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ORIGINAL ARTICLE SOFTWARE ENGINEERING

Towards an Enhanced Approach for Big Data Requirement Generation Based on the KAOS Model: A Case Study of Electronic Health Records in Benghazi-Libya

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ABSTRACT

Problem statement: Big data systems face a challenge in the requirements engineering phase, given that the nature of their data differs from that of traditional systems. They include structured, semi-structured, and unstructured data, come from multiple sources, and are characterized by the 5Vs (volume, variety, velocity, veracity, and value). Despite increasing research efforts, there is still a lack of a comprehensive framework for managing the requirements of big data systems across their various engineering stages, making their development a complex process. **Methodology**: The study proposed an approach for generating big data requirements based on the KAOS model, with the aim of organizing and analysing requirements in a systematic manner. The proposed approach was applied through a case study on the electronic health records (EHR) system in Benghazi and evaluated through a questionnaire involving 100 participants who are specialists in the field to assess the effectiveness and applicability of the proposed methodology. The questionnaire was not just a series of questions; the proposed approach was presented to participants, who were then given the opportunity to express their opinions about it. **Findings**: The survey results showed that participants had positive impressions of the quality of the proposed approach and its suitability for big data applications. Participants indicated that the approach could be adopted in the future as an effective tool for improving the quality of the requirements engineering process in big data environments. **Contribution**: This study contributes to filling a knowledge gap in the field of requirements engineering for big data systems by: presenting an applied approach based on the KAOS model for requirements generation; integrating theoretical and practical aspects through a real-world application in the health sector; and providing a quantitative evaluation mechanism to measure the acceptability and quality of the proposed approach. **Limitation**: The approach was applied to only one area (electronic health records), leaving room to try the proposed approach in other areas so that its results can be more widely disseminated. Furthermore, the approach focused only on the requirements generation process as a supporting approach to the requirements engineering phase, which includes other activities such as requirements documentation, verification, and management.

نحو نهج معزز لتوليد متطلبات البيانات الضخمة استنادًا إلى نموذج كاوس: السجلات الصحية الإلكترونية في بنغازي - ليبيا كحالة دراسية

محمد حجل [1,*]، سناء الترهوني [2]

الكلمات المفتاحية
متطلبات البرمجيات
البيانات الضخمة
نموذج كاوس
نماذج استخدام خرائط الحالة
لغة النمذجة الموحدة
نظام السجلات الصحية الإلكترونية

الملخص

المشكلة: تواجه أنظمة البيانات الضخمة تحديًا في مرحلة هندسة المتطلبات، نظرًا لاختلاف طبيعة بياناتها عن تلك الخاصة بالأنظمة التقليدية. فهي تشمل بيانات منظمة وشبه منظمة وغير منظمة، وتأتي من مصادر متعددة، وتتميز بخمس خصائص (الحجم والتنوع والسرعة والدقة والقيمة). على الرغم من الجهود البحثية المتزايدة، لا يزال هناك نقص في إطار شامل لإدارة متطلبات أنظمة البيانات الضخمة عبر مراحل هندستها المختلفة، مما يجعل تطويرها عملية معقدة. **المنهج** : اقترحت الدراسة نهجًا لتوليد متطلبات البيانات الضخمة استنادًا إلى نموذج كاوس، بهدف تنظيم المتطلبات وتحليلها بطريقة منهجية. تم تطبيق النهج المقترح من خلال دراسة حالة على نظام السجلات الصحية الإلكترونية في مدينة بنغازي وتقييمه من خلال استبيان شارك فيه 100 مشارك من المتخصصين في هذا المجال لتقييم فعالية المنهجية المقترحة وقابليتها للتطبيق. لم يكن الاستبيان مجرد سلسلة من الأسئلة؛ فقد تم عرض النهج المقترح على المشاركين كطريقة أولى للتقييم (تجريبية)، من ثم أتيحت لهم الفرصة للتعبير عن آرائهم حوله. **النتائج**: أظهرت نتائج الاستطلاع أن المشاركين لديهم انطباعات إيجابية عن جودة النهج المقترح ومدى ملاءمته لتطبيقات البيانات الضخمة.. أشار المشاركون إلى أن النهج يمكن اعتماده في المستقبل كأداة فعالة لتحسين الجودة. **القيود**: تم تطبيق النهج على مجال واحد فقط

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(السجلات الصحية الإلكترونية)، مما يترك مجالاً لتجربة النهج المقترح في مجالات أخرى بحيث يمكن نشر نتائجه على نطاق أوسع.
علاوة على ذلك، ركز النهج فقط على عملية توليد المتطلبات كنهج داعم لمرحلة هندسة المتطلبات، والتي تشمل أنشطة أخرى مثل توثيق المتطلبات والتحقق منها وإدارتها.

Introduction

Big Data is now a crucial element in many businesses where vast amounts of data are produced, saved, and examined. The phrase "Big Data" was initially used in academic settings [1] and describes large datasets that are examined to find trends and patterns that help with decision-making in a variety of fields. However, the complexity of these datasets—which include structured, unstructured, and semi-structured data from diverse sources—makes it challenging to extract meaningful insights due to their size and heterogeneity [2]. These difficulties highlight the necessity of specific requirements engineering (RE) techniques that can handle the distinctive qualities of Big Data, including volume, diversity, velocity, truthfulness, and value [3]. A key component of RE, requirements elicitation is essential to the construction of successful information systems [4]. Because gathering needs from stakeholders in Big Data systems is very different from traditional systems, researchers are looking for novel ways to make this process easier. Finding functional and non-functional requirements that support business goals is the task of software requirements engineering. Issues during the RE phase, like as ambiguous or contradictory requirements and inadequate stakeholder engagement, are the root cause of many software project failures [5].

The procedures and difficulties involved in creating Big Data systems have been the subject of numerous research. An exploratory case study in the Oil & Gas area, for example, brought to light the difficulties in designing such systems and their consequences for every step of the software engineering life cycle [6]. The elicitation, specification, analysis, and prioritizing of system needs, the sources utilized to find requirements related to big data, and the use of big data technologies and attributes in RE and system design were among the main topics covered. In addition, the study identified a deficiency of project-specific RE techniques, tools, and frameworks for efficiently managing needs related to Big Data and recommended additional research to improve comprehension in this area.

Further study has highlighted typical issues in RE for Big Data systems, including as unclear or incomplete requirements, poor prioritizing, and low user interaction, all of which have an impact on requirement quality. In order to improve the accuracy and quality of requirements, researchers have put forth frameworks that combine agile approaches, mind mapping, and classical elicitation techniques [7]. The lack of specific tools, methods, and frameworks designed for Big Data systems makes it difficult to effectively capture and analyze requirements in spite of these efforts [8][9]. Additionally, research has shown how difficult it is to manage a variety of stakeholders and match system requirements with business goals, as well as how requirements might change over time [10]. These results highlight the need to further explore elicitation strategies appropriate for such complex contexts and close the research-practice gap in RE for Big Data systems.

Due to the complexity of the needs, the unique properties of the data, and the inherent constraints of stakeholder participation, effectively collecting requirements for Big Data systems is extremely difficult. As a result, a more efficient method that improves the requirement generation process in Big Data situations is obviously needed.

The issues of efficiently creating requirements in Big Data systems are addressed in this work by presenting an enhanced method for requirements generation in Big Data systems that incorporates the KAOS model with the phases of requirements engineering activities.

The rest of this paper is organized into the following sections: The proposed approach is presented in Section II. Section III describes the case study. Section IV explores the results and discussion of this study. The conclusion is discussed in Section V, and Finally, Research recommendations are then presented in Section VI.

The proposed approach An enhanced approach for generating requirements for big data systems based on the KAOS model is presented in this section. The defined phases within this approach collectively form a comprehensive framework aimed at streamlining the entire requirements development process. This approach consists of four key components: the Goal Model, the Responsibility Model, the Object Model, and the Operating Model. The proposed approach seeks to integrate the KAOS model with various requirements engineering activities, including requirements elicitation, analysis, design, documentation, and validation. To effectively address the challenges associated with requirements gathering in big data systems. Fig.1. shows the proposed approach.

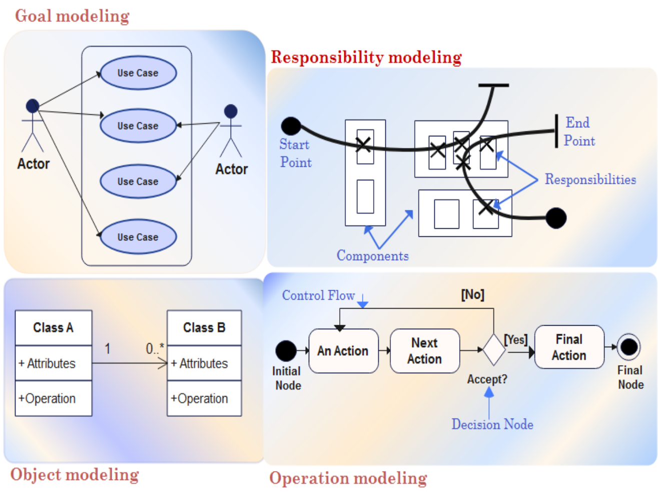

Fig. 1: The proposed approach

The life cycle of the proposed approach consists of the following phases derived from the integration of the KAOS model and requirements engineering activities.

<u>**Goal Model**</u>: In this phase, the primary goal is to derive goals and understand needs and expectations through interaction with stakeholders and system users. A variety of techniques, including interviews and observations, are used during requirements elicitation to gather and define high-level goals from stakeholders and system users. It can be considered the

most important phase in developing high-quality systems. Failure at this phase will result in a significant increase in cost and time in later phase of development. These goals are then adapted through a use case diagram, one of the diagrams in the UML, which serves as a guide for the requirements elicitation process.

In order to record the various stakeholders involved in the system and provide crucial details about their roles and influence, a stakeholder record is also developed. One important result of the stakeholder identification process is this document (Table 1).

After identifying the stakeholders and understanding their roles, the information that aids in analyzing the goals collected from the stakeholders is organized in the goal model, and these goals are adapted using a use case diagram. Fig.2. bellow shows the proposed goal model.

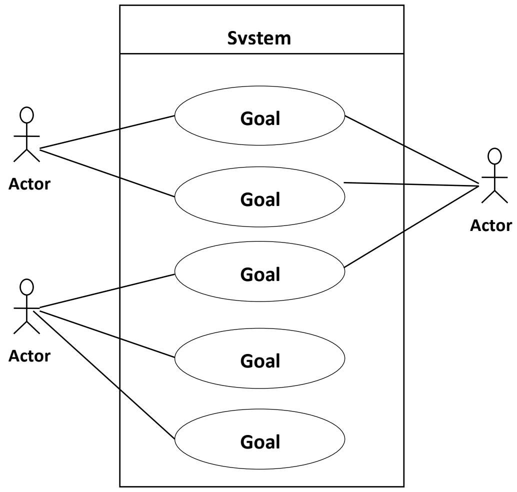

Fig. 2: Goal model

In addition to, a conceptual class is a diagram in UML, where it is considered an abstract representation of an object or entity within the system during the analysis phase, where the focus is on its basic features and behaviors without going into specific implementation details. It includes the basic properties and relationships of an entity, providing a high-level overview of its structure and interactions within the system. Which contributes to creating a clear conceptual understanding without investigating the technical complexities of its implementation. Fig.3. shows the conceptual class diagram.

<ins>**Responsibility Model:**</ins> responsibilities are identified and allocated to the actors with the aim of achieving the goals specified in the goal model. Each responsibility is adapted as a functional requirement and modeled through Use Case Maps (UCMs). UCMs represent a scenario-based visual notation that facilitates the definition of

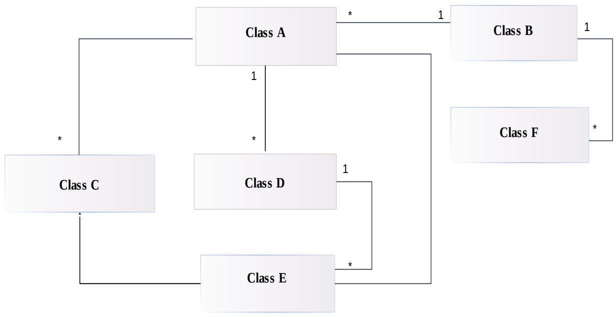

Fig. 3: Coneptual class diagram

requirements for complex systems, developed at Carleton University [11]. Utilizing UCMs provides a high-level abstraction to precisely define and document all functional requirements of a system during the analysis phase, ensuring a clear and concise representation of requirements. This facilitates stakeholders' understanding and validation of functional requirements. Table 2 illustrates the comprehensive understanding of the relationship between the characteristics of big data represented by (variety, velocity, volume, veracity, value)، goals, and responsibilities, and how these characteristics affect the effectiveness of the system.

Table 2: relationship between the characteristics of big data represented by (variety, velocity, volume, veracity, value), goals, and responsibilities

Project name:					
Goal ID#	Goal	Functional Requirement ID#	Responsibility (functional requirement)	Characteristic	Impact

Where each goal encompasses one or more functional requirements (Responsibilities), and each functionality is represented using UCMs. Fig. 4. shows the proposed responsibility model.

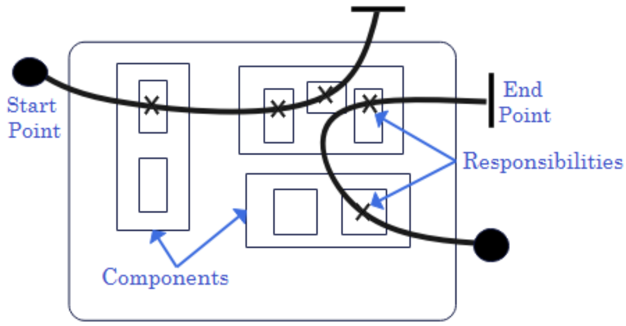

Fig. 4: The responsibility model Adapted from [11]

Table 1: The stakeholder's documentation

Stakeholder Record						
Project name:						
Name	**Types of stakeholders (P) Primary (S)Secondary**	**Role**	**Level of interest**	**Level of influence**	**Requirements or Expectations**	**Issues and concerns**

Object Model: An object model serves as a fundamental component that highlights entities or elements associated with a system during the design phase. This model specifically concentrates on identifying each component within the use case maps, which has been adapted in the responsibility model to represent an entity within the system, offering a low level of abstraction. Adapted through a class diagram in UML, this model helps illustrate the relationships between classes, attributes, and methods. The class diagram plays a crucial role in offering a comprehensive view of the system's structure, aiding developers in understanding the planned software architecture. Fig.5. shows the proposed object model.

User Interface Design (UID) is a pivotal element in software systems development, focusing on enhancing the interaction between users and the system. GUI design consists of three basic components: navigation, input, and output. The design process involves careful structuring of navigation, where Window Navigation Diagram (WND)acts as an important prototype in user interface design, facilitating a comprehensive understanding of how users interact with interface components.

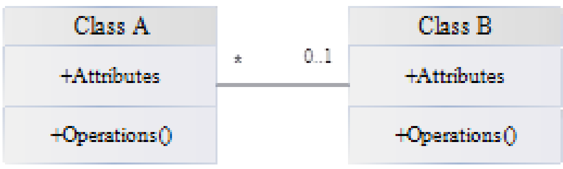

Fig. 5: The object model

Operation Model: An operation model is a critical phase in system design because it focuses on describing the operations that entities within the system must perform to achieve specific goals. It has been adapted using an UML activity diagram. Fig.6. shows the proposed operation model.

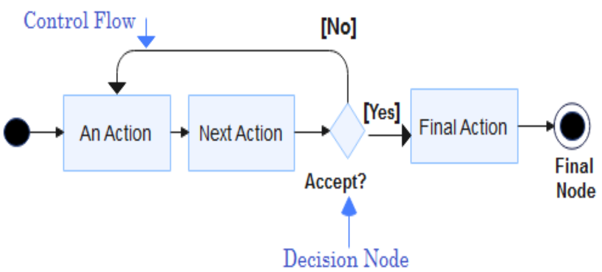

Fig. 6: The operation model

Specification and Validation

After ensuring that the analysis process has been completed using the above models, as illustrated in Figure 1, it must be adopted into a unified documentation process followed by an validation of the documentation to ensure that the requirements specification process has been successfully completed. The specification and validation phases are summarized in the following:

- Requirement specification: The requirement specification phase is an essential phase in system development, as it focuses on clearly documenting user needs, system requirements, and constraints. The identified requirements are described in detail in the SRS document, which is an important repository that contains all the functional and non-functional requirements, operational constraints, and additional details necessary for the system to achieve its goals. The SRS document acts as a guide for the development team, guiding the development process and serving as a communication tool between the team and stakeholders. It ensures a common understanding, facilitates the sharing of requirements, and verifies that the proposed solution meets the basic needs. The IEEE 830-1998 standard was proposed for the specification of software requirements.

- Requirement validation: the focus is on ensuring the accuracy, completeness, and consistency of documented requirements. This phase evaluates how well the proposed approach, based on the KAOS model, addresses challenges in requirements elicitation for big data systems, particularly in the context of electronic health records (EHRs). A questionnaire using a validation checklist was employed, and responses were gathered using a five-point Likert scale to assess the effectiveness of the approach. Statistical analysis was conducted using the 25th edition of the Statistical Package for Social Sciences (SPSS V25) to analyze the questionnaire. This involved employing a range of statistical methods aligned with the study objectives, including Scale stability testing was performed to ensure the reliability and validity of the study's measurement instruments using Cronbach's alpha coefficient.

In the descriptive analysis, demographic statistics are first presented using frequency tables and graphs to provide general information about the sample. The purpose of demographic statistics is to offer a comprehensive overview of the sample being studied, helping to understand its composition. Following this, descriptive statistics for the variables (Questions) are conducted, including weighted means, standard deviations, frequencies, and relative means. the purpose of this analysis was to identify trends within the study sample and evaluate response tendencies. Specifically, the arithmetic mean of responses to questions will serve as an essential measure of central tendency.

Case study

To evaluate the proposed model, a case study focusing on the electronic health record system in Benghazi was conducted. The primary objective of this case study is to demonstrate how the proposed approach can effectively generate EHR system requirements in Benghazi while showcasing its adaptability and potential to improve the quality and efficiency of the EHR system development process. Moreover, the case study highlights the effectiveness of the approach in handling big data systems. Analyzing the unique challenges and needs of the healthcare environment in Benghazi provides valuable insights into the practical implementation of the proposed model.

Goal Model: In the goal model, the high-level goals of the EHR system are defined by stakeholders. This phase involves two levels: First, stakeholders are identified and documented using different methods of information gathering to understand their roles and the key services the EHR system should provide. A stakeholder documentation table helps them develop a shared understanding of the scope and goals of the system.

- Data Collection Methods: To apply the proposed approach to the case study, field visits were conducted to eight healthcare institutions in Benghazi, covering both public and private sectors. This included interviews with healthcare professionals and observations of EHR-related tasks. Additionally, a review of similar global EHR systems was performed to understand workflows and requirements. Table 3 outlines the data collection methods.

Table 3: Methods used in data collection

Methods	Data collection
Interview	Receptionists, doctors, pharmacists, laboratory and radiology technicians, and IT staff were interviewed to understand the specific goals associated with building an EHR system.
Observation	Observation is one of the methods used to collect requirements in the system.
Literature	Similar electronic health record systems and global practices adopted in the healthcare field were studied to comprehend the workflow and various requirements for electronic health records.

Second, the goals of the EHR system are defined in collaboration with stakeholders using use case diagrams, which help simplify and clarify the relationships between actors and system goals. Fig.7. shows the proposed approach to the EHR goal model.

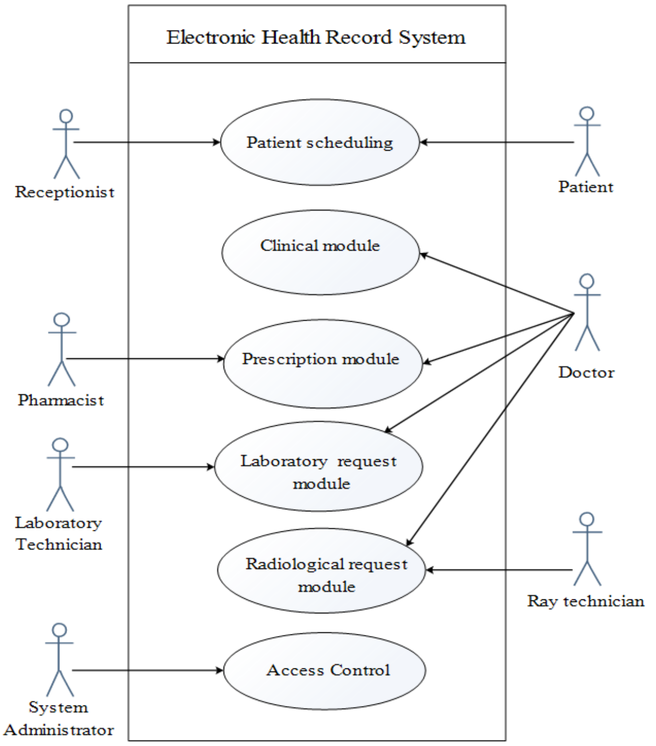

Fig. 7: Goal model of the EHR system

<u>Responsibility Model</u>: In the responsibility model, responsibilities are defined and distributed among actors, such as healthcare providers and receptionists, according to their roles in the electronic health record (EHR) system. This distribution ensures that the functional objectives of the system are achieved. Table 4 illustrates the relationship between the characteristics of big data (variety, velocity, volume, reliability, and value) and their impact on the objectives and responsibilities in the system. Where, each functionality requirement is represented using UCMs (Fig.9. Illustrates an example of functional requirements UCM).

A conceptual class diagram describes an abstract representation of conceptual classes during the analysis phase within the EHR system, providing a high-level overview of their structure and interactions within EHR. Fig.8. shows the conceptual class diagram

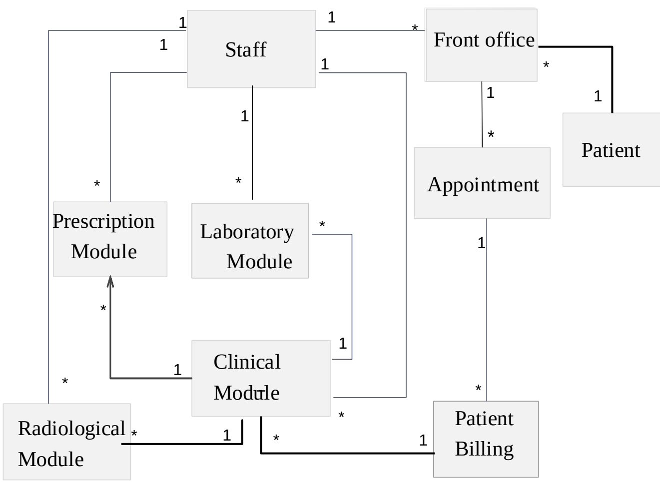

Fig. 8: The conceptual class diagram

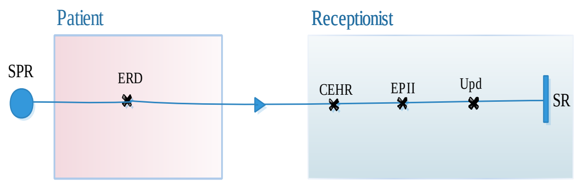

Fig. 9: The Use case maps for Patient Recording

SPR: (Precondition): Patient Registration.
ERD: Enter Recording Details.
CEHR: Create a new electronic health record for the patient
EPII: Enter basic patient identification information.

<u>Object Model:</u> The object model highlights entities associated with the EHR system, describing their characteristics and relationships to provide a detailed understanding of the system's structure. Fig.10. bellow shows the proposed object model.

In addition to, User interface design, using Windows navigation diagram (WND) aids in visualizing and refining the interface architecture of the EHR system in its early stages. This enhances usability and healthcare workflow efficiency by improving the interface based on early insights gained from the prototype. Fig.11.shows the WND of an EHR system.

<u>Operating Model:</u> The operating model defines the dynamic behavior of an EHR system, seamlessly detailing the operations of each interface, as shown in Fig.12 ,and the interactions between modules to achieve healthcare goals. It also provides stakeholders with a complete view of the system's workflow and key use cases, aided by activity diagrams for clarity and refinement. Fig. 12 shows the login process where user credentials are verified for accuracy and security. ensuring secure access.

Table 4: The relationship between the characteristics of big data, the goals and responsibilities of the EHR system, and how these characteristics affect system effectiveness

The relationship between big data characteristics and the goals and responsibilities Electronic Health Records system					
Goal ID#	**Goal**	**Functional Requirement, ID#**	**Responsibility (Functional requirement)**	**Characteristic**	**Impact**
G_1	Patient Scheduling	FR_1	Patient Registration	Volume	Reflects the ability to handle large data.
		FR_2	Appointment Booking	Value	Improves service efficiency and saves patient time.
G_2	Clinical module	FR_3	Diagnostic Recording	Velocity	Continuous registration and updating of medical information reflects the need for high-speed data processing.
		FR_4	Update medical information		
G_3	Prescription Module	FR_5	Prescription dispensing	Variety & Value	Integration with different departments reflects the need to analyze various types of data and improves diagnostic and laboratory accuracy, saving time for patient.
G_4	Laboratory request module	FR_6	Laboratory request		
G_5	Radiological request module	FR_7	Radiological request		
G_6	Access control	FR_8	Identity Authentication	Veracity	Ensuring data security and privacy reflects the need to ensure data accuracy and integrity.

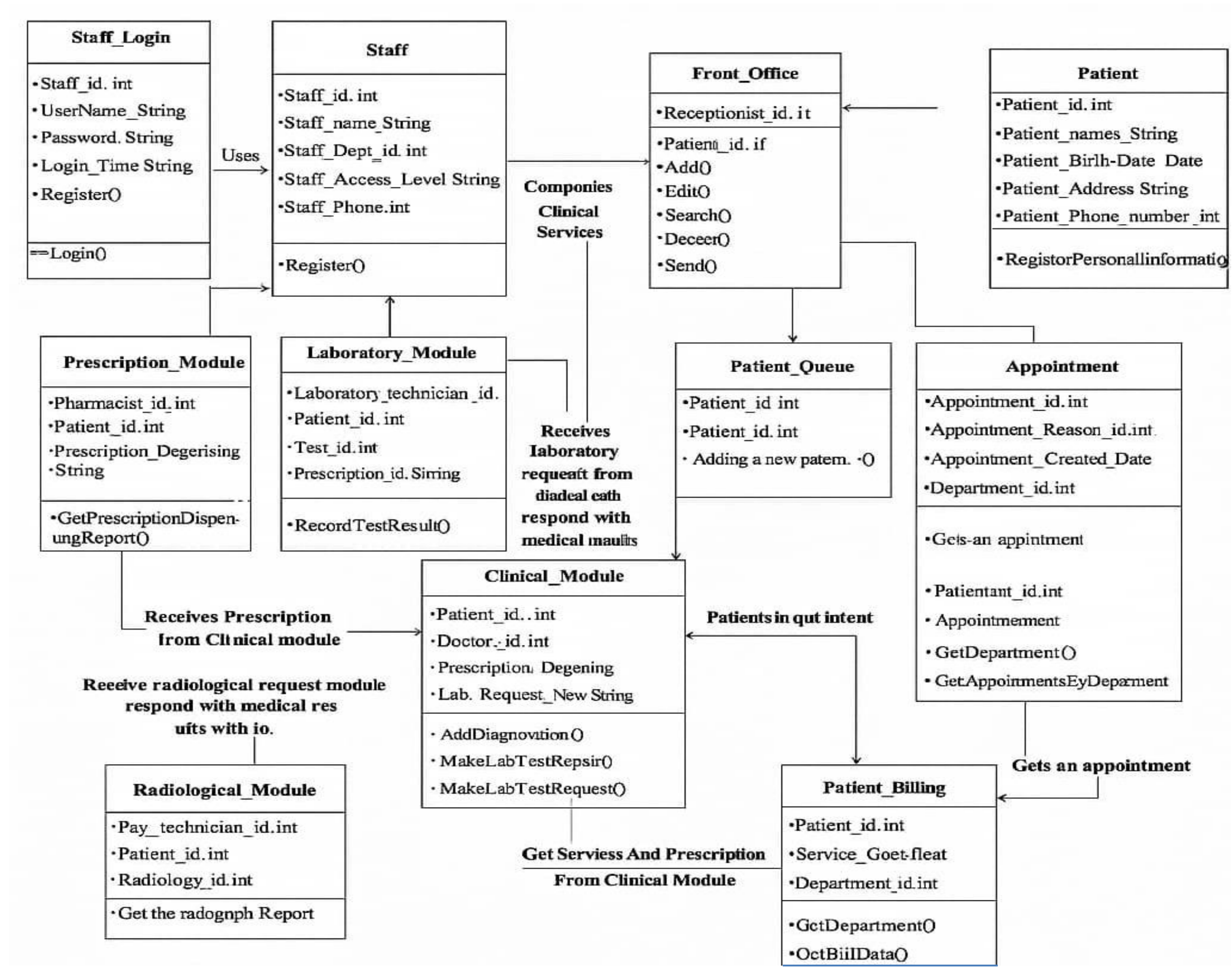

Fig. 10: Object model

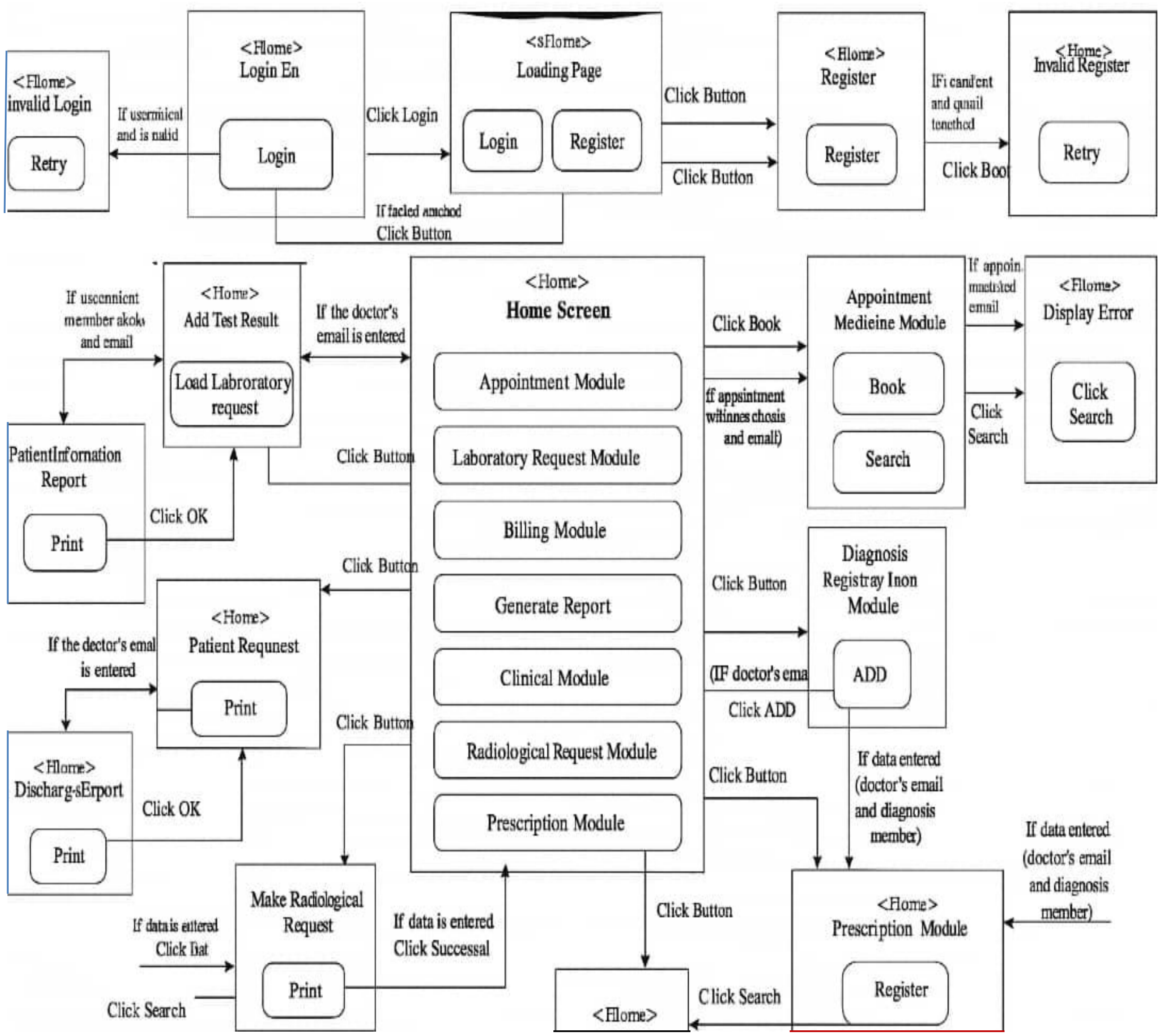

Fig. 11: WND of an EHR system

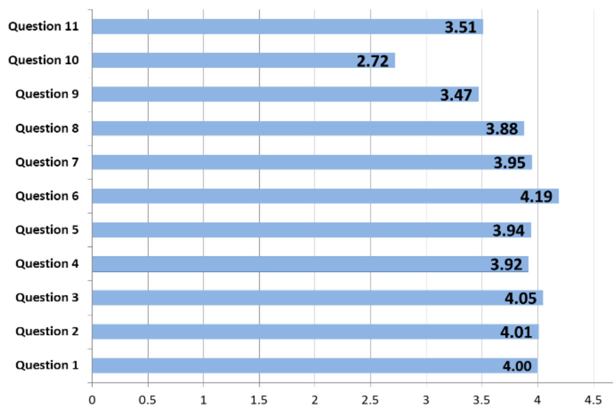

Fig. 12: Activity Diagram of Login

Specification and Validation

Requirement specification: The Requirement Specification phase is crucial for defining user and stakeholder needs in an EHR system, particularly due to the large data sets involved. It involves documenting functional and non-functional requirements, system constraints, and other key details in an SRS document to ensure the system meets its goals.

Requirement validation: This approach was also validated to examine the effectiveness and applicability of the proposed approach in gathering EHR requirements in Benghazi. Validation was performed through the questionnaire using the validation checklist technique. A questionnaire was distributed to a sample of 100 participants. The study focuses on eight hospitals in the public and private sectors in Benghazi. The questionnaire's demographic statistics, provide a comprehensive view of the target sample.

Descriptive statistics were also conducted for the questionnaire to evaluate the proposed approach related to EHR implementation. The results of the questionnaire indicated a general average was (77%) of the quality of the proposed approach and the possibility of adopting it in the future (Fig. 13 below).

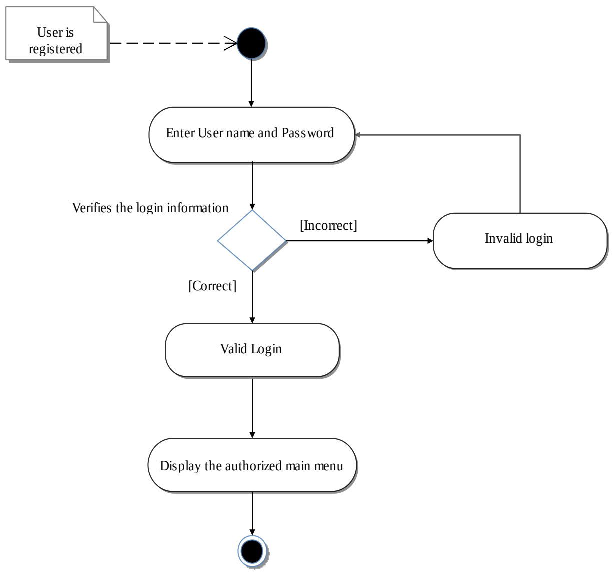

Fig. 13: The results of the arithmetic mean for evaluating the proposed approach related to the implementation of the EHRs.

Results and discussion

The results of the study showed that the proposed framework, which was based on integrating the KAOS model with requirements engineering activities, helped effectively address the challenges associated with collecting and documenting requirements for big data systems.

This study is consistent with what Arruda &Laigner (2020) referred to, as their study highlighted that the absence of clear frameworks to collect and analyze the requirements of big data systems is one of the biggest challenges facing development teams. However, their work was exploration and did not provide an integrated practical model, while the current approach contributes to providing an implementable applicable framework.

On the other hand, the study of Hesham et al. (2021) addressed the problems of gathering requirements by integrating some techniques such as brainstorming and mind mapping, but they remained general and did not link the results to the system goals in a hierarchical manner, as this research did.

As for Palomares et al. (2021) pointed out that weak stakeholder engagement leads to incomplete or conflicting requirements, which this research attempted to overcome by integrating stakeholders from the early stages via goals and responsibilities models, which led to improved alignment between requirements and strategic objectives

Therefore, it can be said that the proposed framework adds scientific value by linking the characteristics of big data (such as volume, variety, and velocity) directly to the requirements engineering process, which has not been adequately addressed in previous studies. Also, it contributed to clarifying functional roles and responsibilities, and highlighting the dynamic behavior of the system in a way that facilitates verification of compliance of requirements with specified objectives. This in turn improved the quality of the requirements engineering process output, both in terms of documenting functional and non-functional requirements and in terms of providing an integrated representation of them in a Software Requirements Specification (SRS) document. This is consistent with the result of the questionnaire that was distributed to a sample of 100 participants from eight hospitals in the public and private sectors in Benghazi, which showed that the average satisfaction of the respondents reached 77%, which reflects a positive acceptance of the possibility of adopting the model in the future.

CONCLUSIONS

Requirements engineering for big data systems presents unique challenges compared to traditional systems, demanding the development of a specialized model and processes specifically designed for big data requirements engineering. Hence, in this study, the proposed and enhanced approach is to generate big data requirements based on integrating the KAOS model with RE activities. By addressing the challenges in generating requirements for big data systems, this proposed approach was applied to a case study of electronic health records in Benghazi. The study contributed to the development of requirements engineering practices in the field of big data. The verification result shows that implementing the proposed approach in the case study proves effective in providing a structured and efficient approach to generating and modeling requirements, thus providing valuable insights into improving the requirements engineering process in the context of a big data system.

Furthermore, the study's scope focused on improving the requirements engineering phase, while the remaining software development lifecycle phases were not targeted in this study and were left as future work that could be undertaken to provide a comprehensive approach covering all phases of software development with regard to big data systems.

Recommendations

Given the importance of RE in the context of big data systems, further analysis and testing are necessary to evaluate the effectiveness of the proposed approach. Future research could focus on assessing the approach in various contexts and exploring additional research methods to enhance the proposed model of big data requirements engineering. This includes expanding case studies to conduct further validation and evaluate the generalizability and scalability of the approach across different fields and industries. Such studies would provide a more Given the importance of RE in the context of big data systems, further analysis and testing are necessary to evaluate the effectiveness of the proposed approach. Future research should focus on assessing the approach in various contexts and exploring additional research methods to enhance the proposed model of big data requirements engineering. This includes expanding case studies to conduct further validation and evaluate the generalizability and scalability of the approach across different fields and industries. Such studies would provide a more comprehensive understanding of its impact and potential adaptations. Additionally, continuous improvement of the KAOS model is essential to better align it with the evolving demands of engineering practices and technological advancements in big data. This may involve incorporating new features or adapting the model to meet emerging trends in data management and analytics.

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