UML Framework: National Institute for Health and Care Excellence (NICE) Diabetes Guidelines Based Diabetes Information System

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Abstract

Diabetes is a chronic disease that is a very common health problem around the world. Without proper care and treatment of diabetes, it could become a life-threatening disease. Currently, innovations in health information systems facilitate the patients and healthcare providers in the care and treatment processes. Diabetes management process is well-illustrated by the National Institute for Health and Care Excellence (NICE) diabetes guidelines. In this paper, we aim to propose a diabetes management information system (DMIS) based on NICE guidelines. The proposed DMIS is built on a design model through the Unified Modelling Language (UML). We validate the proposed DMIS and its UML models with respect to NICE recommendations by means of traceability techniques. The validation and verification were carried out involving software and health experts. The results show that our proposed DMIS model is comprehensive and incorporates all the NICE recommendations.

Key Words: Diabetes management information system, NICE guidelines, UML design, traceability techniques

1 Introduction

Diabetes Mellitus is one of the major chronic diseases in the world. It is a metabolic disorder that makes the body unable to produce insulin or incapable to efficiently use the produced insulin [19]. Due to the insulin deficiency, excessive amounts of blood glucose will be in the bloodstream. This may result in many health complications. Diabetes has two major types which are diabetes type 1 and type 2. In diabetes type 1, the body does not produce insulin, or produce insufficient amounts that do not serve the body's needs. The conventional treatment of diabetes type 1 requires insulin injections several times a day. On the other hand, in diabetes type 2, the body produces insulin but in an insufficient amount.

The initial stages of this type do not require insulin injections. Patients can successfully manage their condition by making careful adjustments to their lifestyles. If diabetes was not managed properly, it could lead to dangerous complications that can threat the patient's life. Hence, to avoid them and to live a healthy life, a proper management of the disease is required. Managing diabetes can be a tedious task due to the continuous attention it requires in monitoring the patients' conditions and following up with their medication. Various healthcare models to manage diabetes have been developed to overcome challenges associated with the management of diabetes [11, 18].

This paper proposes a Unified Modelling Language (UML) framework of a diabetes management information system (DMIS). The DMIS incorporates an intelligent decision support system that follows diabetes medical guidelines developed by the National Institute for Health and Care Excellence (NICE). After designing the model DMIS using UML, we carry out the validation and verification by the means of the traceability techniques from NICE recommendation to the system models of DMIS.

2 Literature Review

Information and Communication Technologies (ICT) play a key role in addressing health challenges [2]. A variety of e-health systems have been developed to provide a wide-range of healthcare services and share medical knowledge from different platforms by the utilization of ICT [7]. Examples of e-health applications include electronic health records, telemedicine, multimedia-based medical images, AI-based decision making and virtual reality based medical analysis that could be used by researchers, patients, healthcare providers, and health organizations [4]. Health stakeholders require information systems in order to store and process valuable medical data. In particular, patient require these information systems in order to monitor their health without the assistance of physicians [1].

Diabetes e-health systems and tools provide integrated platforms to serve the needs of the patients and healthcare providers [15]. Many health monitoring devices, sensors and mobile tools have been developed in the past decades and they have proven to enhance the quality of services provided to people who have long term or chronic conditions such as diabetes [10].

Management of diabetes requires tracking various aspects related to patients' conditions, including medication, physical activity, dietary intake and body reading. This would result in generating large amounts of data, and the new health related information technologies have provided user-friendly platforms for patients to manage their health conditions [17]. With the use of information technology and health information systems, it

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became possible to provide prevention, diagnosis, treatment, and follow-up measures to patients in different settings [16]. Therefore, health authorities set high expectations in health informatics impacts on diabetes management [5].

Nowadays, a wide range of diabetes management systems have been developed to ease the lives of diabetic patients [5]. Reviewing these systems reveal that existing systems vary in different aspects such as the target population, restricted features, the medical instruments, and information system processes. In Table 1, we list some of the diabetes available solutions and discuss their main contributions. From the above literature survey, we have observed that different information systems have supported different features which are considered of central importance in the process of maintaining the disease effectively. These information systems have aimed to ease the life of diabetic patients by providing a platform that stores and operates diabetes related information. Some of these systems are moderately comprehensive as they have integrated a wide range of parameters and functionalities that help in achieving better control of diabetes and in coordinating the communication and data exchange between patients and healthcare providers. In Table 2, we provide a comparison between the features incorporated in the existing diabetes information systems. We list 15 features in Table 2.

Table 1: Literature description and key contributions

Reference	Description	Key Contributions
[9] Lelis & Motta [2018]	The paper presents a glucose management information system that supports patients in the management activities. The system uses a prediction rule-based method for glucose measurement based on glucose levels that have been collected previously.	▪ Monitor Glucose. ▪ Predict blood glucose levels. ▪ Collect food intake data. ▪ Collect data about insulin dosages.
[6] Gia et al. [2017]	The paper proposes a real-time continuous glucose monitoring system based on internet of things (IoT). Through the system healthcare providers and caregivers can easily monitor patients via web-browser or mobile application.	▪ Real time transmission of glucose and body temperature data. ▪ It uses NFR communication protocol to achieve energy efficiency.
[8] Kart et al. [2017]	The paper describes a clinical decision support and monitoring system for diabetes using evidence-based guidelines.	▪ Diagnose, and manage the treatment of diabetes based on medical guidelines. ▪ Monitor patient's glucose levels and other inputs. ▪ Generate reminders and motivational messages. ▪ Alert healthcare providers in critical situations.
[2] Adeyemo et al. [2016]	The paper discusses the development of an online support system for diabetes management which allows diabetic patients to provide detailed information about their health condition.	▪ Monitor different aspects of diabetes such as blood glucose, blood pressure, exercise, and food intakes. ▪ Medical reminders. ▪ Appointment booking. ▪ Real-time chat platform for healthcare providers and patients.
[17] Supriya & Rekha [2015]	Android based diabetes monitoring application (MediMinder) to monitor blood glucose levels and assist patients and healthcare providers to monitor the diabetes conditions.	▪ Sugar level monitoring. ▪ Medicine reminders. ▪ Decision support tool. ▪ Alert healthcare providers in critical situations. ▪ Generate medical reports.
[3] Akter & Uddin [2015]	The paper presents an Android application for diagnosis and treatment of diabetes and hypertension.	▪ Monitor blood glucose and blood pressure. ▪ Diagnose diabetes and hypertension. ▪ Generate medical reports.
[15] Sabbar & Al-Rodhaan [2013]	The paper discussed the implementation of a diabetes monitoring system on Android platform for managing and monitoring diabetic patients. The system monitors the daily data of diabetic patients in addition to arranging monthly visits to healthcare providers.	▪ Bluetooth enabled technology. ▪ Real-time data transmission of blood glucose levels. ▪ Monitor HbA1c levels. ▪ Remote communication with healthcare providers. ▪ System supports Arabic language.

Table 2: Features comparison of existing systems

Feature	[9] Lelis & Motta [2018]	[6] Gia et al. [2017]	[8] Kart et al. [2017]	[2] Adeyemo et al. [2016]	[17] Supriya & Rekha [2015]	[3] Akter & Uddin [2015]	[15] Sabbar & Al-Rodhaan [2013]
Diabetes diagnosis			✓			✓	
Monitor blood glucose	✓	✓	✓	✓	✓	✓	✓
Laboratory data (HbA1c…)			✓			✓	✓
Monitor blood pressure				✓		✓	
Monitor treatment (insulin, other medicines)	✓				✓		✓
Send medicine reminders				✓	✓		✓
Book appointments				✓			✓
Send appointment reminder				✓			✓
Communicate with healthcare providers				✓			✓
Decision support system (treatment, recommendation, monitoring plans)	✓		✓			✓	
Track physical activity			✓	✓			✓
Nutrition (Monitor food intakes, manage diet)	✓		✓	✓			✓
Alert healthcare providers in critical situations		✓			✓		
Integrate with other hospital departments							✓
Others (BMI, temperature, psychological state)		✓	✓			✓	
Generate medical reports					✓	✓	✓

3 Proposed SIBBIS System

We propose a diabetes management information system (DMIS) based on NICE diabetes guidelines. In 2015, the National Institute for Health and Care Excellence (NICE) produced well-defined guidelines that focus on Diabetes Mellitus [12, 13]. These guidelines are evidence-based and will help to develop a tailored individual therapy for each patient in achieving good control of diabetes. NICE guidelines target three key stakeholders:

1. Healthcare providers.
2. Diabetic patients and their families.
3. Hospitals and service institutions.

After a thorough study of NICE diabetes guidelines, we have gained an understanding of the features that must be considered when providing care and treatment for diabetic patients. NICE guidelines have provided detailed recommendations to successfully manage patients' health conditions and allow them to lead a healthy life. These recommendations cover the areas of care and treatment that must be managed to achieve a full control of patients' conditions. In Figure 1, we provide an abstract view of the proposed system. Figure 1 illustrates how the proposed DMIS is built systematically. Additionally, we want to add features extracted from NICE diabetes guidelines, and then check their traceability in the different system's models.

4 SIBBIS System Requirement

The proposed system's requirements have been extracted from NICE diabetes guidelines. The requirements of the proposed DMIS are:

- The system shall diagnose diabetes based on patient's medical information.
- The system shall provide education to patients about diabetes, self-management roles, and medical recommendations about lifestyle adjustments.
- The system shall manage blood glucose levels by reminding patients to measure it, identifying target values, and detecting risk values.
- The system shall manage patient's diet by tailoring nutritional advices and counting calorie intakes.
- The system shall manage patients' physical activities by providing tailored activity advices.
- The system shall manage patients' treatment by assessing

patient's medical date and recommending the appropriate treatment.

- The system shall manage blood pressure levels by reminding patients to measure it, identifying target values, and detecting risk values.
- The system shall manage the HbA1c levels, the test frequency and target level for each patient.
- Health complications associated with diabetes are managed by providing assessment to patients' symptoms and referring them to the appropriate hospital department.

In addition to these requirements, we aim to incorporate the requirements and features of existing diabetes information systems that have been reflected in Table 2. These requirements will be used by target DMIS stakeholders. The system's objects represent the stakeholders. These objects perform different activities in the system to fulfil their roles. Table 3 shows the system's main objects and the set of activities that each object ought to perform

To provide a high-level view of the system components, we have developed a context diagram of our proposed DMIS in Figure 2. The figure reflects the entities that interact with the system, their inputs to the system, and the outputs they receive from the system. The system will be used by multiple entities, each with a different set of roles. We emphasized the intelligent aspect of the system in red lines.

5 UML Design Models

We apply UML to describe our proposed DMIS requirements. UML is a very popular general-purpose software engineering

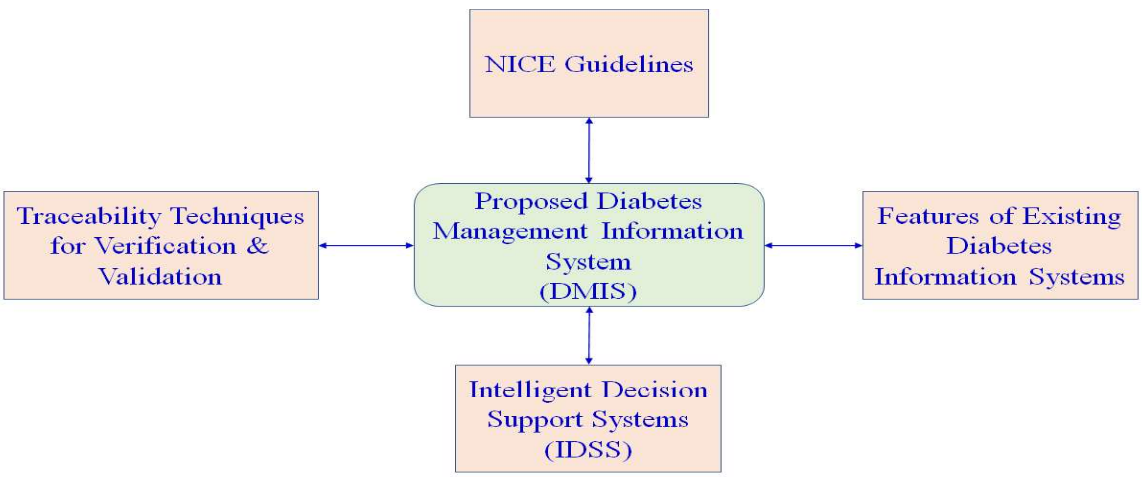

Figure 1: Abstract View of the proposed SIBBIS system

Table 3: SIBBIS system objects and stakeholders

OBJECT	ACTIVITY
Admin	create user account, authenticate user, update profile, manage accounts
Physician	diagnosis, view profile, request tests, view results, messages, referrals, medical recommendation, prescribe medicine
Lab Technician	conduct test, update results
Patient	make appointment, communicate to physicians, follow-up care and treatment, view results, evaluate doctor
Pharmacy	check medicine availability, update medicine records
Intelligent System	alerts, reminders, intelligent decisions, comprehensive medical recommendation
Dietician	view profile, update profile, determine diet plan and action plan
Physical Trainer	view profile, update profile, determine workout plan

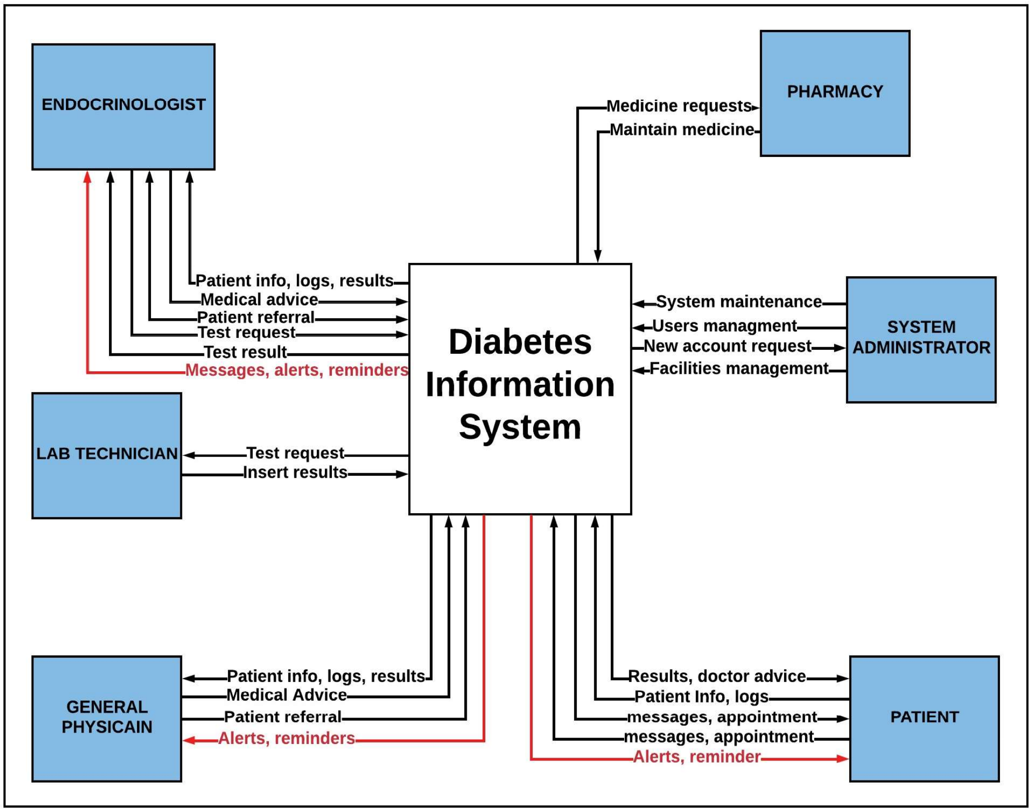

Figure 2: DIS context diagram

modelling language [14]. By utilizing it, one can develop a system's blueprint that assists in the following system's development and implementation phases. The features of UML will be used to guide software developers in specifying, visualizing, constructing, and documenting the artifacts of software systems. To present the diabetes system in a comprehensive manner, we develop different UML models that have different levels of complexity.

5.1 UML Class Diagram

The class diagram shows the overall structure of the system. Figure 3 shows the DMIS class diagram. In these diagrams, we can see that we have two base classes, "User" and "DiabetesCareAndTreatment", from which the rest of the classes are inherited. The first class identifies the system's users such as patient, system admin, and different healthcare providers. It shows the classes of these users interacting with the classes of the system and each of them has an account. The second class, DiabetesCareAndTreatment, reflects all the aspects that different users of the system interact with each other to deliver or receive services of diabetes care and treatment. This diagram will assist programmers in specifying the classes they must include in the implementation phase.

5.2 UML Use Case Diagram

The use case diagram is used to visualize the primary actors and their activities of the system. Through use case diagrams, we understand the functionalities of the system and the objects that initialized them. In Figure 4, we draw a high-level illustrative use case diagram of the DMIS. The diagram summarizes the relationships between the actors and the use cases. This diagram is used to show the primary requirements of the system without giving deep details or the exact order in which these functional requirements are performed.

The use case diagram in Figure 4 reflects the intelligent capabilities of the system. The intelligent decision support system is responsible for generating reminders related to appointments, medication, and medical check-ups. Moreover, the intelligent system will generate alarms at different levels in critical conditions. Also, it can produce different diabetes related management advice.

5.3Activity Diagram

Activity diagrams provide aggregated behavior model of the system. It shows the coordination of activities and how they flow when providing a service. Figure 6 reflects the diabetes diagnosis procedure and the users involved in this process. Several activities are conducted before reaching the final diagnosis. The intelligent system assesses the patient's health condition and suggests intelligent decisions to assist the physician. The physician views the recommendations and writes the final decision.

6 Traceability Checking

In this section, we check the traceability of NICE guideline recommendations in the different levels of the system's UML diagrams. NICE guideline processes have been reflected in diagrams that deal with specific aspects of the system's functionalities. The UML diagrams would permit the system developers to integrate the system's components. In the system development phase, the different UML diagrams with different levels of complexity would be combined. Therefore, establishing traceability between the different NICE recommendations in the UML diagrams is important.

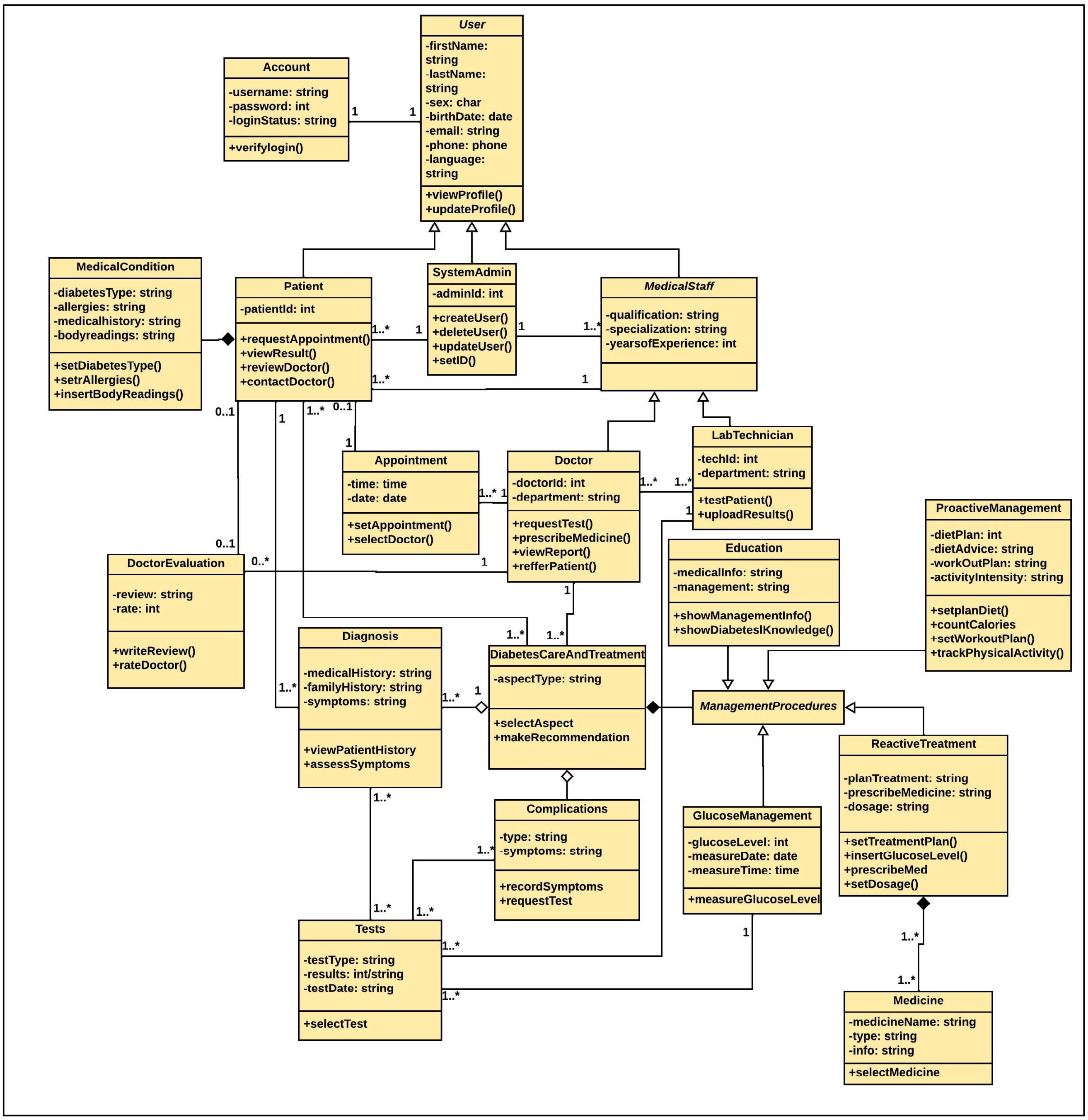

Figure 3: DMIS class diagram

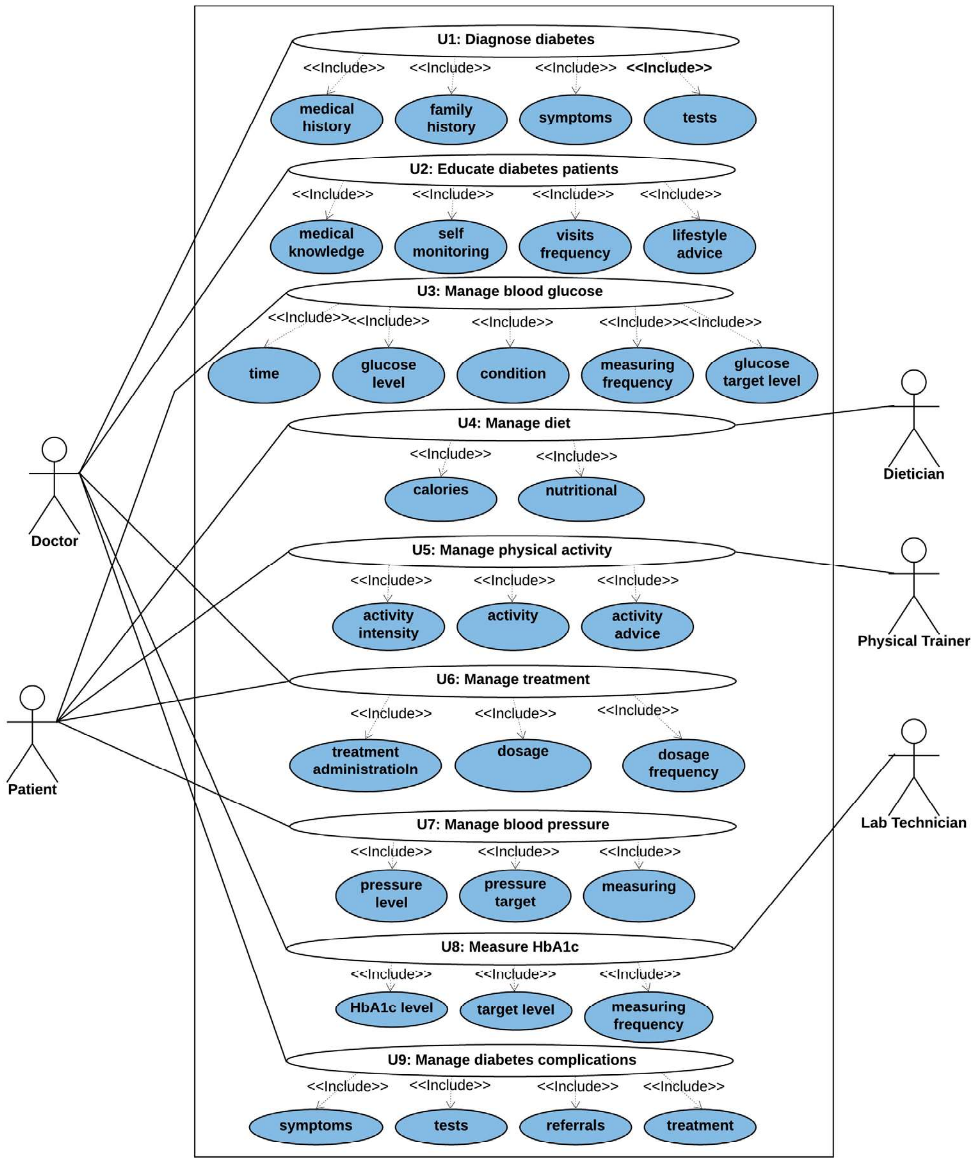

Figure 4: DMIS use case diagram

6.1 Traceability Checking Method

To check traceability, we have developed a questionnaire in which target participants were asked to check the traceability of NICE guideline recommendations in the different levels of the system's UML diagrams. The guideline recommendations have been listed to be initially checked against the system's use case diagram. Each recommendation has been represented in a stand-alone use case. Afterward, we continued checking the traceability of recommendations in corresponding activity diagrams and class diagram.

Instrument: A self-administrated questionnaire has been distributed to a few faculty members and IT graduate students. The first section of the questionnaire aimed to identify the respondents' profile. In the second section of the questionnaire, we have checked the traceability of NICE guideline diabetes recommendations in the UML diagrams.

Subjects: The questionnaire was administrated online using Google Forms. Our main target was collecting the responses of individuals who have software development knowledge. Therefore, the questionnaire link has been sent to faculty members and graduate students who took the system development and analysis course.

Questionnaire Design: We have developed a 5-point Likert scale. The scales were labelled as (1) VP= Very Poor; (2) P= Poor; (3) A= Acceptable; (4) G= Good; (5) VG= Very good. For the sake of efficiency, we have included the main system diagrams that reflect the integrated diabetes management

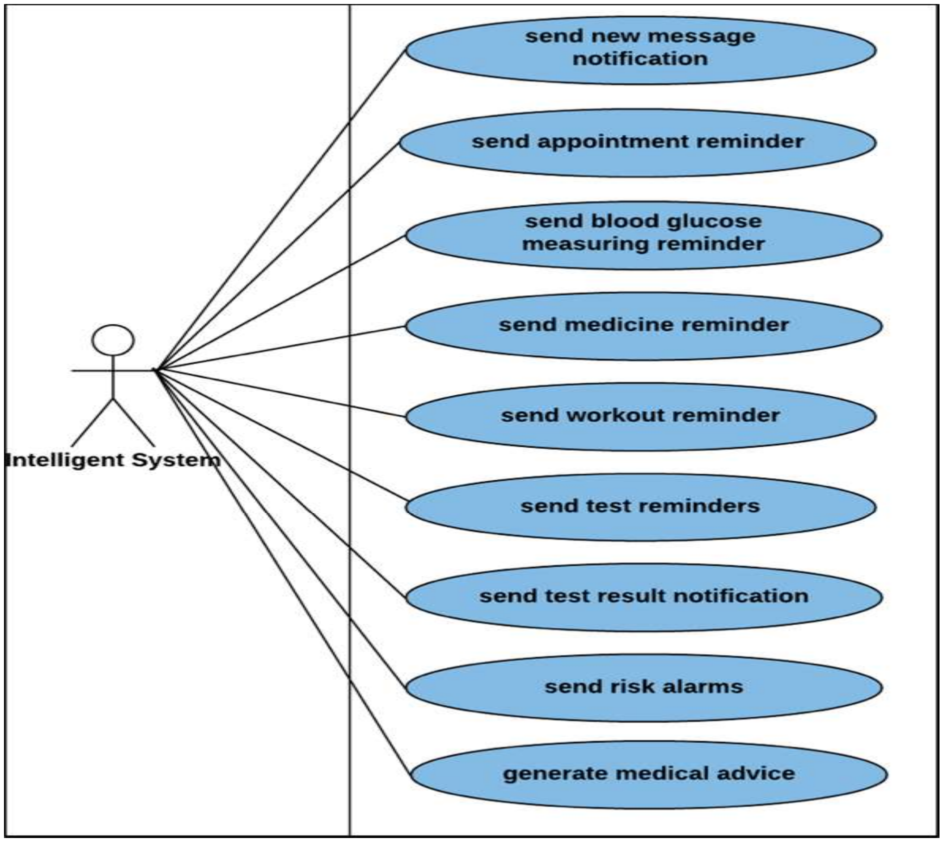

Figure 5: Intelligent system use case diagram

processes. In the questionnaire, we have assessed 3 types of diagrams which are use case, activity, and design class diagrams. At first, users evaluate the traceability of the extracted NICE recommendations in the systems' use case diagram. Then, the traceability would be checked for each use case and its corresponding activity diagram. Finally, participants check the traceability of each activity diagram in the system's design class diagram. Respondents were requested to select one option per statement. From the responses, we would assess the quality of the UML design models for the extracted processes.

6.2 Measured Results

In this section we discuss the obtained results.

Demographics: Table 4, reflects the demographics of our participants. A number of 20 individuals have participated in our questionnaire. The age range of the participants was (20 and above 50). Most of the participants were in the age groups (21-30) and (31-40) years. In terms of gender, most of our participants were females. Moreover, participants were categorized based on their positions in the Information and Technology Department in Kuwait University into two groups, faculty member and graduate students.

Reliability Test: To validate data's reliability, we have used Cronbach's Alpha test in SPSS software. Alpha's value should be .7 or higher to be considered reliable. Table 5, shows the reliability results for the questionnaire's variables. The Alpha results show that all the variables have good reliability results.

Traceability between NICE Recommendations and their Corresponding Use Cases: In Table 6, we show descriptive statistics for the traceability of system's use cases and their source NICE diabetes recommendation. Through the results we would understand respondents point of view regarding the effectiveness of the system's use case diagram in reflecting the textual medical recommendation. The results show that a higher number of responses were on the good and very good sides. From that it is understood that our respondents agree that the use cases succeeded in reflecting nice recommendations in a comprehensive method. Thus, traceability between each use case and its source is established.

In Figure 7, we can see a graphical representation of the traceability between each use case and its corresponding NICE recommendatiuon.

Traceability between Use Cases and Their Corresponding Activity Diagrams: In Table 7, we display statistics for the traceability of activity diagrams to their corresponding use

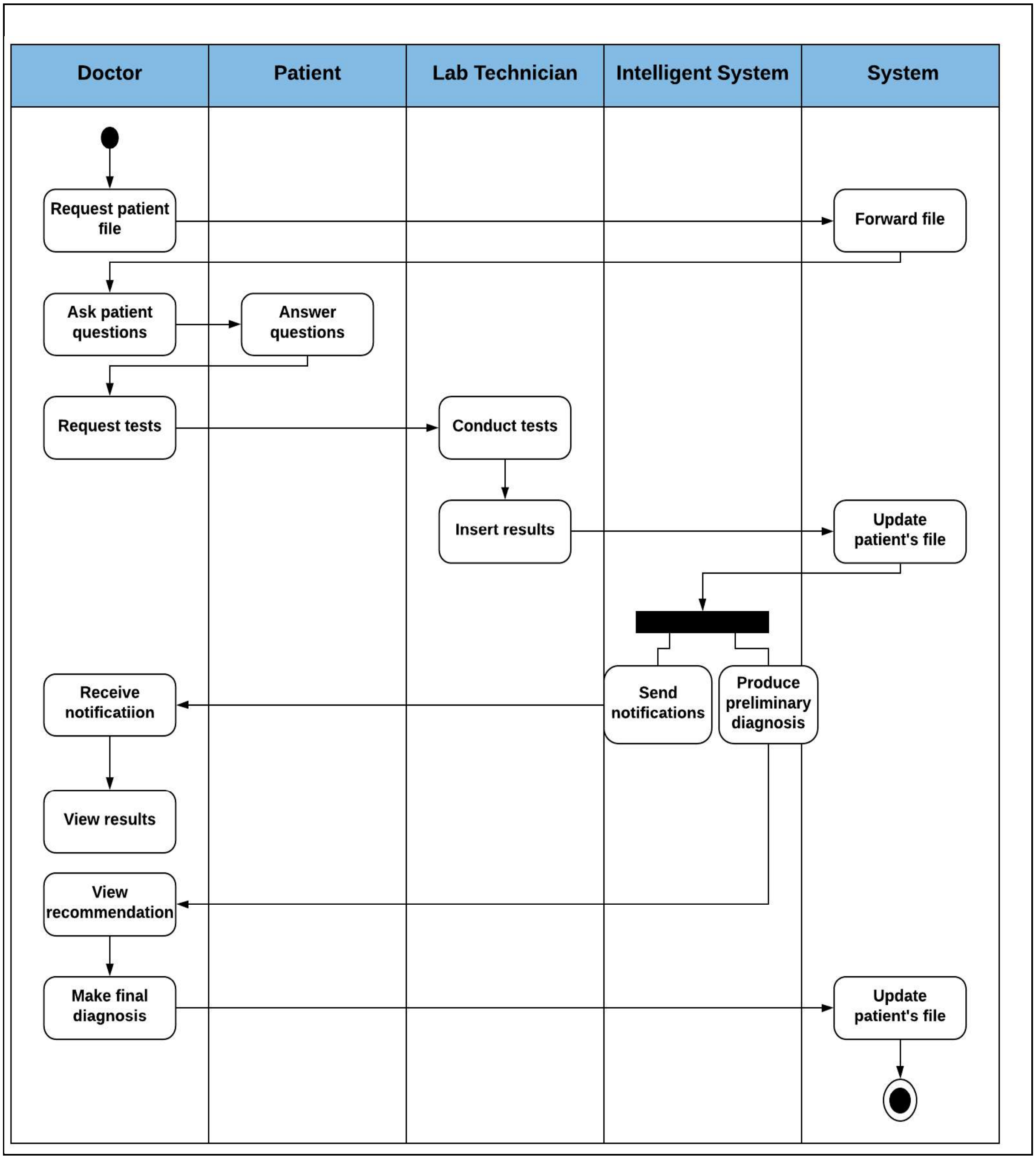

Figure 6: Diabetes diagnosis activity diagram

cases. From the results we can see if traceability of NICE recommendations is captured between the system's activity diagrams and use cases. Results show that the majority of responses agree that traceability between activity diagrams and their corresonding use cases is estaablished in a good and very good mnner. From this we understand that the activity diagrams were effective in reflecting NICE use cases.

Traceability between Activity Diagrams and their Corresponding Class in the Class Diagram: Table 8 shows the descriptive statistics of the traceability of design class diagram to the activity diagrams. From results we understand that the classes, in the class diagram, have captured the activity diagrams in good ways. Therefore, the components of the design class diagram can be traced back to more detailed diagrams.

In Figure 9, the graphical representation shows how the traceability between an activity diagram and its corresponding class in the class diagram was established.

Table 4: Demographics

Variable		Frequencies	Percentage
Gender	Male	7	35%
	Female	13	65%
Age Group	20-30	6	30%
	31-40	8	40%
	41-50	3	15%
	Above 50	3	15%
College Position	Faculty member	3	15%
	Graduate student	17	85%

Table 5: Reliability test

Variable	Alpha	No. of Items
Use Case Diagram	.909	9
Activity Diagrams	.976	8
Design Class Diagram	.938	9

Table 6: Traceability between NICE recommendations and use case diagram

Use case traceability to NICE recommendation	U	VP	P	A	G	VG
R1: Diagnose diabetes based on clinical grounds by considering symptoms and the history of a suspected patient.	**U1**	0%	0%	10%	70%	20%
R2: Offer structured education, to diabetes patients, that includes the following components: diabetes knowledge, management, self-monitoring, and lifestyle adjustments.	**U2**	0%	0%	20%	60%	20%
R3: Advise patients about glucose management and educate them about the target levels they must achieve different conditions, and tests frequency.	**U3**	0%	0%	15%	45%	35%
R4: Provide individuals with tailored dietary advice to control weight and manage blood glucose.	**U4**	0%	0%	25%	50%	25%
R5: Provide physical activity advice to diabetes patients and produce an activity program for those who choose to integrate physical activities into their lifestyle.	**U5**	0%	0%	20%	55%	25%
R6: Develop a treatment plan based on the diabetes type and the medical background of each patient.	**U6**	0%	0%	15%	55%	30%
R7: Advise diabetes patients about how to achieve the target blood pressure level, the measuring frequency and the procedures of avoiding its complications.	**U7**	0%	0%	10%	60%	30%
R8: Test HbA1c level in diabetes patients periodically, to assess their glucose management performance.	**U8**	0%	0%	15%	60%	25%
R9: Manage health complications associated with diabetes. Provide assessment to patients who have complication symptoms and refer them to the appropriate hospital department.	**U9**	0%	0%	15%	60%	25%

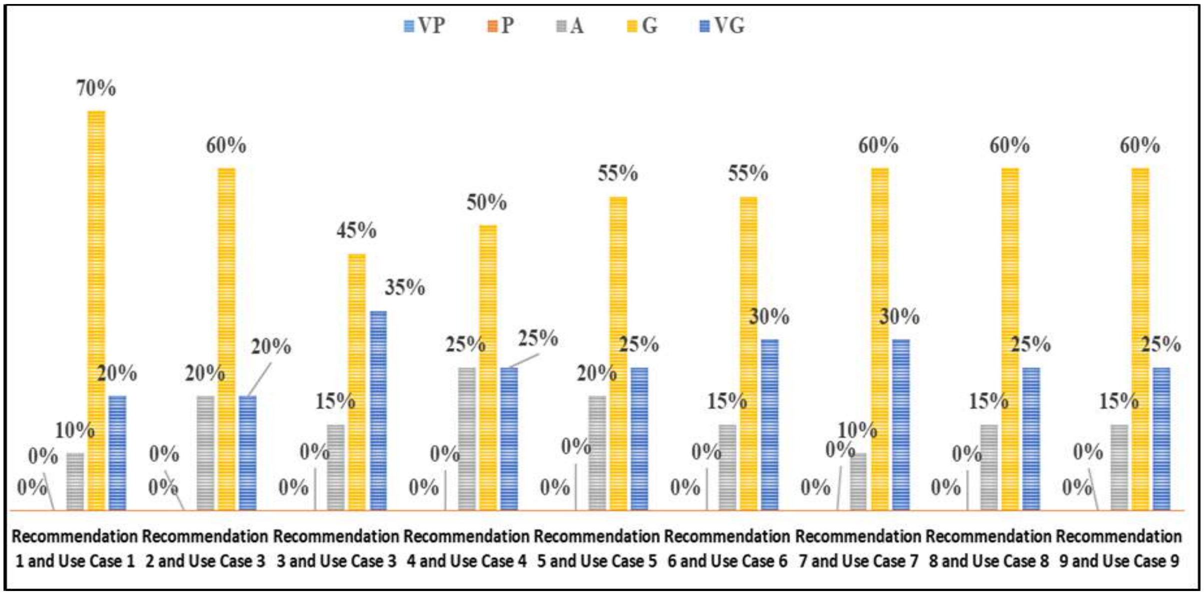

Figure 7: Traceability between use case diagram and NICE recommendations

Table 7: Traceability between activity diagrams

Activity Diagram Traceability to Use Case Diagram	VP	P	A	G	VG
Use Case 1 and Activity Diagram 1	0%	5%	20%	45%	30%
Use Case 2 and Activity Diagram 2	0%	0%	20%	50%	30%
Use Case 3 and Activity Diagram 3	0%	0%	30%	50%	20%
Use Case 4 and Activity Diagram 4	0%	5%	20%	50%	25%
Use Case 5 and Activity Diagram 5	0%	5%	25%	45%	25%
Use Case 6 and Activity Diagram 6	0%	0%	25%	45%	30%
Use Case 7 and Activity Diagram 7	0%	0%	20%	55%	25%
Use Case 8 and Activity Diagram 8	0%	0%	20%	55%	25%
Use Case 9 and Activity Diagram 6	0%	0%	25%	45%	30%

7 Discussion

In the previous sections we have checked traceability between NICE recommendations and the UML design models of our system. Our target respondents have checked the traceability between medical recommendations and the UML diagrams. Results have indicated that the traceability factor between the recommendation and the diagrams is achieved. Responses showed that the recommendations have been reflected in a good way in the use case diagrams. Traceability between the use case diagram and the corresponding activity diagrams and classes, in the design class diagram, was well established. Therefore, NICE recommendations were reflected very well in the system's UML designs.

8 Conclusion and Future Work

This paper discussed a diabetes information system DIS through the unified modelling language UML. The system's requirements have been extracted from diabetes medical guidelines developed by the National Institute for Health and Care Excellence (NICE). After identifying the requirements, we have modelled our system through UML. The system models aim to comprehensively reflect the functional requirements of the system that allow effective delivery of care and treatment services of diabetes. Additionally, we checked the traceability of NICE recommendation in the main system's UML models. We have distributed a questionnaire in the Information Technology Department in Kuwait University to faculty

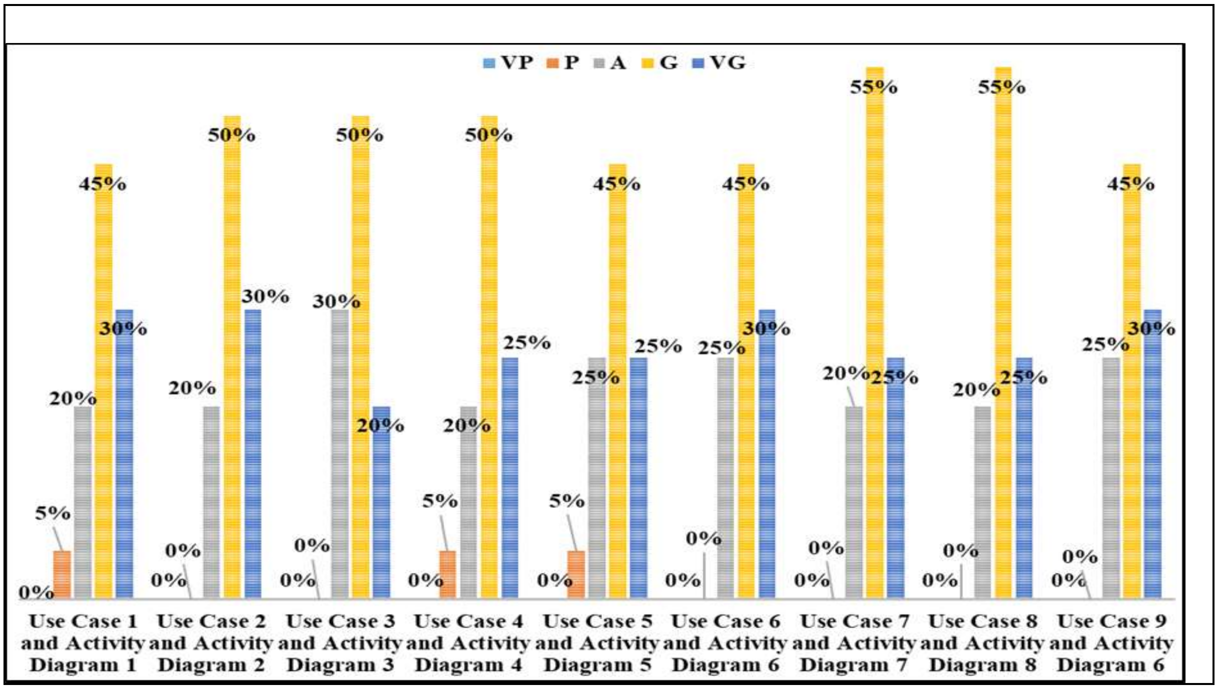

Figure 8: Traceability between activity diagrams and use cases

Table 8: Traceability between activity diagrams and class diagram

Activity Diagram Traceability to Class Diagram	VP	P	A	G	VG
Activity diagram 1 and Class 1	0%	0%	15%	55%	30%
Activity diagram 2 and Class 2	0%	0%	25%	50%	25%
Activity diagram 3 and Class 3	0%	0%	20%	55%	25%
Activity diagram 4 and Class 4	0%	0%	20%	50%	30%
Activity diagram 5 and Class 5	0%	0%	20%	45%	30%
Activity diagram 6 and Class 6	0%	0%	20%	50%	30%
Activity diagram 7 and Class 7	5%	10%	25%	40%	20%
Activity diagram 8 and Class 8	0%	0%	25%	45%	30%
Activity diagram 6 and Class 9	0%	0%	20%	20%	60%

members and graduate students. Results have shown that traceability of NICE recommendations in the systems' design models is achieved. With a traceability component we manage to reduce or avoid complications in the implementation phase. Additionally, we achieve consistency between the system's requirements and the design outcome. In the future, we plan to extend the work and incorporate security mechanisms. Additionally, we aim to develop a prototype of our system.

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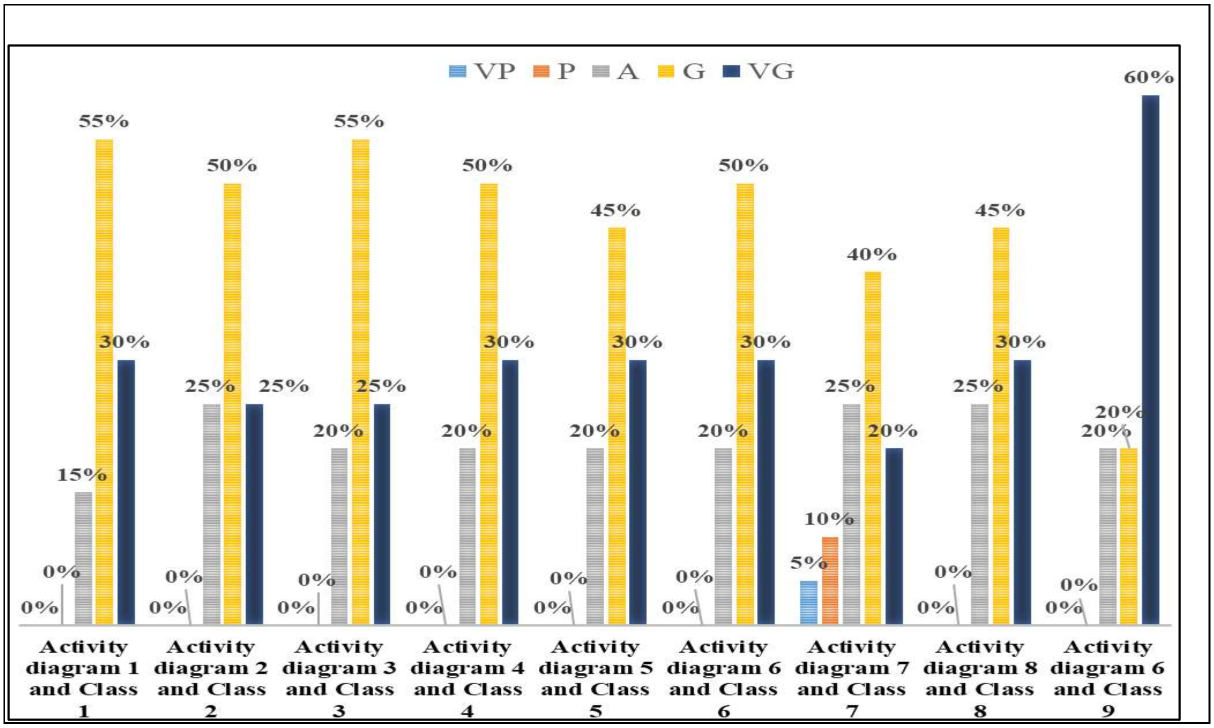

Figure 9: Traceability between activity diagrams and class diagram

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