Clinical Decision Support System based Virtual Telemedicine

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***Abstract*—Telemedicine is a blessing for the people of remote areas because it provides high level medical facilities in an efficient way at low cost. Store-and-Forward method of telemedicine suits more to the progressive countries like Pakistan as not only because it is easy to set up but also due to its cheap operating cost. However, the high response time taken by store & forward telemedicine becomes a critical factor in emergency cases, where each minute has a price. The response time factor can be overcome by using virtual telemedicine approach. In virtual telemedicine, a Clinical Decision Support System (CDSS) is deployed at rural station. The CDSS is intelligent enough to diagnose a patient's disease and prescribe proper medication. In a case, the CDSS can not answer a query, the CDSS immediately sends an e-mail to a medical expert (doctor) and when the response is received the CDSS knowledge-base is updated for the future queries. In this research paper, we not only report a NL-based CDSS that can answer NL queries but also present a complete architecture of a virtual telemedicine setup.**

Keywords- Telemedicine, Clinical Decision Support System, Virtual telemedicine

I. INTRODUCTION

Telemedicine is one of the most developing applications in the field of clinical medicine. Telemedicine makes use of the modern technologies such as telecommunication & information technology to deliver clinical care at remote areas. [1] Through telemedicine, improved medical facilities can be provided in an efficient way to the people of remote areas. An overview of the typical telemedicine is provided in the remaining part of the section.

A. Telemedicine

Moreover, telemedicine is an easier and cost-effective solution [2] for medical consultation as patient's medical information is transmitted through telephone, internet or satellite and a medical specialist can examine the patient's report, diagnose the diseases and prescribe medication remotely. [3] Typically, telemedicine basically works in two different ways:

1) Store-and-Forward Method

In store and forward method of telemedicine, patient's medical data such as X-rays, bio signals (such as blood pressure, body temperature, weight, pulse rate, blood sugar level, etc), blood test, etc is first collected and then transmitted to doctor for offline assessment. [4] In such method of telemedicine, a patient has to wait for medical assessment till 24 to 48 hours. [5] This method of telemedicine is cheaper and easy to set up and deal with. However, the response time is very high as in more of the cases; patient needs immediate treatment and can't wait up to 48 hours.

2) Real Time Method

In this method of telemedicine, doctors monitor patient remotely using various modern technologies such as video conferencing. [5] Real time method based telemedicine is quite expensive for progressive countries like Pakistan due to high cost of hardware and communication channels for audio and video streaming involved in video conferencing. There is online communication between doctor and patient such as video conferencing which is costly for the countries like Pakistan. High bandwidth is required for data transmission.

B. Telemedicine in Pakistan

Pakistan is a developing country with high population and low resources. Moreover, 60% population of Pakistan lives in rural and distant areas. [6] However, this is not possible to provide high quality medical facilities in distant areas due to shortage of medical experts and financial resources. Health care report of 2005-2006 shows that there are 113,937 doctors [7] in Pakistan and doctor-people ratio is one doctor for 1400 people. Similarly, there are 968 hospitals and 4813 dispensaries [8] and one hospital/dispensary has to support 6000 people. In addition to scarcity of resources, the qualified doctors do not prefer to work in remote areas and such attitude of medical experts make this scenario more complicated.

To provide better medical facilities in remote areas of Pakistan, telemedicine can be a solution. Due to shortage of financial resources, store and forward method based telemedicine can be a cost-effect solution. As the response time of store-and-forward method is very high, solution like virtual telemedicine [9] can be used. Virtual telemedicine proposes the use of a virtual physician at the remote medical center to provide immediate response to the patients. An expert system based telemedicine solution presented in [9] that provides a base for improved and efficient virtual telemedicine systems. However, the presented system demands following improvements:

- Accuracy [9] of the diagnostic algorithms is needed to be improved to improve usability.
- To make a better analysis of the patients data.

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- A better and enhanced medical explanation [9] is required to make medical system more useful.
- Expert Systems do not provide automated support for updating medical expert's opinion

To address these issues and provide a better and improved framework for virtual telemedicine we propose the use of a Clinical/Diagnosis Decision Support System (CDSS/DDSS) [10] in place of an expert system. A CDSS typically takes the patients data and propose a set of appropriate diagnosis. A Decision Support System (DSS) [11] is better in many respects when compared to a typical expert system. Expert systems are better for smaller domains where as DSS are better for larger domains such as medical experts. Similarly, a CDSS is based on active knowledge systems which use two or more items of patient data to generate case-specific advice. Moreover, a DSS offer decision support to improve patient outcomes and reduce errors. A DSS can be knowledge-based or algorithm based. In out approach we are using knowledge-based DSS.

Major contributions in this research paper are manifold. Firstly, we present a CDSS based virtual telemedicine framework to overcome the long time constraint in typical store-and-forward method. The presented framework is simple and easy to set up. Secondly, we report a clinical decision support system that is used in the proposed framework of virtual telemedicine. The presented CDSS is based on an efficient knowledge base as it contains knowledge of all the common diseases and implemented. Thirdly, we solve a case study from the domain of medical systems to test the designed system and evaluate the performance of the presented system.

Rest of the paper is structured as section 2 presents the related work. Section 3 highlights the architecture of the designed medical decision support system. Section 4 presents the implementation details. Section 5 presents case study and the results of the case study are used to evaluate the presented approach. Finally, the paper is concluded with the future work.

II. Related Work

This section presents the related work to presented research. The major areas covered are such as Telemedicine, virtual telemedicine and Clinical Decision Support System.

A. Telemedicine

Field of telemedicine is being proved the technology of the electronic age. In 1959 telemedicine was first introduced by P.Doulas [11] was the first researcher, who worked to make the efficient use of available resources by using store & forward telemedicine method. [8] Dena used telemedicine for the rural areas of America and gave its benefits. For the help and care of diabetic patients DIAB Tel [10] named telemedicine service is working efficiently.

Telemedicine unit for patient and doctor, which is low in cost was given by Tayab [2] and covers the main issues of high speed network forms. In 2007 remote display protocol (RDP) was used in telemedicine on two different platforms WAN [6] and over wi-fi [7] by Albert and Joson. Home telemedicine architecture was given. UCD Health system [4] for pharmacy using video conferencing was used by UC Davis. Paper highlights the role and benefits of advance technology in psychiatric and medical education. My main concern is with the use of telemedicine in psychiatry. Initial results after using telepsychiatry are valid and reliable. Usage of telepsychiatry is increased by secure email and telephone. Technical designs and recommendations are given to develop telemedicine devices with help of advance telecommunication technology [17].

Institute of Tropical Medicine, Antwerp, Belgium, is a low cost telemedicine project that planned to facilitate the introduction of antiretroviral therapy (ART) for patients affected by Human Immunodeficiency Virus (HIV) and Acquired Immune Deficiency Syndrome (AIDS) in developing countries, providing training, distance support and education to healthcare providers working in those settings. Telemedicine Network model is presented for the developing countries specially Pakistan, which would improve the quality of medical facilities in the rural areas of Pakistan. Paper briefly discusses the present situation of the health sector of Pakistan and the improvements which could be seen after the use of Telemedicine Network Model [38].

Proposed solution to over come the time constraint of telemedicine is virtual telemedicine. Virtual physician is developed which is basically an artificial intelligent based expert system. Heart of expert system is knowledge base medical expert; its task is to diagnose the correct disease from symptoms given as input, after that give proper treatment. Expert medical system gives proper treatment immediately and efficiently. Experiments show that 90% cases were treated locally and accuracy of results was 85.5% [39].

B. Clinical Decision Support System

The concept of Decision Support Systems (DSS) was first introduced in late 1960s and with the passage of time DSS gained importance in almost all field of science. [41] In 2007, Arthur Tatnall and Stephen Burgess build and used simple Decision Support Systems (DSS) for two postgraduate subjects at Victoria University in Melbourne. To examine the logic behind decisions is difficult; the proprietary nature and the cost of commercial DSS make their use in teaching less than ideal. It was to produce a simple system using Excel, Visual Basic and Visual Basic for Applications and it was proved to be quite successful. It enables students to look inside how system works with a feature to customize it. In 2009 David C. Klonoff, M.D., FACP and Lt Col Mark W. True, M.D., and FACP2 declared decision support software as a necessary component which could accelerate the advancement and acceptance of telemedicine. To demonstrate innovative practices, it was suggested that decision support software should be used in U.S. MHS. New generation of physicians should know how to work with decision support software for diabetes and other diseases [20].

III. USED METHODOLOGY

A CDSS based virtual telemedicine framework has been discussed in this section. Typically, a CDSS is a DSS that is primarily designed to achieve clinical advices for patients by incorporating knowledge management (historical patient data). The CDSS is an important component of the presented framework of virtual telemedicine. The proposed framework of virtual telemedicine works as a dispenser from remote location gathers patient data and processes data using a clinical decision support system. The CDSS processes the patient's report and diagnosis the diseases and prescribe the medication. If the CDSS can not diagnose the disease (in a case it is new disease, not updated in medical knowledge base), an email is sent to a medical expert (doctor). When the medical expert gives his response, the response is updated in CDSS medical knowledge base. The working of overall system is shown in figure 3.1.

Figure 1. A Virtual Telemedicine System

There are multiple issues involved in the development of a conventional telemedicine system as following:

- First of all there is need of infrastructure that is based on hardware, software and connectivity mechanism of multiple nodes (patient and doctor).
- A dispenser who is enough expert to record patient's medical data such as X-rays, bio signals (such as blood pressure, body temperature, weight, pulse rate, blood sugar level, etc), blood test, etc and prepare a patient's symptoms report.
- Typical medical equipment is required at the patient end where a dispenser (literate person) can transmit patient's information to the medical expert (if required).
- A natural language processing system that can understand and analyze input patient report and extract symptoms and signs.
- A clinical decision support system (CDSS) is required that can diagnose a disease by reading symptoms (and signs) of disease and prescribe appropriate medication.
- There are important issues like accurate information exchange, security, transmission bandwidth, protocols, data sets etc.

A CDSS has been embedded in typical telemedicine system due to the high time constraint of conventional telemedicine system. A CDSS based virtual telemedicine is presented to cover up this time constraint and make telemedicine more effective and efficient. Virtual telemedicine is the extension of conventional telemedicine. A new component 'clinical decision support system' is the major contribution. The CDSS is able to understand and process natural language patient reports. Second major contribution is that Stanford parts of speech (POS) Tagger to improve accuracy in diagnosis. A patient's symptoms report is processed in multiple phases and all these phases are explained in detail in following:

A. Process NL Patient's Symptom Report

Natural language processing is performed to read the given text and extract the related information. Used NLP steps to analyze text are [15]:

- *Sentence Splitting*: First of all the sentences are split by reading the input text document and separately stored in an array-list.
- *POS Tagging*: Each input sentence is handed over to Stanford POS tagger to tokenize the input English text and identify the particular parts of speech of each token.
- *Morphological Analysis*. The POS tagged text is further processed to identify and analyze morphemes. For example a verb "feels" is stored as "feel+s" and a noun "vegetables" is stored as "vegetable+s".

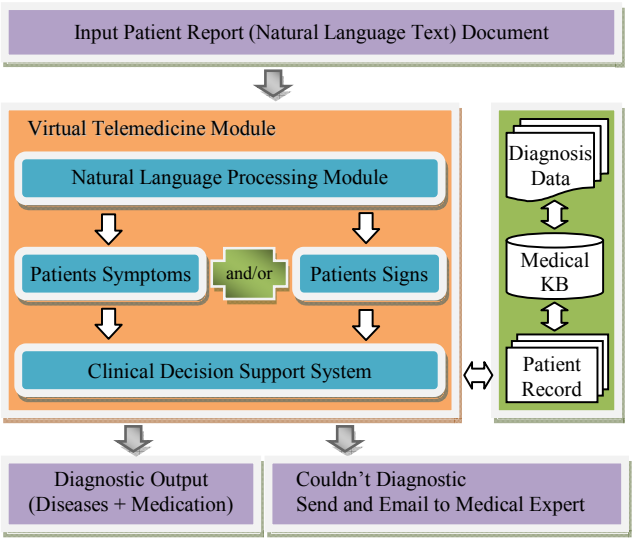

Figure 2. A Virtual Telemedicne Framework

- *Syntactical analysis:* The pre-processed text is further processed to identify their particular role in the sentence and grammatical rules also assist this type of analysis such as subject, verb, object, etc.
- *Semantic analysis:* The input text is further semantically analyzed by doing roll labeling to extract symptoms and signs those are further used to identify patient's disease.

B. Clinical Decision Support System

This virtual medical expert based system is shown in figure 3. This system has robust ability of reading the patient's symptoms and immediately diagnosing the disease and also prescribing the appropriate medication for the patient. A natural language processing (NLP) based medical expert system is the base of the proposed health care system. The designed rule based expert system has following major components [19].

1. Data management system
2. Module system
3. Knowledge engine
4. User Interface

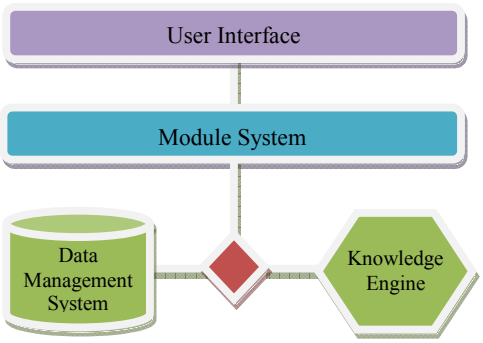

Figure 3. Architecture of used Clinical DSS

1) Data Management System: Data management system is one of the important parts of CDSS and mainly consists of a database system used to store the patient's physiological data so as to retrieve it when required.

2) Knowledge Engine: Facts, rules, structures and procedures based on expert knowledge are included in Knowledge Engine. It contains decision making rules, which are based on the previous experiences and the expertise of the doctors. Accuracy of the diagnosis depends on the information contained in Knowledge Engine.

3) Module System: Module system is the brain; responsible for creating a health model and comparing the data in the database with the model to formulate a diagnosis. Module system and knowledge engine works as a unit to diagnose the patient and to take decisions.

*4) User Interface:*User interacts with user interface which allows verifying the correctness of the diagnosis and decisions of the CDSS.

IV. Implementation Details

Rural areas of Pakistan [1] are relatively backward in terms of technology. A number of challenges are to face in setting up a system for virtual telemedicine. Some of the major challenges are following:

- Budget and financial constraints are more significant [14]. First of all expensive medical equipments are required at the telemedicine centers. High bandwidth for communication is also an expensive solution.
- At the site, adequate human resources are required [15] i.e. technicians to implement the proposed virtual Telemedicine system, a medical assistant having medical training to perform basic tests of the patients and some health workers having basic literacy of computer and capable of using computers.

A complete infrastructure is required to actually set up the proposed virtual telemedicine framework. A satellite based wireless internet work or WiFi system supporting speed of 1.0 Gbps or above is required. 3G cellular technology is also getting very popular these days [16] in the field of telehealth. This technology can help out in fast video sharing, video male and video conferencing. On the other side, a telemedicine center at the remote area needs basic eequipments [12] i.e.

- Virtual telemedicine software
- Camera (s), lights, projector
- Digital X-Ray System
- UPS system
- Computer hardware, system and application software and accessories

V. Results and Discussion

To evaluate the performance of the designed CDSS, a sample case study is presented. The case study was consisted of a NL patient's report containing nursing data. that was generated by a dispenser. Following is the problem statement of the solved case study.

> *The patient's age is 43 years and weight is 65 Kg. The patient has high fever and patient's body temperature is 104C. The patient's is getting fever in alternative days. Other symptoms during fever are shivering and perspiration. The blood pressure of patient is 76 and 122. The patient has no Latex allergy.*

The patient's LOC is drowsy the psychosocial status of patient is restless. The patient's skin is dry. Patient may have chest infection as there are also signs of cough. DVT/PE risk is medium.

In the solved case study, there were 10 sentences. Smallest sentence was composed of 4 and the largest sentence was composed of 12 words. Average length of all sentences was 9. Similar to this case study four other case studies were solved with the designed health care system. A medical assistant was involved to use the system. A multiple step procedure is involved to use the designed medical health care system. The steps are following:

1. Registration patient
2. Recording patient's data
3. Processing patient's report
4. Diagnosis and Medication

Brief description of all these phases with the help of a case study has been provided in the later part of the section.

A. Registration Patient

A patient is needed to register with his personal details i.e. name, age, sex, address, family history, previous cases, etc for using the proposed virtual telemedicine system. Figure 4.1 shows the form that is used to register the patient first.

B. Recording Patients's Data

After registration, the medical expert performs basic tests of a patient to get the reading of temperature, blood pressure, blood group, sugar level and ESG (if required). Then he records the common symptoms of the patient in the system. Besides these tests, the data i.e. color of tongue, color of eyes, heart beat, face color; etc is also captured and is updated in the system. The output of this step was a patients report in English.

C. Processing Patient's Report

Medical assistant can also use digital stethoscope and electrocardiograph file with ECG recorder or images with the examination camera [13]. A text file containing the patient's case details is prepared. A prescription will be generated after the patient's data is submitted. If the knowledge base cannot reply then the patient's data will be emailed to expert. The correctness of the decision made by the software and the medical expert is based on the accuracy of the data captured by the medical assistant. The quality and accurateness of the images and video of the patient is also quite important.

D. Diagnosis and Medication

Finally, CDSS diagnosis the patient's disease and prescribes medication (including dose details and side effects, if possible) with diet details and exercise details. At this phase, facility of explaining and reasoning of the system to the user is also provided. User can make different queries regarding the system domain and system.

To validate the precision and affectivity of the designed system symptom reports of three groups of ten patients were defined. For each group three reports i.e. easy, average an difficult were generated for each group. The symptom reports were carefully prepared and processed for each patient using the designed health care system. For correct and wrong diagnosis of a symptom report various points were given. Table I shows the details of the results.

	Symptoms	Diagnosis	Average Accuracy
Case 1	97%	94%	95.50%
Case 2	91%	89%	90.00%
Case 3	87%	85%	86.00%
Case 4	94%	91%	92.50%
Case 5	92%	89%	90.50%
Average	92.20%	89.60%	91.00%

Table I- Virtual Telemedicine Based Healthcare System

Following are some benefits over using the proposed framework virtual telemedicine.

- Improved and immediate access the specialty care
- Upgraded emergency medical services
- Reduction in un-necessary duplication of services
- Less dependency on the medical expert
- Easier diagnostic consultation
- Expanded disease cure education
- More patient health queries
- Remote medical consultation
- Reduction in health care cost
- Automated patient record keeping

VI. CONCLUSION & FUTURE WORK

Virtual Telemedicine is the new concept which actually works faster than that of the traditional telemedicine systems. An expert system has been deployed in place of a medical expert that has ability to immediate respond. This immediate response can help to treat patients in time and more effectively. 95% queries can be entertained locally. The accuracy achieved with the designed system is 91.00%. The Virtual expert system becomes more robust and

intelligent with the passage of time as the knowledge-base grows and the level accuracy will also improve. For the under developed and developing countries like Pakistan, Bangladesh, Sri Lanka etc the usability of the Virtual telemedicine will be more useful and beneficial. The experiments were performed on a simulator and it is acceptable that these results may vary when the system will be run real time. In future enhancements the algorithms is needed to be improved to increase the accuracy level of the system. Medical explanation module is also needed to enhance its usability.

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