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Analysis of Health Care Systems using Advanced Requirement Engineering Process

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Abstract: There is an enormous growth and increasing interest in home health care systems. Many patients, especially elderly people, are having their health care needs taken care of at home. The technological advances in computing, networking, medical devices, sensors, and the pharmaceutical industry have their tangible impact on improving the home health care processes. This paper analyses the requirements of home health care systems, and attempts to apply the Requirements Engineering process. Functional Requirements, Non-functional requirements, constraints, and modelling notations will also be dealt with.

Keywords: Home Health Care Systems, Software Requirements Engineering, Software Engineering, Health Informatics

I. INTRODUCTION

Home health care is a vital demand for a growing number of patients with both chronic and acute health problems. A number of factors have combined to significantly alter the approach for treating acute and chronic diseases. These factors include the emergence of new technologies, the improvements in the pharmaceutical industry and computational drug design, varying reimbursement policies, and the persistent request of patients and their families to remain in their homes. Home health care is only appropriate for patients whose medical needs can be safely handled at home and the required time, financial, physical, and emotional resources have been taken into account [14].

The increasing number of senior citizens is calling for more burdens on the health resources of current health care services. The growth in granting home care is looked upon as an encouraging substitute for the traditional health care approach. With the aid of Sensors and digital networks, older people can experience extended independent living in their own residences. There is no doubt that their quality of life is improved when they stay at an environment they have been accustomed to while receiving home care. Home health care will relieve both formal and informal caregivers of their worries about their older patients [25].

Based on what has been mentioned above, it is very demanding to develop a software system for home health care. Requirements Engineering (RE) is the first key sub process following the conclusion of a statement of need. It has to do with the identification of goals to be accomplished by the potential system, the filtering out of such goals and manipulating them to determine the specifications and constraints. Software requirements characterize what should be done to satisfy the needs of the stakeholders [9], [17], [22]. Software requirements must satisfy the stakeholders' needs to ensure the right system is later developed. The process by which these needs are identified is referred to as requirements engineering (RE). In order for the requirements engineering process to be successful, it must not only recognize the needs of customers and users, but it must exhibit further understanding of the context in which the software will run. RE involves modelling, analysing, negotiating, documenting, validating, and managing requirements [2]. There are a number of techniques for developing requirements specifications. These include structured, object-oriented, algebraic specification, prototyping, and domain model methods [23]. A critical issue here is to understand user requirements. Misunderstanding of requirements among software developers and stakeholders will trigger problems in satisfying needs, isolating and fixing defects, and estimating costs and schedules during the software development process [8].

One of the main objectives of Requirements Engineering (RE) is to enrich systems modelling and analysis potentials so that businesses can better comprehend vital system aspects before they actually develop the system [20]. The functional requirements together with quality attributes and other non-functional requirements will establish the software requirements specification [26]. Functional Requirements are the domain specific capabilities of the system. They represent what the developed system will do without any regards to how it should be done. Non-functional

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Requirements are the constraints placed on the functional requirements, or quality requirements. These include a variety of properties including performance, policy constraints, safety, privacy, reliability and security. They are generally determined at some point after the business process modelling is carried out. The non-functional characteristics of the business are believed to be harder to encapsulate in business process modelling, as the focus of the modelling is on functional behaviour [16]. In situations where patients are involved, security and safety are critical. Security goals evolve when stakeholders ascertain that tangible or intangible objects in the context of the system have direct or indirect value that the stakeholders want to protect. Based on these goals, security requirements are derived as constraints on the functional requirements [6]. For information security to be effective, it must be built into the software development process rather than affixed to an already insecurely designed system. Appropriate security requirements that are well lined up with the business goals are indispensable for secure design that improves product capability and return on investment [24].

Requirements engineering for home health care is a hard process as it involves a number of stakeholders including patient, primary doctor, other doctors, nurse, formal caregiver, informal caregiver, government agencies, and other agencies [5], [18]. Home health care systems encompass a number of stakeholders who have different interests and are capable of impacting the performance, operation, and behaviour of the system in different ways [12]. Each party participating in the home care system has diverse viewpoints, perspectives, desires, and liabilities. These are further complicated by being subject to change as a result of changing conditions and behaviours of both the stakeholders and the system [4], [11].

Home care systems are distinguished by key features. They are multi-user, multi-stakeholder, collaborative, and distributed. A home care system interaction is multimodal, and its needs are dynamic. Furthermore, care conditions and care relationships are complex. The complexity of home care software requirements makes granting home care solutions a hard assignment [13]. Information technology support for home health care is
a growing area within health care systems development. Home health care distinguishes itself from other care delivery styles in various ways. The construction of home health care systems must be established on a thorough analysis of essential software requirements to secure safe and reliable health care [10]. Furthermore, some cognitive analysis of the home health care process reveals important requirements that should be met [1].

There are a number of techniques to modelling, representing, and checking requirements. Some of the approaches are; Case-Driven, Viewpoint-Based, Behavioural Pattern Analysis (BPA), Software Architecture Orientation, and Formal Methods approaches [3], [7], [15], [19], and [21].

This paper attempts to analyse home health care systems and provides a thorough study on various essential requirements for such systems. Both functional and non-functional requirements will be demonstrated. In addition various constraints on home care systems are presented. Finally, a number of modelling notations will be investigated.

II. FUNCTIONAL REQUIREMENTS

A. Functionality

The functionality of a system is measured by how well that system meets the functional requirements of the stockholders. The functional requirements exhibits what the system should do without any regard on how they could be done. A partial list of functional requirements that are deemed to be necessary for home care systems include:

A.1 The system shall allow its user to update their personal information.
A.2 The system shall allow the primary doctor to update patient information, such as diagnosis, remediation, referrals, health conditions, and prescriptions.
A.3 The system shall allow the primary doctor to review the records of a specified patient.
A.4 The system shall allow the primary doctor to establish a health plan for a specified patient, which includes the identification of short-term and long-term goals based on a patient's own specific conditions.
A.5 The system shall allow the primary doctor to review and modify the home care plane.
A.6 The system shall allow the primary doctor to write prescriptions and forward them to the patient's pharmacy.
A.7 The system shall allow the primary doctor to review the medical prescriptions of a specified patient.
A.8 The system shall allow the primary doctor to get health status reports for a specified patient from the caregiver.
A.9 The system shall allow doctors to categorize patients into various risk levels so that the patient can have different priority-based treatments when an emergency occurs.
A.10 When an emergency event is encountered, the system shall automatically generate an alarm to notify the patient's primary doctor, and, when necessary, the available emergency department (911).

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A.11 The system shall allow the patient's primary doctor to summarize the patient's home stay status.
A.12 The system shall allow the patient's primary doctor to schedule appointments for their patients, for both home and office visits, depending on their case progress.
A.13 The system shall allow direct communication between the patient's primary doctor and patient's caregiver regarding their patients.
A.14 The system shall allow doctors to search and review the information available about home care agencies' services to recommend effective service for their patients.
A.15 The system shall allow communications between doctors and home care agencies when necessary.
A.16 The system shall allow caregivers to read and automatically record the temperature, blood pressure, and sugar level for a specified patient using medical equipment and sensors.
A.17 The system shall allow the caregiver to get the prescription written by the primary doctor for a specified patient.
A.18 The system shall allow the patient to review their prescriptions and doctors instructions.
A.19 The system shall allow hospitals to access and update patients' health records whenever they are hospitalized for any reason.
A.20 The system shall generate bills and forward them to the insurance company, government agency, and the patient.

B. Data

Data Requirements refer to the type of data, its precision and accuracy, the persistence of data, and the data format. Below, we present some of the home health care data.

B.1 Fixed Data Fields: These fields include the standard attributes that all users share including name, date of birth, address, phone number, email address, sex, and ID.
B.2 Medical Data: This category includes diagnostic and treatment data using both medical codes and text.
B.3 Sensors Data: This data represents the readings from various sensors, such as temperature, blood pressure, and blood sugar level.
B.4 Image Data: Under this category, various images are stored, such as X-rays, and EKG images.
B.5 Accounting Data: This data provides all the fields needed for producing bills and invoices.
B.6 Service Data: Includes data needed for government agencies and home care agencies.

III. DESIGN CONSTRAINTS

Design constraints force designers to ensure that their final product will be created based on these constraints. If these constraints are not taken into consideration, the system will suffer and ultimately fail.

A. Physical Environment

Physical environment refers to the equipment and devices used, locations where the system will run, inferences such as temperature, pressure, and noise, constrains on programming languages, operating systems, and database management systems, constraints on the power supply, heating and cooling, etc.

A.1 The system will use devices and sensors for various measurements, such as temperature, blood pressure, and sugar level.
A.2 The sensors and devices should be located at the patient residence.
A.3 The room temperature shall be set to that required by medical devices to allow them to function properly.
A.4 The programming part shall be written using Java.
A.5 The database management system will be the same as the one in the primary doctor's office.
A.6 The system should run under Windows 7, Linux, and UNIX.
A.7 The computer and all the devices should be connected to Uninterrupted Power Supply (UPS).
A.8 Depending on the status of the patient, a generator may be needed.
A.9 An emergency alarm system will be installed and connected to the home care system.

B. Interfaces

Interface includes all interactions between humans, other software systems, and various devices with the home care system. It should be unambiguous, easy to use and learn, flexible, robust, and cater to various skill levels and environments. Some of these interfaces involve:

B.1 The system should provide various techniques of interface including GUI, voice, and touch screen.
B.2 The system should tailor the interface to each user's needs to enforce privacy and security of the patient's information.

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B.3 The home care systems should allow an interface with hospital systems (computers).
B.4 The home care system should offer an interface with government agencies' systems.
B.5 The home care system should provide an interface with home care agencies' systems.
B.6 The home care system should present an interface with the lab to get the test results directly.
B.7 The home care system should grant an interface with the X-ray and EKG units to acquire the images directly.

C. Users

One of the reasons behind the complexity of home care systems is the large number of stakeholders with different needs and viewpoints. The stakeholders involved in the home health care system include hospitals, primary doctors, patients, caregivers, nurses, informal caregivers, insurance companies, emergency (911), pharmacies, physical therapy agencies, and home care agencies. The caregiver is the main person who takes care of the patient. The informal caregiver is a family member or neighbor who has the capabilities to help the caregiver take care of the patient. Other stakeholders could be later added as appropriate.

IV. PROCESS CONSTRAINTS

A. Resources

Resources are very critical for home care systems as they can have crucial impact on the well being of patients. These involve personnel including IT team, equipment, and materials needed for continuous and efficient operation of the system. Examples of the needed resources include:

A.1 Software Engineers/developers.
A.2 IT maintenance (software and hardware) team.
A.3 Network engineers.
A.4 Primary doctors, formal and informal caregivers.
A.5 Personal computers or laptops.
A.6 Servers.
A.7 Medical devices.
A.8 Medical devices maintenance engineers.
A.9 Batteries for various medical equipments.

Documentation

Poor documentation will have its tangible drawbacks on systems no matter how efficient and robust their designs are. Documentation requirements must take the needs of different users into consideration. Various documents are needed including:

B.1 An online help system and tutorials for each user.
B.2 Online and hard copies of user manual for each individual user involved in the system.
B.3 The Software Requirements Specification (SRS) document.
B.4 The software requirements document.
B.5 Documentation of the architectures
B.6 Documentation of the design
B.7 Documentation of testing and test cases.
B.8 Documentation of maintenance procedures.
B.9 Programmer manuals.
B.10 Interface documentation including devices and sensor interfaces.

B. Standards

Systems must abide by some external or internal (within the organization) norms. These may include legal, ethical, and environmental control standards. The home care system will be constrained by the following standards:

C.1 The system shall adopt the ICD-9-CM diagnostic codes issued by International Statistical Classification of Diseases and Related Health Problems (ICD) required for completing CMS (standard claim form) billing forms.
C.2 The system shall follow the guidelines for Medicare, and for home medical equipment.
C.3 The system should follow the Prospective Payment System (PPS) and Pay for Performance (P4P) for home care reimbursement mechanisms.
C.4 The system shall abide by the privacy rules of HIPAA (The Health Insurance Portability and Accountability Act).

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V. NON-FUNCTIONAL REQUIREMENTS

Non-functional Requirements represent constraints or quality measures that the system should abide by. They depict some quality attributes that the home care system must own, such as performance, security, privacy, and reliability.

A. Performance

Performance deals with constraints on the speed of executing various parts of the system, storage size data flow, and response times. Below are some of these constraints.

A.1 The system should allow every user to sign in within 5 seconds.
A.2 The system should be able to list a summary of a patient's records, when requested by the primary doctor, within 30 seconds.
A.3 The system should be able to retrieve the patient's standard information within 5 seconds.
A.4 The system should be able to list the detailed home care information of a specific patients (could be a home care plan, prescription, physical examination report etc. based on doctor's selection) within 5 seconds.
A.5 The system must ensure that the prescription be sent to the pharmacist within 15 seconds.
A.6 The patient's physical examination report must be retrieved within 5 seconds.
A.7 If an emergency is encountered, the system should process the alarm signal within 2 seconds.

B. Usability and Human Factors

These are the constraints dealing with training humans, and how easy using the system would be as a result of this training.

B.1 Primary doctors need to be trained on updating (modifying, deleting, inserting) the patient records, and obtaining detailed and summary reports.
B.2 Formal caregivers and informal caregivers should be trained on using the sensors and devices.
B.3 Formal caregivers and informal caregivers should be trained on entering data and obtaining summary reports.
B.4 Accounting staff should be trained on the accounting part of the system to enter invoices and create billing reports for insurance and patients.
B.5 Home care agencies should be trained on accessing the information related to the patient's needed services.
B.6 Patient and caregivers should be trained on using the alarm in case of an emergency.
B.7 Since doctors deal with critical patients' information, their training should make it extremely easy to avoid devastating consequences.
B.8 Any misuse of the sensors and devices could give raise to dreadful results. Therefore, training patients, and caregivers should make misusing devices out of the question.

C. Security

Security is essential for home care systems. Several organizations and individuals collaborate including medical centers, insurance companies, government agencies, and pharmacies. These collaborative boundaries stipulate strict security measures. Security requirements will ensure the security measures are met in order to detect vulnerabilities and prevent attackers from exploiting these weak points in the system to cause some harm. Some of the home care system security constraints are:

C.1 The home care system must grant each authorized patient a unique identification, user name, and password.
C.2 The home care system shall authenticate each patient with a unique identification.
C.3 The home care system's users should authenticate each other prior to communication.
C.4 The communication between the patient and other users shall not allow any other person to intrude.
C.5 The home care system shall send the prescription to the pharmacist in a strictly secure manner.
C.6 If the patient requests a copy of the prescription from the home care system, the home care system shall ensure the transmission of the prescription to the patient is secure.
C.7 The home care system shall guarantee that any bill sent to the patient is transferred securely.
C.8 If the patient is insured, the bill imposed by the home care system needs to be sent to the insurance company in a secure mode.
C.9 If the patient or a family member has to pay for the bill of the visit using a credit card, the home care system shall protect the credit card details.
C.10 The home care system shall allow primary doctors to only access their own patients' records.

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D. Privacy

By law, patient information is strictly confidential. Privacy constraints force home care systems to treat all patient's details in a very high confidential manner. Samples of these requirements include:

D.1 The home care system shall guarantee the privacy of the communication between the patient and the doctor.
D.2 The home care system shall enforce the privacy of the test results, which will be sent to the patient, or informal caregiver.
D.3 If the doctor needs to write a prescription to the patient, the home care system shall ensure the prescription's privacy.
D.4 The details of the consultation, including any test results, which are communicated to the patient and the doctor, will be strictly confidential.
D.5 Only patient's insurance-related information shall be sent to the insurance company.
D.6 The home care system shall ensure that home care agencies receive only the patient's information related to services and social work.
D.7 Government organizations associated with home health care shall only receive information regarding the services offered to patients and the bills.
D.8 The home care system shall allow the lab staff to enter test results without being able to access patients' medical information.

E. Reliability and Availability

Quality home care systems cannot have many failures, but if they do, there must be a long time between failures. These systems are critical for patients. If they become unavailable, tragic consequences (possible deteriorated health conditions or even death) may be experienced. Reliability and availability requirements will ensure these consequences will be prevented or at least their impact minimized. Here are some of these requirements.

E.1 The system shall be available 24 hours per day, 365 days per year.
E.2 The sensors and devices at the patient's residence shall be available 24 hours per day, 365 days per year.
E.3 The system shall be able to detect and isolate faults, and be able to correct them automatically.
E.4 The mean-time-between-failures (MTBF) should be at least 6 months.
E.5 The system should be able to restart within 15 minutes after a failure.
E.6 The system should be backed up on a daily basis. E.7 The backup copies must be stored on external hard disk and saved at a different location where they shall be protected from fire or water damage.

F. Maintainability

Developed health care systems may suffer from flaws that were not detected through the various testing techniques that were applied. In addition, new requirements may arise in the future. If these flaws force a complete re-development, the system is not maintainable. The safeguards against this problem are the following maintainability requirements.

F.1 The system should be flexible enough to allow error correction.
F.2 The system should be flexible enough to allow future improvements.
F.3 The system should provide for self-maintenance whenever possible.
F.4 The system should be able to run for at least one year before initiating any improvements.
F.5 After the first year, only new functionality could be added to the system.
F.6 The system should have backup power support to avoid power failure.
F.7 The system should be able to generate fault reports automatically, and allow exporting them into a file, displaying them on the screen, or printing them.

VI. SYSTEM MODELS

Home care system specifications can be represented using some system models. These are graphical notations that depict business processes, the problem that we are investigating, and the system we want to develop.

They represent the bridge between the analysis and the design processes [22]. They supply an ample construct for what should be elicited, and adjusted. Furthermore, they offer the foundation for early discovery and correction of errors in requirements [9].

Below are some of these models. The figures below were produced using IBM Rational Software Architect.

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A. Entity –Relationship Diagram

The Entity Relationship Diagram (ERD) is a conceptual model that identifies the objects involved, their features, and how they interact with each other. Figure 1 depicts an ERD for the home health system.

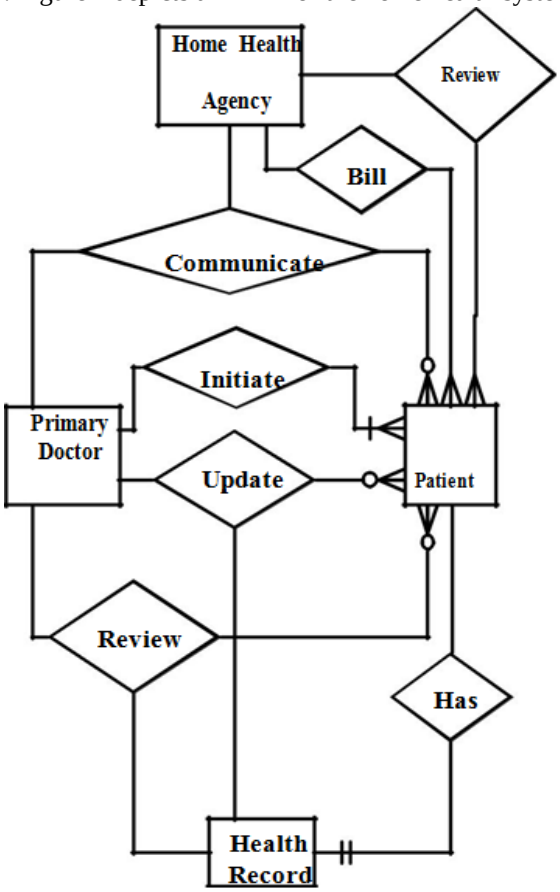

Figure 1: An ERD for Home Care System

B. UML Class Diagram

The Class Diagram is a UML model that relates classes in the specifications to each other. It reveals the attributes and methods for each class. It also describes various relationships between the classes. This is illustrated in Figure 2.

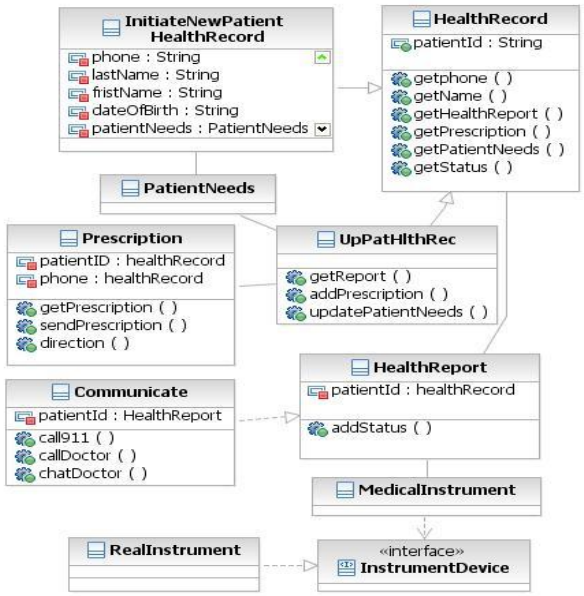

Figure 2: A Class Diagram for Home Care System

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C. Data Flow Diagram

The Data Flow Diagram is used to understand how data flows between various entities and the functionality of the system. Figure 3 shows a data flow diagram.

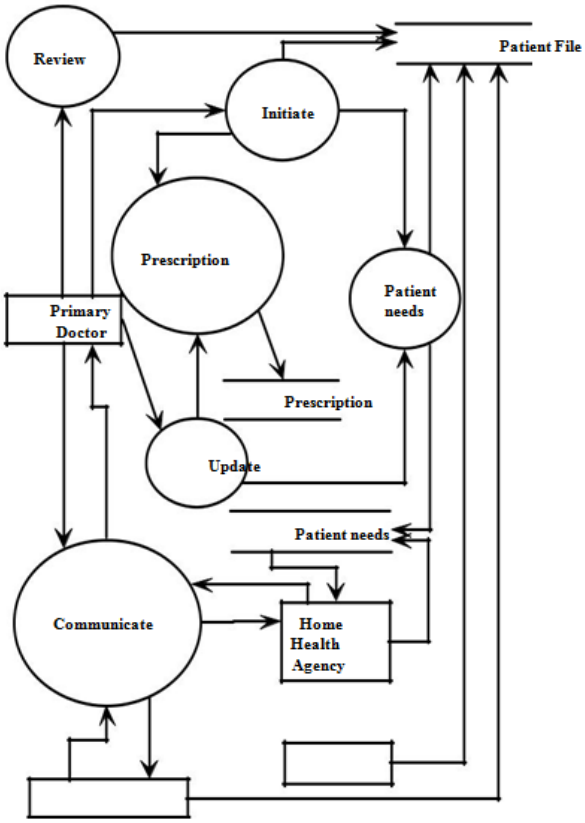

Figure 3: A Data Flow Diagram for Home Care System

D. Use cases

Use cases encompass several likely scenarios connected to some usage of the system. They describe system functionality in terms of interaction between the system and its environment [17]. Figures 4 and 5 illustrate this.

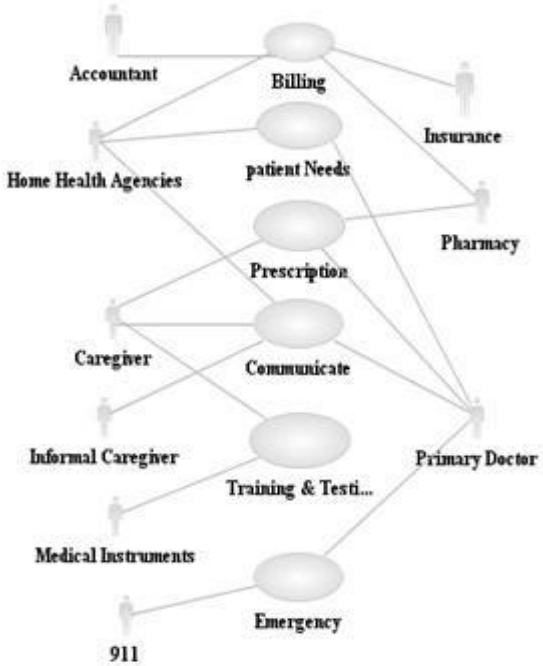

Figure 4: A Use Case Diagram for Home care System

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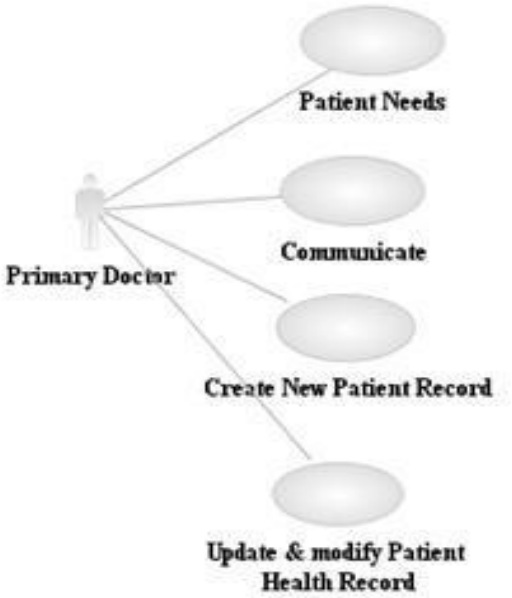

Figure 5: Primary Doctor Use Case Diagram

VII. CONCLUSION

Software Requirements Engineering is a very critical process for software systems. This is particularly valid for health home care systems. With the increasing rate of elderly needing home care, this engineering process should ensure that the needs of the patients are fully met to avoid future fatal consequences when the system is implemented. The output of this process─ system requirements─ is used as an input and a guide for all ultimate processes including design, testing, and maintenance. If this input has flows or is incomplete, the design will be incorrect or incomplete.

This paper presents a thorough analysis of home care system requirements using the requirements engineering process. Both functional and non-functional requirements are investigated. Furthermore, design and process constrains are examined. To get better insight into the home care business processes, the problem, and the system, a number of graphical notations are used. This will help developers to further understand and analyze the requirements.

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