Design of Application Framework for Vital Monitoring Mobile-Based System

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ABSTRACT

In the realm of modern healthcare, continuous monitoring can leverage the affordable wearable devices available on the market to manage costs. However, these devices face several limitations, such as restricted access for other parties, including nurses and doctors, and the need for redevelopment to integrate new devices for data accessibility. This study addresses these challenges by establish an application framework tailored for mobile-based systems, by ensuring accessibility by external parties. The research contribution is encompassing two key aspects: the potential implementation of Feature-Oriented Domain Analysis (FODA) in the domain of mobile-based vital sign monitoring, particularly in the absence of prior studies addressing the same context, and the identification reusable (frozen spots) and adaptable components (hot spots), providing guidance for the development of mobile-based vital sign monitoring. FODA is utilized during the analysis activity. Design patterns are then implemented when creating class diagrams in the design activity. This study finding reveal 7 primary features and 18 sub-features essential that must be incorporated into the application framework. The framework includes 5 hot spots and 7 frozen spots, with the implementation of Strategy and Filter design patterns. In conclusion, the developed application framework represents a significant advancement in vital sign monitoring, particularly within mobile-based systems. This study emphasizing limitations in analysis and design phases. In future research, the focus will shift to the construction and stabilization phases, all crucial for refining the framework. Implementing framework in actual applications can aid in developing vital sign monitoring systems and potentially improving healthcare outcomes

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1. INTRODUCTION

Healthcare has achieved essential breakthroughs in various technologies, particularly in vital signs monitoring. Vital sign monitoring is essential for improving medical diagnosis and patient health. Various medical devices have been used to help monitor, diagnose, and treat many diseases [1]–[5]. Continuous monitoring of a patient's health offers a more thorough understanding of their condition and facilitates efficient information exchange for surveillance, therapy, and recovery [6]–[10]. This approach is also applicable in home care settings, where continuous monitoring can significantly improve the quality of care provided to patients [11]–[13]. Effective monitoring is typically conducted in Intensive Care Units (ICUs) using patient monitors that can rapidly and continuously capture vital sign data. However, the high cost of these devices limits their availability in hospitals, and they lack remote monitoring capabilities.

Many studies have explored the creation of wearable sensor-based medical devices and the use of the Internet of Things (IoT) for remote monitoring of patient vital signs [14]–[19]. These innovations not only simplify patient care but also have the potential to reduce healthcare costs [20]–[22]. However, most of these tools are still in the prototype stage, making patients difficult to get them.

Currently, wearable devices like smartwatches with vital sign sensors are available in various marketplaces at affordable prices. These devices usually come with mobile applications that display vital sign data. However, they can only be accessed through their specific applications and cannot send data to other systems, preventing monitoring by other people. Several studies have developed mobile-based vital sign monitoring systems [23], [24], with one study attempting to address this issue by developing a system that utilizes affordable wearable devices for remote monitoring of patient's vital signs in homecare settings [25]. Another issue that arises is the introduction of new devices, which requires developers to update applications, spending both time and resources.

Based on the explanation above, the integration of new devices, such as smartwatches with vital sign sensors, into existing systems often requires redevelopment. Therefore, to address this challenge, it is imperative to develop service infrastructure [26]–[28]. This approach is further supported by previous studies, which suggest the need to design and develop infrastructure for mobile applications in their future investigations [25]. This infrastructure must also be capable of handling the limitations of wearable devices in accessing and transmitting vital sign data to other systems. This objective can be achieved by considering the design of an application development that can integrate data into a platform accessible by other parties, such as doctors and nurses.

This study addresses several identified problems outlined above. Purpose of this research is to design an application framework for problem domains vital sign monitoring mobile-based. Similar to the general development life cycle (SDLC), the development process for an application framework also encompasses several important stages: specification and analysis, design, development, validation, and evolution. with the analysis and design stages being particularly crucial [29]–[31]. This study has limitations only describes on the analysis stage, followed by the design stage. During the analysis stage, the primary aim is to delineate essential functionalities, often achieved through stakeholder interviews, brainstorming sessions, surveys, or questionnaires [32]. For analysis stages will use Feature-Oriented Domain Analysis (FODA) method as a viable approach for feature analysis in this study. FODA is employed due to the abundance of existing vital sign monitoring systems and its ability, based on the some studies showing that by leveraging existing applications, this method can systematically identify, categorize, and analyze features [33]. The outcomes serve not only to comprehensively outline feature requirements but also to pinpoint the identification reusable (frozen spot) adaptable components (hot spots) within the domain, a process often conducted at an advanced stage in the software development [34]. In the design stage of this study, class diagrams are designed with the concept of a design pattern.

The related work about potential of Feature-Oriented Domain Analysis (FODA) is not only limited to discussions earlier mentioned. It has been used in analyzing features on Learning Management Systems (LMS) [35]. These studies provide valuable insights into feature requirements in online learning environments. Additionally, FODA has been explored in feature modeling applications [36]–[38], introducing the concept of feature model abstraction to represent software product lines. The application of FODA in the context of frameworks has also garnered attention, providing a solid theoretical and practical foundation for feature analysis in system development. Some studies apply FODA to identify similarities and variations between three common blockchain platforms used to deploy smart contracts [39]. Their research proposed a reference model for intelligent contracts that demonstrates the framework's ability to enable developers to generate structural code. Furthermore, recent studies has applied FODA to analysis in design of framework architecture for telemedicine and vital sign domains [34], including hot spots and frozen spots of the system that produced artifacts as a guide for writing code at the development activity stage.

The contribution of this research lies in several key aspect. Firstly, it explores the potential application of Feature-Oriented Domain Analysis within the domain of vital sign monitoring, particularly in mobile-based systems. Unlike previous studies focusing on domains like Learning Management Systems [33], [35], Telemedicine [34], and Smart Contracts [39], this study fills a gap in existing literature by specifically addressing the domain of monitoring vital signs in mobile-based systems. Furthermore, the design outcomes generated from this study serve not only to provide valuable contributions for developers to build similar systems but also have the potential to address future work outlined in a previous study to design and develop an application framework for a mobile application specifically tailored for connecting with BT/BLE-based medical devices, such as smartwatches or other wearable sensors [25]. Despite the limitation of this research to the analysis and design stage, these design outputs are in the form of artifacts as guidelines for writing application framework codes in the development activities. This study comprehensively describes of each conducted activity and the produced artifacts. In particular, the study delves into the following inquiries: (1)

Which features were derived from the FODA analysis results? (2) What hot spots and frozen spots were identified? (3) Which design patterns is implemented to address the identified hot spots?

2. METHODS

This section outlines the theoretical foundations and key aspects of the research. The study includes several stages. Starting with problem identification through a literature review and information gathering. The next stage is analysis using Feature-Oriented Domain Analysis (FODA), which involves evaluating applications, context analysis, domain modeling, and architectural modeling to systematically understand domain features and their relationships. Based on this analysis, the final stage focuses on design, guided by the adaptable components (hot spots) identified. These stages are visually represented in Fig. 1.

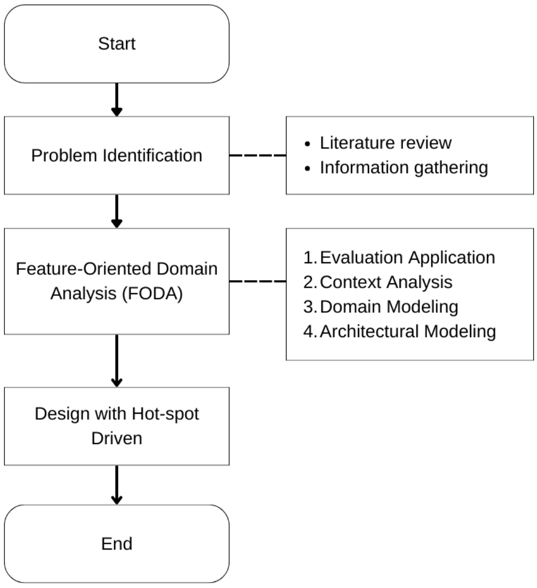


Fig. 1. Flowchart of the research procedure

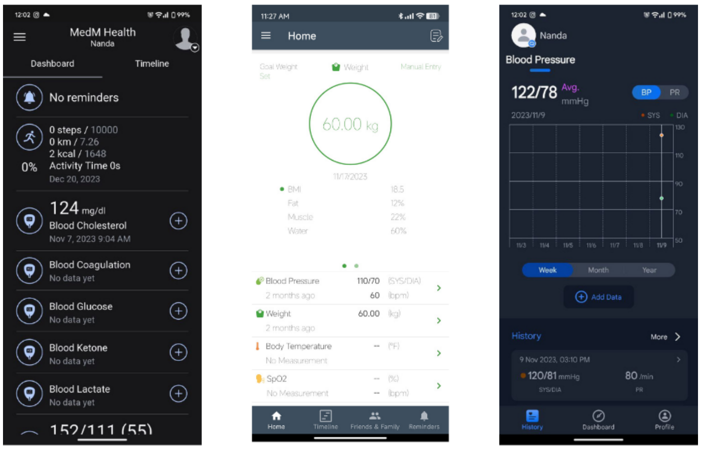
2.1. Problem Identification

In this stage, a literature review and data collection were conducted. During the literature review stage, the researcher conducted a search specifically related to the topic of vital sign monitoring systems and Feature-Oriented Domain Analysis (FODA). This process includes searching for information from various sources, such as documentation, user guides, and demonstration videos, to gain a comprehensive understanding of the functions offered by the application [34]. Vital sign monitoring systems that have mobile-based applications have been analyzed in-depth, and the results are presented in Table 1. This table includes apps from MedM, Qardio, and ViHealth. These applications were chosen because they are readily available for free and offer detailed explanations through their video demonstrations, enhancing the researcher's understanding of their functionalities.

Table 1. Vital Sign Monitoring Application

Domain	Application	Official Site
Vital Sign Monitoring Mobile-based System	MedM Health	medm.com
	Qardio	qardio.com
	ViHealth	viatomtech.com

At the time of the research, the MedM Health application was using version 2.14.235, Qardio was using version 2.4.6, and ViHealth was using version 2.74.81. These versions reflect the current state of the apps at the time of the study. Furthermore, the results of collecting information from the various applications will be the basis for forming a list of features that will be used in the next stage. Fig. 2 is a screenshot of the application to provide a visual representation of the available interface.



MedM Qardio ViHealth

Fig. 2. Overview of the application

2.2. Feature-Oriented Domain Analysis

The Feature-Oriented Domain Analysis (FODA) approach is employed in this research to identify and analyze common or special features of software systems in the vital sign monitoring domain. The features obtained can address attributes or properties that can be seen by domain users. Using FODA is utilized to identify mandatory, optional, and alternative features [36]. Feature modeling in FODA is key and is the basis for much of the subsequent work [40].

The Feature-Oriented Domain Analysis method has several phases, including Context Analysis, Domain Modeling, and Architecture Modeling. These phases are illustrated in Fig. 3.

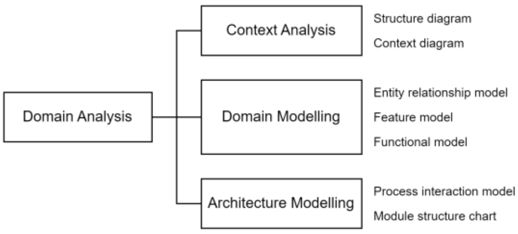


Fig. 3. Phase of Feature-Oriented Domain Analysis

In the context of this study, the Feature-Oriented Domain Analysis (FODA) method is applied across several phases, as illustrated in Fig. 3. Context Analysis involves gathering information and identifying the entities constituting the application within the vital sign monitoring domain, utilizing techniques such as context diagram creation to illustrate existing processes. Domain Modeling further advances the analysis by exploring similarities, differences, and relationships between entities, encompassing feature analysis, entity-relationship modeling, and functional analysis. Subsequently, Architecture Modeling defines the framework for developing applications within the domain [41]. The main goal of FODA is to create reusable domain products. In architecture modeling, focus on high-level application design in the domain for process identification and allocation of features, functions, and data objects defined in the modeling domain [42].

2.3. Design with Hot-Spot Driven

In this phase, the features identified in the previous phase are analyzed. The features are further analyzed to identify hot spots and frozen spots. This hot spot investigation process involves the use of hot spot cards [34]. The hot spot investigation consists of two main stages: hot spot identification and hot spot definition. The hot spot identification stage involves the utilization of hot spot cards to provide valuable information regarding the level of flexibility of each hot spot. This information is crucial for effective system development, as it allows for determining the complexity of the features and the appropriate design patterns to be used for each hot spot [43]–[45]. Each hot spot identified during the domain analysis process will then be determined using a hot spot card. The purpose of this investigation is to comprehensively understand how these hot spots function. It should be noted that the hot spot card should be flexible enough to adapt to changes required during the development cycle but not so flexible that it obscures the information required for feature development.

The results of hot spot design can be described through modeling using class diagrams. These class diagrams are generated by applying the rules of the patterns contained in the initial design. This process enables a visual realization of the structure and relationships between the classes that represent the hot spot, strengthening the understanding of the overall design [46], [47].

3. RESULTS AND DISCUSSION

1.1. Results

The first step in this research is to gather information from applications within the vital signs monitoring domain. These applications serve as the primary sources of information. Based on the review conducted, 7 main features and 18 sub-features have been identified which are the focus of the analysis of the vital signs monitoring domain in the mobile-based system. The main features obtained during the application review process can be seen in Table 2.

Table 2. Main Features

No	Features	MedM	Qardio	ViHealth
1	Account Management	✓	✓	✓
2	Vital Sign Data Input	✓	✓	✓
3	Vital Sign Measurement Results	✓	✓	✓
4	Devices Connectivity	✓	✓	✓
5	Export Measurement Data	✓	✓	✓
6	Remote Patient Monitoring Support	✓	✓	✓
7	Application Settings	✓	✓	✓

Table 2. summarizes the main features available in the applications MedM, Qardio, and ViHealth. Each feature is marked with a check (✓) to indicate its presence in the respective application. These features form the basis of the analysis, guiding the evaluation of vital signs monitoring functionalities across different applications.

The analysis activity conducted in this research utilized the Feature Oriented Domain Analysis (FODA) method. The first phase in FODA is context analysis. The result of the context analysis is a context diagram, visually represented in Fig. 4, which illustrates the relationship between actors and the specific feature functions they can access and utilize.

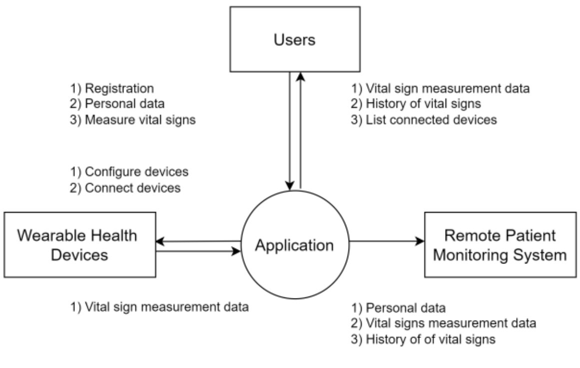


Fig. 4. Context diagram

This context diagram provides a comprehensive overview of the system's environment, outlining the interactions between different entities and functionalities, particularly within the domain of mobile-based vital sign monitoring. By visually mapping out these connections, stakeholders gain valuable insights into the system's architecture and behavior. The creation of this diagram stemmed from a meticulous context analysis conducted [48], aiming to establish a profound understanding of the application environment within the vital sign monitoring domain.

The second phase in FODA is domain modeling, which yields feature model diagrams as its outcome. These diagrams serve as comprehensive visual representations of the interconnected features and functionalities within the domain, particularly in the context of mobile-based vital sign monitoring. In this study, six meticulously designed feature model diagrams were crafted to encapsulate the diverse features and functionalities intrinsic to the application. The feature model holds significant importance in the domain analysis process, serving as a pivotal tool for mapping out stable areas within the domain, commonly referred to as frozen spots. These stable elements are represented as mandatory features within the feature model diagram, as exemplified in Fig. 5. Moreover, the feature model aids in identifying hot spots, which denote optional or alternative features within the application. For instance, in the context of device connection features, this can be observed in Fig. 6.

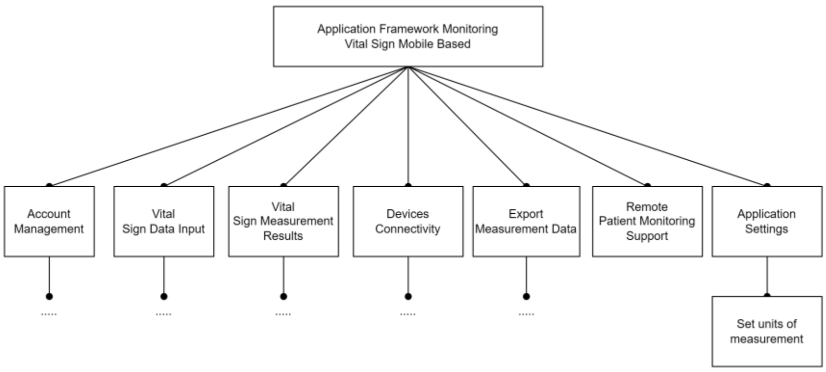


Fig. 5. Feature model

Fig. 5 displays the feature model, showcasing 7 key features essential to the mobile-based vital sign monitoring system. This diagram simplifies the understanding of the application's structure by highlighting its main components.

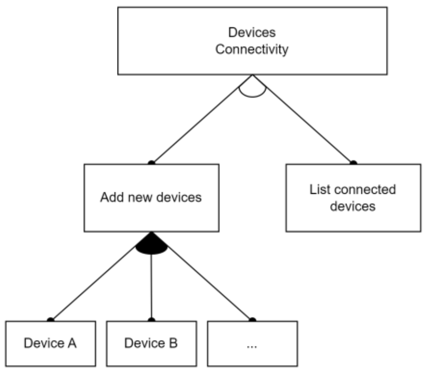


Fig. 6. Feature model diagram for Devices Connection

Fig. 6 illustrates the feature model diagram specifically focusing on device connection features in the mobile-based vital sign monitoring application. This diagram provides insights into how devices connect and function within the app. Moreover, the presence of distinct connection types can be regarded as hot spots, critical areas where decisions regarding system functionality and design may be made.

From the feature model diagrams those have been made, we can determine the common spots (mandatory features) and hot spots (optional and alternative features). Table 3 provides an overview of static features or characteristics that remain consistent over time in this application framework, emphasizing the elements that fundamentally maintain stability. Table 4, on the other hand, points towards dynamic components or features, often subject to change and referred to as hot spots, marking the flexibility and adaptability of the application framework.

Table 3. Frozen Spot Classes

No	Name	Class Type
1	Account Management	Control
2	Vital Sign Measurement	Control
3	Add Notes	Control
4	Detailed Measurement Results	Control
5	Application Settings	Control
6	Remote Patient Monitoring Support	Control
7	List Connected Devices	Control

Table 4. Hot Spot Classes

No	Name	Design Pattern
1	Measurement Method	Strategy Pattern
2	Filter Time Interval	Filter Pattern
3	Export File	Strategy Pattern
4	Measurement History View	Strategy Pattern
5	Add New Devices	Strategy Pattern

Continuing within the domain modeling phase following the feature analysis, a functional analysis was conducted, resulting in the creation of use case diagrams. Fig. 7 illustrates the use case diagram, specifically focusing on the device connectivity features within this application framework.

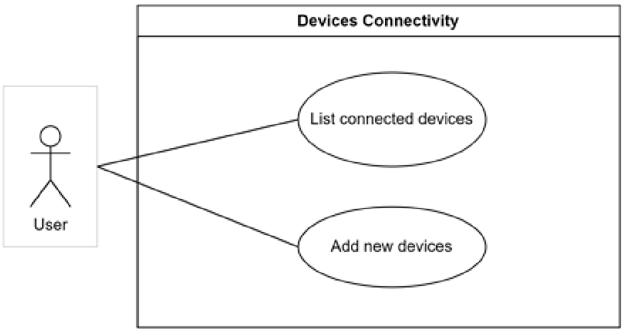


Fig. 7. Use case diagram for Devices Connection

The use case diagram in Fig. 7. provides a visual representation of the various interactions and functionalities related to device connectivity. It helps stakeholders understand how users interact with the system to establish connections with external devices for vital sign monitoring.

To provide a more detailed understanding of the device connectivity feature, Table 5. presents the use case description. This table outlines the specific actions and scenarios associated with device connectivity within the application.

Table 5. Use Case Description for Devices Connection

Use Case Description	Design Pattern
Name	Devices Connection
Short description	Users connect the Wearable Health Device with a smartphone
Actor(s)	User
Precondition	Permission to access Bluetooth and other permissions for applications to run normally
Postcondition	Wearable health device successfully connected to the smartphone
Normal course	1. Users select the Add Device menu 2. Users wait for the device to be scanned successfully 3. Users select appropriate wearable devices
Alternate course	Users can connect to devices that have been connected before without adding new ones which can be seen in the list of connected devices
Exception course	If the Bluetooth smartphone is turned off, a message will appear to turn it on first

These use case descriptions in Table 5. offer a deeper insight into the functionality and behavior of the device connectivity feature, aiding in the comprehensive analysis and design of the application.

This functional analysis step involves identifying the interactions between various features, mapping the functionality, and constructing detailed usage scenarios. As such, the results of this use case analysis provide a solid foundation for understanding how users will interact with the device connectivity features, describing the workflow and potential functionalities accessible to users. Fig. 7. and Table 5. are important tools in detailing the functional aspects of the device connectivity features in this application framework, providing the necessary information for further development as well as a deep understanding of the overall application usage.

In an effort to present a thorough understanding of the implementation of the vital signs monitoring attributes that have been the focus of the research, Fig. 8 shows an activity diagram that illustrates the series of steps involved in the application.

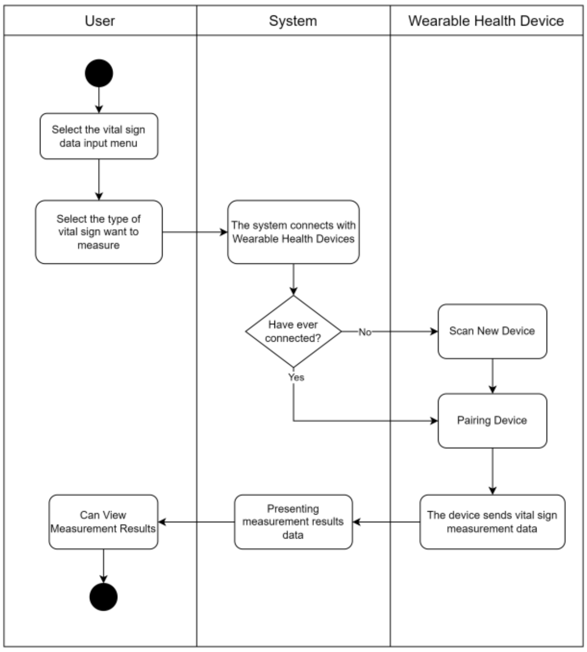


Fig. 8. Activity diagram for Devices Connection

Fig. 8 is an activity diagram presenting a systematic sequence of steps within the vital signs monitoring application, involving three key actors: User, System (application), and Wearable Device. Initially, the User selects a menu option and chooses the vital sign to access. Subsequently, the System initiates connection with the Wearable Device, conducting a scan if no prior connection exists, followed by pairing to establish communication. Once connected, the Wearable Device transmits the measured vital sign data to the System. The System then displays this data to the User via the application interface, enabling them to view and analyze the vital sign information.

Based on the utilization of the use case diagram, it is possible to create use case descriptions and develop activity diagrams through the creation of hot spot cards. In this particular investigation, five hot spot cards were formulated to identify areas of flexibility in vital sign monitoring. Fig. 9 provides an example of one such hot spot card, taking the connectivity feature of the device as the part that has flexibility in use.

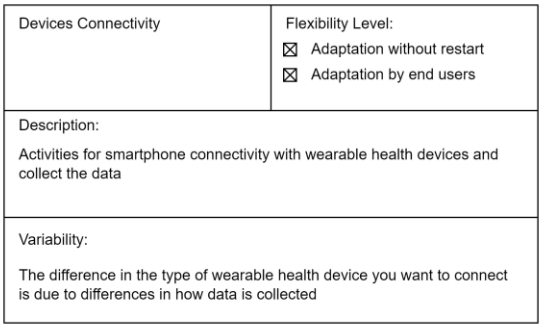


Fig. 9. Hot spot card for Devices Connection

The ensuing analysis led to the development of the architecture modeling seen in Fig. 10. Through this stage, the research produced a clear picture of the implementation of vital signs monitoring attributes in the context of the application. Architecture forms the essential foundation for building the application framework.

Fig. 10 depicts the architecture model, illustrating the intricate connections and interactions between the mobile application, web services, and peripheral devices. In this case, the app needs to communicate with the web services and the peripheral devices simultaneously via syncing data from one to the other. A wearable device like smartwatch is connected to the mobile phone and constantly communicates with its app via BLE. At the same time, the app transmits data to the web services. The mobile application does not only perform the role of the user-facing part of the system, but also acts as a mediator between utterly different parties.

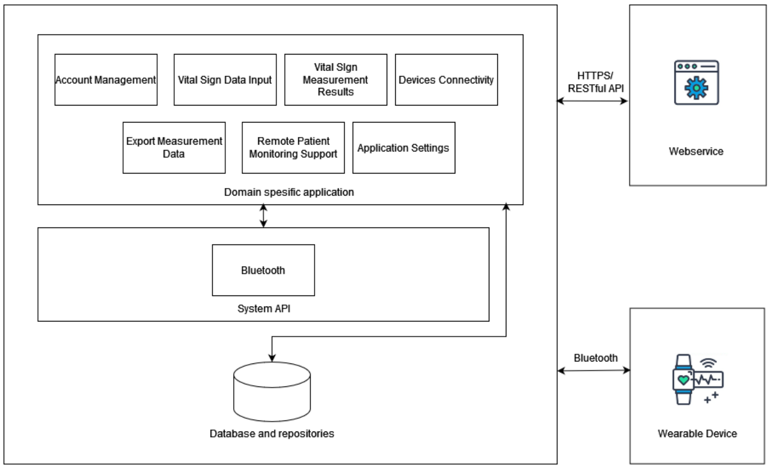


Fig. 10. The architecture model

The importance of architecture in the development of application frameworks becomes increasingly clear in the context of application frameworks [49]. Application frameworks, generally designed to support a specific application domain, include user interfaces, business data processing systems, telecommunications, or collaborative multimedia environments. They can be thought of as partially completed applications, encompassing frozen spots, which are stable features required for a turnkey application, and hot spots, which are application components that can be changed to meet design specifications. Therefore, application frameworks provide a comprehensive view of the structure and functionality to be developed. The modeling architecture seen in Fig. 10 is not only the main guide in development but also a reference to ensure the consistency of the product model during development, especially when new features are introduced without changing the basis on which the product is built [35].

The final result of the previous stages culminated in the formation of hot spot classes with the application of design patterns. In Table 4., each hot spot class is obtained from the analysis and designed according to the relevant design pattern. For example, the class design for the "Add New Devices" hot spot utilizes the Strategy Pattern design pattern, which is depicted in Fig. 11.

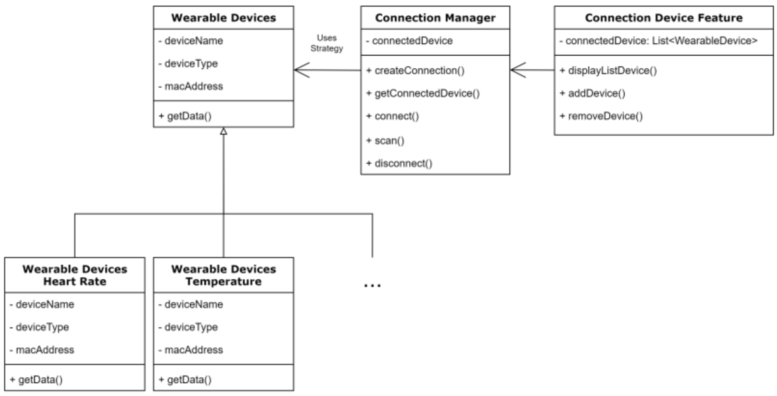


Fig. 11. Class diagram for add new devices

Fig. 11 depicts the class diagram for adding new devices. The selection of the strategy pattern is based on the consideration that the design pattern is suitable for situations where there are multiple algorithms that can be used for a particular task, and the client has the freedom to choose which implementation to execute at run time [50], [51]. In the case of the "Add Device" feature, there is a need to use different techniques or algorithms to capture and read data from different Wearable Health Devices (WHDs). This is due to the variation of sensors owned by each device, making one of the main reasons for applying strategy patterns in the implementation of these features.

1.2. Discussion

Several previous studies have explored the use of Feature-Oriented Domain Analysis to identify features within a domain, such as in Learning Management Systems (LMS), which successfully categorized 34 features for teachers and 14 features for students [35]. Another study on Canvas LMS categorized 36 features for teachers and 26 features for students [33]. In the case of Telemedicine, 14 main features and 45 sub-features were categorized [34]. However, in this study, focusing on the domain of mobile-based vital sign monitoring utilizing FODA, a total of 7 main features and 18 sub-features were identified. This demonstrates the successful application of FODA in conducting analysis, utilizing existing applications.

This research demonstrates the utilization of Feature-Oriented Domain Analysis in ascertaining system characteristics through domain analysis for use in designing application frameworks. Specifically, the domain analyzed is vital signs monitoring on a mobile-based system. The approach used in this study involved selecting three applications from the domain. The selection of three applications as the quantity of choice is based on the premise that if a feature exists in two applications, then it can be considered as the main feature. However, in this investigation, a feature is considered important only if it is present in all three apps, as evidenced in Table 2. This is because the number of important features becomes too large when the key features are selected based on the presence of two apps. In survey and studies looking for existing applications, we encountered difficulties in finding applications due to challenges in locating comprehensive documentation about them.

This study has limitations as it solely focuses on the analysis and design activity. However, it is worth noting that this research can serve as a response to previous studies aiming to build an application framework for vital sign monitoring on mobile devices [25]. For analysis activity use Feature Oriented Domain Analysis (FODA) and for design activity, class diagrams are designed with the concept of design pattern. The utilization of the visual representation of FODA in the feature model depicts the nomenclature of the application framework as the root, as shown in Fig. 5. After that, the root is broken down into domain derivatives in the feature model, taking the role of key characteristics. As an illustration, the main features of the domain consist of Account Management, Vital Sign Data Input, Vital Sign Measurement Results, Devices Connectivity, Export Measurement Data, Remote Patient Monitoring Support, and Application Settings. These main features can then be subcategorized into sub-features, as shown in Fig. 6. In addition, the notation used in the feature model can indicate features that have the potential to become hot spots, as evidenced by the Add New Devices feature. After undergoing analysis through use case diagrams, use case descriptions, and activity diagrams; it can be seen which features have the potential to become modifiable parts (hot spots). As the final result in the analysis stage, the output produced is a hot spot card. The hot spot card contains information on the level of flexibility and variability, which ultimately becomes the basis for determining the design pattern according to the decision taken based on the hot spot card. The design patterns obtained are then implemented into a class diagram, as exemplified in Fig. 11. Subsequently, it is important to note that the resulting class diagram from this process is the outcome of the design phase.

2. CONCLUSION

This research describes the design steps of an application framework for mobile-based vital sign monitoring. This shows the possibility of representing a domain through similar applications in the domain. From the description above, the Feature Oriented Domain Analysis (FODA) methodology can assist in discerning the requirements of the application framework. FODA also aids in identifying features that are common spots and hot-spots within the framework.

The contribution of this research lies in the application of FODA to design application frameworks in the context of vital sign monitoring, which has previously been applied to other domains. The result of this design can provide insights for guiding the development of similar domain applications, specifically in mobile-based vital sign monitoring. By understanding the common features and potential modifiable features based on the hot spots and frozen spots generated, developers can streamline the analysis and design process. Moreover, the design patterns depicted can serve as insights for future code development, helping developers reduce the time required for in-depth analysis and design.

However, the limitations of this study are confined to the analysis and design phases of the vital sign framework. In future research, the focus will shift from analysis and design to construction and stabilization phases. Construction involves writing the application framework code, while stabilization includes testing, bug fixing, and documentation. This progression is essential for refining the framework. Implementing the framework in an actual application can aid in the development of vital sign monitoring systems and potentially advance healthcare delivery and patient outcomes.

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