Architecture Design of Cloud-Base Clinical Decision Supported CPOE for Smart Devices

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ISLAMABAD

SEP, 2017

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A thesis submitted in partial fulfillment of the requirements for the degree of

MS Software Engineering

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September, 2017

Declaration

I certify that this research work titled "*Architecture Design of Cloud-Base Clinical Decision Supported CPOE for Smart Devices"* is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

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Signature of Supervisor

Copyright Statement

Acknowledgements

I am thankful to my Creator Allah Subhana-Watala to have guided me throughout this work at every step and for every new thought which YOU setup in my mind to improve it. Indeed I could have done nothing without YOUR priceless help and guidance. Whosoever helped me throughout the course of my thesis, whether my parents or any other individual was YOUR will, so indeed none be worthy of praise but YOU. I am here up to which level is only and only blessings.

I am profusely thankful to my beloved parents who raised me when I was not capable of walking and continued to support me throughout in every department of my life.

I would also like to express special thanks to my supervisor Dr Shoab Ahmed Khan for his help throughout my thesis and his tremendous support and cooperation.

I would also like to pay special gratitude to Dr Mumtaz Ahmed my mentor for his tremendous support and cooperation throughout my Bachelor and Masters Degrees.

I would also like to pay special thanks to Dr Muhammad Naeem Ashraf, Registrar Urology Department DHQ Hospital Faisalabad for his tremendous support and cooperation about Order Sets and other hospital related work.

I would also like to thank Dr Muhammad Usman Akram and Dr Wasi Haider Butt for being on my thesis guidance and evaluation committee and express my special Thanks to Dr Arslan Shoukat for his help. I am also thankful to Shehzada Zesshan Waheed, Muhammad Hummayun, Muhammad Shafique and all my colleagues for their support and cooperation.

Finally, I would like to express my gratitude to all the individuals who have rendered valuable assistance to my study.

Dedicated to my exceptional parents and adored siblings whose tremendous support and cooperation led me to this wonderful accomplishment.

Abstract

"Health is wealth" a well renowned quote cum reality. Good health is a very basic need for humans, so to maintain good health our health care systems should be state of the art and in parallel with emerging technologies. As we are living in the era of automation, so it has become the necessity that our healthcare system should be automated i-e computerized to minimize the risks and to increase the quality of health care. Because the clinicians have to do many tasks, so the risk of human error increases as ‘‘Men are men; the best sometimes forget.’’. To reduce such risks now a days Clinical Decisions Support Systems (CDSS) are being used in health care in accompany with Computerized physician order entry (CPOE). DSS have reduce the risks and lapses of memory in many clinical situations. In this research our aim is to make CPOE prescribing error free, more user-friendly and more use of CPOE in hospitals. We investigated the problem that many physicians avoid using it in inpatient care due to problem of mobility (moving system bed to bed). So to overcome this hindrance in CPOE use we purposed solution for it i-e CPOE should be on portable smart devices so that it is very flexible to use by physicians in inpatient care as well as outpatient. In this study we purposed the cloud base architecture of CPOE for smart devices integrated with CDSS. In this investigation, two kinds of CDSS assessed, drug-drug interaction and drug allergy interaction which are the most commonly used and roots many prescribing error. We examined the architecture of CPOE including the interface, quality attributes, multi-lingual capacity, security and privacy. On the basis of this analysis we decided to make our CPOE system cloud base as it can be easily availed by the hospitals systems using SaaS and smart devices can be use it as MBaaS. We will use a multi-tenant databases for our CPOE on cloud. To implement our purposed architecture we made a prototype using android and for this we create the Order Sets for Urology department of DHQ Hospital Faisalabad. This implementation was done in software engineering context, followed software development life cycle process. We evaluated the purposed approach by using a mix methodology of control experiment and action research to identify observations of physicians about the designed CPOE system for smart devices. The empirical results showed the significant improvements in physician's satisfaction. This cloud-based CPOE along with CDSS will encourage hospitals and physicians to adopt CPOE with very less operational and maintenance cost to improve the healthcare facilities.

Key Words: *Computerized physician order entry (CPOE), Architecture design of CPOE, Clinical Decisions Support Systems (CDSS), Cloud base CPOE, CPOE as MBaaS.*

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CHAPTER 1: INTRODUCTION

"Health is wealth" a well renowned quote cum reality. Good health is a very basic need for humans, so to maintain good health our health care systems should be state of the art and in parallel with emerging technologies. As we are living in the era of automation, so it has become the necessity that our healthcare system should be automated i-e computerized to minimize the risks and to increase the quality of health care. Because the clinicians have many diverse tasks to do, so the risk of human error increases as ''Men are men; the best sometimes forget.''(Shakespeare, Othello, 1605; Act II, Scene iii). To reduce such risks now a days Clinical Decisions Support Systems (CDSS) are being used in health care in accompany with Computerized physician order entry (CPOE). DSS have reduce the risks and lapses of memory in many clinical situations. In this research our aim is to make CPOE more user-friendly and more use of CPOE in hospitals. We investigated the problem that many physicians avoid using it in inpatient care due to problem of mobility (moving system bed to bed). So to overcome this hindrance in CPOE use we purposed solution for it i-e CPOE should be on portable smart devices so that it is very flexible to use by physicians in inpatient care as well as outpatient.

1.1 Introduction

There is always a risk of medical practitioners erring in the course of their practice. These errors include medical and drug errors. Medical errors are those instances when medics wrongly diagnose a disease and then end up giving the wrong or the less efficient treatment [1]. The prescription process is one of the steps which health care providers have to go through in giving a patient the correct medication [2]. While in medical school, Medical practitioners acquire limited therapeutic training required in prescription. Thus, it is necessary that they learn this skill while practicing to avoid such errors. The scenario steps for outpatient appointments are the following: The patient comes to his/her appointment and does the registration in the clerk's desk then waiting for the call. The nurse calls the patient and enters the Physician's clinic. The Physician should first examine a patient and collect any relevant medical history, then define the patient's problem and specify the therapeutic objective. After that, the doctor should then choose among the possible treatments of that particular condition and for that particular patient. The medication should be both efficient and safe for the patient. The next step is to write the actual prescription, then instruct the patient on how to use that particular medication [3]. This instruction includes time, amount and the condition under which they should use the drug. The last step is to monitor the patient's progress. One can ask the patient to return if the condition persists after treatment or return for a checkup dependent on whether or not the condition persists. According most of studies, there are lots of medication errors that happen during the process of prescribing medication. These errors occur due to erroneous medical decisions [4]. There are errors of lapses, unintended errors, omissions, wrong instructions as well as poor handwriting. Some errors occur if physicians fail to make a background check of their patients' earlier treatment. Wrong or poor prescribing can lead to unsafe treatment exposing a patient to more health problems [5]. It is important therefore for physicians and other healthcare providers to strictly adhere to the right prescription process based on the individual patient and the disease. Medication or prescription errors occur due to the failure of healthcare providers to follow strict guidelines as well as other reasons. To mitigate prescription errors, healthcare providers need consistent training on prescription while practicing [6]. There is a need to automate systems in hospitals to allow effective communication among medical practitioners. There is also the need to review and ensure consistent counter checks to ensure that doctors give correct prescriptions.

1.2 Research Background

Medication errors are a major issue in general practice and in hospitals [7]. Medication errors as defined by National Coordinating Council for Medication Error Reporting and Prevention are any adverse drug reaction that may cause an unsuitable medication use or lead to patient harm while the medication used in any procedure in the control of the health care practice including prescribing medicine [8]. Prescription errors are major problems in medication errors [7, 9]. To address these issues, [10] investigated that technology plays a vital role in preventing medication errors and improving patient safety. Information technology in health can increase the performance of healthcare providers and improved quality [11]. Health Information Systems had a great influence on the quality of care given to the patients. HIS consists of a large number of networking technologies, electronic health records, databases for clinics, and other financial and administrative technologies that are used to store and generate healthcare information [12]. [13] Also agreed that the use of information technology – computerization in all ordering, pharmacy systems, and use of bar coding and event monitoring could reduce the medication error rates. Since the order is directly entered into the computer, it has fewer transcription errors, increased accuracy and the order can be entered into multiple locations at the same time [14]. Studies have suggested that the use of CPOE systems may reduce the medication errors count [15]. CPOE system refers to a system where clinicians insert medication orders, medicines and tests directly into the computer system, from where it is then transferred to the pharmacy directly [16]. It decreases the interruption in order completion, the errors related to transcription and handwriting are reduced and error checking for incorrect tests or duplicate doses can also be provided. CPOE is thus patient management software [17]. Many studies have evaluated the impact of (CPOE) and investigated the link between CPOE and reduced medication errors. Decision Support System (DSS) is about a processing rules obtained from storing and modeling the human expertise and knowledge for further problem solving. DSS is one of the most effective ways to reduce medication error. It integrates knowledge-based and expert based concepts to support on deciding the suitable medication [18]. Studies have shown that Clinical Decision Support System (CDSS) can reduce the costs and improve healthcare quality [19]. Thus; Healthcare organizations are increasingly implementing CDSS, which provide physicians with patient diagnosis or recommendations helps in decision making [20]. Many studies have presented that using CDSS reduced medical error and the results of some studies shown that CDSS also improved for drug preventive care and other [21]. CPOE with CDSS can reduce medication error and improve patient safety because electronic order are reliable more than a hand written and the knowledge based CDSS guaranteed the integrity of order. CDSS categories into two stages [22]. See figure 1.1**:**

- **Basic DSS -** includes Drug-Allergy, duplicate therapy checking, formulary decision support, Drug–Drug Interaction and basic dosing guidance**.**

- **Advanced DSS -** includes guidance for medication-related laboratory testing, dosing support for renal insufficiency, drug–disease contraindication and drug– pregnancy checking.

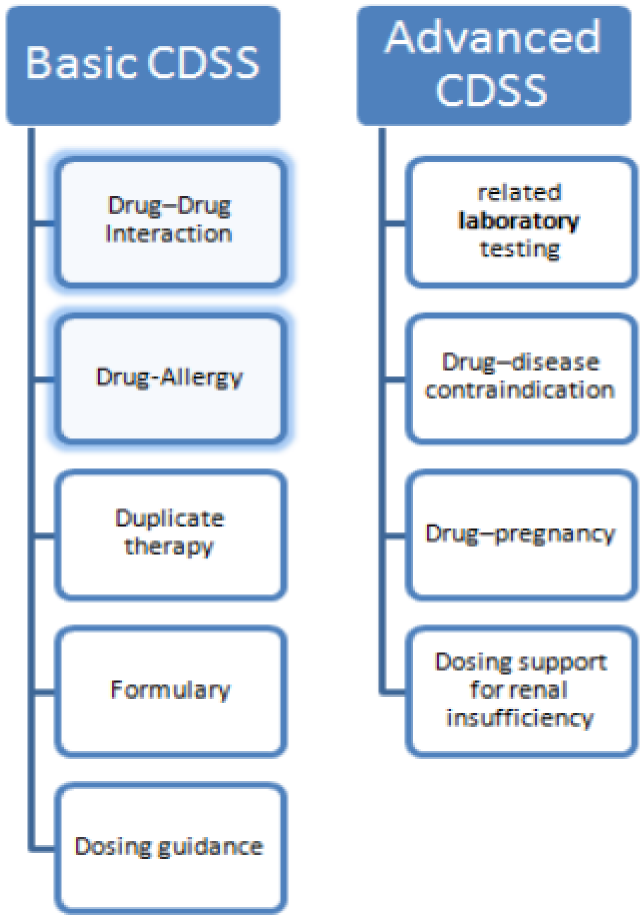


Figure 1. 1: Clinical decision support categories

In this research we focused on two types of CDSS, which are the most common and causes most of prescribing errors. The other CDSS types are complicated and need more time to be implemented. The most prescribed errors are medicine interaction, drug – food interaction and drug allergy [23]. The types of CDSS covered and implemented in this research are the following.

• **Drug-Allergy Checking -**generates an alert when a physician orders a medicine to which the patient has documented allergy.

• **Drug–Drug Interaction Checking -** several drugs in combination with other drugs, can cause untoward reactions that may be harmful and deadly, so it is best to avoid such type of combination. CDSS must be effective, usable and support the physicians by providing clear warning and recommendation. To achieve this, expertise should define the medical knowledge and the data needed in making decisions should be available in the CDSS. Designs should be user friendly for the physician that present and respond to the alert in an appropriate way. Some organizations buy commercial CDSS form one of CDSS knowledge-base vendors and customizes their drug medication knowledge bases even removing some alerts.

1.3 Problem Statement and Motivation

Ensuring the patient safety is one of the most significant challenges facing healthcare today. CPOE systems are very efficient in decreasing medication errors and refining health care systems but many physicians avoid it in inpatient care due to mobility problem and somehow rate of prescribing error is high. To overcome this we purposed cope for mobile devices. And to reduce prescribing error we implemented CDSS.

The role of a hospital's leadership is to make patient safety a priority as well as upholding their responsibility to manage programs to support patient safety by preventing medical errors [24]. While prescribing medication is an essential order of medical practice and could improve patient safety, the method of prescribing them is complex and may cause medication prescription error. The main reasons for the cause of medication error are patient data misinterpretation and traditionally, prescriptions are recorded on paper that causes readability and retrieval problems [25]. Also the lack of CDSS that is capable of automatic detecting and identifying the information about drug interaction and adverse drug events. The physicians depend on their knowledge and experience in medicines, they must have more knowledge and awareness about all patient's conditions in order to decide the appropriate treatments including the prescribed medication [26]. They proposed a prototype system which integrated with data mining techniques that 16 generates drug interactions alert and suggestions that minimizing prescription errors and improving knowledge sharing of prescription [26]. Most likely prescription mistakes are interaction drug, interaction history patient, drug – food interaction and drug allergies [23]. In attempts to respond to these issues, many studies have utilized knowledge- based, intelligence systems, and data mining techniques to provide CDSS for prescribing medication with knowledge and up to-date information about drug interaction. Healthcare providers depend heavily on information and data of patient medical history, drug prescription order and medical expertise, which are uncertain and complex in nature. Since most of the work in the healthcare organizations are paper based, transferring from paper to computer based need to use patient data and medical knowledge in the system to support CDSS [25]. CPOE with CDSS can reduce medication error and improve patient safety [22].

1.4 Summary

There is always a risk of medical practitioners erring in the course of their practice. These errors include medical and drug errors. Medical errors are those instances when medics wrongly diagnose a disease and then end up giving the wrong or the less efficient treatment. The prescription process is one of the steps which health care providers have to go through in giving a patient the correct medication. Studies have suggested that the use of CPOE systems may reduce the medication errors count. CPOE system refers to a system where clinicians insert medication orders, medicines and tests directly into the computer system, from where it is then transferred to the pharmacy directly. It decreases the interruption in order completion, the errors related to transcription and handwriting are reduced and error checking for incorrect tests or duplicate doses can also be provided. CPOE is thus patient management software. Many studies have evaluated the impact of (CPOE) and investigated the link between CPOE and reduced medication errors. Decision Support System (DSS) is about a processing rules obtained from storing and modeling the human expertise and knowledge for further problem solving. DSS is one of the most effective ways to reduce medication error. It integrates knowledge-based and expert based concepts to support on deciding the suitable medication.

CHAPTER 2: LITERATURE REVIEW

To improve patient safety, we should learn about causes of error to design health care systems using this knowledge to reduce common error. The effects of poor quality and medical error have impacted our lives. Throughout this chapter, we present an overview of related works and the relevant literature regarding medical errors, healthcare information systems that discussing CPOE and CDS systems, CPOE systems are very efficient in decreasing medication errors and refining health care systems but many physicians avoid it in inpatient care due to mobility problem and somehow rate of prescribing error is high, we will find the reason for the physicians hindrance, then the challenges in healthcare systems as the last concept.

2.1 Medical Errors

The 1999 Institute of Medicine (IOM) report 'To Err is Human' highlighted that medical errors were the eighth leading cause of deaths in the U.S and brought to the forefront the issue of patient safety and the need to eliminate medical errors from hospitals [27]. Rates of medical errors that affect patient safety are increasing daily [28] and it is costing millions of lives in U.S. [29]. In an analysis of 110 discharge medication lists in the Augusta Mental Health Institute of Maine, 22% contained errors [30]. Causes of medication errors can involve medicines, diagnosis, surgeries, and lab reports in healthcare systems [31]. Medical errors can happen anywhere in the health care system: In the clinics, surgery centers, diagnosis, lab report and pharmacies [28]. Medication Errors occur mostly at the prescribing stage [32]. One of the studies has shown that prescribing errors are caused by multiple factors related to health professionals and health care systems. This may be due to poorly written prescriptions, illegible or unclear handwriting [31], miscalculation or errors in unit expression, faults in patient identifications, information in ordering forms, problems in memory, such as memory lapses [33],[34]. In addition, lack of knowledge on the part of the prescriber is one cause of medication error [31]. Thus, many hospitals engage in efforts to prevent patient incident reports due to medication error such as dosing and conflict [35]. In Pakistan, a recent study indicated that prescribing errors affect 16.9% of all prescriptions, and the impact of these errors varies from minor to serious [31]. The following figure represents medical errors.

Dosing errors	• (22.1%)
Routing errors	• (12.0%)
Errors in clarity	• (11.4%)
Frequency errors	• (5.4%)
Incompatibility	• (1.9%)
Incorrect drug selection	• (1.7%)
Duplicate therapy	• (1%)

Figure 2. 1: Most prevalent medications prescribing errors

2.2 HealthCare Information System (HIS)

HIS is an integrated, comprehensive information system that has been designed to control and manage all the hospital's operations like financial, administrative, medical, and legal issues and provide the corresponding services [36]. Healthcare information system can save a lot of money in the long run and the major benefits for hospitals are cost effectiveness, the efficiency of the system and safety of medical deliveries [37]. Electronic medical/ health record (EMR/EHR) systems are generally adopted in all hospitals for information system [38]. EMR is an electronic health care information record, which keeps patient information. EMR system helps to link the work of different departments in hospital. All information related to the patient is stored in the patient record [39]. The role of technology in healthcare is overcoming various challenges facing it and as such helping improving the quality as well as the safety of care. Among the greatest challenges of all time facing healthcare is the medication errors [40]. It has been shown that information technologies are viewed to have the greatest potential in helping to improve safety standards in healthcare provision, specifically in the decrease of medical errors [41]. In the 1999 IOM "To Err is Human: Building a Safer Health System" report, the main conclusion is that the majority of medical errors do not result from healthcare providers, but rather from poor systems which must be modified and upgraded to support patient safety [27].

2.2.1 Computerized Physician Order Entry (CPOE)

In response to the shocking IOM report, many hospitals have invested considerably to design, attain, and execute these advanced systems, including the current focus on computerized physician order entry (CPOE). CPOE represents an important step forward for healthcare organizations because it embodies a shift from traditional, paper-based care coordination activities to automation of the order entry processes. This shift can be an agent for change, eliminating confusing or illegible handwritten order documentation, minimizing transcription errors and reducing clinical mistakes [39]. Computerized Physician Order Entry (CPOE) is the portion of a clinical information system that helps health care providers enters an order for a medication directly into the computer, and then the system transmits the order to the appropriate departments [42]. Implementation process has seen organizations use commercial systems. This is due to the high demand for the use of CPOE. Others have developed CPOE in their house for ease date recording and reduction of errors. National Quality Forum recommends the use of CPOE for “Safe Practices for Better Healthcare.” CMC (Computerized Medical Orders) since august 2012 showed improvisation of CPOE. The use of alternate measure shows that more than 30% of the authorized and eligible hospitals (POS 21 OR 23) utilize CPOE. The basic functions CPOE can provide are: (a) order creation; (b) modification; (c) dictionary management of orders; (d) patient’s order profile management; (f) routing orders to various departments; (g) reporting; and (h) summarization. Overall care process can be shown as the following [43]:

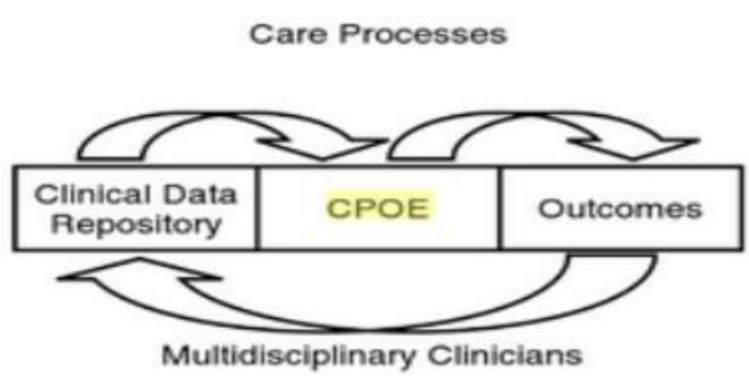


Figure 2. 2: CPOE Care Processes

The system uses an online network to send and receive information from one department to another. Hence, the system eliminates transcription and as such errors associated with transcription. It improves its efficiency; the CPOE is also linked with the Electronic Health Records System (EHR) to access patient history [44].

2.2.1.1 **Impact of CPOE in reduce medication error**

According to [45], CPOE has been developed to address problems arising in patient medication process resulting in medication errors. Here, the physician instead of writing the order on the file, he or she places the order electronically. CPOE comprises of a system of the computer that is linked. For instance, the physician's computer is linked to the laboratory, pharmacy, radiology and other important departments [35]. Therefore, instead of writing the order on file and handing it to the clerk to take it the pharmacy, the physician electronically sends the order directly to the pharmacist. At this point, the system eliminates the errors that might arise from poor handwriting as well as transcription errors [46]. A significant number of medication errors have been associated with the poor handwriting used by the 27 physicians. The handwriting results in transcription errors. The doctor might also confuse patients and write an order for the wrong medication. However, the CPOE system utilizes the double check mechanism to ensure that physicians enter the correct order [47]. Currently there is considerable effort to use CPOE to facilitate the improvements in delivering health care by increasing medication safety, improving the efficiency of providers and decreasing cost [48]. [49] Conducted a study to determine the efficiency of the CPOE system in decreasing medication errors. The study was conducted in the form of random effects of meta-analytic technique. The study's results show that CPOE is effective in reducing medication errors. Ordering medication through the CPOE system reduces the likelihood of medical errors occurring by at least 48%. This number means that in the USA alone, more than 17 million cases of medication errors can be averted each year. These figures are impressive. As such, the hospital management should consider purchasing the CPOE system to reduce the cases of medication errors [14]. One of the studies which compared medication errors six months before and nine months after implementing a CPOE system in hospitals reported that CPOE bring about a 55% decrease in medication errors [35]. With the addition of decision support features to the CPOE system, medication errors were reduced by 81% [50]. Another study in the academic medical center in Chicago, conducted with pharmacists at a 700-bed facility, reviewed a week's worth of medication error orders and determined that, of the 1111 errors, 64.4% could have been prevented by a CPOE system [51].

2.2.1.2 Prescribing medication order entry

In any hospital or health care institution, there are steps that are followed before the patient is given medication [52].The first step is normally ordering. Here, the physician selects the drug, dosage as well as the frequency. The next step is transcribing. Here, the clerk must be able to read the order and communicate it correctly to the pharmacist. The step that follows is dispensing. While dispensing, the pharmacist must check for all drug-to-drug interaction as well as the allergies among others [44]. The last step is always administration. Here, the nurse must receive and administer the medication as directed by the physician. As you can see, this process is long and involves multiple personnel. This phenomenon creates room for medication errors. An error might occur during transcription, dispensing or even administration [53].

2.2.2 Decision Support System (DSS) in health care

Generally, the practice that is followed is, all the information from healthcare providers (clinics, doctors, hospitals, emergency rooms, etc) is entered into the Electronic Health Record (EHR) [54]. Through the electronic exchange, the information is then sent to local, regional and national databases. The data that flows from these databases is then used for decision support and decision-making. The Healthcare information system has the following model for information flow as in Figure 2.3 [55].

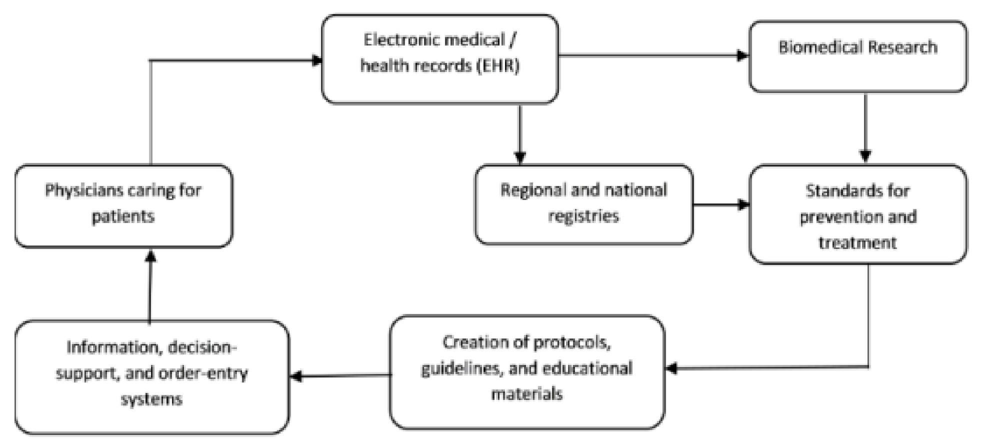


Figure 2. 3: HIS information workflow

CPOE systems are generally coupled with one or the other type of decision support system. The figure 2.4 shows the software engineering of [56].

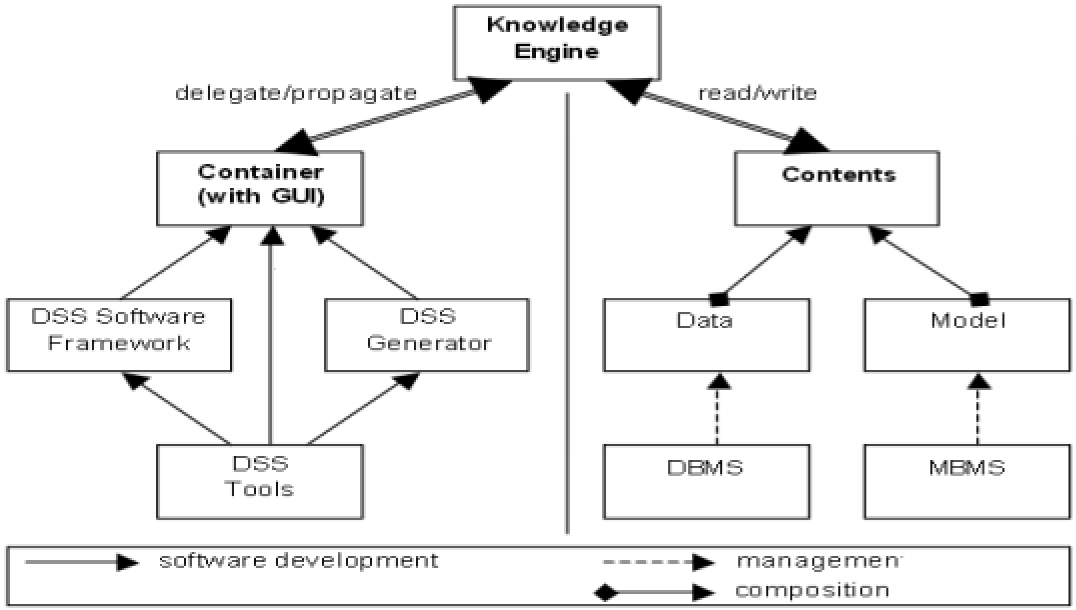


Figure 2. 4 Software Engineering of DSS

A decision support system is an information system that use of available data into generating decisions for the user through human-system interaction (Zhou et al., 2008). 30 In healthcare, DSS is used in several fields; clinical or operational to serve aims such as utilization of resources or efficiency of services [57].

2.2.2.1 Clinical Decision Support System (CDSS)

To improve the medical care services' quality, the practice of evidence-based medicine is being followed through the application of CDSS. CDSSs are designed to combine patient data, medical knowledge base and an inference engine to provide case-specific clinical advice [58]. CDSSs are used to support clinicians at the hospitals. There are two types of CDSSs: (a) knowledge based; and (b) non-knowledge based. Doctors make use of the output of the CDSS system to determine which diagnosis would be most relevant for the patient. CDSSs help in reducing the mental workload of the clinicians and improve clinical workflows. Many a times, CDSS applications are adopted with electronic medical records (EMR), as EMRs along with CDSS applications can be used a part of CPOE and electronic prescribing systems [59].

(a) Knowledge-based CDSS:

The rules and compiled data are associated with IF-THEN rules in knowledge based CDSSs. For example, for determining drug interactions, the rule applied can be, IF medicine Y is taken and then medicine X is taken THEN alert the user [60].

(b) Non-knowledge based CDSS:

In this, the rules are not applied and computers have to find patterns from clinical data or learn from past experiences. Doctors use them for post-diagnosis systems as they suggest outlines for clinicians to look into in more depth [61]. CDSS is considered an important component of medical intelligence. It includes artificial Intelligence (AI) helped health workers in data manipulation and evaluates every order that the doctor enters. The system is largely based on the information from the electronic patient records among others. The system utilizes the patient history, medication and so forth. CDSS uses this information to counter check all the entries made by the physician [62]. The information may be used to alter decisions made in a clinical set up. One of the decision rules are made using Arden syntax programming language that aids in encoding. For example, in Brigham and Women Hospital a laboratory technician puts an electrolyte on patient's blood sample. The results showed 2-9 mm/L of potassium was low. It was entered into the information system. The message obtained contained patient's ID number and his potassium results. There are various different types of system, each with a different overarching architecture. The first is an integrated CDS system that is designed to work with other healthcare applications, which are based on a common database style of architecture. The other major type is the service-based CDS system, which are connected with interface brokers and work on a service-oriented architecture [63]. These both have their advantages and disadvantages in clinical systems, and both support integration in a different way, which means that careful consideration must be given in order to assess which is most suitable for use in the current healthcare setting.

2.2.2.2 Computerized Physician Order Entry (CPOE) with Clinical Decision Support System (CDSS)

Early implementation of CPOE system had some adverse consequences, which led to failure in providing medications in emergencies. But, with the experience in CPOE implementation, careful planning, maximizing the system's use, all these adverse events have been averted. With the use of CPOE, the physician can provide the decision support at the time of care

[36]. The decision maker has to interact with the computer directly. Decision support helps in reducing the medication error rate and thus helps in ordering clinically cost-effective and appropriate medications and tests for the patients [64]. CPOE is connected with the pharmacy department, laboratory and other relevant departments in the hospital. The CDSS is connected to the whole system to alert the physician on drug allergies, medication history among other important alerts [35]. CDS systems, when well implemented and designed, helps a lot in improving healthcare quality, reducing errors, increasing efficiency and reducing health care costs. When CDS alerts and recommendations are not attended properly, it poses challenges for all those who are developing, using and implementing CDSS [65]. According to [66], CDSS helps in drug relations checks and provides services for the patients with reduced ADEs for about 7 to 10 times. The system aids in recognizing situations with extreme drug event and in reaching out for clinical decisions using computerized services when making order entry. In 2008, meta-analysis study showed that about 12.5% of medical errors were reduced.

2.2.2.3 Clinical Decision Support Systems Alert

[67] Depict the few sorts of system alarms given by CDSS. Among them is the sensitivity caution. For example, the patient may be susceptible to penicillin. Thus, upon the doctor requesting penicillin, the system raises the medication sensitivity caution. CDSS also checks the drug-to-drug interaction [40]. The interaction between the biomedical and physical of certain medications can result in adverse events. Hence, CDSS reviews the interaction of various drugs in the patient system giving alerts where a problem is detected. The system also considers the demographic data such as age and gender to ensure the medication ordered safe and efficient for that specific patient. The EMR system includes the CPOE screens and the CDSS are used for prescriptions and preventive care. One such example of how CPOE screen along with CDSS works is shown below:

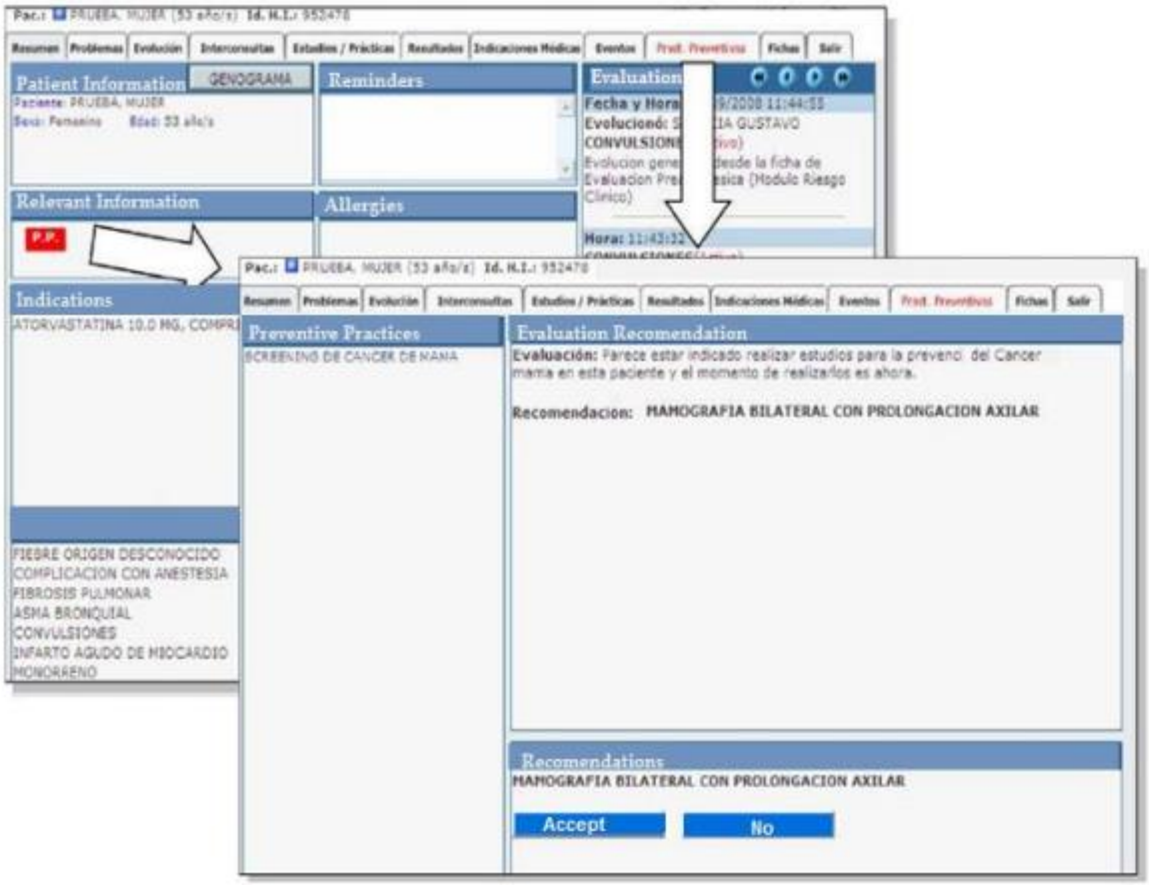


Figure 2. 5 Example of CPOE and CDSS screen

In this sample above, CDSS screenshot is shown. An active reminder is indicted by the red "PP" flag in the important information screen. By clicking on the red marker section, the recommendation is shown. If the physician agrees with the recommendation, he would order that. Reason should be mentioned in case of non-acceptance of the recommendation [46]. CDSS displays alerts in several ways, such as a pop-up warning. The pop-ups are interruptive and as such the physician can note them immediately. The other method is through highlighting of relevant patient information. For instance, the system might highlight the age, gender, allergy, past conditions and current medications to try and help the physician make the right order for the patient. The other common method used is the provision of links. These links are created automatically and lead the physician to points where he or she can access relevant patient 40 information. Some of these links might be to the EHR patient portals and so forth [67]. However, [58] notes that sometimes some of these alerts might be too many and also interruptive. The alerts, especially the pop-up alerts can be disruptive and as such affecting the physician's efficiency at work. Moreover, there are cases where CDSS raises false alerts. This problem, therefore, affects the effectiveness of CDSS in improving the safety and quality of medical care [62].

2.3 Challenges in Healthcare Information System (HIS)

Though the HIS provides a huge potential and the opportunities to transform the healthcare sector, there are many challenges currently being faced which are evident. Firstly, the adoption of the information technology in healthcare has really been very slow and lags behind major industries of IT by almost 10-15 years [68]. The resistance to use information technology by healthcare professionals and the failure in HIS implementation is also one of the major challenges in healthcare. The challenges may vary from technical issues, issues in healthcare settings, regulatory environment, and system users' settings. Some of the barriers to the adoption of IT in healthcare in U.S are: the adoption rate by doctors and hospitals is very less, issues with privacy and security, medical errors committed [69]. Commitment to quality is a critical factor in which healthcare personnel must commit. The use of systematic process ensures that a database related method is used to keep track of the medical records [66]. It is recommended that trained and informed personnel should only be allowed to update the data. Further, there is the need to provide sufficient training. The users can be trainer of the trainees. There are several requirements which need to be considered when dealing with healthcare software, such as security, reliability and performance. Data accuracy and availability is also a critical characteristic [70].The development of requirements that include clinical decision support and workflow configuration may increase the success of CPOE implementation. The most advanced implementations of such systems provide a real-time clinical decision support such as drug and drug-allergy interaction checking and duplicate therapy warnings and dosage [42]. The deployment of health information systems is especially challenging for hospitals because of high implementation cost, technical complexity, lack of information and communication technology (ICT) infrastructure, and lack of well-trained employees [39]. Upon implementation of the CPOE system, the hospital must ensure that they have resources that can support the facility. Notably, the decisions made must be based on the cost benefit analysis founded on the scope. In this way, decision integration can be implemented. The current context has shown relatively low response in the implementation of the system [71]. HITECH Act 2009 is focused in ensuring that the incentives provided meet the threshold of rendering meaningful health care. Medication errors are expensive and in some cases harmful to the patient. For that matter, it is the duty of every health institutions' management to put measures into place to address the medication errors. Some of the medication errors do not arise from arising from individuals, but rather a system that is already in place. Some other factors such as the shortage of staff further increase the chances of medication errors. For that matter, organizations require an effective solution: CPOE and CDSS [72]. The hospital administration can also conduct a survey to obtain the feedback from physicians regarding the CPOE System. The survey would be best carried out in the form of an interview. The major topics covered include ease of using the system, time and effectiveness in reducing medication errors among others [73]. The hospital administration can also conduct a survey to obtain the feedback from physicians regarding the CPOE System. The survey would be best carried out in the form of an interview. The major topics covered include ease of using the system, time and effectiveness I n reducing medication errors amongst others [73].

2.4 Importance of smart devices in HIS

Numerous medicinal applications for cell phones have been produced and broadly utilized by physicians and patients. The utilization of smart phones is getting more consideration in health care gradually. These applications make cell phones helpful apparatuses in evidence-based medical systems at hospitals, apart their utilization in portable clinical correspondence. Additionally, cell phones can assume an imperative part in understanding instruction, illness self-administration, and remote checking of patients.

Recently from many years it have been observed that healthcare experts along with the ordinary peoples had increased the usage of smartphones [74]. In current years, healthcare experts have essential access to several technologies in hospitals, for example:

1. Hospital Information Systems (HISs) containing Electronic Medical Record (EMR) systems or Electronic Health Record (EHR), Picture Archiving and Communication Systems (PACSs), Clinical Decision Support Systems (CDSSs), Laboratory Information Systems (LISs), etc.
2. Evidence-based applications i-e Up-to-Date and PubMed.
3. Medical applications i-e drug databases, disease diagnosis applications and medical calculators.

4. Clinical communication i-e text messaging, voice calling, video conferencing, and email messaging.

In hospitals access to all above mention is mostly given through static computers, which does not completely fulfill the requirements of mobile environment of healthcare. To overcome this, extra moveable and wireless mobile information communication technologies (MICTs) such as Computers on Wheels (COWs) or Workstations on Wheels (WOWs) are in practice in some hospitals to make information technologies easily accessible at hospitals. [75]

Thus through introduction of smart phone in CPOE there is a great chance of error reduction.

2.5 Summary

HIS deliver extraordinary reliability, improved readability, lessening the medical costs and raises the whole worth of the healthcare [76]. The government should invest in technology in healthcare to help achieve desired outcomes [77]. The implementation of CPOE surely ensures the safety of the patients. CPOE is also recommended as one of the 30 "Safe practices for better healthcare" by the National Quality Forum. In conclusion, medication errors are a huge problem in health care. However, the CPOE system seems to be one of the most solution used to solve this problem as the previous relevant studies. CPOE allows electronic entry and the sending and receiving of orders. This reduces the chances of medication errors by around 48%. CPOE is connected to CDSS, which counter checks all the entries based on the information from EHR and other areas to ensure safety of the medications offered to the patient. Introduction of smart devices in CPOE can also be a cause of error reduction and improvement in patient's safety.

Chapter 3: Research Methods

In this chapter methods of the research are described which are used to solve our problem statement, including the ethical issues. In this project, both qualitative and quantitative methods were applied to implement the CPOE system for smart devices, used to support the research validation from their feedback and measures the usability. These evaluations should be used to further improvement and enhancement in the CPOE systems.

3.1 Ethics in Research

Ethical permission was obtained from the DHQ hospital Faisalabad in order to conduct this study. Questionnaires used by the physicians needed in this research will be kept for studying the issues. Due to the hospital policy, all data used to test the cases (patient information) will be kept confidential.

3.2 Research Methodology

This research followed the systems development life-cycle, the set of activities which encompass requirement gathering, system design, building prototypes and evaluation. These activities are interdependent to each other. The output of the previous phase is the input of the next one [78]. Requirement gathering phase focus on data collection and the requirements which used in the next phase: system design. System design shows the database and user interface. Building prototypes describe the function codes used. The last phase is evaluation and shows the system evaluation process and the results. In order to build a prototype system with the same CPOE characteristic and CDSS as a deliverable for the decision making process for smart devices, a rapid prototyping software development life cycle model has been considered to derive this software. Prototyping is a simple system showing the main functions of the proposed system. Prototyping have more user involvement and allows to interact with a prototype and provide their feedback and specifications. When the final software is developed, it is more likely to satisfy the users.

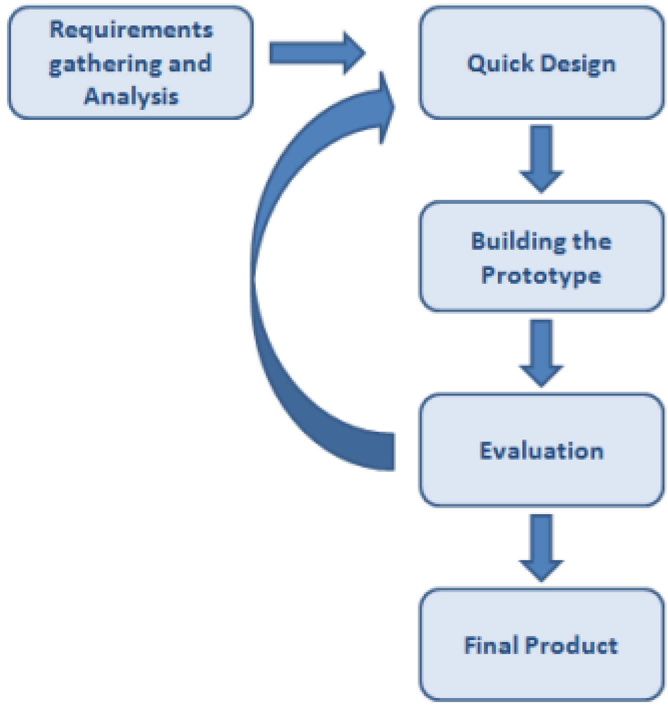


Figure 3. 1 Systems Development Life cycle

3.2.1 Requirements gathering and Analysis

This phase is the main focus of the end user and project managers. Requirements gathering methods were used for implementing the system are both, qualitative and quantitative using an interview and questionnaire. Several interview sessions were conducted with a team of physicians, pharmacists and IT staff. IT staff is responsible for understanding the technical aspects, physicians and pharmacists are best suited to determine how the CPOE system can be implemented. A set of questionnaires were distributed to physicians and pharmacists regarding the challenges that may be encountered during the use of CPOE and have their suggestions on improving the previous system before that helps us there on system implementation. After gathering the requirements, the information gathered is analyzed. Qualitative content analysis used to analyze the interview and pretest study with “Question pro” program used to analyze the questionnaire. The results documented in the business requirement document to be used for the next phase.

3.2.2 Quick Design

The early design of the CPOE system helps in defining overall system requirements, database tables, database schema, uses case diagrams and the user interface of CPOE with CDS for detection errors and alerts. Based on the requirements gathered from the previous phase, the process started when the physicians and pharmacists were both interacted with the system, although the physicians have more interaction. Then, the physician entered the patients' data, prescription information, and receive alerts. The pharmacist received the prescription for the medicine despising process. Next, the database mapping was done with drug medication knowledge bases. Overall, the early system design specifications help in building the prototype system in the next phase.

3.2.3 Order Set Creation

On the basis of the suggestions of physicians and pharmacists we also developed the order sets for the urology department. Which were used in CPOE system.

3.2.4 Building the Prototype

This is the main phase for the developer for coding. E-prescription order pages were created and integrated with the medication error detection components. CDSS Company provides us with the application programming interface (API) for building CDS software in addition to the database files needed, the API software modules were designed with the following software system objectives:

- Ease of implementation
- Performance
- Easily updatable

The test patients and test medication orders were developed in order to evaluate a CPOE system's ability by detecting prescribing errors in different decision support categories to evaluate the system efficiency.

3.2.5 Evaluation

After the codes were developed, an expert tested the system in order to check and remove any errors or bugs, and tested against the requirements by end users to ensure that the system is meeting the requirements need. In this phase, test cases scenarios with User Accepting Testing (UAT) were conducted. Physicians evaluated the improved features of implementing CPOE in. Physicians were the key central players in the decision-making process, as a prescribers. They were involved in the initial efforts of including designing, workflow, system analysis, testing. Test cases scenarios designed to test it with selected patients in order to check the results. The orders and test scenarios took as following steps:

- Selection of specific decision support category that needs to be tested
- Testing patients and orders given
- Checking the results, error detection and alerts
- The order set will be periodically reviewed and revised and modified
- New orders and scenarios introduced to maintain the validity and currency of the test

The developer team evaluated the specific scenarios and alerts response. List of test patients with various medical conditions were downloaded in the CPOE testing environment, then the potential users provided a series of test orders entered and tested with the patients' existing scenario and setting. The CPOE system's responded to the entered orders and then reported through the evaluation system.

3.3 Department of Urology System Case Study

A case study method was selected as it is useful for gaining a rich understanding of the research's context [79]. Using case studies to build theories is considered one of the best methods to do this [80]. In this study, a case study of implementing CPOE for smart devices with CDSS and estimating the cost effectiveness of the system in decreasing medication errors. The study has been conducted in an inpatient department of urology DHQ Hospital Faisalabad. DHQ has its own in-house Pharmacy system and ongoing doctor portal system in hospital's internal site. The system is partially implemented and started to be used in three selected outpatient departments in the main hospital. The doctor portal goal is to build CPOE for patient history and electronic order for all departments, Laboratory, Radiology and Pharmacy. The pharmacy part which is the electronic prescribing medication order is still not implemented. In the doctor portal the physicians can retrieve the patient's previous visits and enter the new diagnosis with treatment plan requests. The study targeted only physicians and pharmacists because mainly they are the most personnel that have a huge part in the system.

3.3.1 Current workflow for prescribing medication order:

Prescribing medication order is paper based, when the patient came to his/her appointment and entered to the physician's clinic, the physician examines the patient and makes the treatment plan, if a prescription is needed he will fill the prescription form and give it to patient who will go to the pharmacy and collect his/her medication. The workflow is as follows in Figures 3.2 and 3.3.

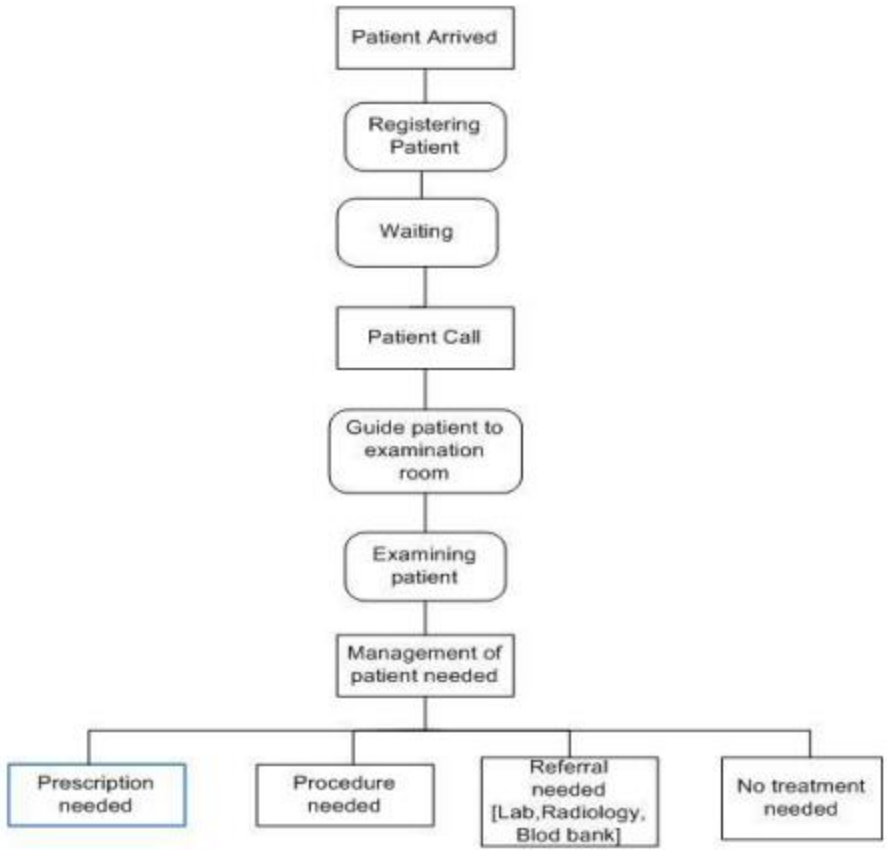


Figure 3. 2 Patient's visit work flow

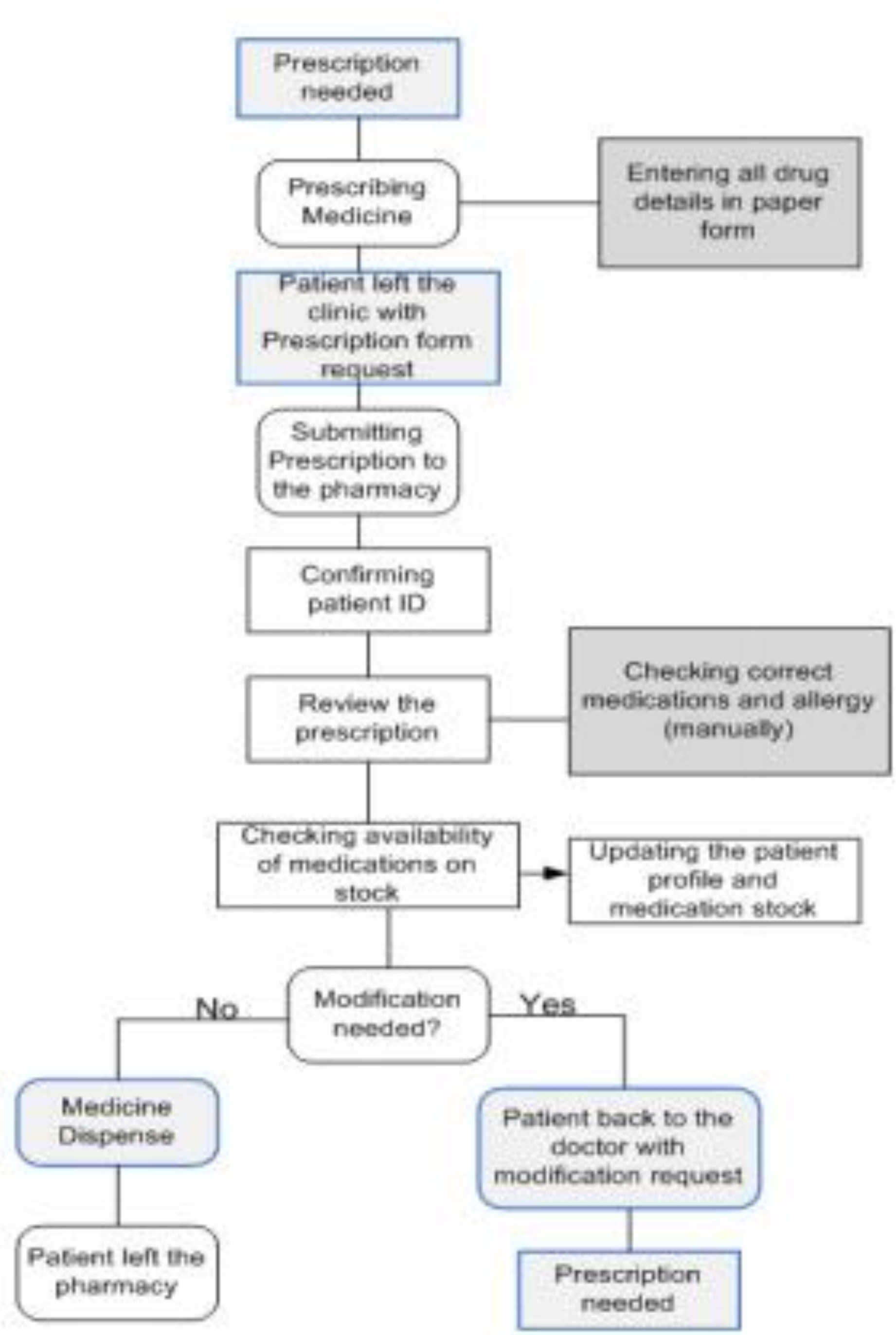


Figure 3. 3 Prescribing mediation work flow

3.4 Summary

In this chapter we outlined the ethics in research and the study research methods within the systems development of a life-cycle which we followed with a brief for each activity. We have also described the DHQ Hospital system case study.

Chapter 4 Architecture Design and Methodology

In this research our aim is to make CPOE prescribing error free, more user-friendly and more use of CPOE in hospitals. We investigated the problem that many physicians avoid using it in inpatient care due to problem of mobility (moving system bed to bed). So to overcome this hindrance in CPOE use we purposed solution for it i-e CPOE should be on portable smart devices so that it is very flexible to use by physicians in inpatient care as well as outpatient. And to reduce prescribing error risk we used CDSS in our Purposed CPOE Architecture. We designed a cloud-based architecture of CPOE for smart devices. The detailed description of architecture is as follows. So our solution may be subdivided into two steps or parts.

1. Integration CDSS with CPOE
2. Architecture design of CPOE for smart devices.

4.1 Integration CDSS with CPOE

As main aim of our study is to make patient care systems error free as maximum as possible. In patient care systems one of the major error which can b deadly is medication error. To reduce these errors we implemented a CDSS system for the following two types of medicine error causes.

• **Drug-Allergy Checking –** checks whether the patient has an allergy with the medicine that physician has prescribed. If yes the system will show alert to physician that patient has allergy with the prescribed medicine, so suggest any other medicine.

• **Drug–Drug Interaction Checking –** several drugs in combination with other drugs, can cause untoward reactions that may be harmful and deadly, so it is best to avoid such type of combination. So whenever such case occur that physician mistakenly selected the both medicines then CDSS will be give alert to the physician and recommend other medicine in parallel.

So it is very important that our system should be as efficient and intelligent that whenever any physicians mistakenly prescribe any medicine that causes allergy or harmful reaction, it will give an alert to highlight the error. To attain all this CDSS should have expertise and predefined medical knowledge. In addition with it the design of CPOE system should also be user friendly and easy to understand able that whenever any alert is generated by the CDSS it should be clearly understandable by the physician (end user).

Our purposed CDSS has capabilities of reducing medication errors and make CPOE systems more reliable and trustworthy. The working mechanism of it is as whenever physician enter or select a single medicine it will check it for both type i-e allergies or drug-drug interaction. The work flowchart of CDSS is given below.

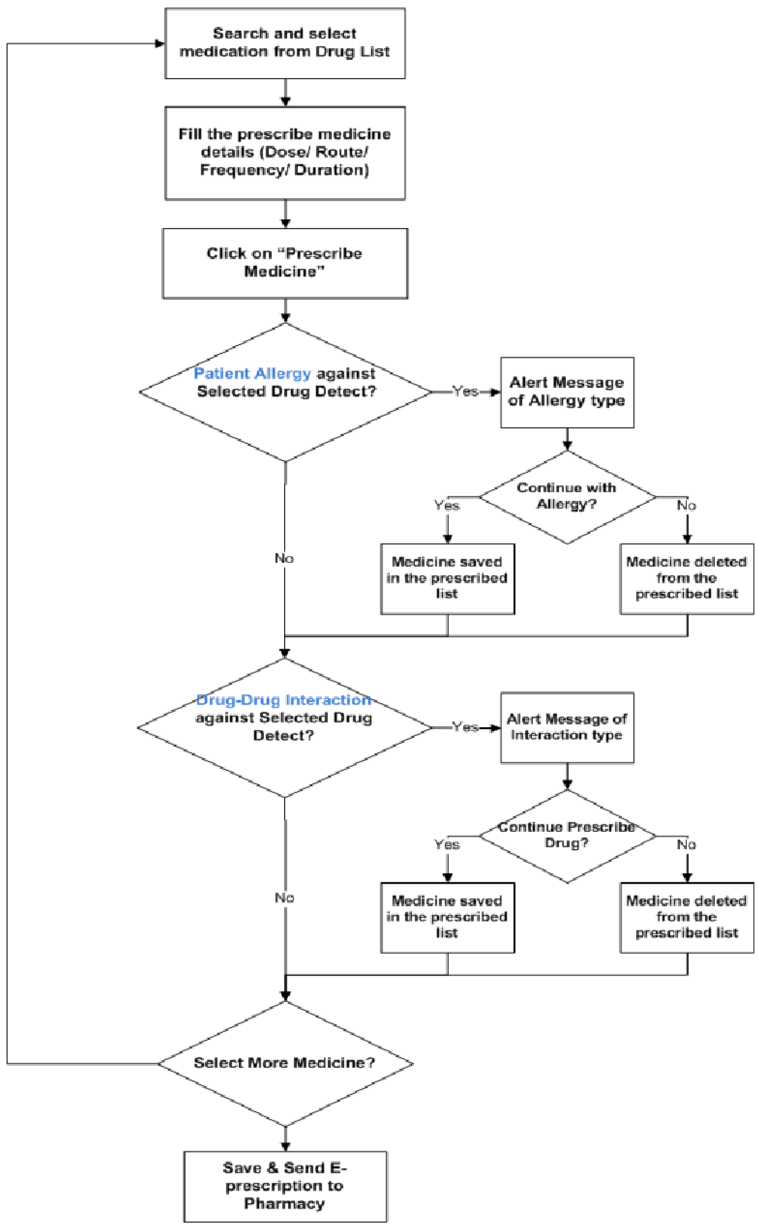


Figure 4. 1 Flowchart of CDSS

4.2 CPOE Architecture for Smart Devices

As main aim of our research is to make CPOE portable and easy to use for physicians. Most of the CPOE systems are desktop base applications which are difficult to use in inpatient care system as it is not possible to move computer system bed to bed and avoided by many physicians. To eradicate this hindrance in CPOE use we purposed CPOE for smart portable devices i-e mobile phone or tablets. For this we need centralized and server base CPOE database so that software application on smart devices can communicate with CPOE system through API as MBaaS.

4.2.1 Cloud Base CPOE

Cloud computing is one of the emerging technologies which provide very cost effective and reliable shared infrastructure for software applications. Cloud computing reduces the network and other infrastructure requirements and cost. So we decided to make our CPOE system cloud base as it can be easily availed by the hospitals systems using SaaS and smart devices can be use it as MBaaS. We will use a multi-tenant databases for our CPOE on cloud following Figure 4.1 depicts database configuration

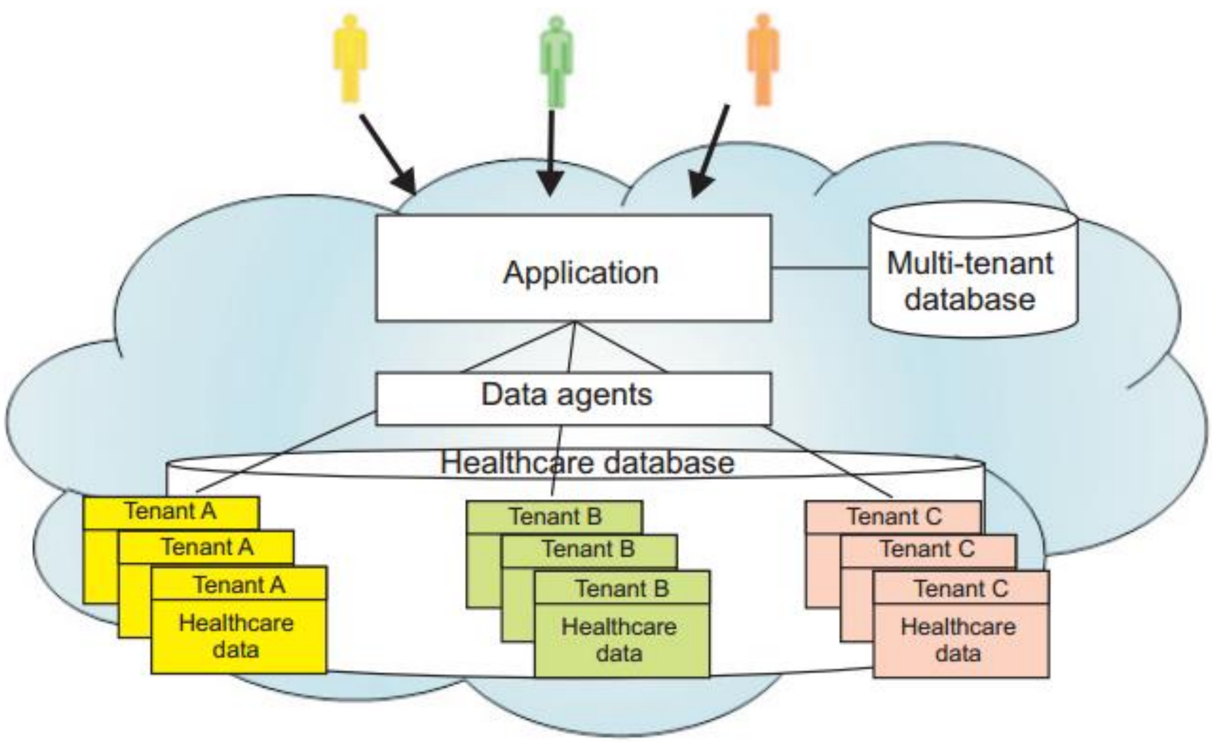


Figure 4. 2 Cloud representation of databases

4.2.1.1 CPOE as SaaS

We placed our CPOE system on cloud and it will be used as Software as a service model. Each computer system in hospital can easily use CPOE system as SaaS. The database will be centralized and each and every order set will be available to every concerned person.

4.2.1.2 CPOE as MBaaS

Our smart devices will use this cloud base CPOE as Mobile backend as Service model MBaaS. And communicate with it using REST or SOAP APIs. Whenever any physician generates an order set on his smart device it will be stored on cloud CPOE's databases and available fo concerned person.

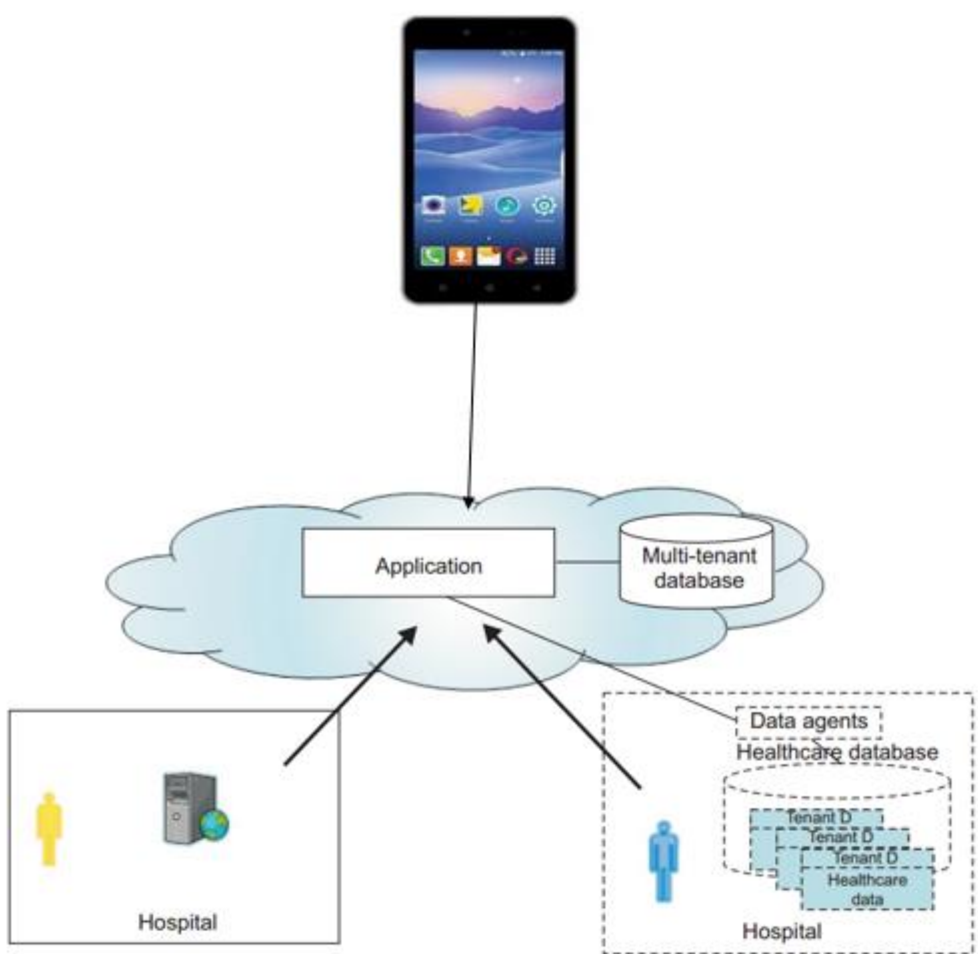


Figure 4. 3 Architecture Model Overview

Figure 4.3 represents the model of complete system as hospitals system can use CPOE as SaaS and smart devices can interact with it as MBaaS.

4.3 Summary

In this chapter we discuss our purposed architecture which is subdivided into two steps

a) Integration CDSS with CPOE
b) Architecture design of CPOE for smart devices.

We integrated CDSS with CPOE to reduce errors and design CPOE for smart devices to make it portable and easy to use.

Chapter 5 Experimental Implementation

For the experimental implementation of our designed architecture we used case study method and implemented our purposed solution for CPOE in a real time environment so that we can accurate testing and feedback about purposed architecture. So to fulfill our testing requirements we design the order sets for urology department of DHQ Hospital Faisalabad. We also develop a prototype for the validation using Android platform (Android mobile app).

5.1 Order Set

Order sets provide an ease to physicians in their inpatient care. For real time evaluation of our purposed solution we designed order sets for urology department inpatient care. These order sets are designed by consultation of a team of specialist physicians under the supervision of Dr Muhammad Naeem Ashraf. Following order sets are designed.

1. General Orders
2. Diagnostic Orders
3. Allergies
4. Pharmacy Orders

5.1.1 General Orders

General Orders contains the inquiries about general diagnostics of patients. It is arranged as follows

- Pulse Rate
- Blood Pressure
- Temperature
- IV cannula Insertion

5.1.2 Diagnostic Orders

Diagnostic orders contains specialized diagnosis questions about urology. Its arrangement is as follows

- USG-KUB

- CT-KUB
- IVU-X-Rays
- Retrograde Uretherogram
- Antegrade Phyelography
- Cystoscopy
- CTU
- MRU
- Urine C/E
- Serum Glucose Fasting
- Serum Glucose Random
- Serum Creatinine
- Serum Urea
- CBC
- HBsAg
- HCV Ab

5.1.3 Diagnosis Order

This order set is for physician to diagnose the patient's disease on the basis of diagnostic orders results and his observations.

- URS
- PIRS
- PCNL
- Pyclolithotomy
- Vesicolitholapaxy
- Vesicolithoclasty
- Vesicolithotomy

5.1.4 Allergies

The Order Sets of allergies is specially designed for the CDSS. As the physician inquires the patient about any type of allergy he have with any drug so that when the physician go for the medicines description the CDSS will check whether the patient has allergy with any of prescribed drug it will prompts alert to physician to change the medicine. Its arrangement is as follows

- Sulfa
- Penicillin
- Tetracycline

5.1.5 Pharmacy Order

The pharmacy orders enlist all the related medicines in accordance with the diagnosis and allergies entered by the physician in respective order sets. This order set consists of all dosages of medicine. The arrangement of it is as follows

- Normal Saline infusion 1000ml
- Soda bicarb infusion 50 ml
- Ceftriaxone 1000 mg injectable
- Omeprazole infusion 40 mg/1000 ml
- Tamsulosin 0.4 mg capsules
- Solifenacin 5 mg Tablets
- Ciprofloxacin 500 mg Tablets
- Diclofanic Sodium 50 mg Tablets
- Uropyrine 200 mg Tablets
- Sodamint Tablets
- Ca gluconate Tablets

5.2 Android Mobile App

We developed a smart phone application using Android platform to evaluate the performance and accuracy of our purposed architecture. This app is connected to central CPOE system through cloud database. The design of app is bases on activities i-e each activity represent one set of order sets. The workflow of the application is described as follows.

5.2.1 Main Activity

This is the main activity when app starts and ask from user whether to start a new patient order set or existing patients' order set.

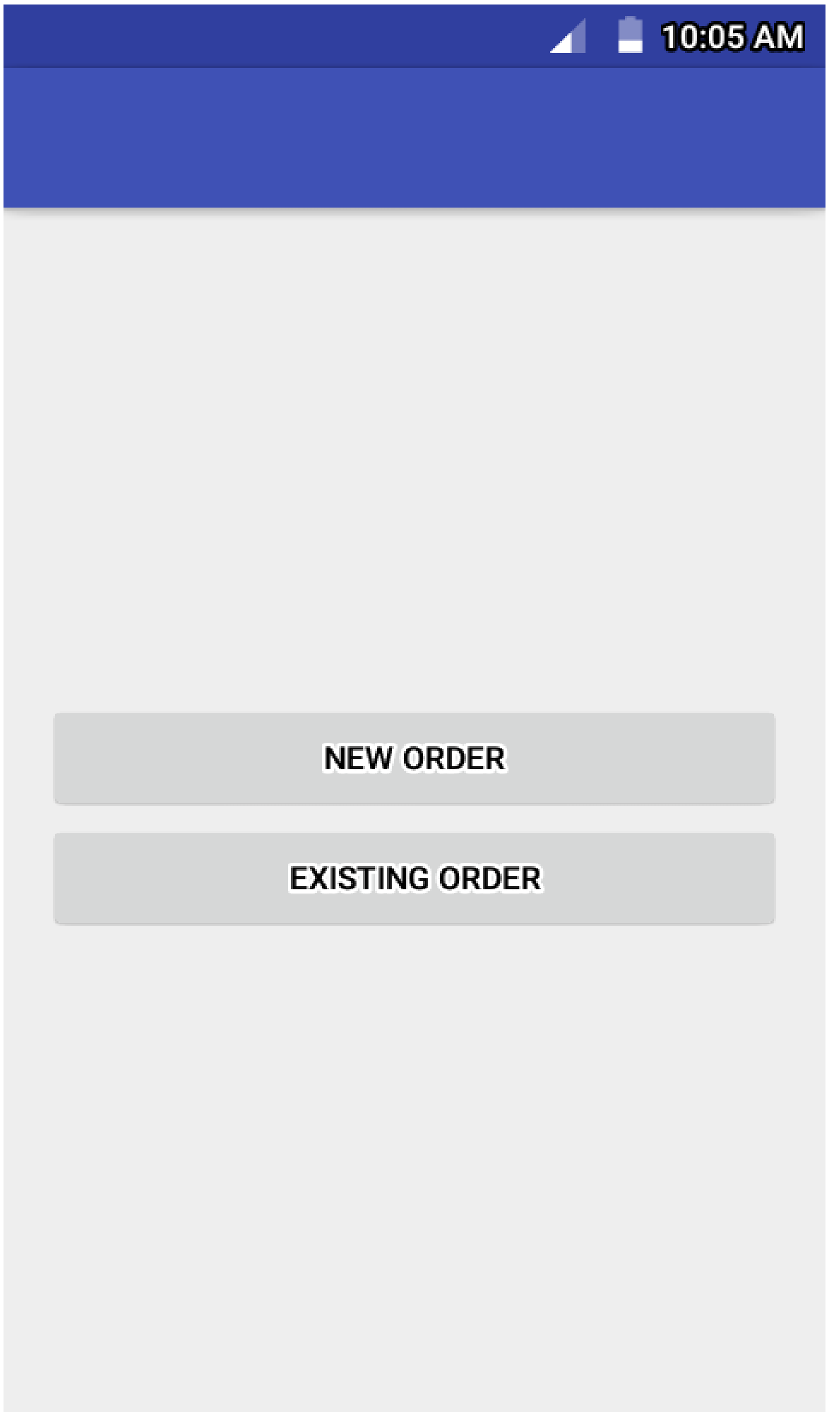


Figure 5. 1 Main Activity

5.2.2 New Order Activity

This is new order activity which collects the important particulars of the patient and generate an order against it.

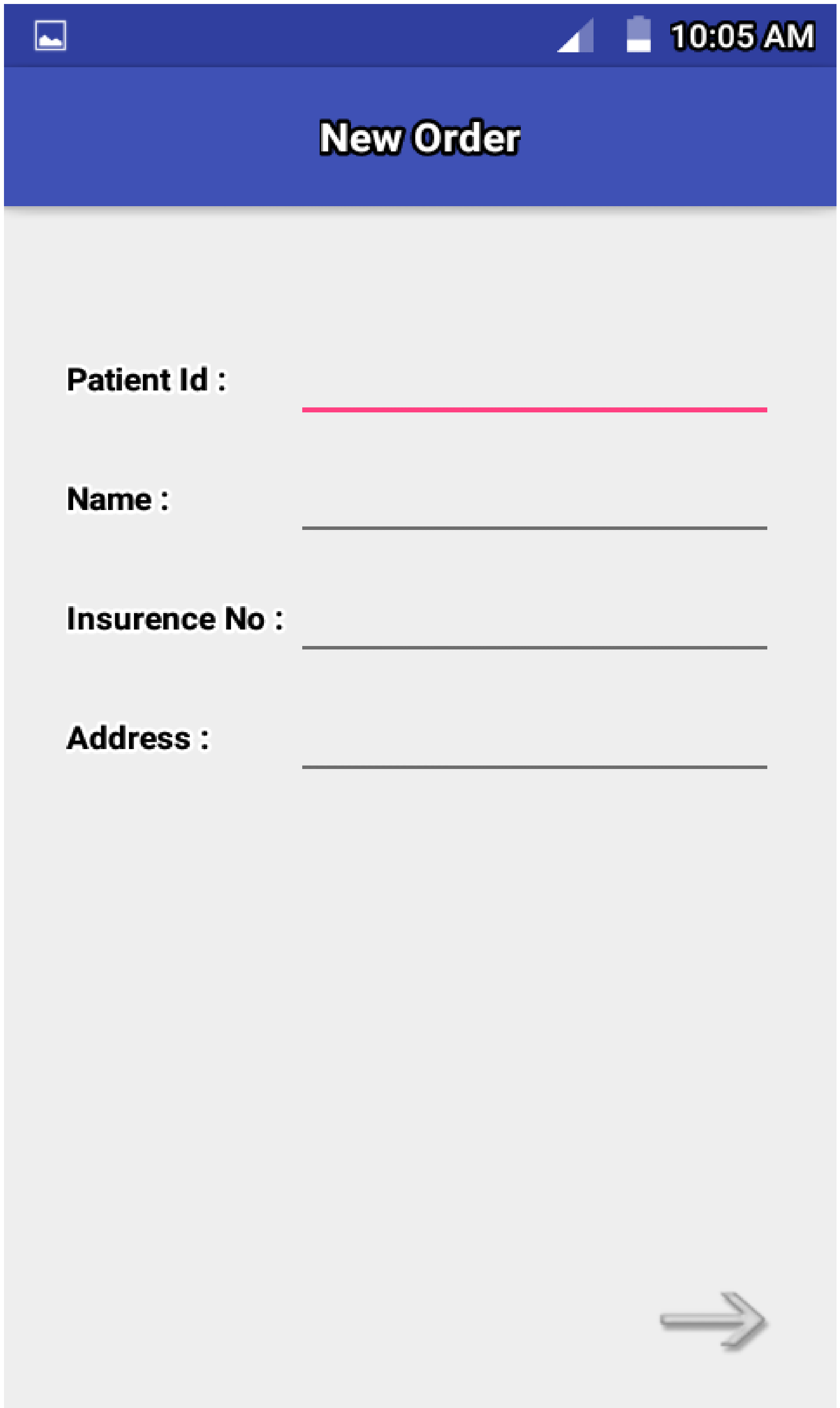


Figure 5. 2 New Order Activity

5.2.3 General Order Activity

This activity shows the general diagnosis order set.

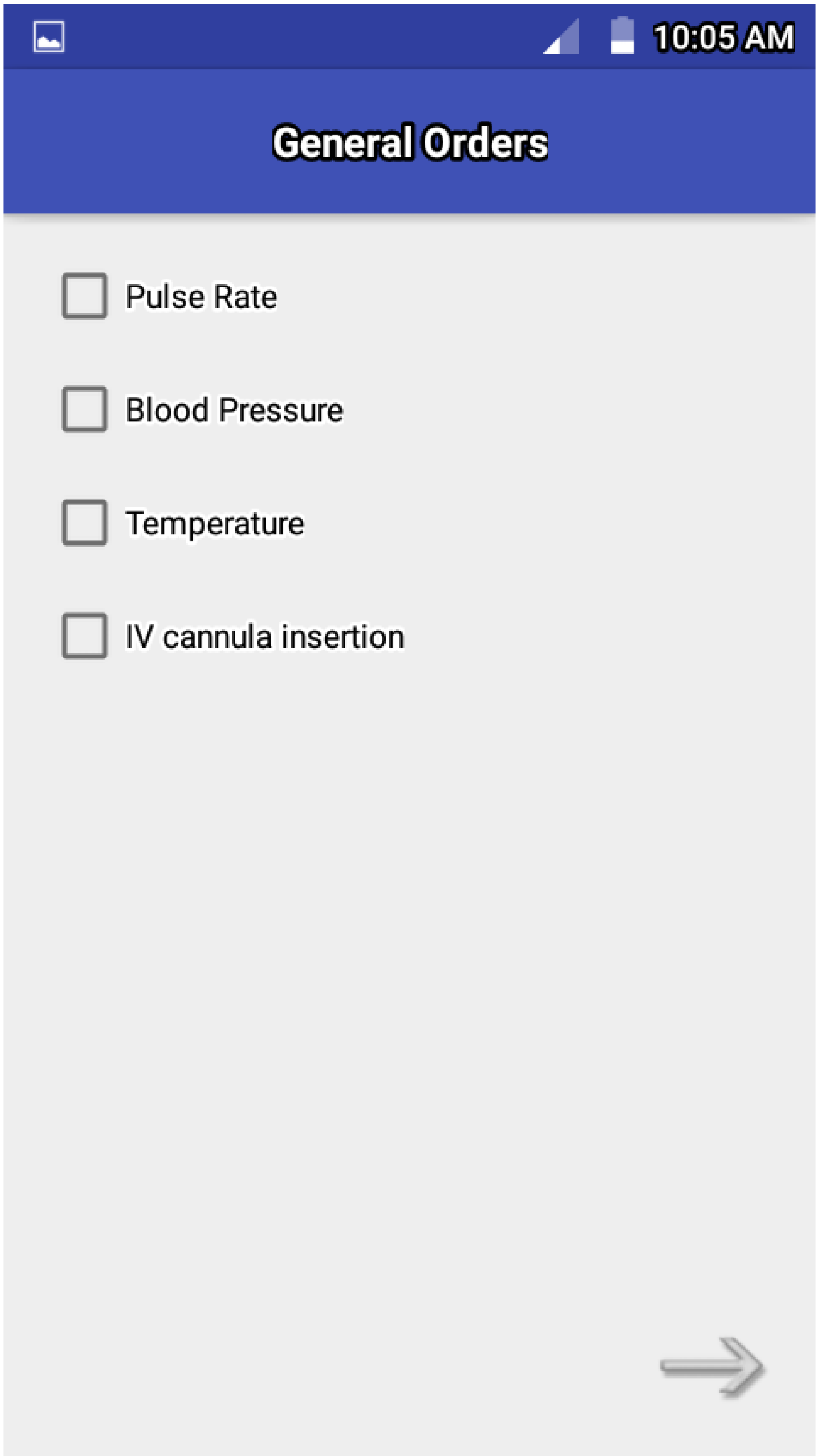


Figure 5. 3 General Order Activity

5.2.4 Diagnostic Order Activity

This activity shows the diagnostic order set.

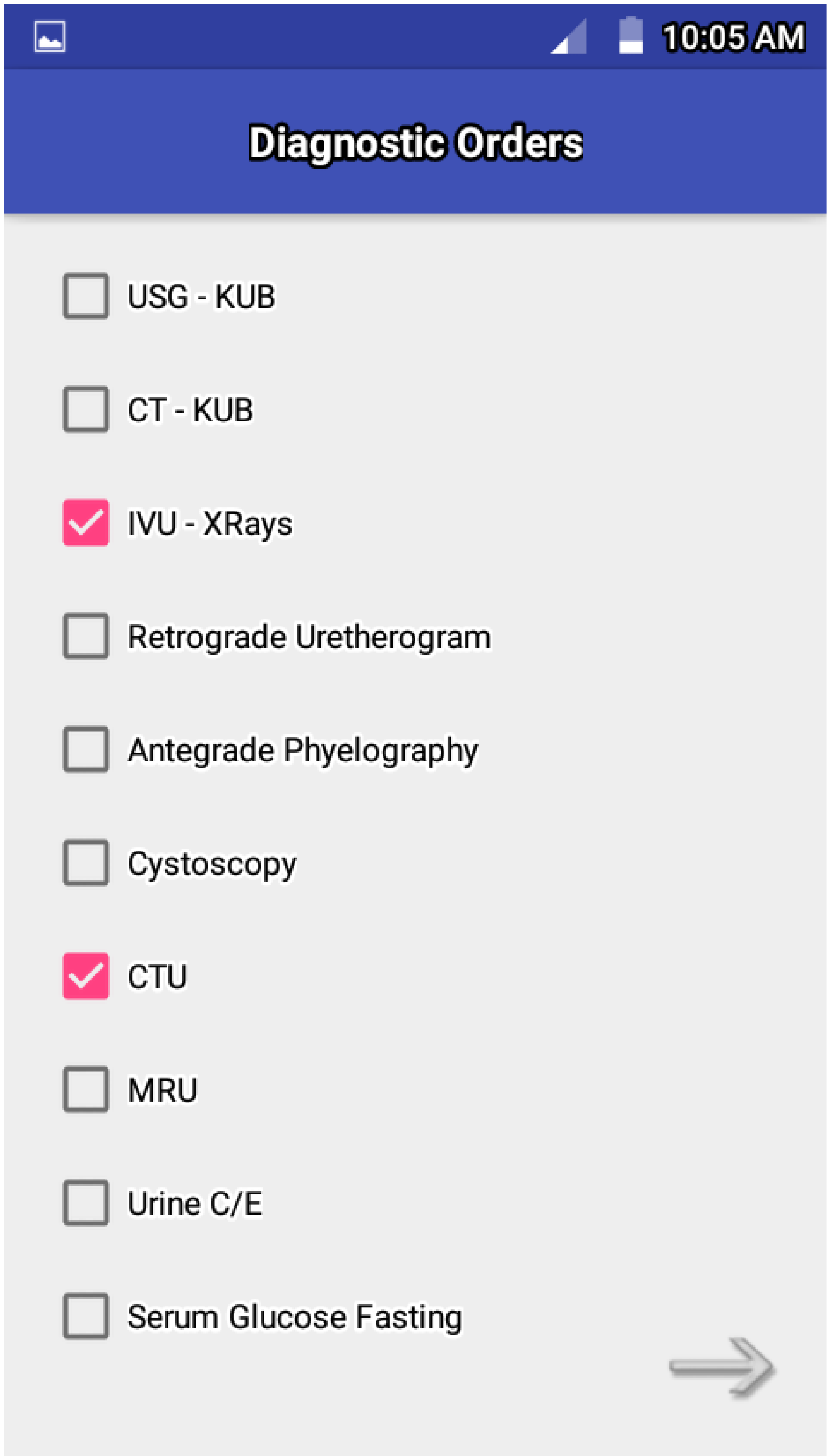


Figure 5. 4 Diagnostic Order Activity

5.2.5 Diagnosis Order Activity

This activity shows the diagnosis order and also saves physicians opinion.

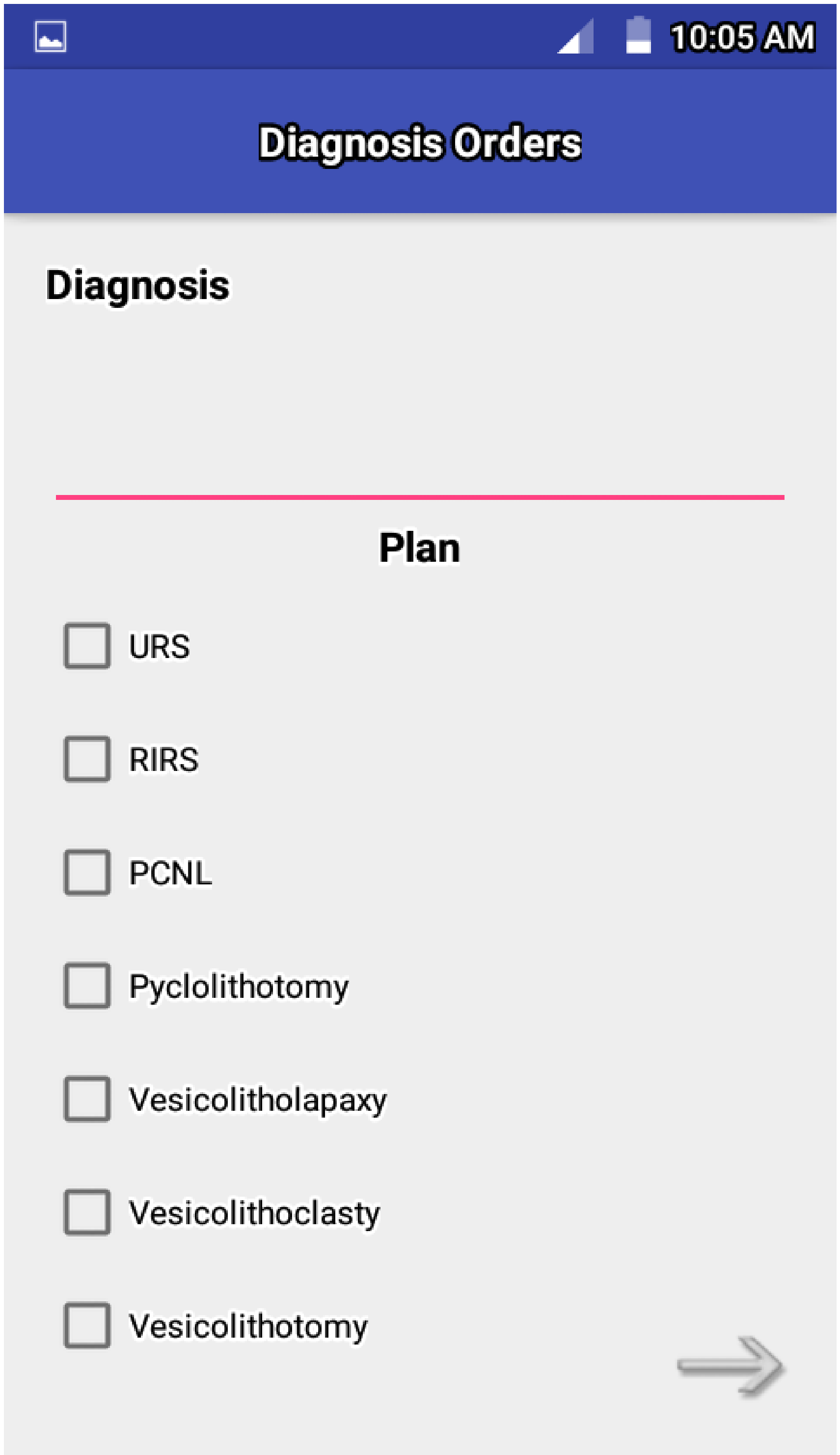


Figure 5. 5 Diagnosis Order Activity

5.2.6 Allergies Activity

This activity shows order set of allergies. If patient has any type of allergy, CDSS will take care of it while physician is prescribing the medicine.

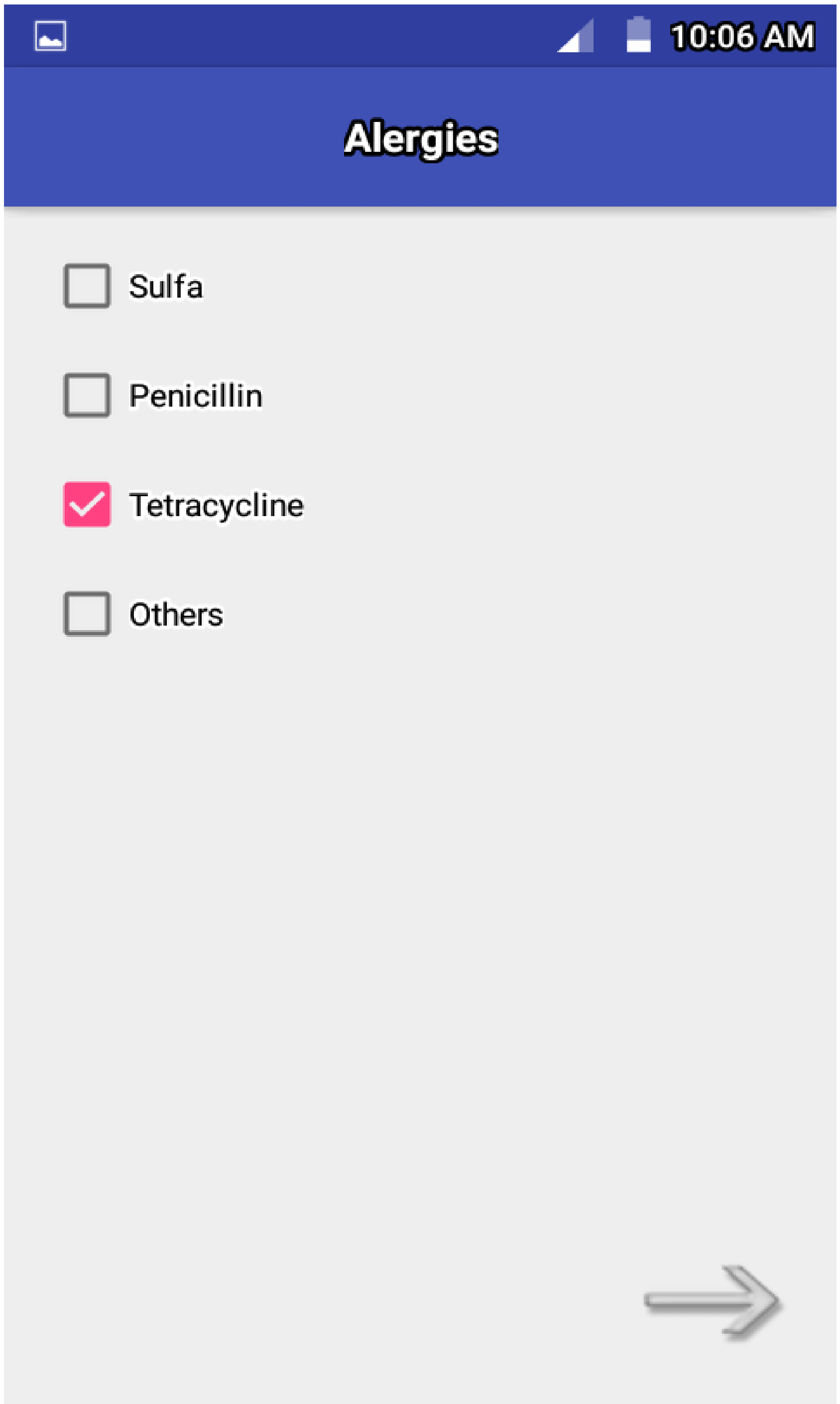


Figure 5. 6 Allergies Activities

5.2.7 Pharmacy Orders

This activity shows the CDSS supported pharmacy order set.

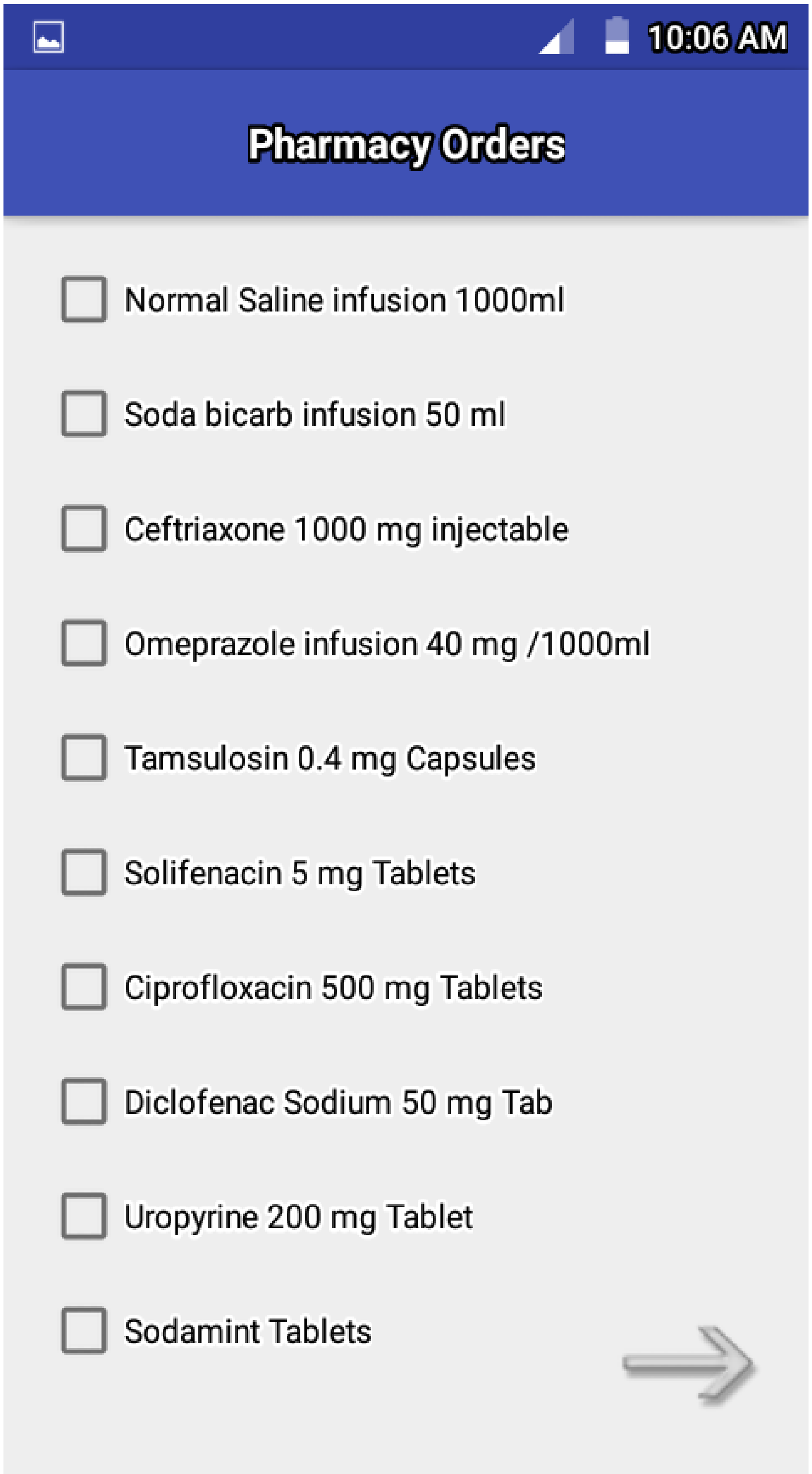


Figure 5. 7 Pharmacy Order Activity

5.2.8 Preview Activity

This activity shows an overview of generated order set.

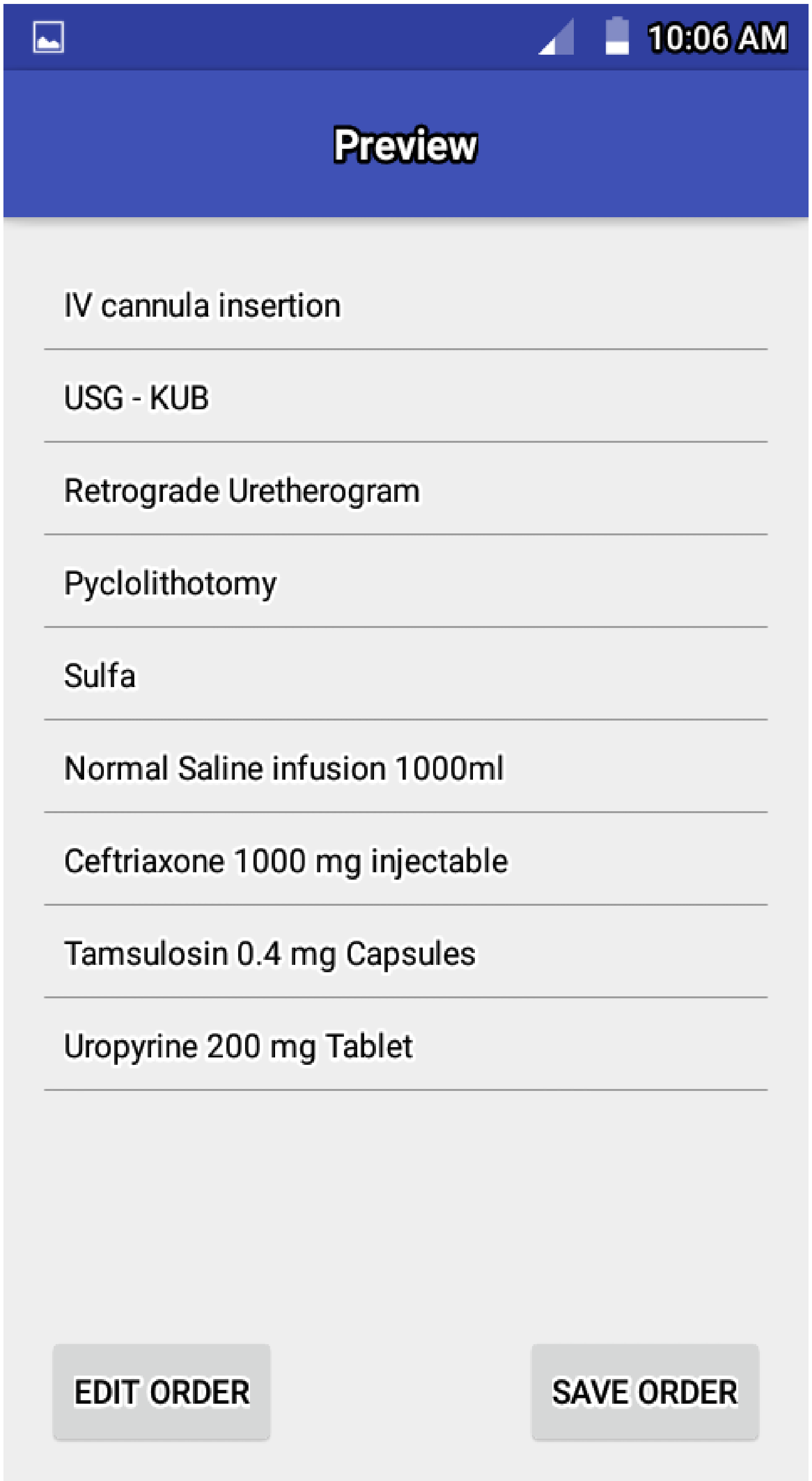


Figure 5. 8 Preview Activity

5.2.9 Existing Order Activity

This activity shows the list of existing order sets.

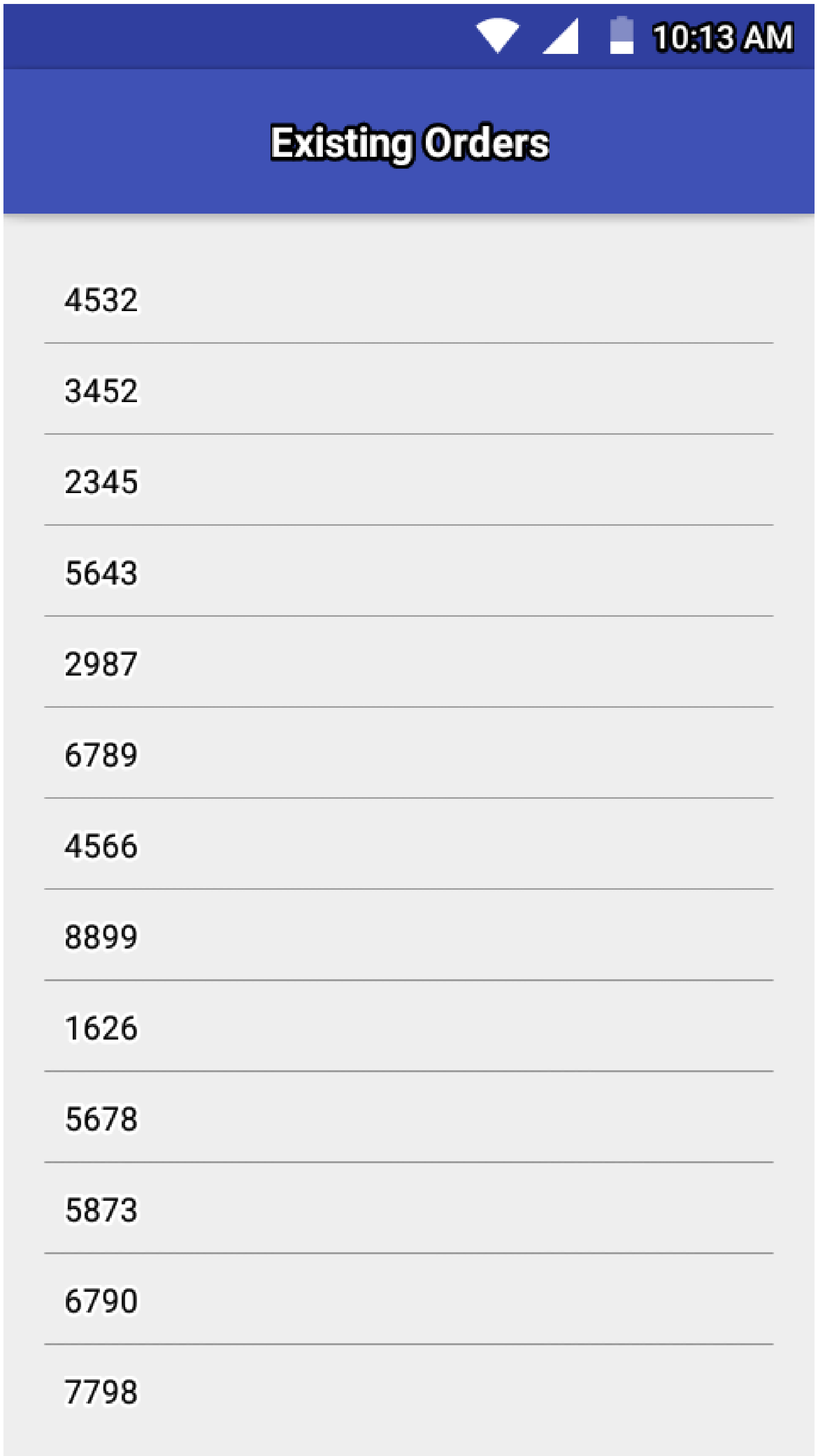


Figure 5. 9 Existing Orders List Activity

5.3 Summary

In this chapter we briefly explain the experimental implementation of our purposed architecture for this we designed order sets for urology department and also develop the android app for testing. This chapter explain each order set and complete workflow of the application.

Chapter 6 Evaluations and Discussion

In this chapter, testing, results and discussion are presented in order to examine and discuss the effectiveness and powerfulness of the system.

6.1 Evaluation

After the prototype was built, we evaluated the purposed approach by using a mix methodology of control experiment and action research to identify observations of physicians about the designed CPOE system for smart devices. Two evaluations are done for the system, first by testing experts to remove any bugs, the other by end users (physician) by applying User Acceptance Testing (UAT) to ensure that the system is meeting, this should read the requirements ‘s need.

6.2 Evaluation by testing expert

The tester did testing on the system that was developed to discover faults or defects in the system and where its behavior is incorrect or does not meet the specifications before they hand it over to end users to start User Acceptance Testing. The expert working under the development department in IT. He has experience in the same field for more than 7 years in a hospital and he was aware about the research objectives. He has worked as a tester and be a familiar with the similarity project like doctor portal. A successful test done for all the following functions:

1. Test the login function using correct and incorrect logins to check that validity of users.
2. Test patient search facility using different patient ID numbers to check that the search results is actually finding correct patient’s detail.
3. Test the system responds when click on “Prescribe medication order” page
4. Test the drug search facility using different selections on medicine to check that the search mechanism is actually finding selected one.
5. Test the mechanism to request new drug to add it in prescription list or to delete from the list.
6. Test the alert message response indicating that there is drug-drug interaction or drug-allergy interaction.

7. Test the user actions on the alert message. Test the system presentation facility to check that information about the patient and all medicine detail lists are displayed properly.

6.3 Evaluation by end users (Physicians)

After the defect testing is done, the UAT is a process where the end users evaluating a new system to make sure it meets their business requirements needs [81]. The goal of the user acceptance testing was to determine the degree of user acceptance for two selected modules of CDSS. The testing was done using demonstration sessions in which physicians participated in scenario testing. Their satisfaction on system usability was elicited using System User Scale (SUS) testing. SUS is questioner test developed by Brooke, its asked user to fill 10 questions on Liker style metric rating on a five point scale of "Strongly Disagree" to "Strongly Agree" [82],[83].The goal of SUS is to measure the user satisfaction of the system and elicit their feedback.

6.4 Participants

In order to start doing UAT, we had confirmed the participant (physicians) names in testing. We have chosen the physician role because it is their own practice and they can view the system from a business side rather than the IT staff who will view the system from a technical side. Six male physicians between 35-45 years old and with general specialty have been a participant .Those physicians are selected from the medical team of the "Doctor Portal" project to be more familiar on the goal of this research.

6.5 Setting

The test environment was established by the IT department at the training room. Technical and Physical requirements includes desktops, chairs, the PCs, network and the main demo screen.

6.6 Material

The UAT document was prepared by the analyst depend on the business requirements to present different test cases with style scenario testing for the two types of CDSS. IEEE Standard 610 (1990) defines the test case as the tests to be performed by end users with any specific data or conditions and the expected results to evaluate business requirements of the structure. A scenario is a story that describes a hypothetical situation. In testing, users check how the program interacts with this hypothetical situation [84]. The most important objectives behind running the test cases are found defects and Improve software quality [84]. For test data the CDSS provider selected medicines and an allergy list to be tested, the common medicine name causes the two types of error (drug – drug interaction and drug allergy. SUS questionnaire form placed in the last page of UAT document.

6.7 Procedure

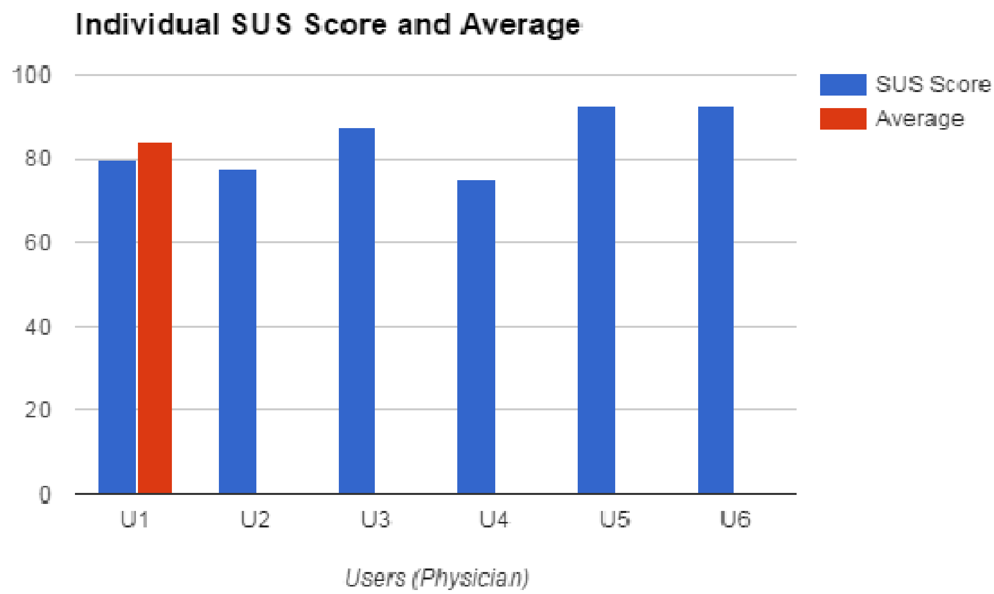
Two evaluation sessions were conducted with three physicians for each session. The session placed in main training room in IT department and lasted four hours starting form 10 am excluding a one hour break from 12-1 pm for two days. For the First 45 minutes the project manager (PM) gave a demonstration of how this prototype system works with instructions .PM started with CPOE main screen after login the system and enter testing patient ID to be used as data test for all cases then click on prescribe medication request page and focus on CDSS alert interactions .At the end of demo PM distributed the UAT document to the tester (physician) then gave instruction of how using it and how to fill the documents. The tester run the system using their user name and password to access and followed the test case steps in UAT. The *tester then records the result for each test cases detailed in "Test cases" section, the* result will be either 'Pass' or 'Fail'. If the test was failed, the tester recorded a "defect log" form, reported it to the IT developer to fix it and tested it again when resolved. The defect log includes the date, test case number and the actual result. The tester fills the SUS form to get their feedback. At the end of the evaluation session, the PM collects the documents to analyze the results.

A	B	C	D	E	F	G	H	I	J	K
Timestamp	I think that I would like to use this system frequently	I found the system unnecessarily complex	I thought the system was easy to use	I think that I would need the support of a technical person to be able to use this system	I found the various functions in this system were well integrated	I thought there was too much inconsistency in this system	I would imagine that most people would learn to use this system very quickly	I found the system very cumbersome to use	I felt very confident using the system	I needed to learn a lot of things before I could get going with this system
U1	4	3	5	2	5	1	5	2	3	2
U2	4	1	5	1	4	2	4	2	3	3
U3	5	2	5	2	4	2	4	1	5	1
U4	3	2	4	2	4	2	4	2	4	1
U5	5	2	4	2	5	1	5	1	5	1
U6	5	1	5	2	5	2	5	2	5	1

6.8 SUS Results

Excel sheet used to calculate the results of 6 SUS forms applied. The individual score and the average of SUS score is presented in Table below

A	B	C
Timestamp	SUS Score	Average
U1	80	84.16666667
U2	77.5	
U3	87.5	
U4	75	
U5	92.5	
U6	92.5	



In above figure the mapping between SUS score and the adjective metric shows that the system achieved its usability goals.

6.9 Summary

We evaluated the purposed approach by using a mix methodology of control experiment and action research to identify observations of physicians about the designed CPOE system for smart devices.

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