general practitioner or by medical specialists a series of medical tests may be requested. The practitioner will prepare the necessary scripts to indicate the type of tests to be conducted and may advise on various test centers where the procedure may be performed. In some cases the tests may also be conducted by the patient at home. In the case that an appointment is necessary with the medical laboratory the patient books an appointment and attends a lab to have the procedure conducted. The laboratory technicians will then forwarded the completed test results to the general practitioner directly or may provide these to the patient for delivery to the medical doctor. Where tests may be conducted at home, the medical laboratory may send test kits directly to the patients' home with instructions on how to conduct the test.

Refer to Specialist: Where the general practitioner feels a more detailed medical examination is required a referral is given to the patient to see a medical specialist. The patient then books an appointment with specialist. Such an appointment may often result in a booking some weeks (even months) ahead. When the patient visits the specialist an initial consultation is once again given with any supporting information provided by the referring doctor. This may also include any medical tests conducted and historical medical records. The specialist may order further tests and hence the scenario to conduct medical tests is then followed.

Diagnosis with Clinical Results: During a consultation with the GP, or specialist, sufficient evidence is presented from presenting symptoms and/or medical test results. The practitioner provides a diagnosis and may refer to additional medical expert systems and record of patient history to make this determination.

Treatment Plan and Follow-up Consultations: With an initial diagnosis the practitioner prepares a treatment plan to correct the patient's medical condition. During this phase of the medical experience the patient receives a script for medicine and other actions to take. Follow-up consultation with the doctor is required and will be periodically booked with the assistance of administrative services.

3.3 Internet Technologies: Features and Capabilities of On-Line Information System

We finally discuss the features and capabilities readily available in many other forms of highly interactive online information systems. These functions are reviewed for applicability to an on-line medical system. This includes videoconferencing, chat, remote input devices (e.g. temperature, blood sampling), and mobility. In particular, the mobility aspect may provide a crucial service to patients in the advent of a medical emergency until first aid crews arrive.

Voice Over IP. Voice Over IP (VOIP) supports a telephony service over the Internet using a personal computer equipped with speaker and microphone. In an on-line system, users may talk with other participants of the system this includes medical practitioners, administrative services, and laboratory technicians.

Video Telephony. Video Telephony adds real time video imagery to the voice conversation over the Internet. This will significantly enhance the ability of the medical practitioner to review presenting symptoms of the patient and monitor progress during the execution of the treatment plan. Video conferencing has a greater requirement for bandwidth when compared to VOIP and hence is dependent upon the quality of the broadband connections in use.

Online Chat. Online chat provides a real time text messaging service to one or many users. This may be particularly useful in waiting rooms before consultation and may also be used to support communication when difficulty is encountered in understanding tone and accent between the users of the system. Online chat has a low bandwidth requirement.

Digital Camera. Cameras may be useful in taking pictures of symptomatic areas on the patient. This may be easily used by the patient and transferred via USB onto the personal computer for uploading and viewing by the practitioner.

Consumer Medical Equipment. Various medical equipment may now be acquired for home use, such as thermometers, blood pressure, and heart rate devices. These consumer devices may be used in real-time by patients and the data can either be described to the GP or uploaded automatically via the personal computer. These devices may also be enhanced for remote control and operation by the practitioner, for instance when operating the blood pressure readings. Other devices may emerge over time, for example, lights attached to the personal computer that can be operated remotely by the physician and used for testing pupil dilation.

Mobile Devices. The prevalence of mobile devices equipped with digital image, voice and video telephony services makes such devices a valuable tool when seeking medical services in emergency situations. This may be particularly useful for emergency response crews in providing critical guidance prior to arriving at the scene of an incident.

HL7 Compliance. Healthcare Level 7 is an international standard amongst healthcare information systems [3]. Where possible the HL7 standards for messaging data and integration are adopted.

4 Online Medical System Design

We now outline the proposed online medical system that will allow patients to consult general practitioners and specialists using Internet technologies. The system is unique in that it provides a full on-line medical experience (and in many cases) without the need to visit the



Figure 1: Online Medical System

physicians' medical center. The expert system makes uses of the most recent advanced in clinical and internet technologies to enable the virtual interaction. The system has the potential to significantly cut down waiting times for practitioner appointments and fast track treatment in many rudimentary cases. The solution is able to facilitate evidenced based medicine by integrating the medical testing procedures, medical research and findings, as part of the on-line medical experience, thus facilitating the capture and retention of medical test results for practitioners to support the clinical diagnosis. Given the significant increase in the number and types of medical tests available an on-line system that facilitates their use will contribute further to effective medical treatment.

4.1 Solution Framework

The diagram shown at Figure 1 provides an overview of the online medical system. The key users, external systems, and components of the solution are depicted. This includes online support for patients, general practitioners, medical specialists/physicians, medical researchers, and other interested parties such as government and medical insurance institutions.

The online interaction with the medical system will enable patients to have medical consultation services with general practitioners, medical specialists, and emergency response teams in critical first aid situations. All interactions are conducted online and where it is necessary for face-to-face meetings, the physician and patient are able to view their historical interactions from the system. It is anticipated that for many rudimentary illnesses an on-line consultation services will be sufficient, providing much needed relief upon the services provided in conventional medical centers.

Users of the system will be able to interact using a variety of media enhanced technologies such as instant messaging, online telephony, and video conferencing.

Together with the use of medical devices by patients at the home the proposed medical online system will facilitate the Patient Centered Medical Home (PCMH) [2].

4.2 System Components

We now expand upon the system components that make up the online medical system. These components are shown at Figure 2. This framework is based upon our experiences in building healthcare and online solutions that address a subset of the functions and interacting systems illustrated in Figures 1 and 2.

Online Web Interactive Interface. This component of the solution provides the graphical interactive web pages that enable patients, practitioners, and other users of the system to interact with the online system. This component provides the foundation components for supporting online chat, internet telephony, and video telephony. Users first accessing this site will be prompted for there username and password and authenticated against the User Registry. The technology supporting the interface will be web browser based connecting with an application server that supports interactive technologies (i.e. Ajax, J2E) over a secure session such as Secure Socket Layers (SSL) to ensure confidentiality during communications.

User Registry. All users accessing the site will have undergone a pre-registration process so that their login credentials (username and password) are stored within the user registry. This database will be a secured database that stores only the login details of the users, which includes patients, administrators, practitioners, and external parties accessing the online system. No personal medical information is stored in this repository. A common approach to implementing the registry is through the use of database that supports Lightweight Directory Access Protocol (LDAP).

Administration Services. Administration Services is the point of entry for patients wishing to seek medical consultation. It is expected that people seeking to use the medical services of the online system will have previously registered with the system with their details and login credentials stored within the User Registry. The administrative services include accounting systems for processing payments, scheduling of appointments, and interaction services for administrative staff to communicate with patients in the virtual waiting room or practitioners currently online. The administrative service also hosts an emergency room to redirect incidents to suitable medical emergency response teams. This component can be implemented as a web application server that supports interactive technologies to allow

Online Web Interactive Interface								
User Registry	Waiting Room	Consultation Room	Administration Services	Healthcare Gateway (External)				
Integration Bus								
Practitioner	Patient	Medical	Decision	Healthcare				
Registry	Data	Historian	Support	Gateway				
(HL7)	(HL7)	(HL7)	System	(Patient)				

Figure 2: Online Medical System Components

staff to communicate with patients in the virtual waiting room.

Waiting Room. When users first log into the online system they are placed into a queue to gain access to administrative services. In most cases there is no need to schedule an appointment and hence patients may be immediately processed and enter the virtual waiting room. Patients in the waiting room will have access to on-line chat and may communicate with others in the room and also view broadcast messages from administrative services. Patients entering the waiting room are then placed into a logical queue and await their name to be called for practitioner visit. In practice, there will be many queues to service requests for specific appointments and general queues used for patients to see the first available general practitioner. In the case that the patient has an appointment with a specialist then they will be queued to that particular physician. The technologies supporting this component are similar to that required for administrative services and the online web interactive interface.

Consultation Room. Each doctor who logs into the online system will be registered with their own consultation room. Practitioners and specialists will gain access to the online system in the same way by using their personal username and password. Doctors may indicate their availability to see a patient, in which case the practitioner will receive a patient at the head of the queue they are registered to service. When a patient is presented to the doctor, the physician has the option to accept the patient and proceed with the medical consultation. In addition to the interactive web technologies both video telephony and/or internet voice will be supported to enhance the consultation experience. The VOIP and Session Initiation Protocols (SIP) are common technologies to support these capabilities.

Healthcare Gateway. The Healthcare gateway will have two purposes and hence will be deployed in tandem. The first node will provide integration with external entities and systems such as laboratories, insurance, billing, and government institutions. This is an HL7 compliant message exchange gateway. The second

instance of the gateway provides the integration with remote diagnostic medical devices at the patients' home, such as blood pressure, cameras, and optical equipment for use during medical consultation. Government institutions that support such deployments are likely to require regulatory compliance and feedback as to the benefits bestowed to justify the costs associated with such an on-line system, hence access for those departments are also supported.

Integration Bus. The integration bus provides the connectivity layer between the various system components of the online medical system. This is a piece of IT infrastructure that enables IT messaging between the components so that the system components may collaborate in fulfilling the functions of the online system. The component is an HL7 compliant messaging bus. Using HL7 formatted data structures also bestows compliance with Health Insurance Portability and Accounting (HIPAA) for electronic data interchange.

Practitioner Registry. The practitioner registry will store the personal information for practitioners, physicians, specialists, and researchers who access the medical records and capabilities of the on-line system. This is an HL7 Reference Information Model (RIM) compliant database for securely storing sensitive medical information.

Patient Data. The Patient database stores medical records of the patients seeking medical consultation of the online system. This will also include historical data on patient treatment and results of tests conducted. This also is an HL7 Reference Information Model (RIM) compliant database for securely storing sensitive medical information.

Medical Historian. The medical historian is intended to gather up historical records on patient data for presenting symptoms, test results, diagnosis, treatment conducted, and resolution. This component is not intended to store patient personal information, but rather the patient information is anonymised so that medical records are stored for future analysis and assists in refining medical procedures. This system may be accessed by various users including medical researchers. In practical deployment, this component may alternatively be replaced by an interface to publish this data in real time to external interested parties.

Decision Support System. The decision support system is intended to provide an expert diagnosis function for practitioners and therapeutic regimes. Using presenting symptoms, results of medical tests, and patient history this component is able to provide information on suggested diagnosis or further actions to take (i.e. further tests etc). The system may also advise on the availability of newer tests available for use to practitioners.



Figure 3: Patient Visit with General Practitioner

This is an expert information service to practitioners; also providing more general medical information. The component is intended to function as a medical encyclopaedia to complement the functions of the decision support system.

4.3 Use Case Scenarios

Building upon the descriptions provided in the previous sections use of the online system is also based upon several example patient use case scenarios. This includes a consultation with a general practitioner, consultation with a specialist, and a scenario dealing with a medical emergency via mobile devices. The example scenarios below are not intended to be detailed flow of steps of how medical practice is conducted, but rather an illustrative example of the general way in which patients and doctors may interact with the system to provide the medical services required.

4.3.1 Scenario 1: General Practitioner Visit

The diagram at Figure 3 depicts a use case scenario chart of the phases and steps of interaction when a patient seeks consultation with a general practitioner.

The following describes the steps of interaction carried out when a patients wishes to seek medical consultation with a general practitioner using the online medical system.

1. Patient logs into the online system, registers with administrative services and enters the waiting room.

- 2. General practitioner becomes available to see patient and the patient is notified with an alert text message and audible tone.
- 3. The initial consultation proceeds where the patient describes presenting symptoms to the GP.
- 4. GP analyses evidence, including additional inputs from remote medical and interactive devices over the web (i.e. blood pressure, heart rate, visible symptoms on patients' body).
- 5. GP decides if further medical tests are required. If no further tests are required, GP constructs treatment plan forwarding any medical scripts (as PDF documents) to patient.
- 6. If further tests are required, the GP recommends tests to be conducted and prepares scripts for conducting tests (as PDF documents).
- 7. Patient exits GP consultation room and is redirected back to Administrative services to arrange bookings with suitable medical labs for conducting tests. If a booking is required these are made with respective labs or tests kits are mailed out to the patients' home.
- 8. Patient executes the required medical tests either at home or at the medical lab at the appointed day.
- 9. Test results are then forwarded to the on-line medical system. Any physical media is sent to an administration facility for scanning and system upload. Patient is notified when test results are available to GP and logs back into the system and is queued to the GP who held initial consultation.
- 10. GP Analyses the data and constructs a treatment plan.
- 11. Treatment plan is executed by patient and holds follow-up consultation with GP to confirm if symptoms persist or abate.
- 12. Treatment ends when patient and GP are satisfied with recovery.

4.3.2 Scenario 2: Medical Specialists Visit

The next example (Figure 4) extends the first scenario of the GP visit with a referral to a medical specialist. This has several additional scenario steps that deal with further testing and medical procedures to be conducted.

The following steps of interaction are carried out when a patient is referred to a medical specialist.



Figure 4: Patient Visit with Medical Specialist

- 1. Patient logs into the online system, registers with administrative services and enters the waiting room.
- 2. General practitioner becomes available to see patient and the patient is notified with an alert text message and audible tone.
- 3. The initial consultation proceeds where the patient describes presenting symptoms to the GP and the GP decides to refer the patient to a medical specialist.
- 4. Medical specialist conducts initial consultation with patient, analysing any preliminary data provided by the referring doctor.
- 5. Specialist determines what further tests may be required and recommends tests to be conducted and prepares scripts for conducting tests (PDF documents).
- 6. Patient exits specialist consultation room and is redirected back to administrative services to arrange bookings with suitable medical labs for conducting tests. If further appointments are necessary with specialists these are also made with administrative services.
- 7. Tests are conducted at medical centre or at home with any supplied test kits.
- 8. When results are available the patient logs back into the system and is queued to the medical specialist at the appointed time and day. Medical specialist sees the patient and analyses medical results.

- 9. Specialist decides if any medical procedure is required and makes arrangements for procedure. Patient exits consultation room and redirected back to administrative services to arrange bookings for medical procedure with specialist.
- 10. Patient undergoes procedure/operation at the appointed time with medical specialist at a designated clinic.
- 11. After medical procedure, any follow-up treatment consultations are held to monitor patient recovery and confirm if symptoms persist.
- 12. Treatment ends when patient and GP are satisfied with recovery.

4.3.3 Scenario 3: Emergency Service via mobile device

A further scenario described is intended to provide remote emergency medical services until medical crews arrive at the scene of an incident (Figure 5).

The following steps of interaction are carried out when a person contacts medical emergency services to request aide.

- 1. Person accesses the emergency room of the online system (no need to log into the system with username and password). A fast track emergency room administration service is provided where the emergency request is handled.
- 2. The incident is described to the emergency medical officer and an initial analysis is conducted to confirm if emergency medical assistance is required.
- 3. More information may be gathered by the emergency medical officer through the use of the remote telecommunications devices. This may include pictures, video imagery, or communicating (where possible) with the patient involved in the incident.
- 4. Medical officer analyses inputs and constructs a first aid treatment plan. The person assisting at the scene of the incident executes the recommended treatment plan until emergency crews arrive.
- 5. Emergency crew arrive at the scene of the incident and control is transferred to the local crew to manage.



Figure 5: Emergency Consultation using Mobile Devices

5 Comparison with existing Medical Expert Systems

In this section we compare the proposed online medical system with other contemporary systems that either provide a medical expert system capability to the practitioner, or provide some form of online eHealth facility. This comparison also serves as a further review of the state of the art in medical expert and online systems.

5.1 CADIAG (Computer Assisted DIAGnosis)

CADIAG is a medical diagnosis and consultation therapeutic system [6, 7]. The system has been designed to provide medical consultation support services for practitioners with a focus on internal medicine and rare diseases. The medical system parameters for functions are as follows.

Input: Patient symptoms, signs, laboratory test results, and clinical findings conjectures.

Output: Detect pathological states, diagnostic hypotheses, or proposing subsequent medical examinations.

As the medical expert system is designed to provide consultation services for medical practitioners, there is no capability to support any online interaction between patient and practitioner. The system has been developed by the department of Medical Computer Sciences together with the department of Internal Medicine at the university of Vienna, Austria.

Strengths: Employs fuzzy logic to represent medical uncertainty; provides diagnosis for rare diseases.

Limitations: Designed for use as a hospital based system or practitioner office setting, hence no on-line medical support.

5.2 DiagnosisPRO

DiagnosisPro is an online medical system that provides diagnostic services for physicians [8], and may also be accessed directly by the public [9]. The system has a database of over 15,000 diseases and allows presenting symptoms, signs and lab test results to be entered. The expert system is characterized as follows.

Input: Signs, symptoms, lab results, and imaging results such as X-ray, MRI and ultrasound.

Output: Disease predicted.

The system was developed by physicians Charles Meader and Hugo Pribor and is available for use in clinical practices by installation on the personal computer.

Strengths: Provides differential diagnosis in several fields including internal medicine, pediatrics, geriatrics, and family practice. Has a broad ranging knowledge-base of diseases and findings.

Limitations: Although the medical system is online [9] there is no support for a patient and doctor interactive medical service.

5.3 5GL Doctor

5GL Doctor is a medical expert diagnostic tool that is used by practitioners [10]. The system runs locally on the practitioners' personal computer and provides a comprehensive interface for accepting signs, symptoms and lab results. The solution is not an online tool but may be also purchased and used by the public. The expert system summary is as follows.

Input: Symptom/indicator pattern and laboratory results.

Output: Disease predicted.

5GL Doctor has been developed by an Australian development company and is available for purchase. The system is available in two editions, one for the medical expert allowing the medical specialist to tailor the system, and a hospital edition for general use that comes preconfigured.

Strengths: The system provides a very comprehensive database of signs and symptoms to aid in diagnosis.

Limitations: Designed for use as a hospital based system or practitioner office setting, hence no on-line medical capability is presently supported.

5.4 Gideon (Global Infectious Diseases and Epidemiology Network)

Global Infectious Diseases and Epidemiology Network (Gideon) is web based medical expert system providing decision support and diagnosis [11, 12]. The focus is upon infectious diseases providing physicians with an evidence based expert system that may be accessed online.

Input: symptoms, signs, laboratory testing and dermatological profile.

Output: Infectious disease diagnosed.

Gideon was developed by the medical schools in the United States and Israel and is now available as a commercial offering by Gideon informatics [12]. A trial is version is available to allow practitioners to explore the system prior to purchasing.

Strengths: Focus on infectious diseases in the fields of tropical and infectious diseases, epidemiology, microbiology and antimicrobial chemotherapy; field trials indicate high percentage of correct diagnosis.

Limitations: Support for general medical practice.

5.5 ILIAD

Iliad is a medical expert system for internal medical diagnosis with over 1,500 diagnosis provided [13, 17]. The medical tool runs locally on the physicians' personal computer providing access to medical knowledge base, diagnosis and strategies. The system covers the medical fields of internal medicine, paediatrics, dermatology, psychiatry, obstetrics and gynecology, peripheral vascular diseases and sleep disorders.

Input: Symptoms, physical signs and laboratory test. Output: Diagnosis ranked by likelihood.

The Iliad system was developed at the University of Utah Medical Informatics department and is now a commercially available medical system.

Strengths: Database of 1,500 syndromes and 11,900 findings. Has modes of operation as an educational tool and as a medical consultative mode that allows additional medical findings and symptoms to be added manually.

Limitations: The system was designed for use within the medical office and does not support an on-line medical interface.

5.6 MetaNet

MetaNet is a knowledge based artificial neural network expert system that attempts to diagnose inborn errors of metabolism in children [14]. This medical system is used by the pediatrician and accepts amino acid test results and symptoms to provide an initial diagnosis.

Input: plasma or urinary amino acid results, and presenting abnormality.

Output: provisional diagnosis

The medical system was developed by a commercial organization and builds upon artificial neural networks and comprehensive knowledge based to aid diagnosis.

Strengths: Diagnosis of inborn errors of metabolism. Limitations: The solution has been developed as a prototype tool. The system is a specialist tool for paediatrics and not intended to address general medicine.

5.7 Prodigy

Prodigy (Prescribing RatiOnally with Decision Support In General Practice studY) is designed to be a prescribing decision support system for use in general practice [15, 16]. The system provides clinical advice and guidance on therapy for both dug and non-drug treatments. The system is used by the general practitioner on the personal computer and has received overwhelming response form GP's for its continued use. Although the system is designed as a tool for practitioner use, there is on-line component available that provides information to patients [16].

Input: Evidenced based.

Output: Diagnosis and Pharmaceutical Prescription.

Sponsored by the UK department of health, Prodigy was first developed as a prototype by a team from the Sowerby Centre for Health Informatics at Newcastle University. The prototype design was later incorporated by several commercial medical solution providers within their clinical medical systems; most recent version is Prodigy III.

Strengths: Encourages cost-effective evidence based medical practice for GPs' and is widely deployed within the UK. .

Limitations: Has limited on-line interactive support however on-line patient information is available.

5.8 Summary of Expert Medical Systems

We now summarize the analysis of the existing medical expert systems with respect to the proposed online medical system. The table below (Table 1), illustrates the various properties that each of these systems exhibit. A definition of each column is given below.

Consultation: Supports inputs such as symptoms, patient quote, and signs. Used by practitioner during medical consultations.

Medical Tests: Accepts some form of medical test results as input; such as imaging, metabolic, and other quantitative markers.

Diagnosis: Provides initial diagnosis and/or recommendations on therapeutic advice to practitioner.

Online: Enables interaction between practitioner and patient using advanced internet media such as chat, voice, and videoconferencing.

Interactive: Enables Patient-Doctor interaction for remote online medical consultation, diagnosis and treat-

Expert System	Online	Interactive	Consultation	Medical Tests	Diagnosis
CADIAG-4	Х	Х	\checkmark	\checkmark	\checkmark
DiagnosisPro	✓	Х	\checkmark	\checkmark	\checkmark
5GL Doctor	Х	Х	\checkmark	\checkmark	\checkmark
Gideon	√	Х	\checkmark	\checkmark	\checkmark
ILIAD	Х	Х	\checkmark	\checkmark	\checkmark
MetaNet	Х	Х	\checkmark	\checkmark	\checkmark
Prodigy	Х	Х	1	✓	\checkmark
Online Medical System	✓	✓	✓	✓	✓

Table 1: Comparison of Medical Expert Systems with proposed Online Medical System

ment.

The aims and scope of the proposed online medical system differ from the existing art, in that it intends to provide a virtual online medical consultation service that allows patients to receive medical consultation from their home. One aspect of the system that will leverage existing designs is the diagnosis component, as these capabilities are well advanced in existing expert systems. Whilst all existing systems accepts medical test results, the capability to integrate with laboratories to accept test results directly is an additional capability of the proposed eHealth system.

6 Discussion and Conclusion

In this paper we have outlined an online medical system that enables patients to seek medical services (consultation, diagnosis treatment) from practitioners from their home or mobile device. The system is based on the most recent and advanced internet and information technologies available within the industry that will provide users with an immersive consultation service with a medical healthcare provider. The system will also allow interaction via mobile devices in order to support medical emergency until response crews arrive at the scene of an incident. A framework is outlined and the major components described, this is based upon our previous experiences in web based interactive systems and eHealth systems. It is hoped that the framework outlined in the paper is useful to emerging medical expert systems as a framework for enhancing their existing solutions to further improve medical care for the community by providing this service online.

6.1 Barriers to Online Medical Systems

The are several ethical points to consider in the development of online medical systems, this includes privacy of maintaining patient data, security of conducting medical practice over the internet, and the likelihood of accep-

tance by both patient and physician. The idea of storing personal information centrally online is a key concern for general users of the Internet and is already observed as a contentious issue for those who regularly use social networking forums. The issue of privacy becomes even more critical when the data stored is of a personal or sensitive nature, such as medical and financial data. Users of the system require guarantees that any personal data is stored in a secure manner that prevents both inappropriate access and tampering. The issue of privacy also extends to the online consultation experience, where any such interaction would require safeguards to ensure a secure and confidential exchange. Security protocols and cryptographic tools exist to ensure such safeguards and have been standardized for use in healthcare [18] and will be fundamental to any system developed to ensure that such systems are acceptable to users from a social and medical perspective.

Further restrictions exist on the deployment of online medical systems that relate to usability and availability of medical devices. This system, for example, would not be suitable for critically ill patients, or patients with certain disabilities may require further support services to be able to effectively use the online medical system. Certain medical devices that enable the features for online medical consultation are likely to be higher cost initially, however once commoditized and produced in large quantities the costs of new technologies inevitably fall. Subsidies from government health services may facilitate adoption to ensure that some of the barriers are overcome. Training and support services are also likely to be required to assist practitioners and new users of the system to become acquainted with the processes involved. This is particularly important to overcome issues in ensuring the validity of medical consultation services and ensure that physicians are not overwhelmed by the clinical data presented to them.

6.2 Approach to Implementation

Given the scope of an online medical system it is suggested that a suitable implementation approach would be to establish a small pilot solution as an initial deployment. This would provide the opportunity to develop more clearly the treatment protocols and validate their use in an on-line medical consultation experience. Such a pilot will also confer the opportunity to assess acceptance by practitioners and patients as well as determining guidelines for the use of the medical system.

6.3 Further Work

As more advanced mobile technology becomes available, there is further work to make use of and integrate these devices for medical care. For example more recent mobile devices and laptops may be used to remotely check pupil dilation using a mobile phone light and the attached camera. These devices may be augmented by allowing the remote physician to operate the device whilst the patient, or local aide, holds the device under the instruction of the physician.

There is also further work to integrate the system with the most recent medical research to enable an evidence based medical capability. Such a capability would require additional functions within the proposed system to accommodate the significance of clinical trials and research during the medical decision making process.

Conflict of Interests

The author is an employee of IBM, a technology and consulting services provider. The views expressed in this paper are those of the author and do not necessarily reflect the views of IBM.

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