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ABSTRACT

The present work aims to design and to implement a pervasive system based on business processes. This system is composed of both a mobile and a web application. The use case has been chosen as a car rental agency. The building approach covered the analysis, the design and the implementation phases successively. The analysis phase identifies the interne and the extern business processes, also the system's components. The design phase elaborates the most suitable UML diagrams. Then jumps into the implementation phase that builds two main applications using the most suitable software tools and these applications are: first, a web application to give to the company an advanced tool for sharing its business process as services provided to its customers. Second and since our system is meant to be pervasive anywhere at any time, a large accessibility has been given to our users by also building a mobile application apt to be manipulated by these users.

Keywords: business process, modeling, UML, web application, mobile application, pervasive systems, car rental.

Résumé

Le présent travail vise à concevoir et à mettre en œuvre un système pervasif basé sur les processus métiers. Ce système est composé d'une application mobile et d'une application Web. Le cas d'utilisation a été choisi en tant qu'agence de location de voitures. L'approche du bâtiment a couvert successivement les phases d'analyse, de conception et de l'implémentation. La phase d'analyse identifie les processus métiers internes et externes ainsi que les composants du système. La phase de conception élabore les diagrammes UML les plus appropriés. Nous passons ensuite à la phase d'implémentation qui construit deux applications principales en utilisant les outils logiciels les plus appropriés. Il s'agit tout d'abord d'une application Web destinée à fournir à la société un outil évolué lui permettant de partager ses processus métiers en tant que services fournis à ses clients. Deuxièmement, et comme notre système est censé être pervasif partout et à tout moment, une grande accessibilité a été donnée à nos utilisateurs en construisant également une application mobile pouvant être manipulée par ces utilisateurs.

Mots-clés: processus métier, modélisation, UML, application Web, application mobile, systèmes pervasifs, location de voitures.

نبذة مختصرة

يهدف العمل الحالي إلى تصميم وتنفيذ نظام واسع الانتشار يستند إلى العمليات التجارية. يتكون هذا النظام من تطبيقات الجوال والويب. وقد تم اختيار وكالة لتأجير السيارات كدراسة حالة. غطى نهج بنائنا مراحل التحليل والتصميم والتنفيذ تحدد مرحلة التحليل العمليات الداخلية والخارجية لنظامنا ، وكذلك مكوناته. تشرح مرحلة التصميم على التوالي المخططات الأنسب. ثم تنتقل إلى مرحلة التنفيذ التي تبني تطبيقين رئيسيين باستخدام أدوات البرمجيات الأكثر ملاءمة وهذه التطبيقات هي: أولاً ، تطبيق ويب يوفر للشركة أداة متقدمة لمشاركة أعمالها كخدمات مقدمة لعملائها. ثانياً ، نظرًا لأن نظامنا منتشر في أي مكان وفي أي وقت ، فقد تم منح المستخدمين إمكانية وصول كبيرة من خلال بناء تطبيق للهاتف المحمول يمكن معالجته والتفاعل معه من قبل هؤلاء المستخدمين.

الكلمات المفتاحية: العملية التجارية ، النمذجة، تطبيق الويب ، تطبيقات الهاتف المحمول ، الأنظمة المنقشية ، تأجير السيارات.

GENERAL INTRODUCTION

Information system (IS) [71] is an integral part of an organization, regardless of its size or industry. These systems typically hold and control the data that the organization needs, such as data about business process services, products, clients, transactions, suppliers and many more. Most, if not all, employees operate these information systems and spend many hours interacting with them at work. A business process [1] is a sequence of tasks that aims to produce a result to help customers by facilitating their tasks. Over the past few decades, these systems have been constantly upgraded. Newer systems have appeared that are able to efficiently handle their processes quicker and more accurately compared to previous iterations. Graphical user interfaces (GUI) have become the norm and replaced old text terminals that lack data. Thanks to changing design approaches, developing these newer systems is done faster than ever. When it comes to the world of modern computing, it's clear that technology is changing fast and links are emerging more strongly between the use of certain key technologies and improvements to the business process services, when we look at things before and compare them to now it is clear that most of the enterprises that equipped themselves with these technologies and share their work through them have achieved more success than other companies that didn't. Nowadays almost every company is integrating pervasive computing systems by owning both a web application and a mobile application, that help them to share their business process not only with computer or laptops users but with any device possible from mobiles to tablets and even watches to anyone and anywhere, enterprises are actually feeling stronger now more than ever because of this availability. That is why the work presented aims to study and implement a pervasive information system based on business processes.

Currently, the modern enterprise, and through its Information System has internal business processes as a set of activities not accessible outside and protected to any other manipulator, and at the same time it provides external business processes through services

published on the web via either web applications or mobile applications, which feels a soft accessible at any time and outside of its building [5].

For this purpose, the problematic of our work focuses to respond to a set of important questions: first how to design a pervasive system based on business processes? Second, How to build a web and a mobile application synchronized to handle the business processes of this system? How are the suitable tools used in both the design and implementation phases, to give the best results?

We chose a car rental agency as a study case of a modernized information system because it offers a variety of internal and external business processes and also because of the lack of car rental agencies in our region that own both types of applications (mobile and web).

The objective of our work followed an approach that will focus on: In the analysis phase, we identify the public and the private business process in the car rental agency and describe its components. In the design phase we focus on representing the internal and external business processes graphically in an easy and simple way by UML models. Our goal is then to: 1) select a car rental agency as a study case, 2) identify and design its internal and external business processes, using a various kind of diagrams (static behavior and dynamic behavior)

The implementing phase will focus on the development of the pervasive system by building two kinds of applications using the most suitable software and developing languages for each type. The first type is a standard web application in which we will use HTML, CSS and JAVASCRIPT and then the second type is a mobile application which will be developed using JAVA.

The present thesis is decomposed as the following: in the first chapter, we have presented multiple concepts that are related to our work which are: first, the concept of business process in which we presented it by defining it and mentioning its types and characteristics and some of its advantages, also the ways to model it, the second concept is web applications in which is we also defined it alongside specifying its types and advantages, the third concept is mobile application and we presented it in an approach

similar to the web applications. Then we synthesized both the web and mobile applications and ended it with the last concept of this chapter which is pervasive computing.

In the second chapter, we introduced our study case which is a car rental agency and also listed its public and private business processes then we focused on the design and modeling side of these business processes using UML by specifying all the interactions that exist between the different actors of our system which are:(client, visitor, administrator, manager) with static views: class diagram, system functionality: use case diagram and then with dynamic views: Sequence diagrams and activity diagrams.

In the thirds and the last chapter, we specified the development tools, languages and the programming environments that are used to make both the online mobile application and web application in which we used it to share the public business processes to the outside world.

This thesis ends with a general conclusion summarizing our work and contribution, it also speaks about the potential features that we plan to add in a future work.

CHAPTER 1: STATE OF ART

1 INTRODUCTION

At a time when competition is becoming tougher and markets are becoming more volatile, the company must stand out from the competition. To be more competitive, therefore, the company must constantly improve and adapt its business processes to fit their own objectives and its environment (market, competition, regulation). It must then identify the strengths and weaknesses, and identify areas for improvement to always improve performance and competitiveness [63]. Currently, the modern enterprise, and through its Information System (IS) has internal business processes as a set of activities not accessible and protected, and at the same time it provides external business processes through services published on the internet via web applications or mobile applications, which feels accessible at any time and outside of its boundaries [64].

This chapter presents a state of art in which it provides definitions of concepts used in our thesis which are: Business process, web applications, mobile applications, pervasive computing systems.

We start this chapter with the concept of business process by defining it and explaining some of its essential characteristics, then we talk about web applications, their types and advantages then we present mobile applications as well, we end this chapter with an introduction and definitions of the essentials of pervasive computing systems.

2 BUSINESS PROCESSES

This section provides the essential notations and definitions of business process.

2.1 Definition of a Business Process

It is very common, in industrial settings, that the performed activities are repetitive and have several persons involved. In these cases, it is very useful to define a standard procedure that everyone can follow. A business process, essentially, is the definition of such “standard procedure”.

Since the process aims at standardizing and optimizing the activities of the company, it is important to keep the process up to date and as flexible as possible, in order to meet the market requirements and the business objectives [7].

There are several definitions of business process. The most influential ones are as follow:

Definition 1

A business process [1] is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer. A business process has a goal and is affected by events occurring in the external world or in other processes.

Definition 2

A business process [2] is a series of steps performed by a group of stakeholders to achieve a concrete goal. These steps are often repeated many times, sometimes by multiple users and ideally in a standardized and optimized way. A business process can be manual or automated. If manual, the process is achieved without the aid of an automation or assisting technology. If automated, a technology aid has been put into place which assists users in implementing the process in a more accurate, standardized or optimized manner.

Definition 3

Formally a business process [7] P is defined as a set of activities $VP = \{V_1, \dots, V_n\}$, a directed graph $GP = (VP, EP)$, an output function $oP : VP \rightarrow N_k$ and $\forall (u, v) \in EP$ a Boolean function $f(u, v) = N_k \rightarrow \{0, 1\}$. In this case, the process is constructed in the following way: for every completed activity u , the value $oP(u)$ is calculated and then, for every other activity v , if $f(u, v)(oP(u))$ is true, v can be executed. Of course, such definition of business process is hard to be handled by business people, but is useful for formal modeling purposes.

2.2 Characteristics of Business Process

The most important characteristics of business process are present as follow [5] [6] [45]:

- Dynamicity, responding to demands from customers and to changing market conditions.
- Long-running: a single instance of a process may run for months or even years.
- Widely distributed and customized across boundaries: within and between businesses, often spanning multiple applications on disparate technology platforms.
- Every process has an owner who has end-to-end responsibility for the whole process.
- Decomposition, a business process can be divided into multiple sub processes.
- Automated: activities are performed by computers wherever possible, for the sake of speed and reliability.

2.3 Benefits of Business Process

Integrating the techniques of business process into the information system of the companies have various benefits such as [5] [11]:

- The increase in efficiency, productivity, output, and profits for the companies.
- The disintermediation by eliminating unnecessary intermediaries.
- The distribution of knowledge.
- The analysis of measurements and support for decision making.
- The automation of manual tasks.
- The increase in customer's focus.
- The satisfaction of the working staff.

2.4 Types business processes

A business process in an enterprise can be internal (private) or external (public). This section explains the two kinds.

2.4.1 Private business process

Private business processes [5] are designed to meet local needs, Provide internal management services such as payroll or hiring process. These processes are triggered within the same company, which has complete control over the resources allocated in these processes and the implementation of individual activities.

The figure below (Figure 1.1) presents an example of a private business process.



Figure 1. 1: Example of private business process.

In the example (figure 1.1) above we see a set of processes that are all happening inside the borders of a company, like determining the order and checking the records, approving or rejecting clients, all these processes provide internal management, they happen without the interference of the external environment. For example when a person goes into a company for a job interview, the guy at the reception determines the order, check his records, and notifies the person if he is accepted or not.

2.4.2 Public business process

Public business [5] process is when an application or client requires features, and no single private process is able to provide them, they are triggered from outside or terminate outside the borders of a company. A lot of abbreviations are used on the public processes (processes that cross the borders of their companies) as:

- B2B (Business-to-Business):** processes between companies, they can also occur when one or more activities in a process are performed outside the company's control circle, while part of a process is outsourced.
- B2C (Business-to-Consumer):** processes between companies and customers.
- B2G (Business-to-Government):** processes between companies and government agencies,
- C2C (Consumer-to-Consumer):** processes between customers (online auction).

The figure below (Figure 1.2) presents an example of a public business process.

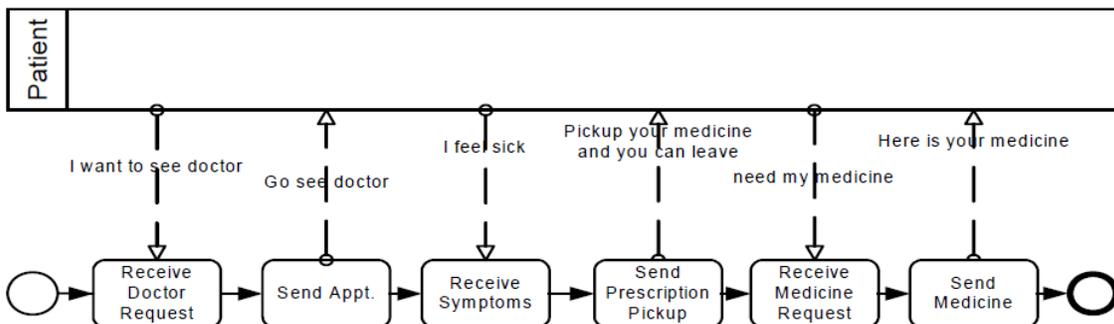


Figure 1. 2: Example of public business process.

In the example above (figure 1.2), a patient feels sick so he wants to go and visit a doctor, he waits until he receives the doctor's request so he can send him his symptoms, then the doctor sends the prescription to the patient so he can go and pick up his medicine. Some of the processes in this example are happening outside the doctor's clinic which makes them public (external) processes.

2.4.3 Synthesis: Examples of public/private business processes

The table below (Table 1.1) presents our own study of some well-known enterprises and their public and private business processes.

Enterprise	Private Business Processes	Public Business Processes
Jumia [19]	<ul style="list-style-type: none"> - Add/delete/modify goods. - Hiring new employees. 	<ul style="list-style-type: none"> - Customers can search for goods/ buy goods / review goods (B2C).
Steam[18]	<ul style="list-style-type: none"> - Clients management (add/delete/modify). - Add/delete games in the steam store. - Updating. 	<ul style="list-style-type: none"> - Registration (B2C). - Registered clients can buy games through steam store. - Connect with admins or other clients (C2C).
Algérie Post [44]	<ul style="list-style-type: none"> -Request a checkbook (carnet de check). -Hiring new employees. -Pay bills inside the office. 	<ul style="list-style-type: none"> -Transfer money/objects -Fixing problems outside the enterprise, Like connection cables. -Clients can pay the bills from their homes.
McDonald's [43]	<ul style="list-style-type: none"> -Preparing and cooking food. -Hiring employees. -Paying employees. 	<ul style="list-style-type: none"> -Ordering food online. -Deliver food to customers. -Sponsor relationships with companies or individuals.

Table 1. 1: Examples of private and public business process.

The present section defines the companies mentioned in the (Table 1.1) above.

Jumia [19]: is an e-commerce site, which promotes itself as an online shopping mall. This site offers products in a wide range of departments, including appliances and electronics, advanced products, fashion, children and concert tickets and hotel nights.

Steam [18]: Steam is a digital distribution platform developed by Valve Corporation for purchasing and playing video games. Steam offers digital rights management (DRM), matchmaking servers, video streaming, and social networking services. Steam provides the user with installation and automatic updating of games, and community features such as friend's lists and groups, cloud saving, and in-game voice and chat functionality.

McDonald's [43]: is an American fast food company, founded in 1940 as a restaurant in San Bernardino, California, United States.

Thus, companies contain private business processes that are kept protected and safe and also they own public business processes used to obtain more flexibility.

2.5 Business Process Modeling

Business Process Modeling [4] is a set of technologies and standards for the analysis, modeling, implementation, and execution of business processes. It allows business analysts and managers to analyze a system they use and optimize it, or to model a new system from the scratch.

We can model and specify business processes by different methods and standards, we present some of them:

2.5.1 Semi-formal modeling

A.UML

UML [Unified Modeling Language] [12] is a modeling language mainly used for specification, visualization, development and documenting of software systems. But business professionals have adapted it as a powerful business process modeling technique. With 14 different UML diagram types, it offers a flexible and powerful way to visualize almost any business process. They are typically used for modeling the detailed logic of a business process. We present the important diagrams as:

- Class diagram:** Describes the structure of a system by showing the system's classes, their attributes, operations (or methods), and the relationships among objects.
- **Sequence diagram:** Describes the different scenarios for using the system.
- **Activity diagram:** Represents step by step business workflows and operational components.
- Communication diagram:** Allows highlighting the message exchanges between objects.
- State-transitions diagram:** Represents states and state transitions.
- Global interaction diagram:** Provides an overview and nodes representing communication diagrams.
- Time diagram:** This is to describe the interactions between objects with strong temporal constraints.

2.5.2 Informal modeling

A. BPMN

BPMN [Business Process Model and Notation] [14] is a standard for business process modeling that provides a graphical notation for specifying business processes in a Business Process Diagram (BPD), based on a flowcharting technique very similar to activity diagrams from Unified Modeling Language (UML). The objective of BPMN is to support business process management, for both technical users and business users, by providing a notation that is intuitive to business users, yet able to represent complex process semantics.

B. BPEL4WS

BPEL4WS [Business Process Execution Language for web service] [41] is a specification proposed jointly by IBM, Microsoft, and BEA, and represents a convergence of the ideas initially proposed by the languages XLANG and WSFL. Which describe business processes in the form of Web services, and how they are interconnected to perform particular tasks. BPEL4WS is an effort to standardize the composition of web services. It is also a language for defining and managing activities of a business process. This language makes it possible to

describe protocols of interactions and collaborations between the web services on which the process is based.

2.5.3 Formal modeling

A. Petri net

Petri nets [65] are specific types of modeling constructs useful in data analysis, simulations, business process modeling and other scenarios. This type of mathematical construct can help to plan workflows or present data on complicated systems. Petri nets use elements like places, transitions and gates to describe complex procedures and model the workings of a system. Tokens and marking systems can show movement through these systems. Much of the model can be delivered in classic mathematical notation, or in specific drawings conforming to the syntax and makeup of the petri net model. Petri nets have many practical applications in technology. One big example is where petri nets are used in business process analysis.

B. FSM

Finite state machine [66] is a mathematical model of computation. It is an abstract machine that can be in exactly one of a finite number of states at any given time. The FSM can change from one state to another in response to some external inputs; the change from one state to another is called a transition. An FSM is defined by a list of its states, its initial state, and the conditions for each transition. Finite state machines are of two types: deterministic finite state machines and non-deterministic finite state machines. A deterministic finite-state machine can be constructed equivalent to any non-deterministic one.

C. Temporal logic

Temporal logic [70] is a branch of symbolic logic which is concerned with problems on propositions that have truth values dependent on time. Temporal logic is considered a variant of modal logic, which is a branch of logic dealing with propositions that can be expressed as a set of possible worlds. Temporal logic is used to touch all approaches to reasoning and representation based on time. Applications of temporal logic include use in reasoning in philosophical issues based on time, as a language in artificial language for encoding temporal

knowledge, and as tool for formal analysis, specification and verification of hardware and software requirements of computer applications and systems.

2.5.4 Benefits of Modeling

Business process modeling brings deeper understanding of how the business processes work and the way the business functions. Other than that, there are several other benefits [3] [4]

-Every person in the company will know what the goal of the processes is, and how they work and more generally he will have a better idea of what is going on the company. If the company have a large number of individuals or teams, Standardization will assure that everyone will have the same idea and all are on the same page.

-Elimination of redundancies.

-Better compliance with industry standards.

2.6 Synthesis: Comparing the different modeling tools

The following (Table 1.2) presents a simple comparison between the different modeling tools mentioned above.

Paradigm	Approach	Domain
Formal	Petri net	-Used in critical systems or issues where safety and reliability and are crucial. -Used in Systems that change in a discretionary way.
	FSM	-Used as a development tool for approaching and solving problems. -Used as a formal way of describing the solution for later developers and system maintainers.
	Temporal logic	-Used in reasoning and philosophical issues based on time. -Used as a language in artificial language for encoding temporal knowledge, and as tool for formal analysis, specification and verification of hardware and software requirements

		of computer applications and systems.
Informal	BPMN	-Used in process design (or redesign) during the Business Process Management stages when a company analyzes, studies and reimagines certain business processes.
	BPEL4WS	-Used in the specification and publication of business processes. -Used in Systems that change dynamically.
Semi-formal	UML	-Used to help system and software developers for specifying, visualizing, constructing, and documenting the artifacts of software systems, as well as for business modeling and other non-software systems

Table 1. 2: Comparing modeling tools.

Analysis:

The current trend is that graphic formalisms in the form of diagrams are more successful than purely textual representations. This accurate prevalence in our case by the fact of using semi-formal models rely heavily on a graphical language, and using formal models combine graphical languages with formal semantics. In the field of software engineering, the model makes it possible to better understand the functioning of the system, it is also a good way to control its complexity.

Formal methods are techniques that make it possible to reason mathematically with computer programs or electronic equipment, in order to demonstrate their validity with respect to a certain specification. They are based on the semantics of the programs that is to say on formal mathematical descriptions of the meaning of a program given by its source code (or sometimes, its object code).

These methods make it possible to obtain a very strong assurance of the absence of bug in software (Evaluation Insurance Level, Safety Integrity Level). They are used in the development of the most critical software. Their improvement and the broadening of their practical fields of application are the motivation for many scientific research in computer science.

Informal methods aim to standardize the scoring systems used for business purposes, and thus presenting business processes in a graphic way. These methods are understandable by any professional user regardless of their profile: from the business analyst responsible for designing the first draft of the project in process, to the technical developer responsible for the implementation of the technology adapted to the project, and finally the manager making sure to put in place these processes

Semi-formal methods are used during the analysis phase of a project to identify the system functionality. They describe the interaction of people or external device with the system under design. They don't show much detail, but only summarizes some of the relationships between use cases, actors, and systems.

3 WEB APPLICATION

In order for companies to publish their public business processes and make contact with their clients, they need to equip themselves with concepts that allow them to do that, so this section presents the first concept which is web applications.

3.1 Definition

A web application [42] is a computer program that utilizes web browsers and web technology to perform tasks over the Internet [20]. It uses a combination of server-side scripts to handle the storage and retrieval of the information, and client-side scripts (JavaScript and HTML) to present information to users. This allows users to interact using online forms, content management systems, shopping carts and more. In addition, the applications allow users to create documents, share information, collaborate on projects, and work on common documents regardless of location or device.

3.2 Functioning steps of web applications:

The web application requires a web server to manage requests from the client, an application server to perform the tasks requested, and, sometimes, a database to store the information [20].

The following figure (Figure 1.3) presents the architecture of web applications.

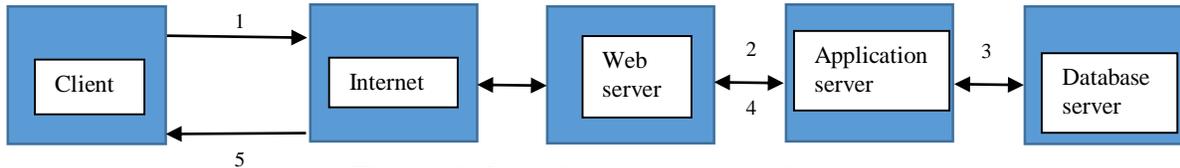


Figure 1. 3: Web applications architecture.

Here's what a typical web application flow looks like, after explaining the numbers in the picture above [20]:

- (1) User triggers a request to the web server over the Internet, either through a web browser or the application's user interface.
- (2) Web server forwards this request to the appropriate web application server.
- (3) Web application server performs the requested task – such as querying the database or processing the data – then generates the results of the requested data.
- (4) Web application server sends results to the web server with the requested information or processed data.
- (5) Web server responds back to the client with the requested information that then appears on the user's display.

The main components of the architecture in the (Figure 1.3) above are the following:

- **Client:** The client [20] is used in client-server environment to refer to the program, the person uses to run the application. A client-server environment is one in which multiple computers share information such as entering information into a database. The "client" is the application used to enter the information, and the 'server' is the application used to store the information.

- **Web Server:** A Web server [68] is a program that uses HTTP (Hypertext Transfer Protocol) to serve the files that form Web pages to users, in response to their requests, which are forwarded by their computers' HTTP clients. Dedicated computers and appliances may be referred to as Web servers as well.

- **Application Server:** An application server [69] is a type of server designed to install, operate and host applications and associated services for end users, IT services and organizations. It facilitates the hosting and delivery of high-end consumer or business applications, which are used by multiple and simultaneously connected local or remote users.

3.3 Types of web applications

In terms of technical implementation, all web applications are either static or dynamic.

3.3.1 Static web applications

This type of web applications is the most basic. They are often created using **CSS** and **HTML** and can handle animated content such as GIFS and videos. Static web apps lack flexibility and has little content or room for movement. Their pages are generated by a server and offer little to none (with no JavaScript code used) interactivity. Usually, no room for personalization exists and any possible change takes effect only after a full page reload [23].

Modifying the content included on static web applications can be tricky, and in order to make any serious changes, you'll need to download the **HTML code**, as well as modify and upload it to the server. Further, if the app wasn't designed by yourself or your company alone, you will likely need to seek out the person who planned and designed the static web application [22].

3.3.2 Dynamic web applications:

In the case of dynamic web applications, they are in place to hold databases or forums with a constant ability to update or change the available information. This is usually as a result of a CMS or Content Management System. A CMS will generally accompany a dynamic web application so that administrators or users can easily update or edit the content that is included. Many different web languages can be used with dynamic web applications. However, PHP and ASP are the most common, as they are the easiest to understand when it comes to structuring content [22]. Although editing the content is easier with dynamic web applications, and upgrading the content itself can be fairly simple. However, the programming part can be more complex depending on the server and other factors. With this said, design elements can easily be modified to match your personal preferences.

The way such web apps are displayed on a user's screen is not predetermined but rather dynamically shaped by app logic that is implemented on the server side or the client side of the application [23].

3.4 Advantages of web applications

Web applications have many advantages, here we present the most important [20] [24]:

- They run on multiple platforms regardless of OS or device as long as the browser is compatible.
- They eliminate any compatibility issue, all users access the same version.
- They require very low specs, any device can run them easily without the need of it being expensive or high powered.
- They are not installed on the hard drive, thus eliminating space limitations.
- They are reachable by anybody, anywhere in the world.
- They reduce costs for both the business and end user as there is less support and maintenance required by the business and lower requirements for the end user's computer.

3.5 Synthesis: Enterprises' web applications

This synthesis presents examples of well-known companies that utilize web applications in order to publish their external business processes (Table 1.3).

Company	Website	Domain
Sonelgaz	www.Sonelgaz.dz	Electricity and natural gas distribution in Algeria.
Amazon	www.amazon.com	E-commerce, cloud computing, digital streaming and artificial intelligence.
Apple	www.apple.com	Designing, developing, and selling consumer electronics, computer

		software, and online services.
Algeria poste	www.post.dz	Handling postal services in Algeria.

Table 1. 3: Examples of companies and their websites.

Analysis:

The (Table 1.3) above shows that almost if not all companies that are active at any domain whether it is medical or educational or even public services management own a website, because Websites work. No matter what your business or profession, a website can generate business, promote goodwill among customers and prospects, and deliver strong marketing messages, whether your business is small, large or in-between, well-established or brand-new.

4 MOBILE APPLICATIONS

This part presents the second concept that companies nowadays utilize to publish their public business processes which is mobile applications. It defines them, their types and advantages, and also gives some recommendations about utilizing them.

4.1 Definition

Mobile applications [46] are software programs developed for mobile devices such as smartphones and tablets. They turn mobile devices into miniature powerhouses of function and fun. Some devices come preloaded with some mobile apps, but many more apps are available through device-specific app stores. The purposes of these apps ranges from utility, productivity, and navigation to entertainment, sports, fitness, and just about any others imaginable. Social media is one of the most popular fields of mobile app development and adoption.

4.2 Types of mobile applications

There are 2 main types of a mobile application: a native application and a hybrid application and they are explained as follows:

4.2.1 Native applications:

Such applications are developed for a single mobile operating system exclusively, therefore they are “native” for a particular platform or device [26]. A native application developed for iOS operating system won’t work on Android devices. If an application is developed for iOS, it will remain exclusive to that operating system. If at all the application has to support Android version, new application has to be built again for Android operating system. Software’s used to develop native apps generally would be Objective-C or Swift for iOS, Java and ADT for Android operating system and .NET(C#) for Windows operating system [27].

Main advantage of native apps is high performance and ensuring good user experience as developers use native device UI. Moreover, an access to wide range of APIs that puts no limitation on app usage. Native applications are distinctly accessible from app stores of their kind and have the clear tendency to reach target customers. Some cons to native apps are higher cost compared to other types of apps – due to the need of creating app duplicates for other platforms, separate support and maintenance for different types of applications resulting in bigger product price [26].

4.2.2 Hybrid applications:

They are built using multi-platform web technologies (for example HTML5, CSS and JavaScript). This type of application has cross-platform compatibility but can still access phone’s hardware. Hybrid multi-platform apps are fast and relatively easy to develop – a clear advantage. Single code base for all platforms ensures low-cost maintenance and smooth updates. Widely used APIs On the other hand, hybrid applications lack in performance, speed and overall optimization in comparison to native apps for instance. Also, there are certain design issues due to app inability to look in exactly same way on two or more platforms [26] [27].

4.3 Recommendations of implementing a mobile application in a company

Most of the companies who own applications, they only have a web application and not a mobile one, despite the big advantages that it bring. There are many causes to creating a mobile application and using it as a channel to promote a business and why a company should consider implementing a mobile application [28]. This section provides some recommendations and notes on implementing mobile applications and they are the following:

- Mobile apps provide higher profit and better marketing for the enterprise and better accessibility for the clients and customers because as of the last years mobile applications are now the go-to solution, When potential customers require a product or services, it is more likely that they will look it up on their smartphone rather than on a laptop.
- There are many ways to let an application gains profit to a company, like paying a fee to download or hosting ads for other companies in the application.
- Clients can utilize the smartphone's existing features like taking a photo or using GPS location.

Studies reveal that most searches are made on-the-go (on the mobile) while traveling, socializing and waiting for appointments rather than during leisure time where one has access to the laptop or desktop system.

However, despite the list of advantages, not all businesses or organizations need a mobile application, before rushing out to have one developed, first assess the following [25]:

- **The high cost of developing an app:** For starters, since not all of the clients use devices with one operating system, an application needs to have at least two versions developed one for iOS and one for Android. Mobile applications take more time and money to develop than web applications. The company also has to take into consideration that it may need to hire a separate teams to have the app developed where each team is responsible for one platform.
- **The complex application development and maintenance process:** the developers have to account for the different operating systems (ios, android) and also the different screen sizes of the devices, it's not done even when the app has been launched in the app store. Mobile apps require a long-term investment due to the need for updates, especially critical ones such as repairing security vulnerabilities or to ensure compliance with new IOS or Android releases.
- **Profit-sharing with the app-store and play-store:** if a company is considering to use its application to drive revenue, either through paid downloads of the application itself or via the purchase of services through the application, then it should be aware that app stores and play stores get a substantial cut of their application's revenue.

4.4 Synthesis: Comparing mobile and web applications

The present table (Table 1.4) provides our comparison between web applications and mobile applications in terms of developing based on the following criteria: Development cost, Development time, Maintenance and update, Availability.

Criteria	Mobile Applications		Web Applications
	Native	Hybrid	
Development cost	The cost is high.	Relatively cheap compared to the native applications.	The lowest cost.
Development time	Fast development if built on one platform and can take be slower if built on multiple platforms.	Relatively fast compared to the native applications.	The fastest development time.
Maintenance and update	Hard if the application is developed for multiple platforms and Easy if developed for 1 platform only.	Easy maintenance and update.	Easy maintenance and update.
Availability	They can be found and stored in playstore for android or appstore for ios.	They can be found and stored in playstore for android or appstore for ios.	There isn't any platform to hold them as they are available everywhere in the internet.

Table 1. 4: Comparing mobile and web applications.

Analysis:

Native mobile application: the cost and development time is high in this type of application because each operating system needs its own version which itself takes time to develop, unless you want the application to be available only on 1 platform (android or ios). Maintenance and update of the application is hard due to the same reason which is the existence of multiple versions.

-Hybrid mobile application: the development cost is low because the application is developed only once. Development time is faster than the native type but it requires high skills, the maintenance and update is easy unlike the native type because you only need to do it once.

-Web application: due to the existence of one code base, the development time and cost is low, the maintenance and update procedures are easy as well.

In terms of choosing the right application type, a company or a person should really consider the following:

- The budget.
- How fast he/it needs the application.
- The complexity of the features you need for your application to work.
- the developing team and his capabilities and skills.

5 PERVASIVE COMPUTING

In the sections above we talked about the concepts that help companies publish and enhance their business processes and those tools are considered as pervasive computing systems so in this part we present the pervasive computing systems, their definition what are the basic concepts related to it.

5.1 History

At the early ages of computing many users used to work on the same computer according to some kind of time-sharing model. The costs of the operation were extremely high because of the expenses of frequent hardware failures and the low amount of mainframe computers caused by the unique production. Later came the new era of personal computers, when everyone started to use a computer by his or her own. [35].

The appearance of wireless networks together with mobile computing created a whole new aspect in computer science. These two technologies together with integrated services lead to the arising of a new technological paradigm, pervasive computing [37]. Pervasive computing was first introduced to the public in 1988 by a chief scientist named Mark D. Weiser that worked at Xerox PARC located in the United States. Mark was also widely considered to be the father of pervasive computing due to his large amount of input into the concept. Pervasive Computing is considered to be the third wave of computer technologies to emerge since the computers were first appeared [35].

The picture below (Figure 1.4) presents the waves of computing evolution.

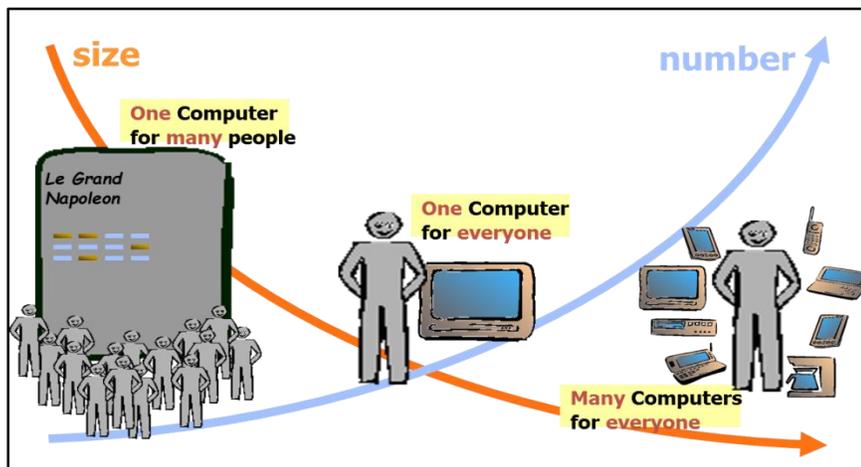


Figure 1. 4: The evolution of computing.

- First Wave: Mainframe computing era: One computer shared by many people, via workstations, containing data and programs and adopting the schema of a client server architecture
- Second Wave: Personal computing era: One computer used by one person. Users largely bound to desktops.
- Third Wave: Pervasive computing era: One person many computers. Millions of computers embedded into environment, allowing technology to recede into the background.

5.2 Pervasive computing definition and concepts

Pervasive computing [33] is where computing is available everywhere using all types of devices in any format and location. It can be implemented into various items, the obvious ones would be mobile phones, tablets and television however this technology is advanced enough to allow us to implement it into household furniture such as tables, mirrors, refrigerators and even windows.

Many people confuse pervasive computing with ubiquitous computing, as they almost have the same meaning, but the two words have slightly different origins, Pervasive comes from pervade (to diffuse throughout) while Ubiquitous comes from ubiquity (be everywhere) [34].

- **Pervasive computing:** describes things that spread through a place to become established everywhere which means wherever you go, there is a computer you can use [34].

Example: internet coffee, mainframe terminals.

- **Ubiquitous computing:** describes things that are everywhere in a place because it is the nature of that place to have those ubiquitous things which means when computers are everywhere inside all things, maybe also within you [34].

Example: IoT (Internet of things).

Pervasive computing spans many disciplines:

- Mobile computing: Many pervasive devices are mobile
- Distributed systems: Multiple machines cooperate to solve a single problem
- Human Computer Interfaces, and Special UI techniques are sometimes needed to deal with the characteristics of the environment
- Operating Systems :OS must provide support for all aspects of pervasive computing

5.3 Technology Trend Overview

The advancement of mobile computing, cloud computing, wearable computing, and smart devices has brought unprecedented opportunities for pervasive computing. In recent years, we have seen a sharp rise in the shipment of smartphones and smart pads. These mobile devices are equipped with CPUs [Multicore Central Processing Units], gigabytes of memory, Wi-Fi and cellular communication components, a GPS [Global Positioning System], and other sensors. As a result, in the not too distant future, they will have more powerful information storage and

processing capabilities than desktop computers. In the meantime, millions of apps have been developed for these mobile devices that provide a wide variety of personalized services.

Previous pervasive computing was often limited by the physical size of the electronic devices. However, this constraint has been overcome by rapid technological developments. A variety of wearable devices have entered the mass market. These wearable devices have successfully extended computation, storage, and communication capabilities to personal gadgets, providing a unique opportunity for expanding the sensing capabilities of users and offering situation-aware information.

This is why nowadays companies are heading towards integrating pervasiveness into their systems, and by that we mean mobile applications because they are considered as pervasive since the clients can use them from anywhere and at any time regardless of their location.

5.4 Pervasive computing framework

The following figure represents the framework of pervasive computing (Figure 1.5).

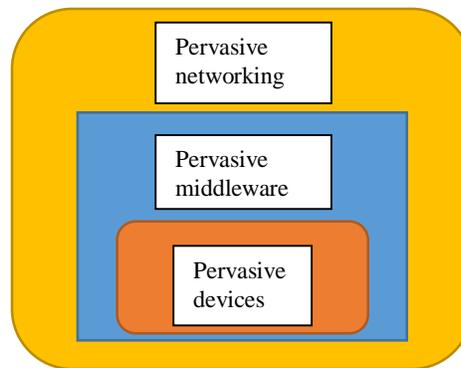


Figure 1. 5: Pervasive computing framework.

According to the (figure 1.5) above, pervasive computing framework contains 3 important areas, which are [29]:

- Pervasive devices:

An intelligent environment is likely to contain many different device types:

- Traditional input devices, such as mice or keyboards, and output devices, such as speakers or light-emitting diodes;

- Wireless mobile devices, such as pagers, personal digital assistants, cell phones, palmtops.
- Smart devices, such as intelligent appliances, floor tiles with embedded sensors, and biosensors.

Sensors that automatically gather information, transfer it, and take actions based on it represent an important subset of pervasive devices. For example, sensors based on the Global Positioning System provide location data that a device can translate into an internal representation of latitude, longitude, and elevation. Stereo camera vision is another effective sensor for tracking location and identity in a pervasive environment. These fast-processing, two-lens digital cameras can record both background images and background shapes. The results are much more robust for tracking motion such as gestures.

- Pervasive middleware:

Like distributed computing and mobile computing, pervasive computing requires a middleware “shell” to interface between the networking kernel and the end-user applications running on pervasive devices. As Figure 2 shows, this pervasive middleware will mediate interactions with the networking kernel on the user’s behalf and will keep users immersed in the pervasive computing space. The middleware will consist mostly of firmware and software bundles executing in either client-server or peer-to-peer mode.

User interfaces are another aspect of middleware. Standard Web browsers represent the high end of interface sophistication. They use more color, graphics, and controls than users typically expect on pervasive devices.

- Pervasive networking:

All the Pervasive devices are connected with other pervasive or any other communication devices through the distributed network. Why this pervasive device connected through distributed network means, because of the global accessibility of the device. The pervasive devices can be connected through the Local Area Network (LAN) or through Metropolitan Area Network (MAN) or through Wide Area Network (WAN) for the global availability. Example: Bluetooth, IEEE802.11, Internet

5.5 Pervasive computing expectations and challenges

The main goal of pervasive computing is to create a technology or an application that can invisibly assimilate into our everyday lives, although pervasive computing offers a lot of new, interesting, and useful possibilities, many challenges need to be overcome before the vision becomes real. The main challenges faced in pervasive computing are as follows:

-Pervasive computing systems are very tightly connected with specific users. Pervasive computing systems often gather and store information on the user's behavior, context, habits, and planning. This information forms the basis for the many benefits the system can offer individual users.

-The omnipresence of pervasive applications typically is achieved by either having devices move with the user or by having applications move among mobile users' devices. In both cases, applications need to adapt to the moving environment, which involves maintaining device connections and adapting protocol for handling mobility. Although some of the problems can be addressed by routing and handovers, many cannot be solved at the network level because knowledge of application semantics is required for runtime adaptation.

-Pervasive applications typically involve many different types of devices working in an orchestrated way. As a user moves around in an environment, the servicing application often moves with him. For instance, the application may switch from a desktop PC to a mobile phone. In addition, the heterogeneous devices complicate the development of high-level applications because different devices provide varied programming interfaces, resource abstractions, and functional capabilities.

-In a pervasive environment, many devices continuously produce huge amounts of raw data. It is challenging to transfer, store, and process these data. In order to provide meaningful semantics for high level applications, some preprocessing of the data may be necessary. For instance, inaccurate data can cause context management systems to produce false context information, which can result in incorrect reasoning for applications.

5.6 Pervasive computing advantages and disadvantages

The table below (Table 1.5) presents the advantages and disadvantages of pervasive computing [31] [32].

Advantages	Disadvantages
-Manage information quickly, efficiently and effortlessly. -Information can be accessed when and where it is Needed, allowing us to easily take action anywhere, anytime. -Removal of wires in the network computing.	-Pervasive Computing is not entirely secure as hackers might try and steal from you. -May threaten privacy. -Very expensive operating costs. -Requires highly skilled specialists to control.

Table 1. 5: Benefits and limits of pervasive computing.

5.7 Pervasive computing recommendations and considerations

Just because pervasive computing makes sense for some companies and despite all its advantages, that doesn't mean it will deliver value for everyone. To be successful, an organization must do several things when undertaking a pervasive computing project [30].

These several things are mentioned in the following notes:

-Define clear goals: Firstly, you need to have a clear idea in your mind about the usage and purpose of pervasive computing in your organization. Determine the features it should have and the functionality you want the devices or the application to serve. Also, identify the type of devices that will be connected to the network. You can consider implementing a pilot project to test the results of pervasive computing before executing it throughout the organization.

-Understand the work environment. This step involves three aspects.

First, gather information about the type of network and bandwidth available in your area. Make sure there are no connectivity issues in any part of your office. If you are planning to incorporate Wi-Fi connectivity, check if there are problems in getting coverage for the entire building.

Second, analyze the costs involved in the project. If your business activities involve massive data sharing and constant internet connectivity, you may need to evaluate the capital investment required for pervasive computing.

Third, determine the type of devices needed, if you require a laptop, tablet, wearable or any other type of internet compatible system. Also zero-in on the other important aspects such as the device's screen size, in-built and expandable memory, stand-by time etc.

-Select a wireless software vendor carefully. There are a number of wireless software companies offering solutions for implementation of pervasive computing. However, you should choose only the reliable provider who has experience in handling wireless technologies. The products it provides should have strict security features and be updated frequently.

-Evaluate the impacts to your technical staff. While pervasive computing products are maturing, most don't yet offer the features needed for enterprise computing out of the box. For this reason, organizations shouldn't underestimate the skills and experience needed to complete a business-critical pervasive computing project.

5.8 Synthesis: Enterprises with pervasive applications

In this synthesis, we present some companies who own both a mobile application and a web application, see (Table1.4).

Company	Pervasive system		Domain
	Mobile	Web	
Harvard	Yes	Yes	Education
Facebook	Yes	Yes	Communication and socializing
EBay	Yes	Yes	E-commerce
Cardinal health	Yes	Yes	Health care

Table 1. 6: Examples of companies who utilize pervasive computing systems.

Analysis:

Users are spending more and more time on mobile applications as latest researches have suggested that 75.1% of Facebook users are using the mobile application compared to the web application and this number is growing every year. A business should be present where its customers are. So, it is the best time for companies to start building mobile applications for their businesses to fully harness the First Movers Advantage to sell their products and services before their competitors does.

The (Table 1.6) above presents some well-known companies who exploited the combination of “web + mobile application” to attract customers’ attention.

6. CONCLUSION

This chapter first introduced the basics of business processes, their advantages, and how can they be represented using different modeling languages. Second, since our project is set to be pervasive, this chapter also talked about web applications and mobile applications in general, their advantages and gave some recommendations on implementing them. We finished this chapter with the term pervasive computing, with a brief history on it and then we talked about its basic components and the challenges that surrounds it.

The next chapter provides the analysis and the conception of our system, it introduces our study case and its public and private business processes then it represents them using the necessary diagrams.

CHAPTER 2: ANALYSIS AND CONCEPTION

1 INTRODUCTION

In the previous chapter we have introduced the concepts used in our work which are business processes, web applications and mobile applications and pervasive computing systems.

In this chapter we define the different external and internal business processes of our study case which is a car rental agency, then we model each of these processes using UML [unified modeling language] by making the necessary diagrams that help us understand and analyze our system and how it works in a detailed manner.

2 STUDY CASE

In this section, we present our study case which is a car rental agency with a motivation of why we chose it and then we define its public and business processes.

2.1 Definition

A car rental agency [47] is a company that rents automobiles and primarily serves people who require a temporary vehicle, for example, those who do not own a car, travelers who are out of town, or owners of damaged or destroyed vehicles who are awaiting repair or insurance compensation.

2.2 Motivations

We chose a car rental agency as a study case of a modernized information system, and this choice is backed by the following motivations:

- It offers a variety of internal and external business processes.
- Easy to distinguish between its processes which leads to a better understanding of how our modeling will be.
- The lack of car rental agencies in our region that own both types of applications (mobile and web).
- Its characteristics are the most suitable for the aspect of our modeling.

2.3 Analysis: Business processes of the study case

After an analysis of the study case environment and its characteristics, we extracted that a car rental agency offers a variety of public and private business processes, we present the most important ones as (Table 2.1):

Public business processes	Private business processes
-Online renting of cars.	-Cars management.
-Clients' accounts management.	-Clients management.
-Talking in the live support.	-Contracts management.
-Online payment.	-Comments and requests management.

Table 2. 1: Advantages and disadvantages of pervasive computing.

2.4 Modeling software tool

Modelio: is an open source modeling tool developed by modeliosoft, it delivers a broad-focused range of standards-based functionalities for software developers, analysts, designers, business and system architects such as UML and BPMN [48]. Modelio is considered as a new generation of tools that wants to provide the best ergonomics for efficient modeling of systems and applications [5].

The figure below (Figure 2.1) represents the GUI (graphical user interface) of Modelio.

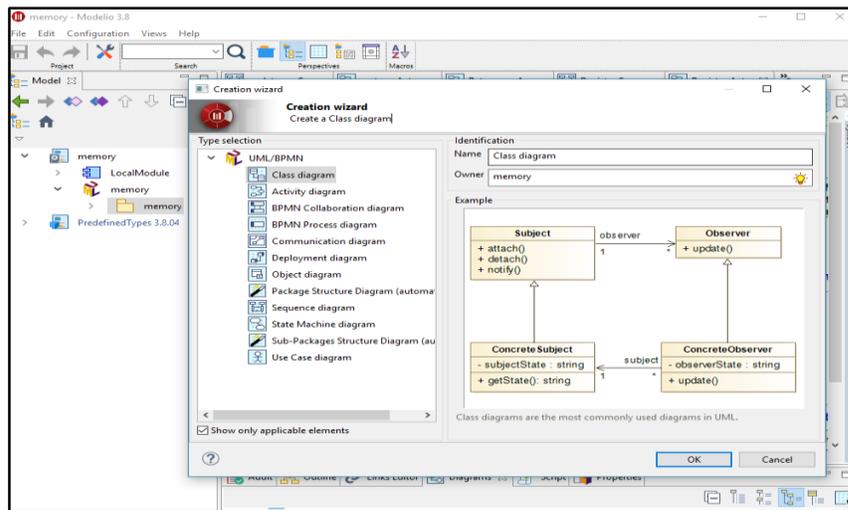


Figure 2. 1: Modelio GUI.

3 SYSTEM CONCEPTION

This section provides the modeling of our car rental agency using UML to elaborate the use case diagram, class diagram, sequence diagrams and activity diagrams.

3.1 Use case diagram

In this part we present the use case diagram of our agency which represents the actions that the different actors can do: clients, guests, administrators and managers, see (figure 2.3).

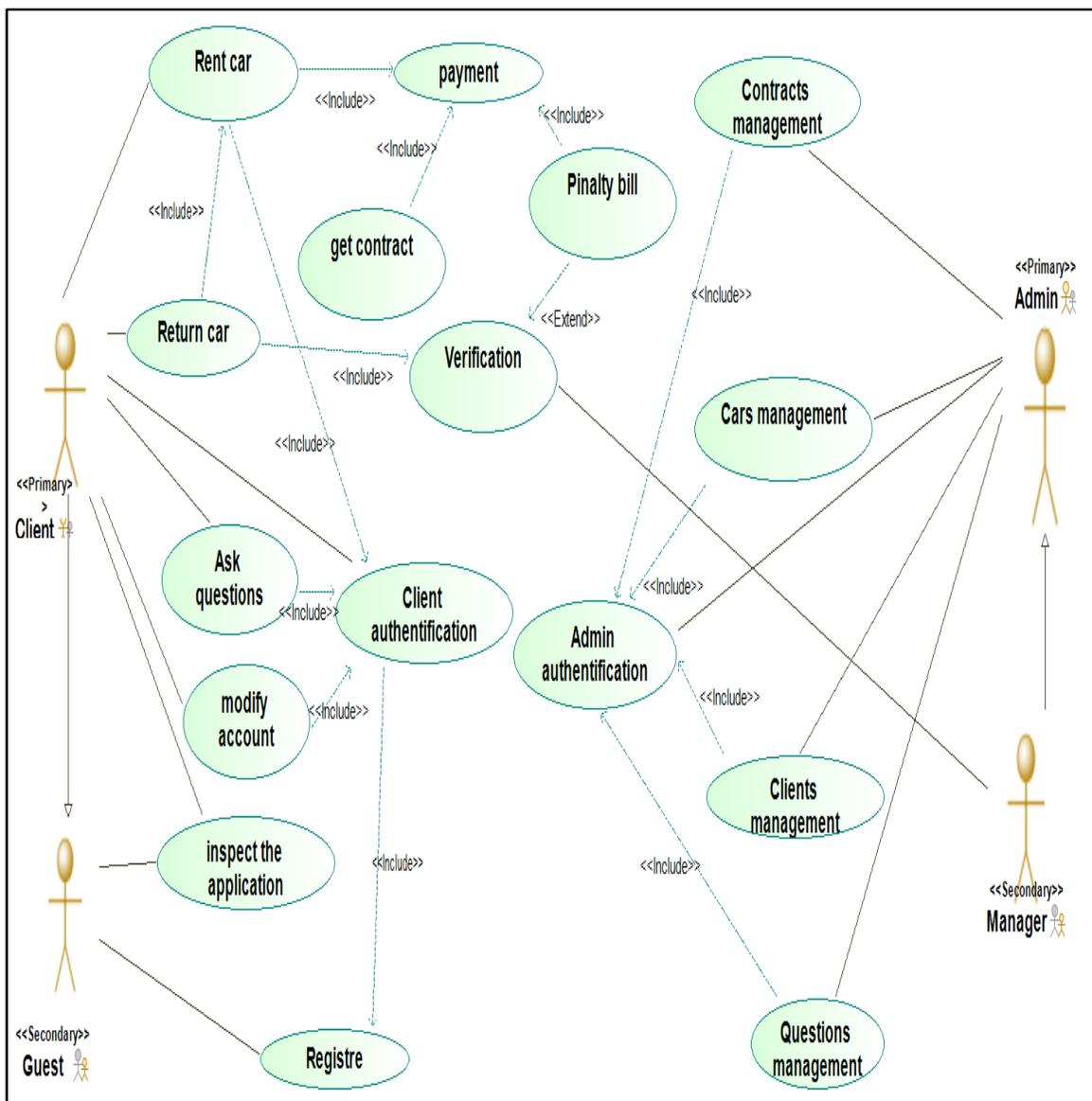


Figure 2. 2: Use case diagram.

The table below (Table 2.2) presents a description of every actor and its use cases in our system (car rental agency).

Actor	Use cases	Description
Client	<ul style="list-style-type: none"> -Inspect the application. -Authentication. -Rent cars. -Use live-support. -Modify account. 	Client is a primary actor in our agency because he interacts with most of the use public business processes in our system except the admin cases, he first needs to be authenticated to be able to perform his tasks.
Administrator	<ul style="list-style-type: none"> -Cars management. -Clients management. -Contracts management. 	Administrator is a primary actor in our agency because he is the one who is going to provide all the internal management and handle the agency.
Visitor	<ul style="list-style-type: none"> -Inspect the application. -Register. 	Visitor is a secondary actor, all he does is just inspect the application and register without the ability to perform the tasks of a client.
Manager	<ul style="list-style-type: none"> -Verify cars when returned by clients. 	Manager is a secondary administrator actor, he verifies cars when returned by clients to the agency and checks if they are in a good state or damaged or in time

		or late to decide whether to make a penalty bill or no.
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Table 2. 2: Actors and use cases description.

3.2 Class diagram

In this part we present the class diagram of our agency which is considered the most important in our design (Figure 2.2).

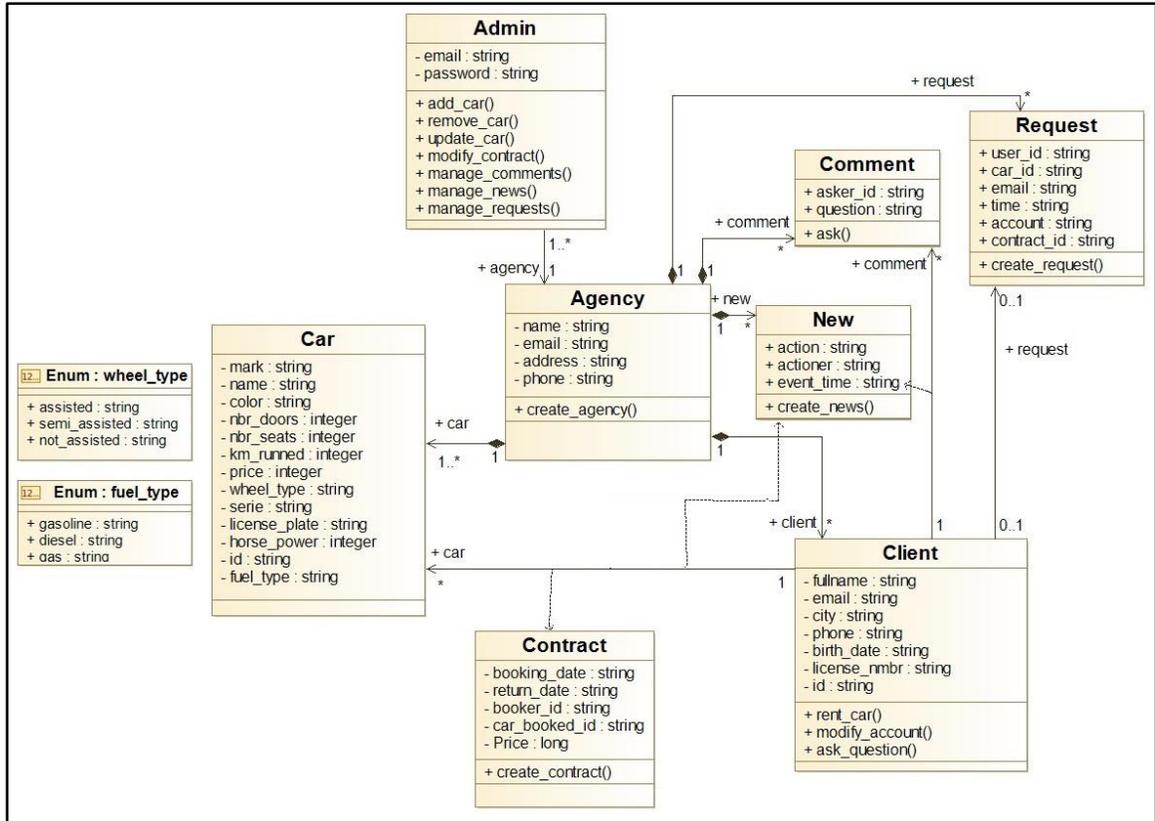


Figure 2. 3: Class diagram.

The table below (Table 2.3) explains each class in the class diagram shown above (Figure 2.3).

Class	Analysis
Agency	It contains 4 attributes: name, address ,phone ,email, It is related by composition with the class Client and Car (contains from 1 to n number of cars, and from 0 to n clients) and also have from 1 to n number of admins and a method : create_agency().

Client	Related with the class agency by composition (clients belong to 1 agency) and by dependency with class car and contract ,Contains 7 attributes which are: fullname, email, city, phone, birth_date, license_number, id.
Car	Related with the class agency by composition where all cars belong to 1 agency ,Contains 13 attributes which are: mark ,name ,color ,nbr_door ,nbr_seats ,km_runned,price,wheel_type,serie,license_plate,horse_power ,id ,duel_type.
Contract	Contains 5 attributes: booking_date, return_date, booker_id, car_booked_id,price and one method which is create_contract().
Admin	Contains 2 attributes: email and password, and 4 methods: add_car(), remove_car(), update_car(), remove_client(), manage_contract().
Comment	Contains 2 attributes: asker_id which is the email of the one who asked the question and the second attribute is the question itself. This class concerns the clients or the admins who ask or answer questions in the livesupport.
New	Contains 3 attributes: action which specifies the action performed by the user whether it is renting a car or commenting, actioner which is the email of the person who did the action, and eventtime which specifies the date of the action. The main focus of this class is to save the history of what happened in the agency so the admins can check them. For example when a client asks a question in the livesupport or rents a car or when a guest registers, these event will be saved as news.
Request	Contains 6 attributes: user_id, car_id, account, time, contract_id, email. This class concerns the clients who are trying to extend their contract. Where admins can either approve or reject these requests.

Table 2. 3: Class diagram analysis.

3.3 Activity diagrams

In this section we present the different activity diagrams of our system, which represents the interaction between the different related actors

3.3.1 Guest registration

The diagram below (figure 2.4) represents the interaction between a guest and the server when tried to register.

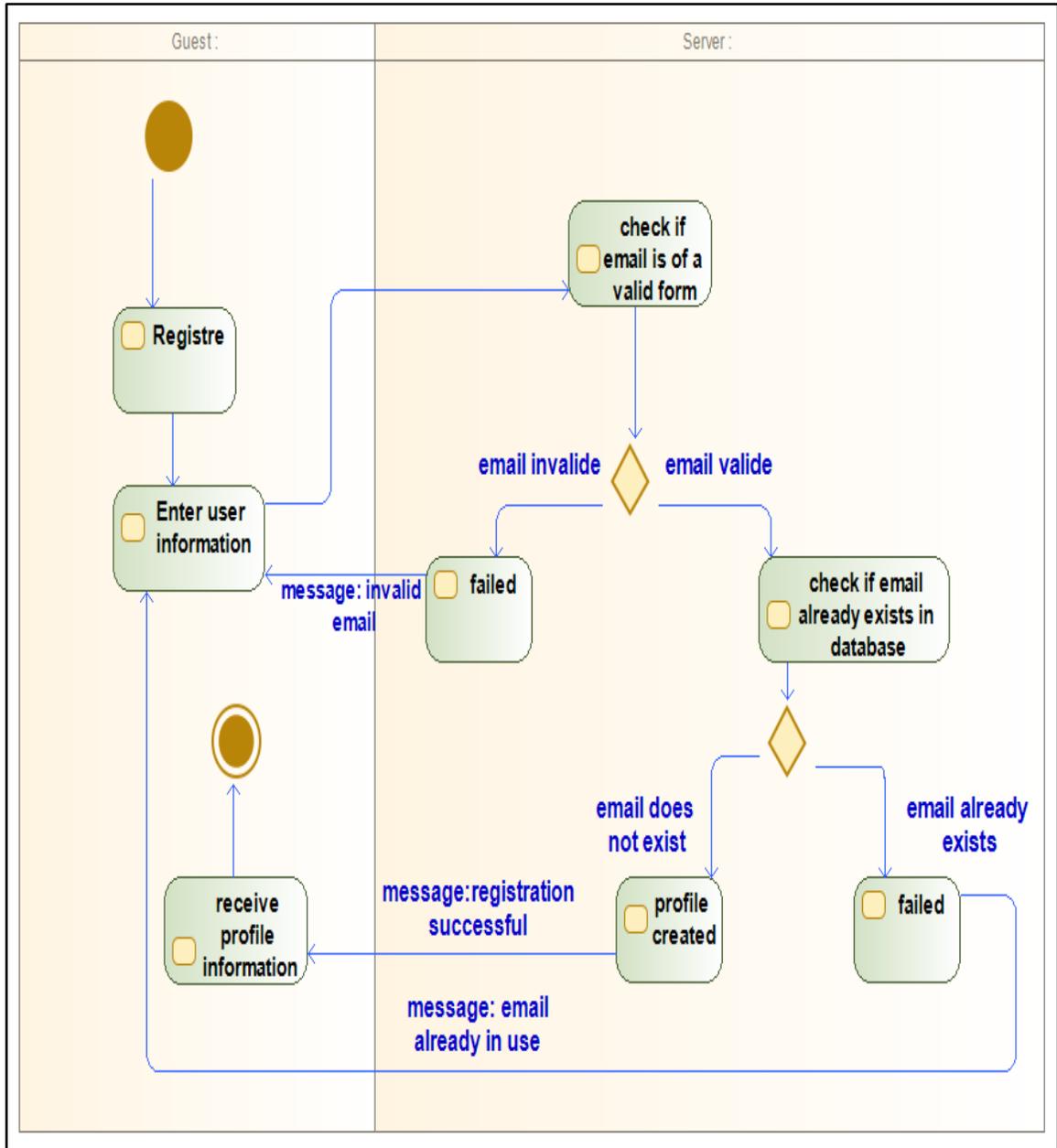


Figure 2. 4: Register activity diagram.

3.3.1 Rent car

The diagram below (figure 2.5) represents the interaction between the client and the agency when the client tries to rent a car.

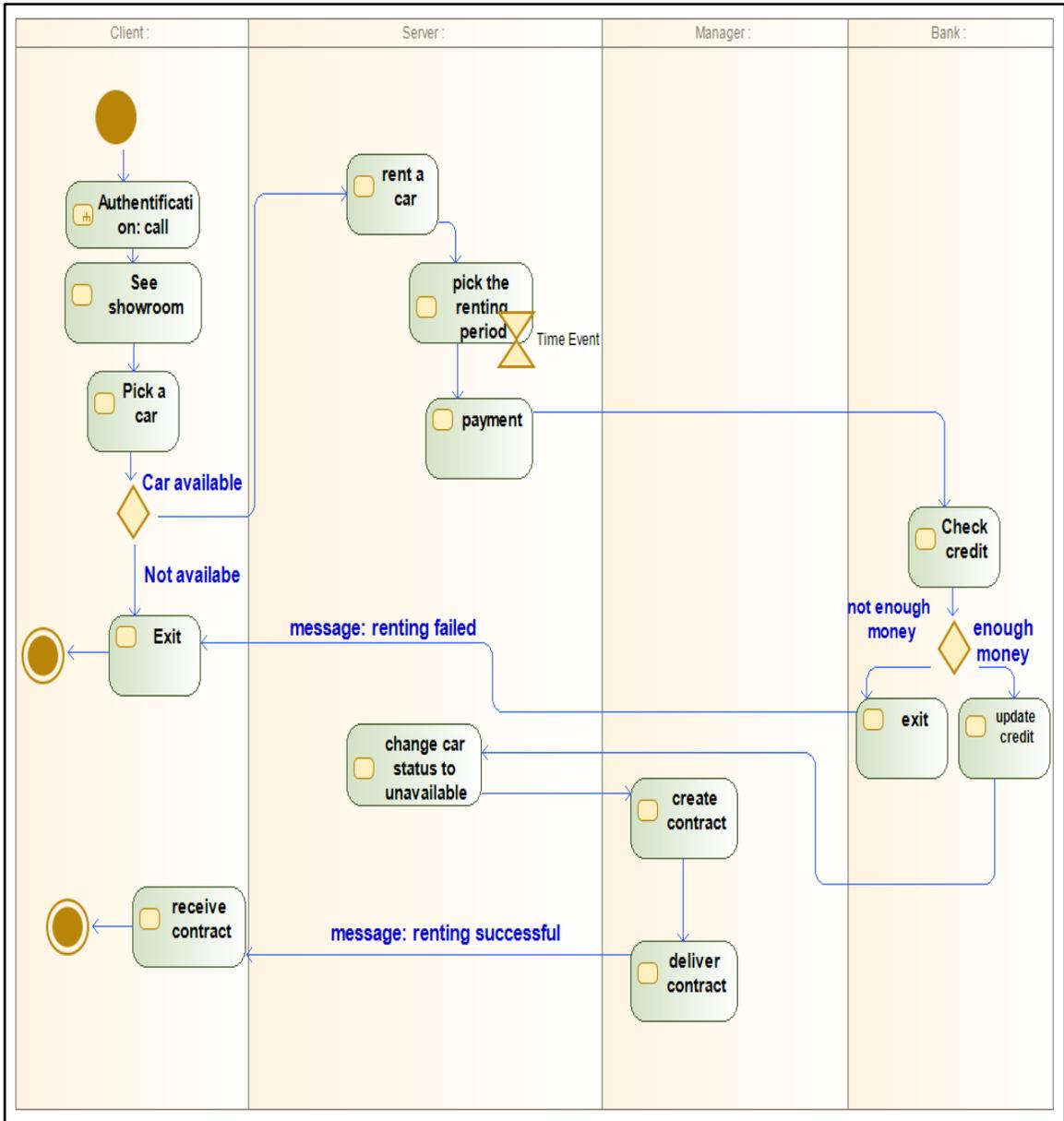


Figure 2. 5: Rent car activity diagram.

3.3.2 Return car

The diagram below (figure 2.6) represents the interaction between the client and the manager when the client returns the car.

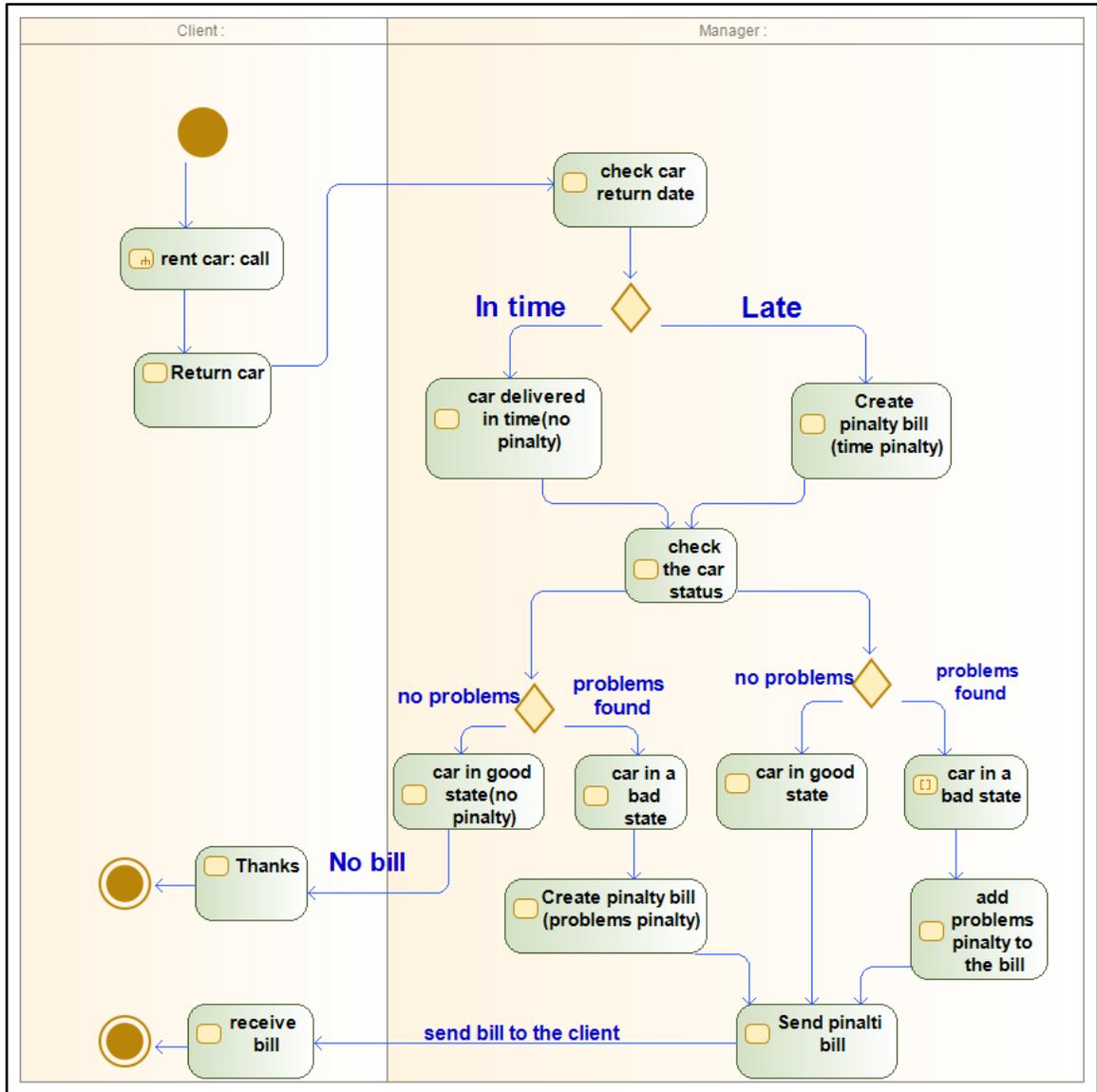


Figure 2. 6: Return car activity diagram.

3.4 Sequence diagrams

This section is concerned about modeling the public and external business processes of our system using the sequence diagram of the unified modeling language (UML).

3.4.1 Authentication

This diagram (figure 2.7) describes how a client/admin authenticates so he can perform all the tasks related to him.

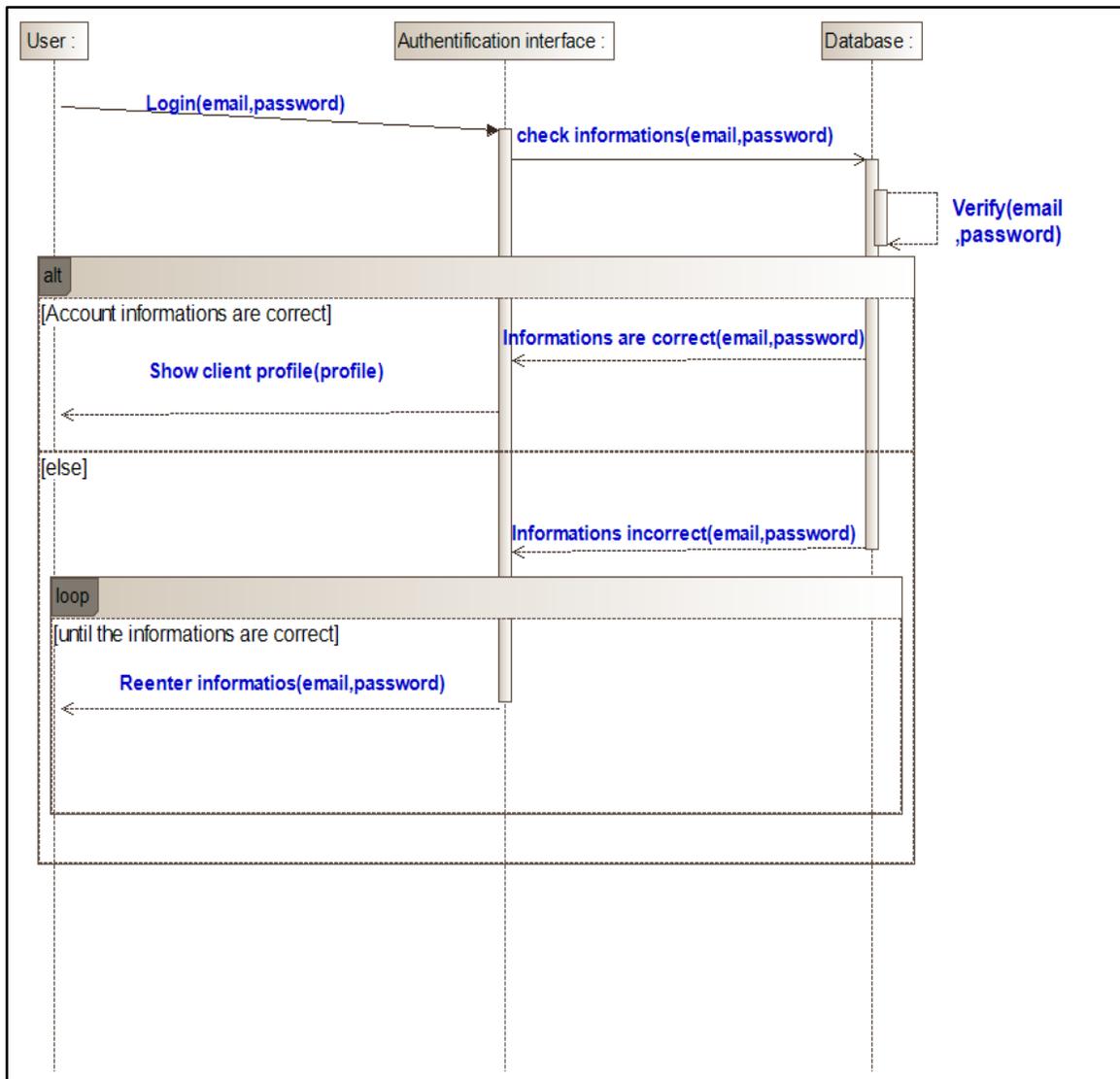


Figure 2. 7: Authentication sequence diagram.

3.4.2 Guest registration

The diagram (figure 2.8) below presents the performed steps by a guest to register and become a client so he can be able to perform all the client's use cases like: renting cars and using the live support (this is considered as a public business process).

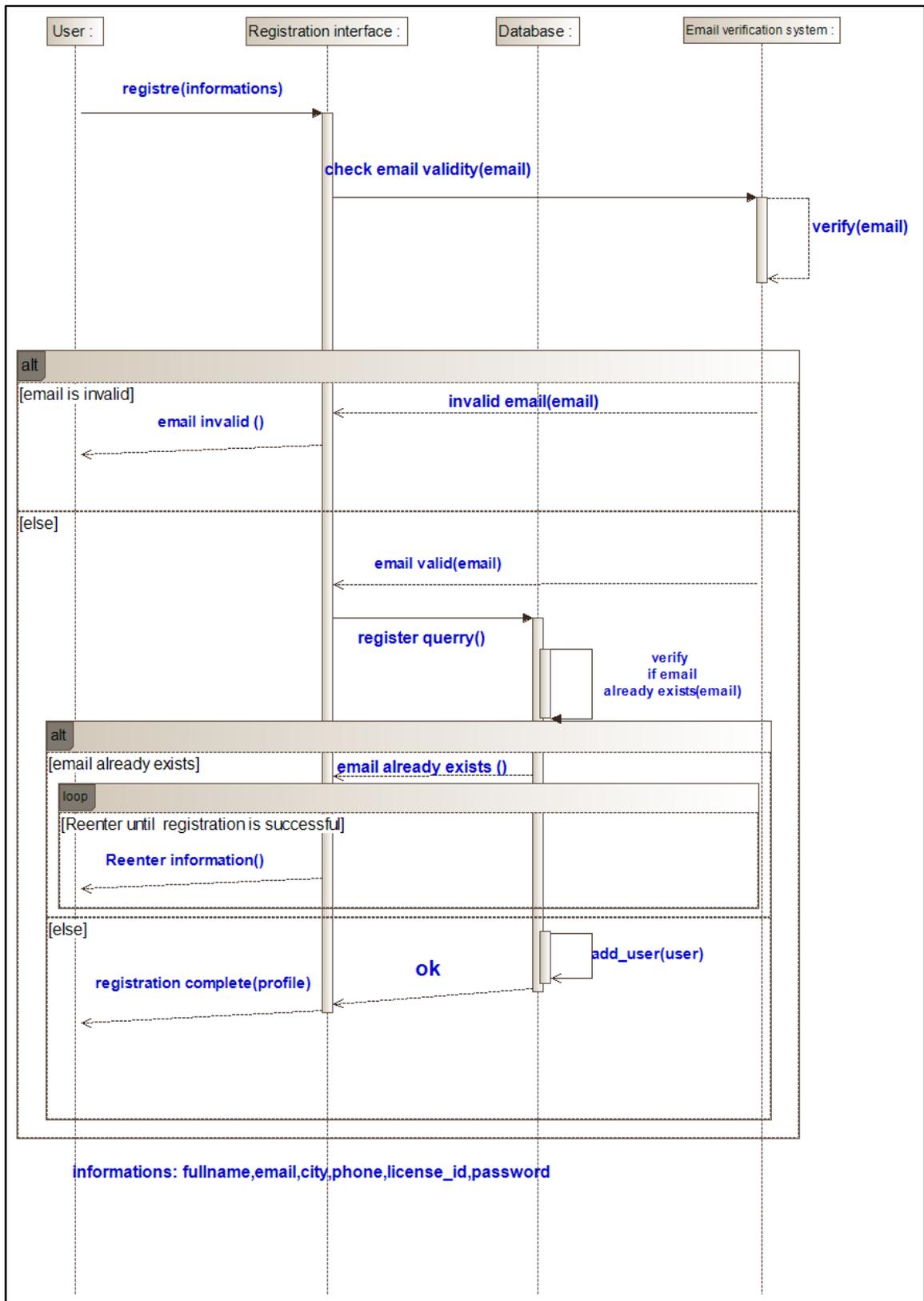


Figure 2. 8: Register sequence diagram.

3.4.3 Rent car

This diagram (figure 2.9) presents the detailed steps of what happens when an authenticated client tried to rent a car (this is considered as a public business process).

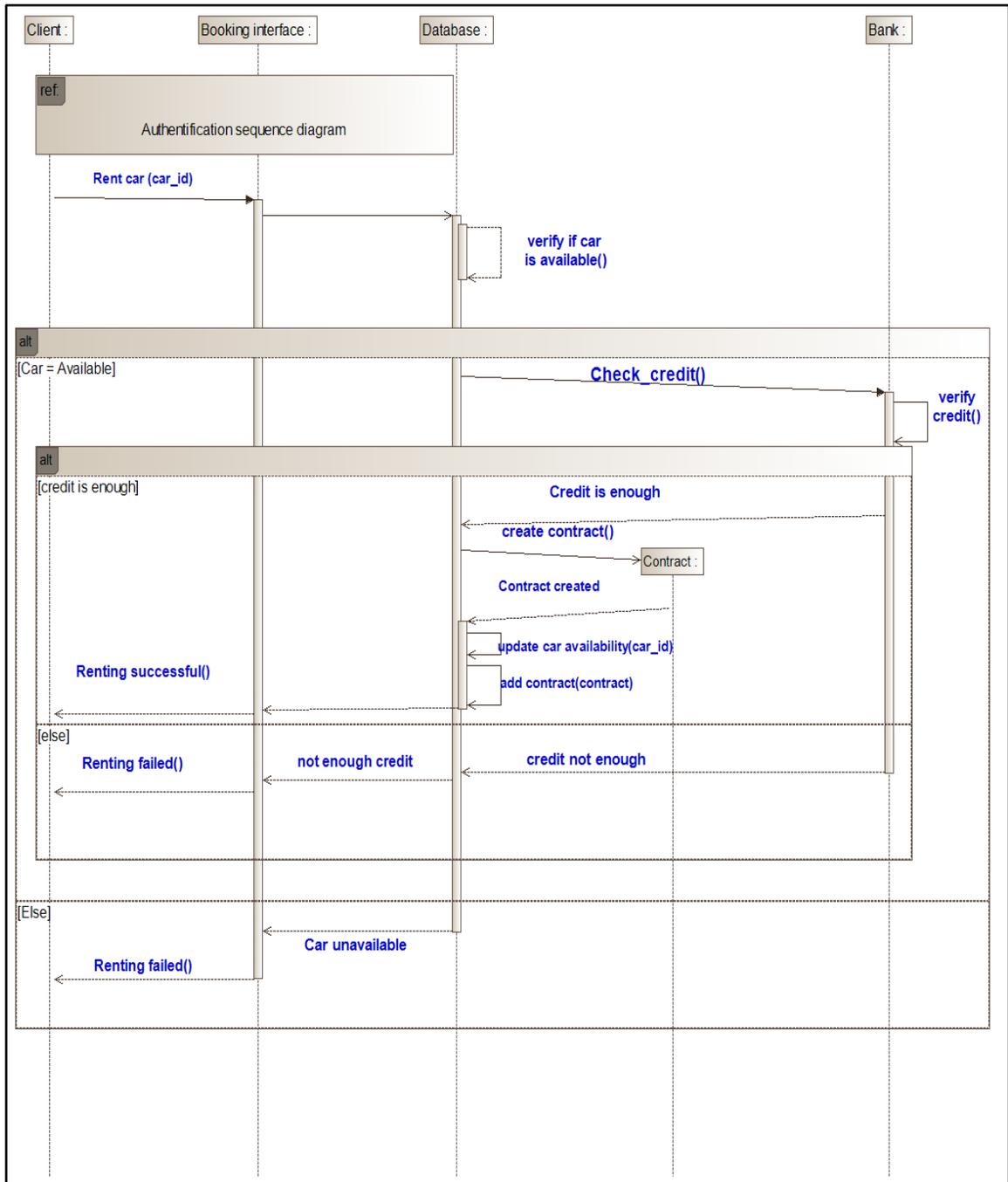


Figure 2. 9: Rent car sequence diagram.

3.4.4 Add car

This diagram (figure 2.10) describes the events that happen after the administrator authentication and when he tries to add a new car to the database (this is considered as a private business process).

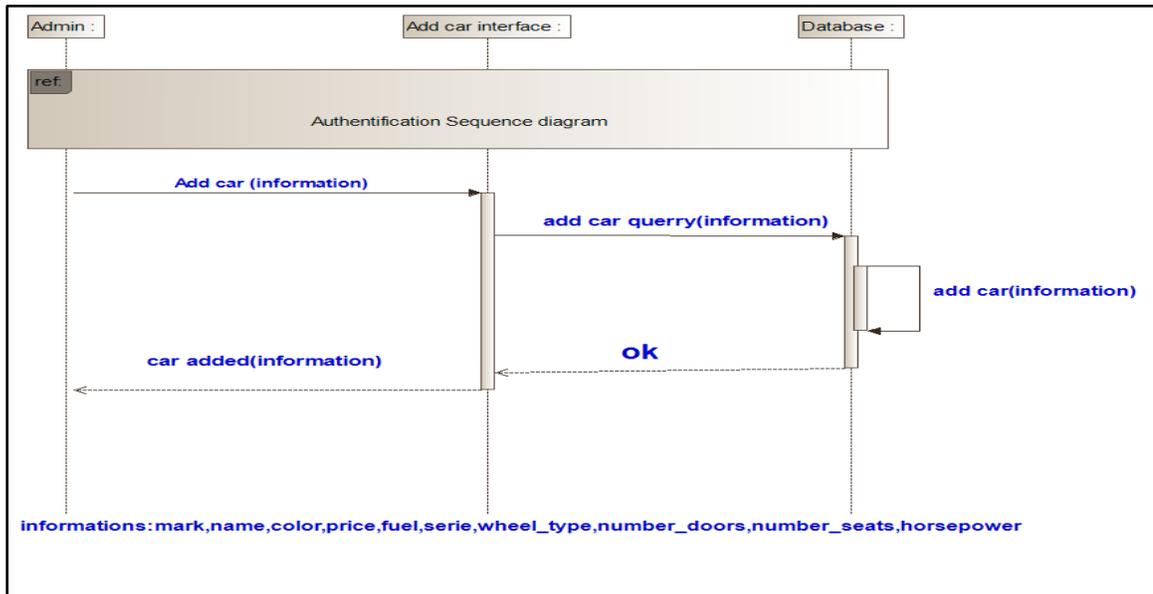


Figure 2. 10: Add car sequence diagram.

3.4.5 Remove car

This diagram (figure 2.11) describes the events that happen after the administrator authentication and when he tries to delete an existing car in the database (this is considered as a private business process).

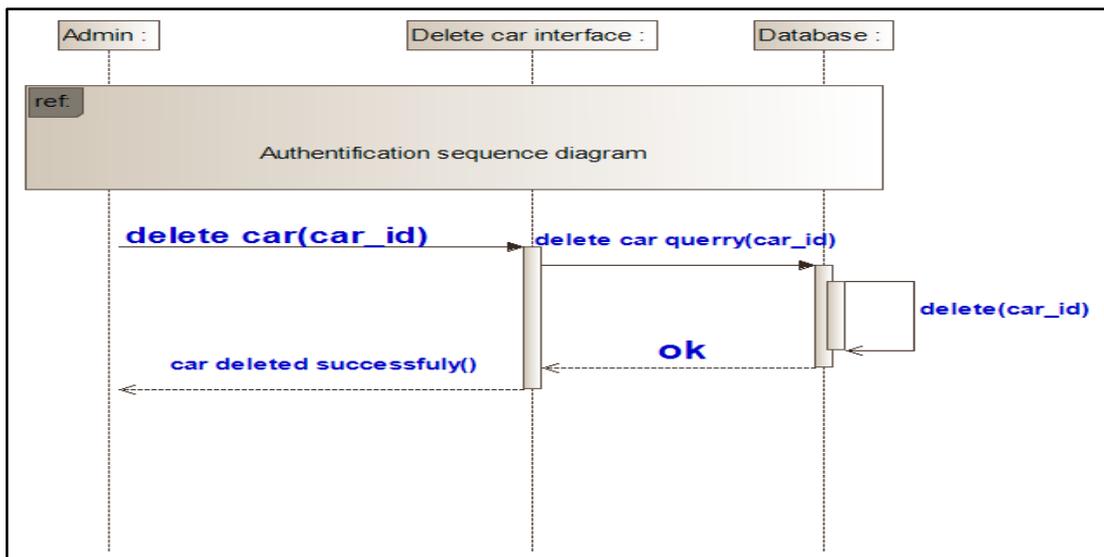


Figure 2. 11: Remove car sequence diagram.

3.4.6 Update car

This diagram (figure 2.12) describes the events that happen after the authentication and when an administrator tries to update some information of an existing car in the database (this is considered as a private or internal business process).

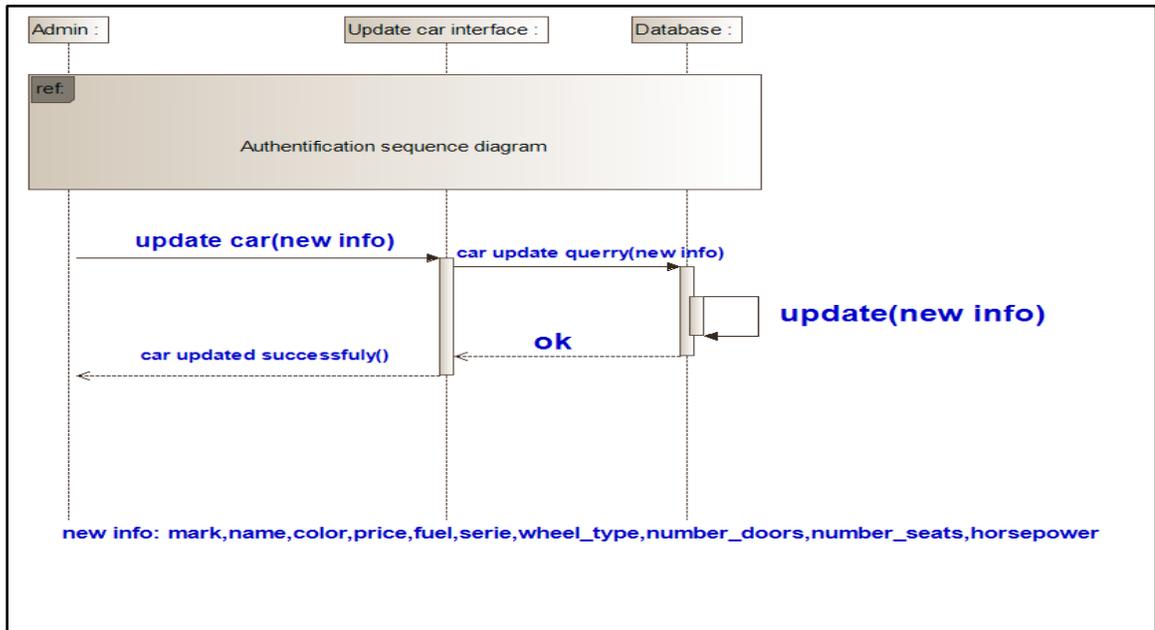


Figure 2. 12: Update car sequence diagram.

3.4.7 Modify account

This diagram (figure 2.13) describes what happens when an authenticated client tried to modify his account’s information (this is considered as a public or external business process).

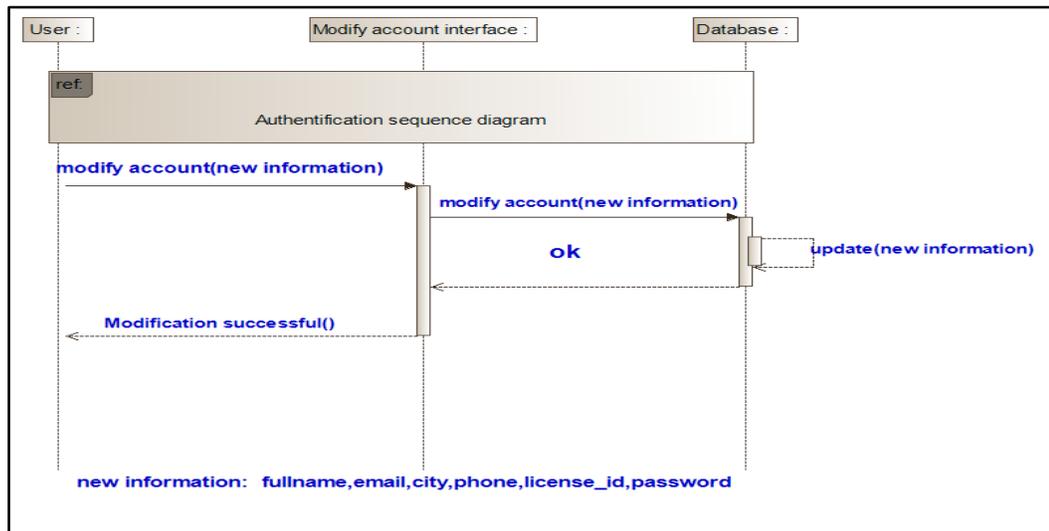


Figure 2. 13: Modify account sequence diagram.

4 CONCLUSION

In this chapter we have chosen a car rental agency as a study case of our pervasive system then we presented this system by first defining it then modeling its public and private business processes using the unified modeling language.

In the next chapter we talk about the implementation side of our system which includes defining the software and tools used in the development phase and then we present the different scenarios of our system through showing multiple graphical user interfaces.

CHAPTER 3: IMPLEMENTATION

1 INTRODUCTION

In the previous chapter we have presented our study case which is a car rental agency and we have used UML diagrams to model its public and private business processes.

In this chapter we focus on the programming side and the actual pervasive applications of our project that represent our car rental agency and these pervasive applications are: -A standard web site which is considered to be the most basic application that almost every agency must have. -Since our project is meant to be pervasive we also build a mobile application.

In this chapter we first introduce the necessary tools and software used in the development phase and then we end this chapter by presenting graphical user interfaces (GUIs) of both the web and the mobile application.

2 DEVELOPMENT TOOLS, ENVIRONMENTS AND LANGUAGES

In this section, we present the necessary tools, software and programming languages used in our development process for both the web and mobile application. We start first with the web application.

2.1 Web application

In order to develop a web application that suits our use case we have chosen the following software tools:

2.1.1 Programing language: Html

HTML [52], Hyper Text Markup Language is a standard computer language devised to allow website creation, the word HTML contains the following:

- a. Hypertext is the method by which you move around on the web by clicking on special text called hyperlinks which bring you to the next page. The fact that it is hyper just means it is not linear. You can go to any place on the Internet whenever you want by clicking on.
- b. Markup is what HTML tags do to the text inside them. They mark it as a certain type of text (italicised text, for example).
- c. HTML is a Language, as it has code-words and syntax like any other language. Often, html is not used on its own in order to create websites.

HTML is usually not used alone in developing websites, so in order to make something that looks pleasant, it needs to be with other programming languages such as Cascading Style Sheets (CSS) and JavaScript [50], as HTML forms a triad with them.

2.1.2 Programming language: CSS

CSS [51], Cascading Style Sheets describes how HTML elements are to be displayed on screen, paper, or in other media. It can control the layout of multiple web pages all at once, CSS brings style to your web pages by interacting with HTML elements.

CSS handles the look and feel part of a web page. Using CSS, you can control the color of the text, the style of fonts, the spacing between paragraphs, how columns are sized and laid out, what background images or colors are used, layout designs, variations in display for different devices and screen sizes as well as a variety of other effects [53].

2.1.3 Programming language: JavaScript

JavaScript [54] is a scripting language used to create and control dynamic website content, features like animated graphics, photo slideshows, autocomplete text suggestions, and interactive forms can all be created with JavaScript, it is considered one of the core technologies of the World Wide Web.

2.1.4 Programming environment: NotePad+

Notepad [5] is a source code editor that supports multiple languages, running on Windows, coded in C++, which integrates the coloring source code syntax for C, C++, java, C#, XML, HTML, PHP, JavaScript, CSS, MATLAB, Assembler, ... etc. as well as for any other computer language, because this software offers the possibility to create its own syntactic colorings for any language.

2.2 Mobile applications

In this section, we present the software tools chosen in the development phase of the mobile application.

2.2.1 Programing language: Java

Java [57] is a general-purpose computer programming language that is concurrent, class-based, object-oriented, and specifically designed to have as few implementation dependencies as possible [56]. It enables programmers to write computer instructions using English-based commands instead of having to write in numeric codes. It's known as a high-level language because it can be read and written easily by humans. Java has a set of rules that determine how the instructions are written. These rules are known as its syntax. Once a program has been written, the high-level instructions are translated into numeric codes that computers can understand and execute.

2.2.2 Programing environment: Android studio

Android Studio [67] is the official integrated development environment (IDE) for Android application development. It is based on the IntelliJ IDEA, a Java integrated development environment for software, and incorporates its code editing and developer tools. To support application development within the Android operating system, Android Studio uses a Gradle-based build system, emulator, code templates, and Github integration. Every project in Android Studio has one or more modalities with source code and resource files. These modalities include Android app modules, Library modules, and Google App Engine modules.

The picture below (Figure 3.1) shows the GUI of android studio.

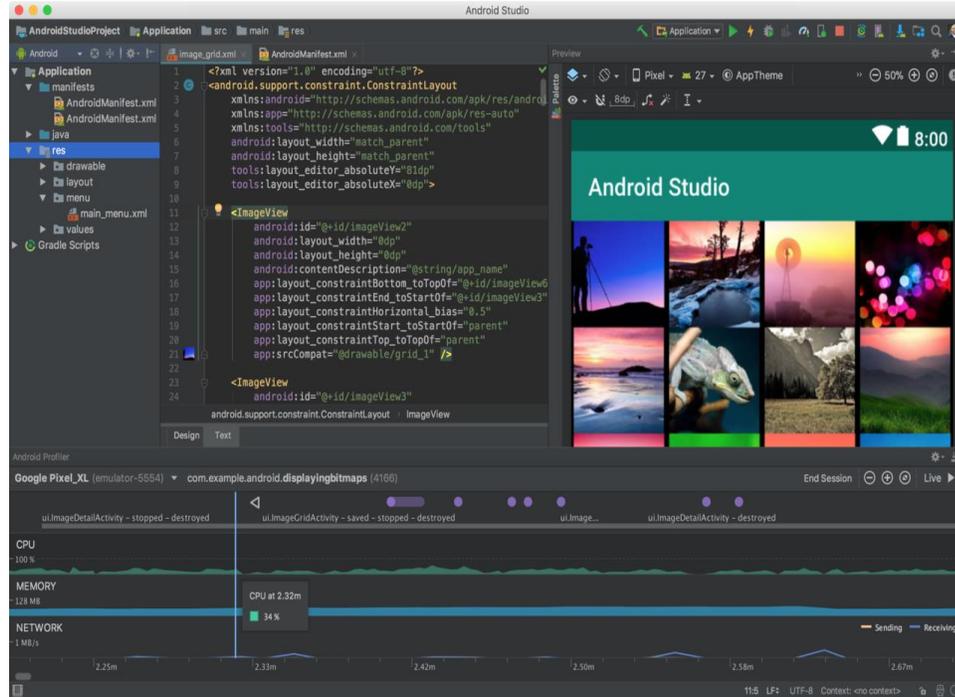


Figure 3. 1: Android studio interface.

2.3 Database of the pervasive system

In this section we present the database system that manages all the data of our agency and according to the class diagram this data is the following: the clients, cars, contracts, comments, requests, news. Firebase has been chosen as our Database Management System.

2.3.1 Definition

Firebase [59] is a mobile and web application development platform developed by Firebase, Inc. in 2011, then acquired by Google in 2014 [60], it is a technology that allows you to make web and mobile applications with no server-side programming.

2.3.2 Services

Firebase offers multiple services to its customers such as [61]:

- Real-time Database
- Authentication
- Test Lab
- Crashlytics
- Cloud Functions
- Firestore

- Cloud Storage
- Performance Monitoring
- Crash Reporting
- Hosting

Out of all the services that firebase provides, we only used the following: the Real-time database, Authentication and the cloud storage and finally the Hosting.

a. Real-time database: is a cloud-hosted NoSQL database that lets you store and sync between your users in realtime. With just a single API, the Firebase database provides your app with both the current value of the data and any updates to that data. When your users go offline, the Realtime Database SDKs use local cache on the device to serve and store changes. When the device comes online, the local data is automatically synchronized. The structure of the firebase database is somehow different than the SQL. Where in SQL we have tables and in firebase we have JSON trees [61].

The present table shows how data are represented using firebase database compared to the SQL database (Table 3.1).

SQL database	Firebase database									
<table border="1"> <thead> <tr> <th>id</th> <th>name</th> <th>message</th> </tr> </thead> <tbody> <tr> <td>message 1</td> <td>Frank</td> <td>Hello Anyone here?</td> </tr> <tr> <td>message 2</td> <td>Jeff</td> <td>Sorry Working on some AI?</td> </tr> </tbody> </table>	id	name	message	message 1	Frank	Hello Anyone here?	message 2	Jeff	Sorry Working on some AI?	 <pre> { "Chat": { "Message 2": { "Jeff": "Sorry working on some AI" }, "Message1": { "Frank": "Hello anyone here?" } } } </pre>
id	name	message								
message 1	Frank	Hello Anyone here?								
message 2	Jeff	Sorry Working on some AI?								

Table 3. 1: SQL and firebase structures.

b. Authentication: Most apps need to know the identity of a user. Knowing a user's identity allows an app to securely save user data in the cloud and provide the same personalized experience across all of the user's devices. Firebase supports authentication using passwords, phone numbers, popular federated identity providers like Google, Facebook and Twitter, and more [62].

c. Cloud storage: Firebase Storage is a standalone solution for uploading user-generated content like images and videos and files from an iOS and Android device, as well as the Web. And all of these files are protected by Google itself. It is where we store all our images of cars and profile pictures [61].

d. Firebase hosting: Firebase Hosting provides fast and secure hosting for your web application, static and dynamic content, and micro services.

The present table (Table 3.2) provides a brief explanation of what firebase services that will be used.

Service	Functionality
Database	Is the database that holds the information of our agency.
Authentication	Is the service that provides authentication to the clients so they can login and see their profiles and interact with it.
Cloud storage	Is where we store all the images of users and cars.
Hosting	Is where we hosted our web application so it becomes reachable online.

Table 3. 2: Description of firebase services that we used.

3 PERVASIVE SYSTEM REALIZATION

In this section we first present our database, the data that it contains and then in order to better understand how our agency work we provide the graphical user interfaces (GUIs) of our both applications the mobile application and the web application.

3.1 Database structure

This part presents the structure and a brief explanation of every Tree in our database as follows:

-**The car tree:** which represents the information and specifications of each car and it has the following attributes: mark, name, color, price, serie, number_seats, number_doors,

-**The Questions tree:** contains the live support questions that are asked by the users, is has the following attributes: the email of the user who asked the question and the question itself (Figure 3.4).

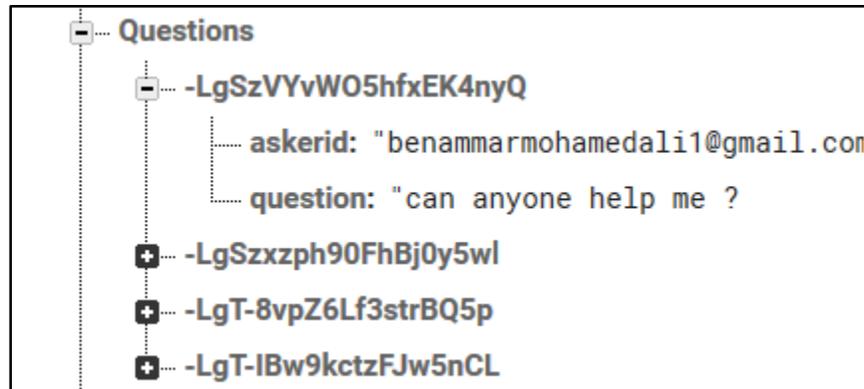


Figure 3. 4: Questions tree structure.

In the tree above (Figure 3.4) a question is read as the following: the question with id=1 is asked by the user with the name="benammar" and the question is="where are u located?"

-**The Contracts tree:** contains all the contracts that are made by the clients when they rent cars and each contract has: the id of the client who did the rent, id of the car that he rented, and the date of rent to the return date, this tree is linked with the Users tree and Cars tree (Figure 3.5).

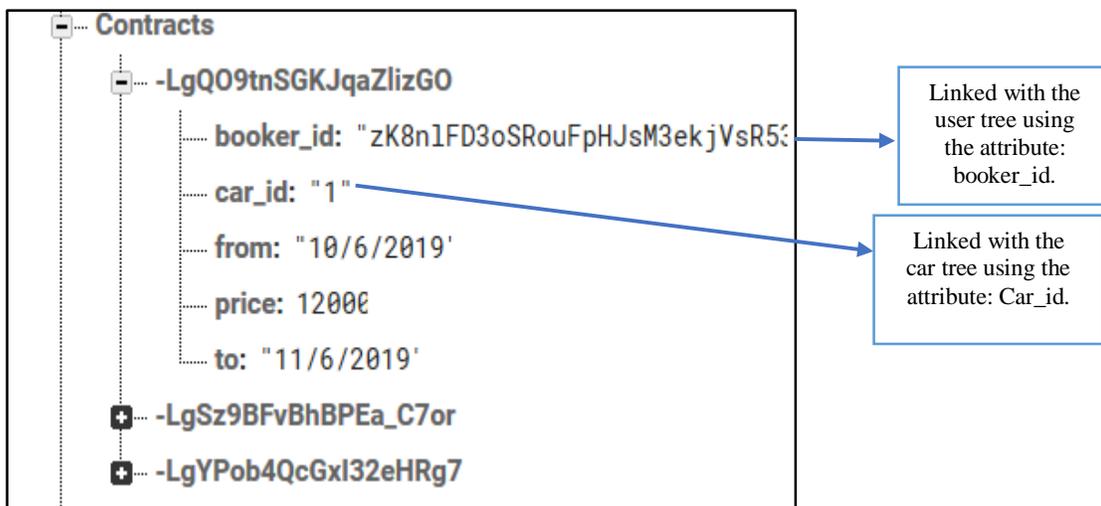


Figure 3. 5: Contracts tree structure.

In the tree above (Figure 3.5) a contract is read as the following, for example the contract with the id=1 belongs to the user with the id"3g6gcWNVLY....." And rented the car with the id=1 and the renting period is from 17/05/2019 to 20/05/2019 and the price is 12000DA.

-The bank tree: used to simulate the payment because in order for a user to rent a car he needs to enter his bank account id and an enough amount of credit, this tree has the following attributes: id which represents the credit card number, credit which is the credit that this card contains (Figure 3.6).

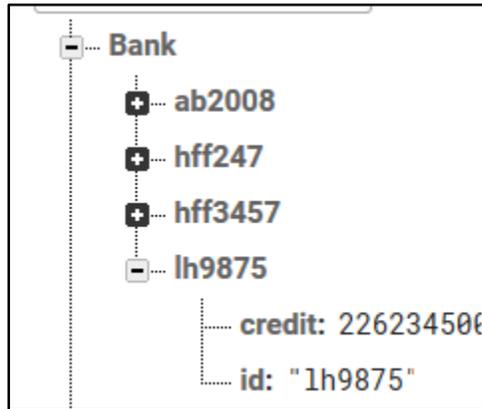


Figure 3. 6: Bank tree structure.

In the tree above (Figure 3.6) a bank account is read as the following, for example the bank account with the id of "hff247" contains 4000 DA.

-The Stats tree: which holds some statistics about our application (Figure 3.7).

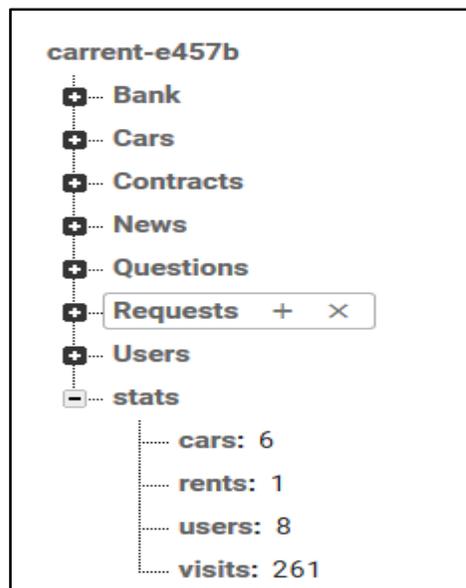


Figure 3. 7: Stats tree structure.

-**The Requests tree:** which holds the requests of the clients who want to extend their contracts by adding more days to it (Figure 3.8).

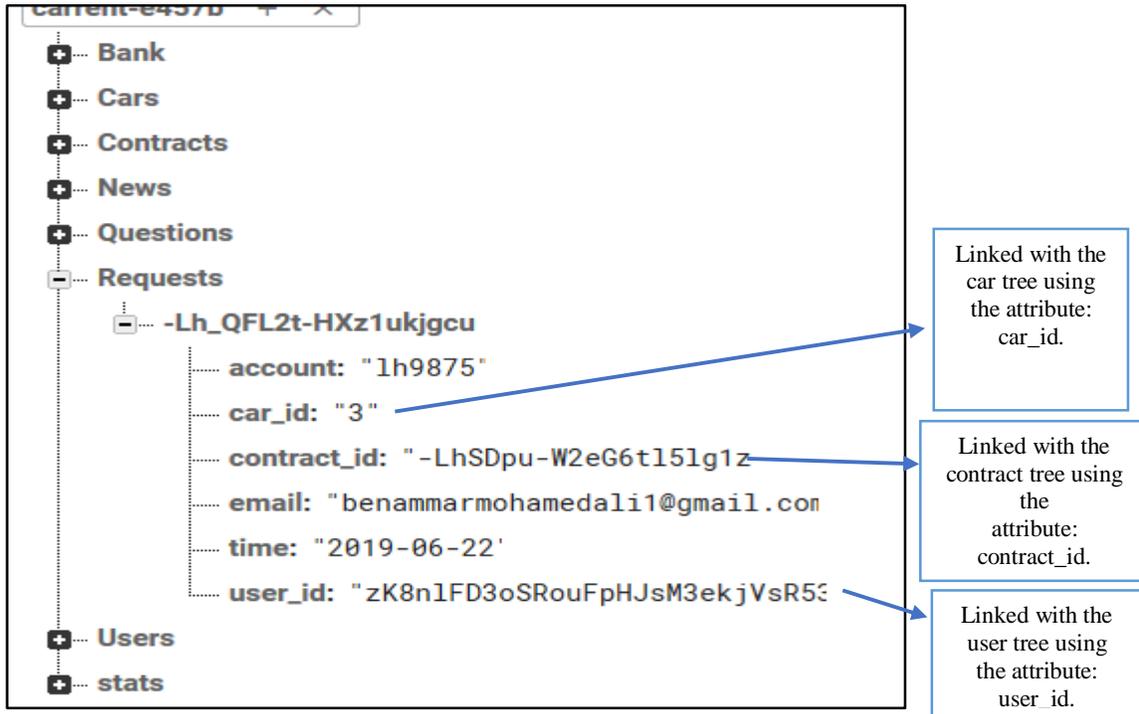


Figure 3. 8: Requests tree structure.

In the (Figure 3.8) above. A request is read as the following: the user with the email="benammarmohamedali1@gmail.com" wants to extend the renting period of the car with the id=3 to the date="2019-06-22" and he will pay using the bank account = "lh9875".

-**The News tree:** which holds all the activities that happened using both our mobile and web application, for example when a user registers or rents a car or asks a question in the livesupport this activity is saved on the news tree. This tree contains the following attributes: action which specifies the activity whether it is renting or asking a question or registering, actioner specifies the user who did the action, eventtime specifies time of the action (Figure 3.9).



Figure 3. 9: News tree structure.

3.2 Presenting the developed applications

The present section focuses on presenting our applications in which we first present the web application then the mobile application.

3.2.1 Web application

In this part, we present the most important parts of our website alongside an explanation of its most important functionalities.

A. Homepage

Homepage is the first page that encounters visitors or clients when they first visit our website (Figure 3.10).

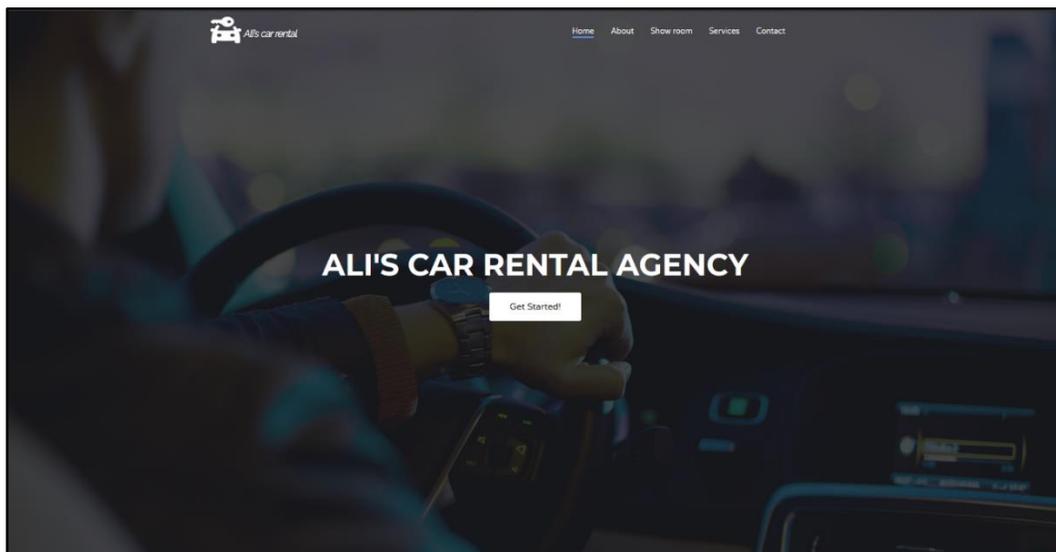


Figure 3. 10: Web application homepage.

The figure below (Figure 3.11) presents a closer look at our navigation bar.

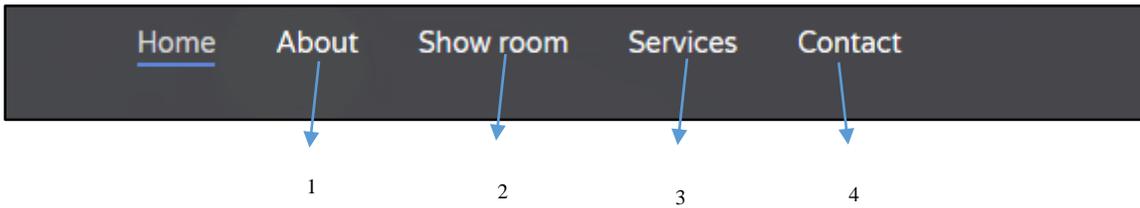


Figure 3. 11: Our website’s navigation bar.

The table below (Table 3.3) associates each element in our navigation bar to where it leads in our website.

Element	Description
1	<p>Leads to where we define our agency and explain some concepts about the different users (Figure 3.12).</p> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <p style="text-align: center;">Welcome To Our Agency's Website</p> <hr style="width: 20%; margin: auto;"/> <p style="text-align: center; font-size: small;">All's car rental agency is private company which provides to its users the ability to rent cars online without the need to its actual location</p> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center; width: 30%;">  <p>Guests</p> <p style="font-size: x-small;">Guests are the non-registered people, they can inspect the website and check the showroom and view cars only.</p> </div> <div style="text-align: center; width: 30%;">  <p>Users</p> <p style="font-size: x-small;">Users are the registered people, they can do all the features of a guest and plus they can rent cars and also use the live support.</p> </div> <div style="text-align: center; width: 30%;">  <p>Mobile</p> <p style="font-size: x-small;">We are also available in phones that run android via our mobile application,download link can be found at the bottom of the page</p> </div> </div> </div> <p style="text-align: center;">Figure 3. 12: About us element.</p>

2 Leads to our showroom, it is the space where we present all our cars(Figure 3.13)

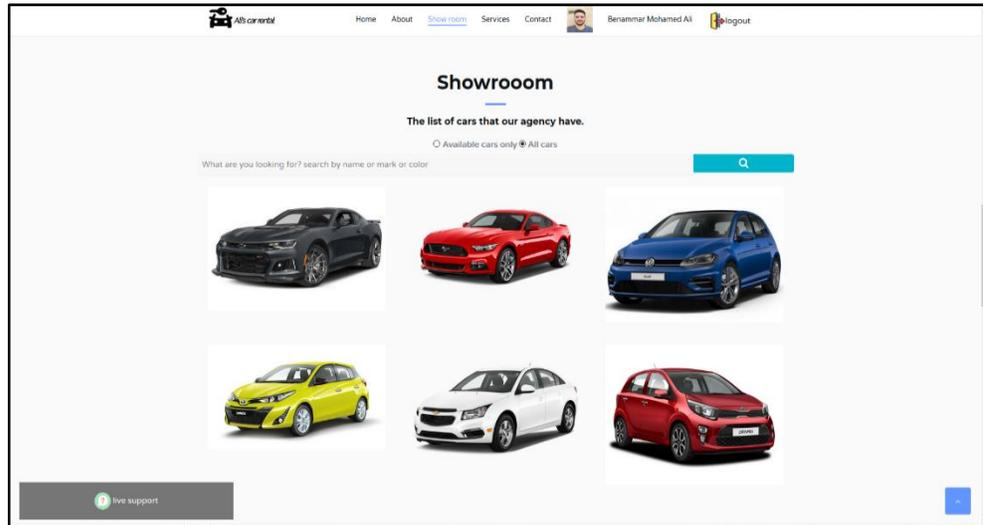


Figure 3. 13: Showroom element.

Users in the showroom (Figure 3.13) can search for a specific car by entering its name or mark or color in the search bar like shown in the (Figure 3.14) below.

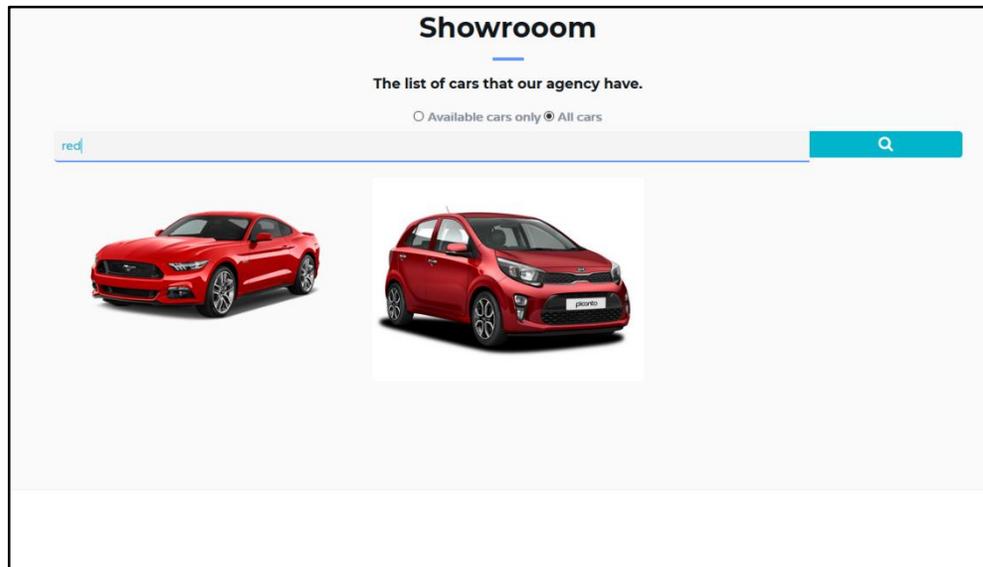


Figure 3. 14: Search by color.

The figure (Figure 3.15) below presents a search by brand (mark).

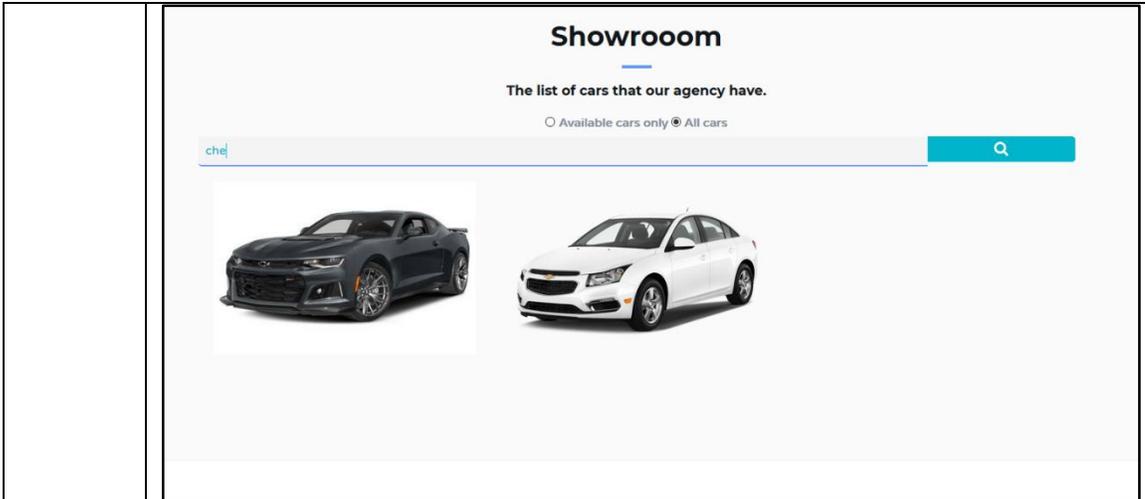


Figure 3. 15: Search by mark.

Users can also search for the available cars only by selecting the available cars only RadioButton in the (Figure 3.15) above.

3

Leads to where we present our services (Figure 3.16).

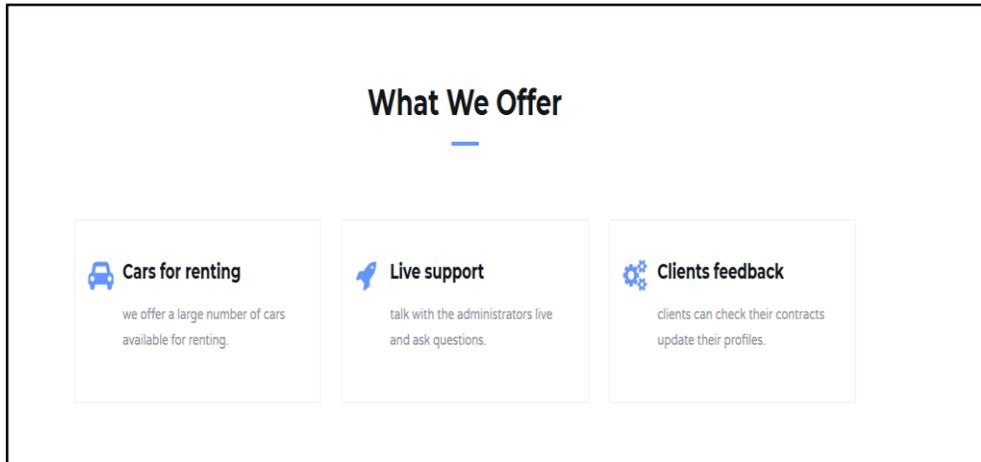


Figure 3. 16: Our services element.

4

Leads to the section where we provide to the clients the necessary information so they can contact us and also some statistics like number of clients (Figure 3.17).

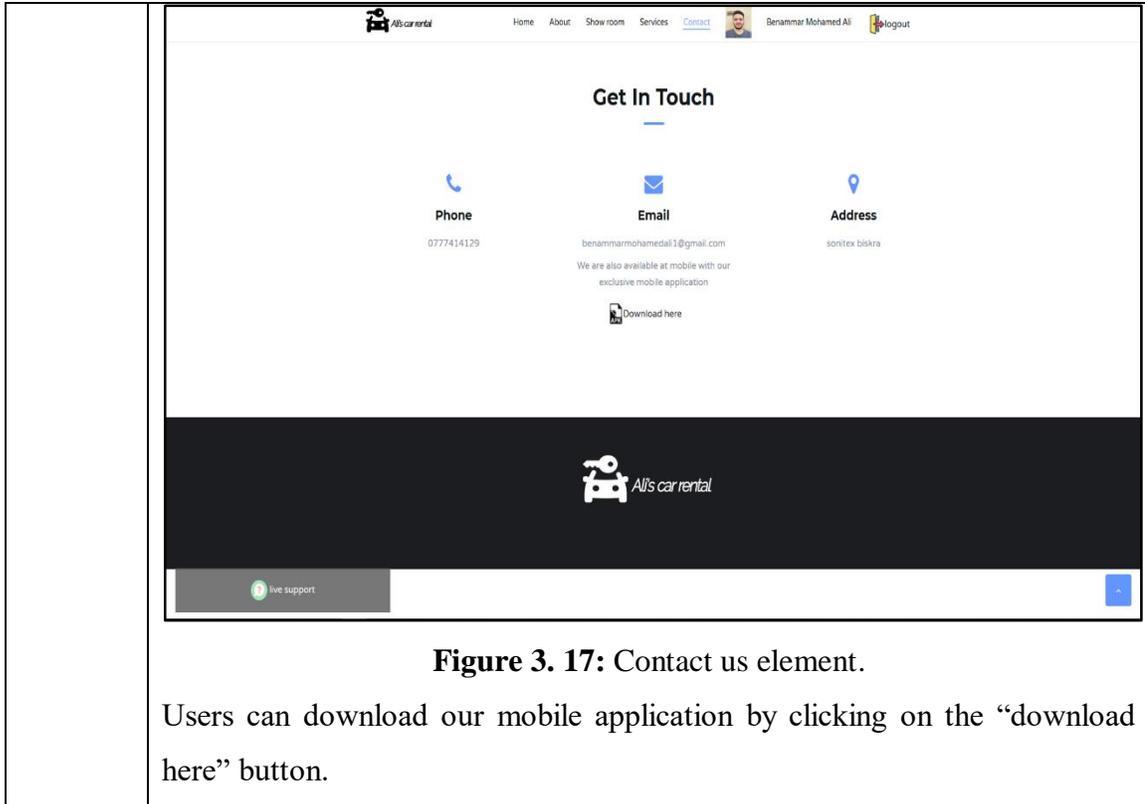


Table 3. 3: Elements of our navigation bar.

B. Authentication

Authentication is considered the most important part in our website, it can be reached by clicking on the “get started button on our home page” it is where normal guests and registered users and admins part ways, here we present the authentication interface (Figure 3.18).

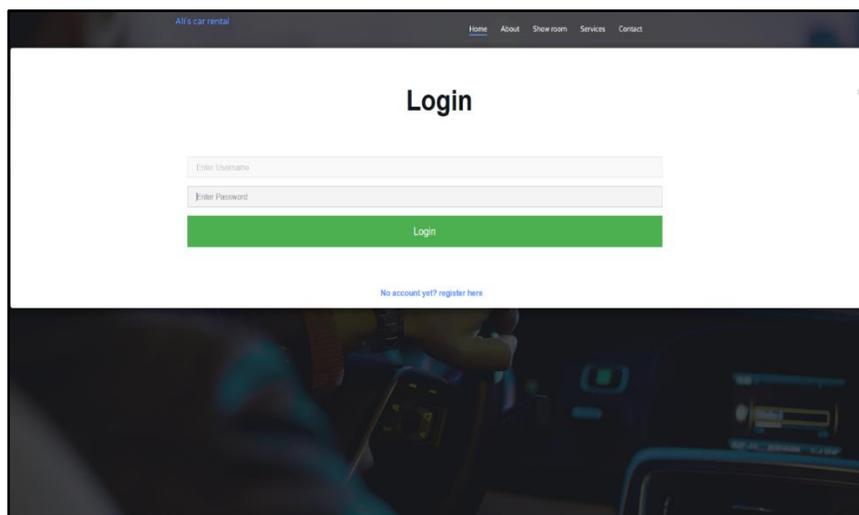


Figure 3. 18: Authentication interface.

Admins and users use this interface to sign-in to their profiles, admins use pre-determined emails that contain “.admin” they do not need to register because they are added from the firebase console. Where clients use the interface below to register (Figure 3.19)

Figure 3. 19: Register interface.

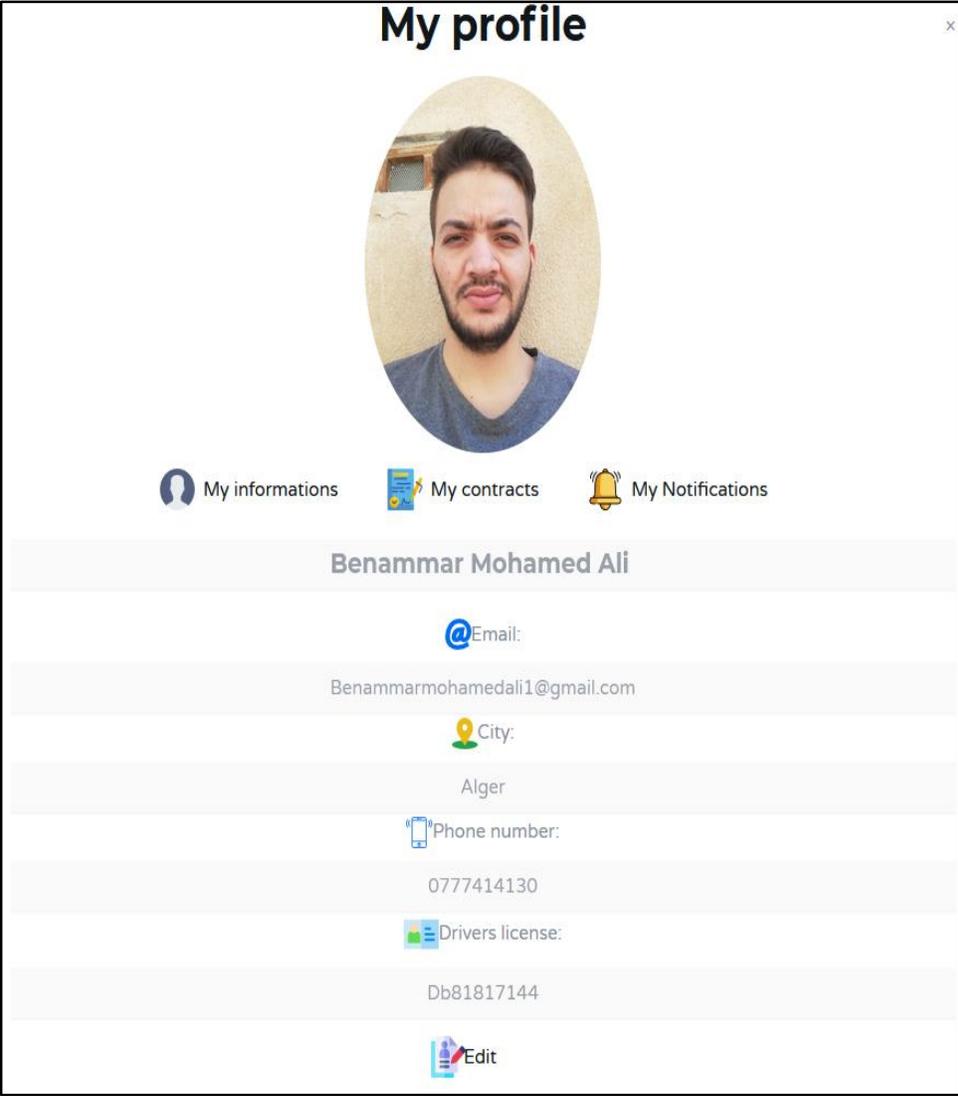
Clients cannot use emails that contain “.admin” for example the email =” ali.admin@gmail.com” will not be accepted because simply it is reserved for admins.

When clients or admins are logged in into their accounts, a user-specific information will appear inside the navigation bar as shown in the table below (Table 3.4).

<p>Client</p>	<p>Figure 3. 20: Signed-in client.</p>
<p>Admin</p>	<p>Figure 3. 21: Signed-in admin.</p>

Table 3. 4: Admin/user login information.

The present (Table 3.5) explains the elements of our post-login navigation bar and where they lead.

	Description
1	<p>A popup box will appear containing all the information of the client And also the choice to see the contracts he made (Figure 3.22).</p>  <p>Figure 3. 22: User profile.</p> <p>When he clicks on my contracts, he can see all his contracts like shown in the following figure (Figure 3.23).</p>

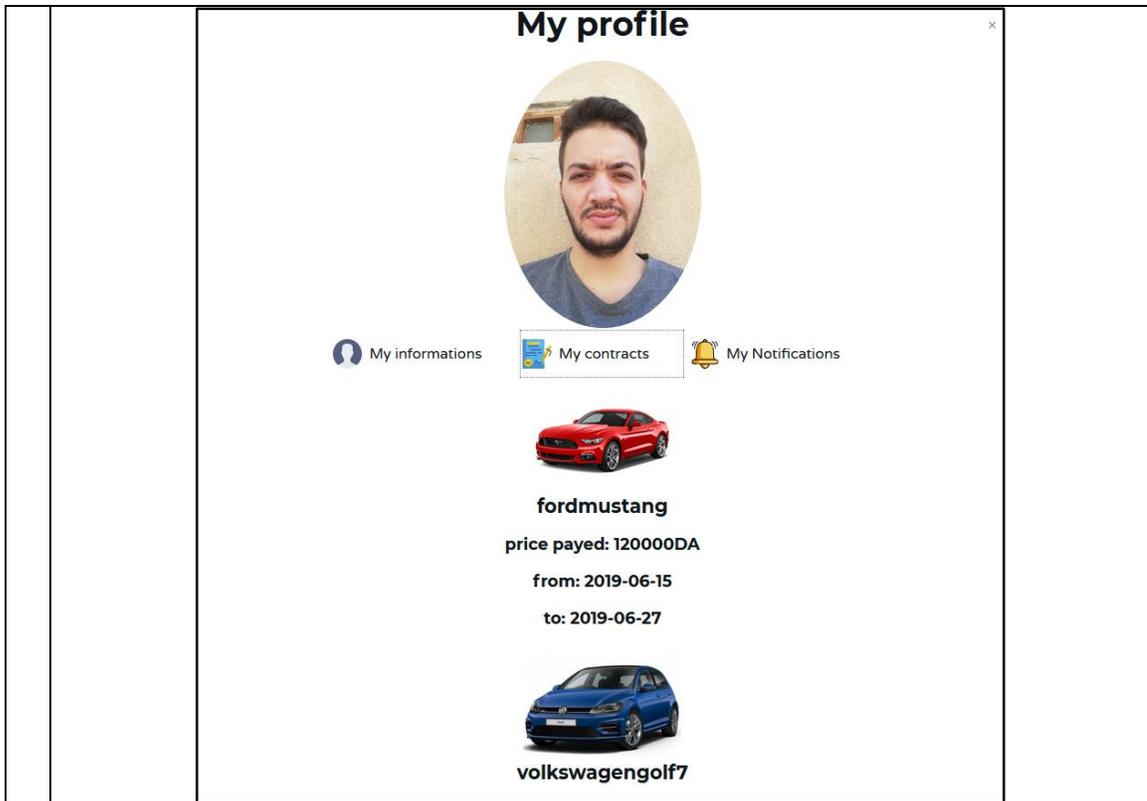


Figure 3. 23: User Contracts.

The (Figure 3.23) means that this user rented two cars from our website (the chevrolet and the ford).

If a client is on the road with his car and he figures he is going to need more days with it. He can click on the contract he wishes to extend and the following window will appear (Figure 3.24).

Figure 3. 24: Extend contract.

The client enters the date and his bank account and clicks on extend. And a request will be sent to the admins for processing. The client can see if his request is accepted or not by clicking on my notifications button in the (Figure 3.23) above, when an admin approves or disapproves request, a notification will be sent to the client.

- 2 Shows the admin's dashboard, it is the space where the admin do all his tasks. First we present clients list space where admin can see all clients (Figure 3.25).

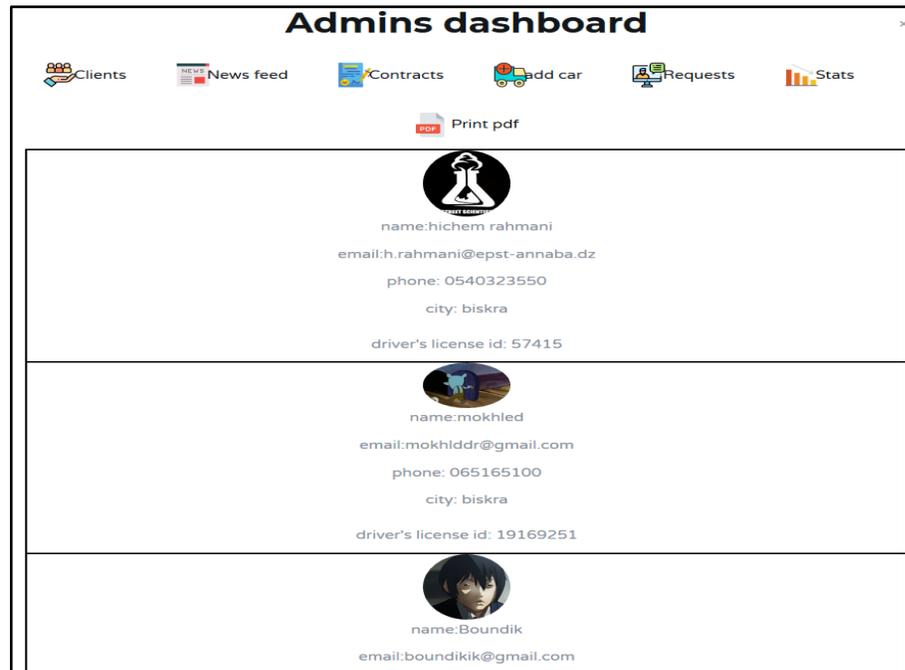


Figure 3. 25: Clients list.

When clicked on the “print pdf” button in the (Figure 3.25) above, a pdf file that contains the list of all the clients will be downloaded.

When clicked on the “news feed” button, admins can see all the activities that happened in both the web and mobile applications. For example when clients register or rent a car or ask a question in the live support it will appear as a news in the newsfeed section (Figure 3.26).

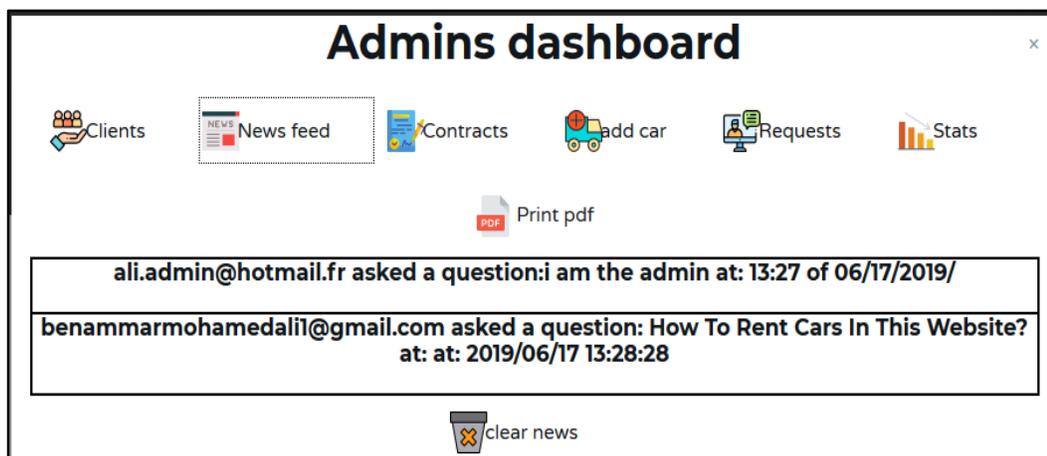


Figure 3. 26: News feed.

Print pdf button also allows the admin to download the list of news as a pdf.

Contracts button displays all previously concluded contracts, where admins can select a contract and either modify it or delete it or leave it as it is (Figure 3.27).

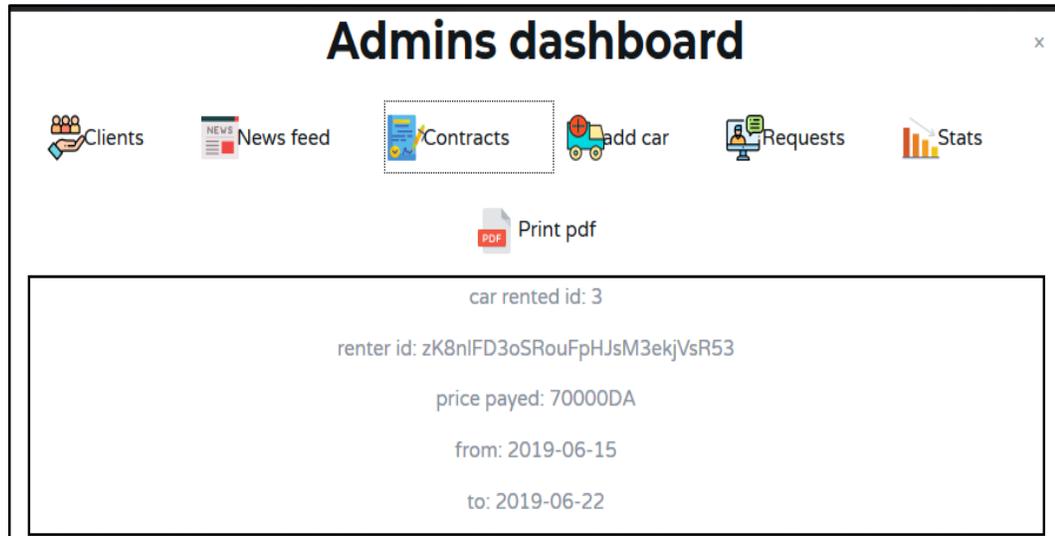


Figure 3. 27: List of contracts.

Print pdf button downloads the list of contracts as a pdf file.

Add car button allows the admin to add a car to the database so it can be available to users in the showroom (Figure 3.28).

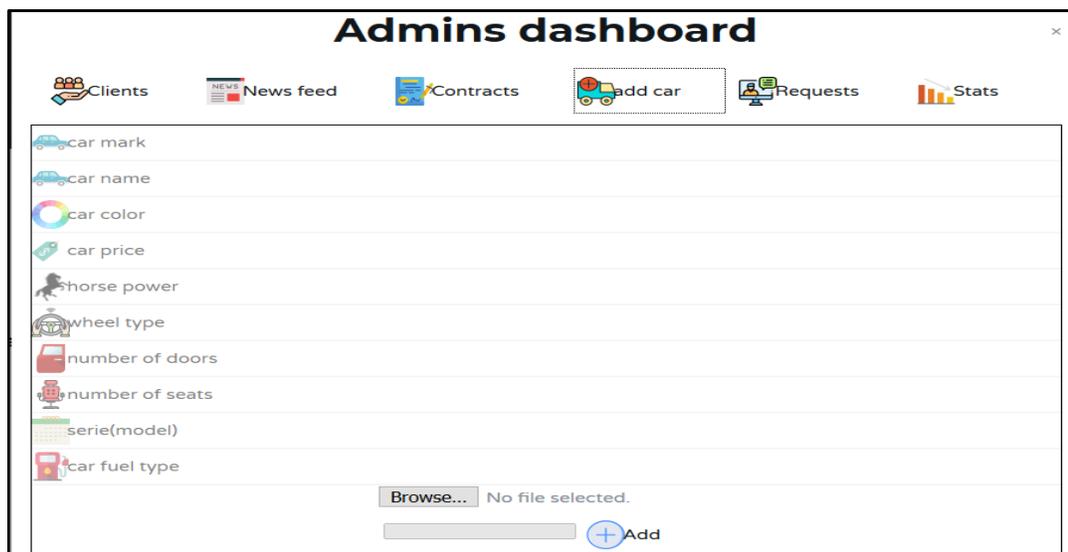


Figure 3. 28: Add car.

Requests button shows the list of the requests made by clients (when they request more days in their contracts) (Figure 3.29).

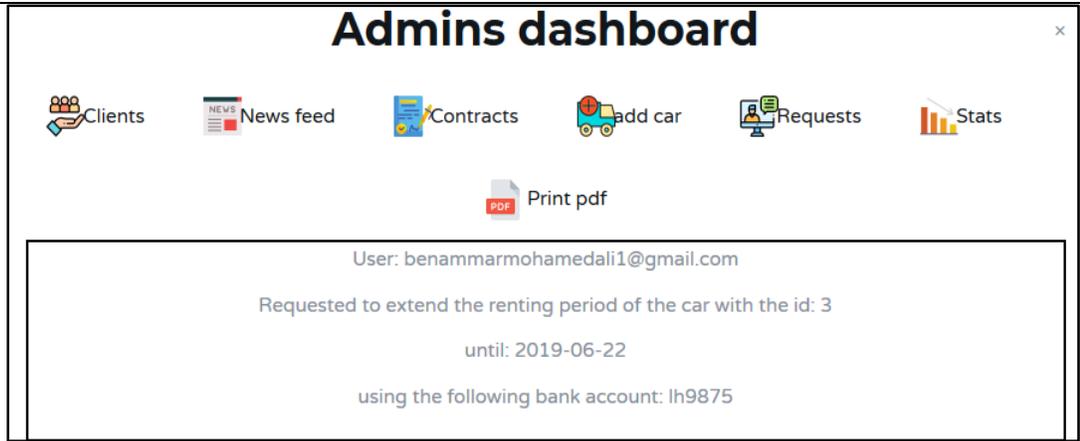


Figure 3. 29: Add car.

Print pdf button in the (Figure 3.29) above downloads the list of requests as a pdf file.

When an admin clicks on a request the following window appears (Figure 3.30).



Figure 3. 30: Requests management.

Admins can either approve or disapprove requests. The contract that is meant to be extended will be updated to the new date and price if the admin approved the request of the user.

Stats button shows some stats that are related to our agency like shown in the following (Figure 3.31).

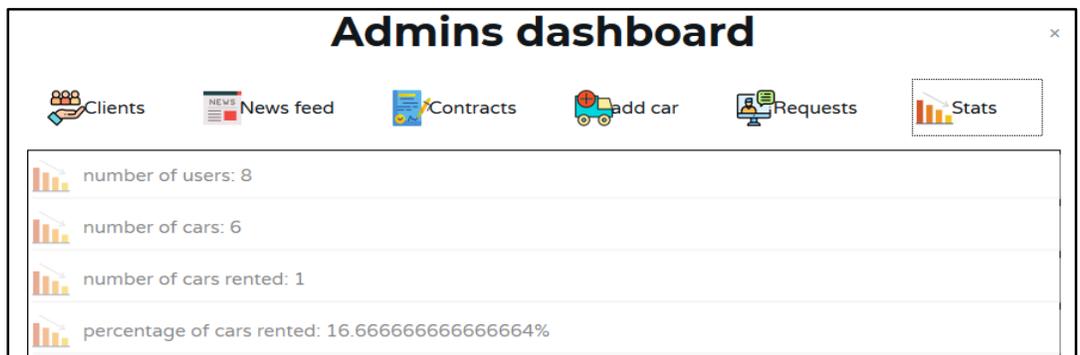


Figure 3. 31: Requests management.

3 When clicked on “3”, the user or the admin simply logs out.

Table 3. 5 Description of the elements of our navigation bar.

As for the “Live support” button situated in the bottom left corner of our website it is responsible for opening the chat box, it only appears when clients or admins are logged in. It is a space where clients can use to ask questions and receive questions live either from admins or other clients, for example when a client asks if a certain car is in a good state or is it worth renting and the clients who rented the car before him or admins themselves can answer his question. The answer is delivered live just like a chat in Facebook. (Figure 3.32) presents our live support.

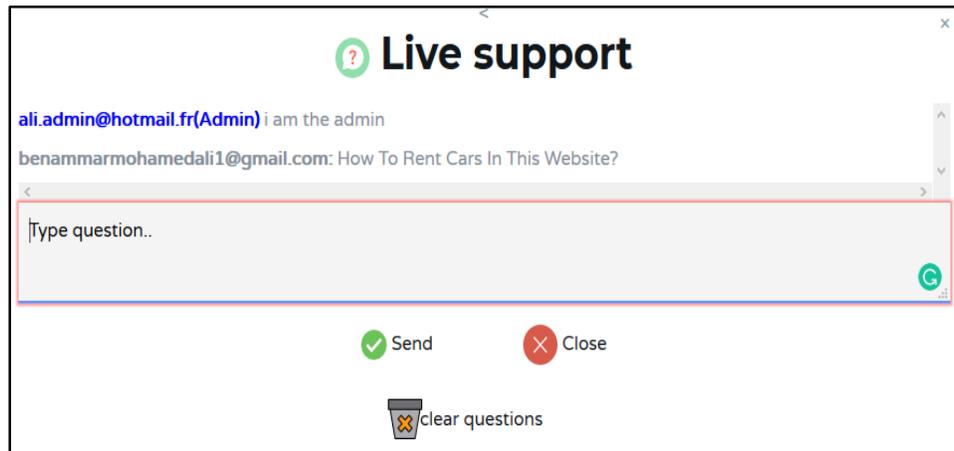


Figure 3. 32: Live support.

Clear questions button in the (Figure 3.32) above only appears for admins. It allows them to delete all the questions.

C. Renting cars

When a client seeks to rent a car from our website, he first checks the showroom and looks for a car that suits him (the price or number of seats if his family is big). If he finds the right one he simply clicks on the car and the following popup appears (Figure 3.33) (Figure 3.34).

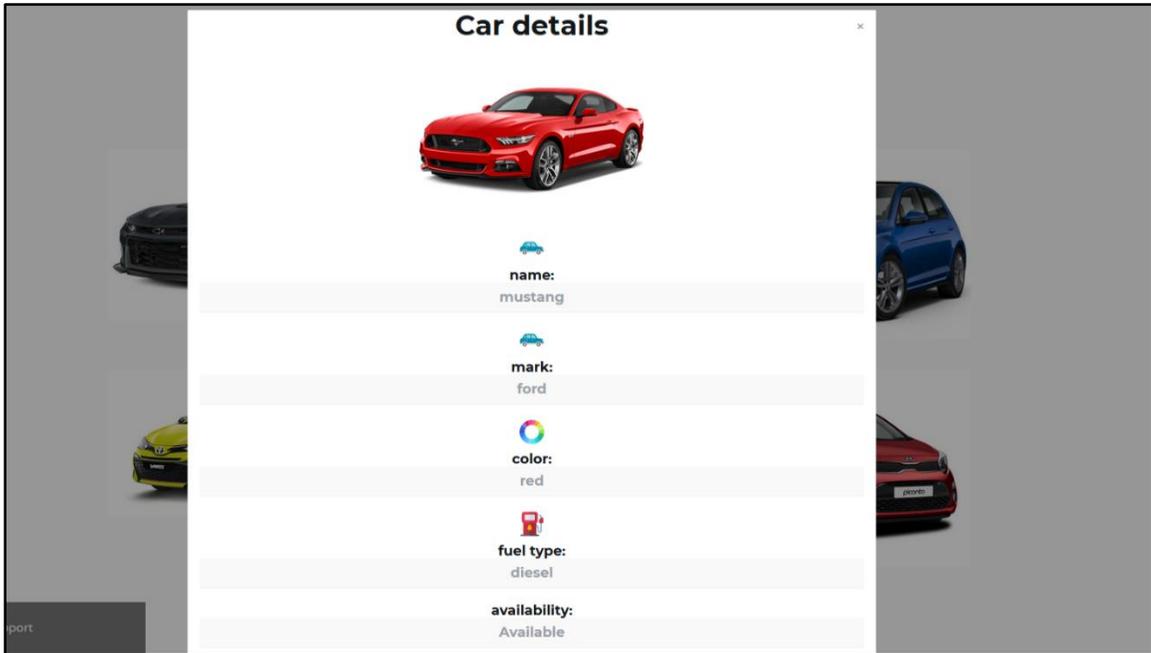
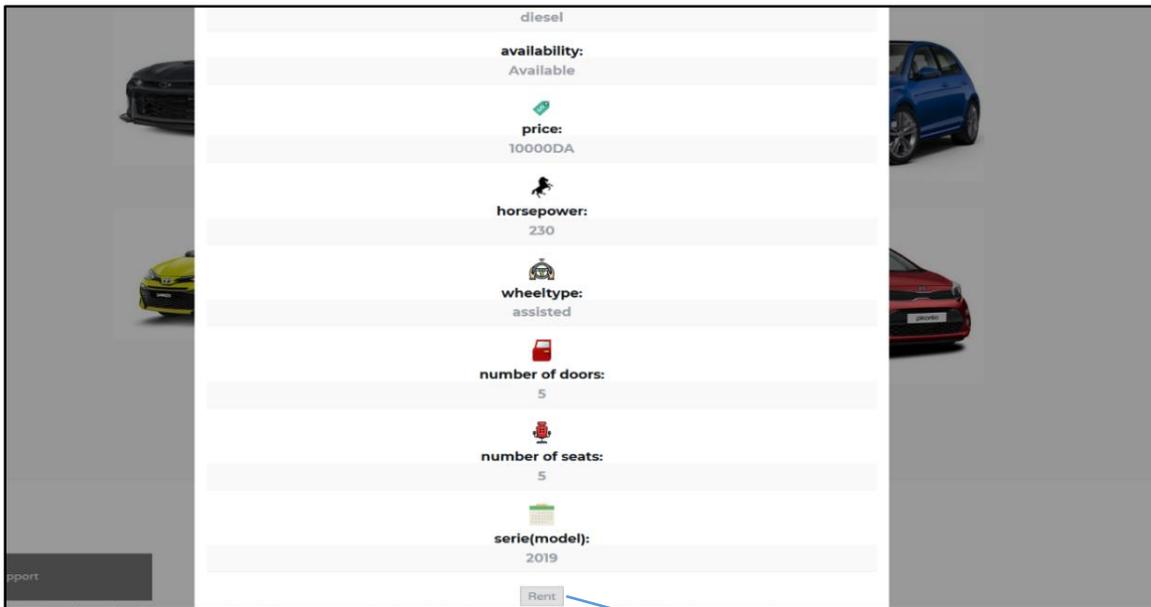


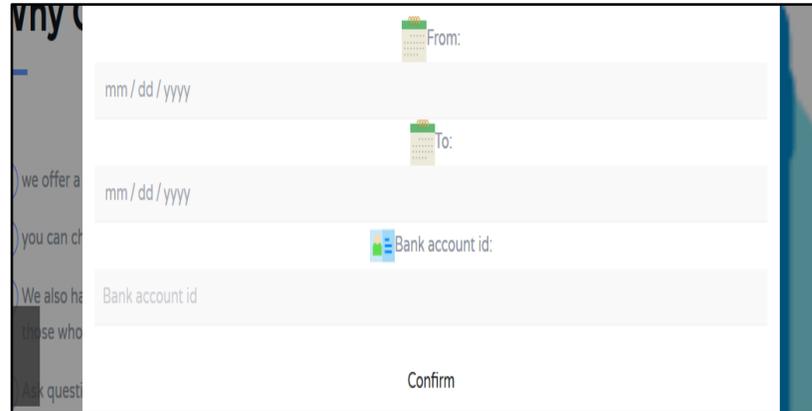
Figure 3. 33: Car details.



Rent button

Figure 3. 34: Car details part 2.

When rent button in the (Figure 3.34) above is clicked, more details appear as the following figure shows (figure 3.35).



The screenshot shows a form with three input fields and a button. The first field is labeled 'From:' and contains the placeholder text 'mm / dd / yyyy'. The second field is labeled 'To:' and also contains 'mm / dd / yyyy'. The third field is labeled 'Bank account id:' and contains 'Bank account id'. Below the fields is a button labeled 'Confirm'.

Figure 3. 35: Rent details.

The client selects the renting period like shown in the following (Figure 3.36).

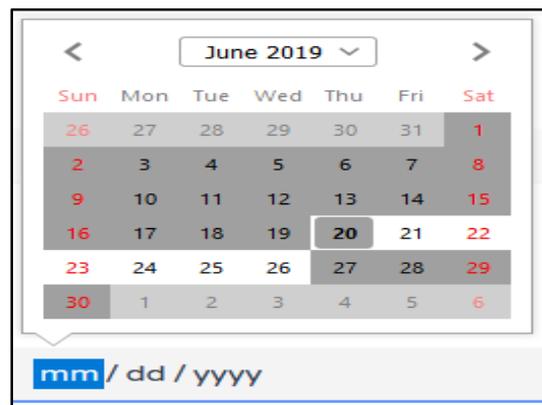


Figure 3. 36: Date picker.

The period is only limited to 7 days starting from the day that the client is in at that moment, he cannot select any date before or after it. Then the user enters his bank account id then clicks confirm, if all the conditions are met then the renting is complete and a contract that holds all the details of this renting operation will be saved in his storage as a pdf file like shown in the following figure (Figure 3.37).

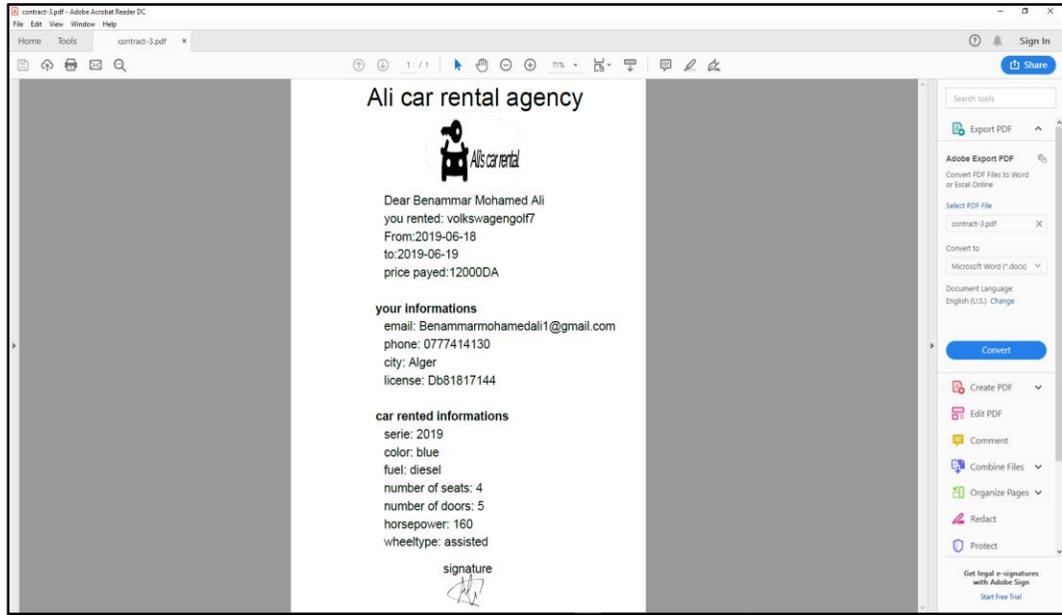


Figure 3. 37: Renting contract.

3.2.2 Mobile application

In this part, we present our mobile application by providing GUIs and explaining how it functions.

A. Home activity

The first activity that displays when the mobile application is opened is the dashboard activity as shown in the (Figure 3.38).

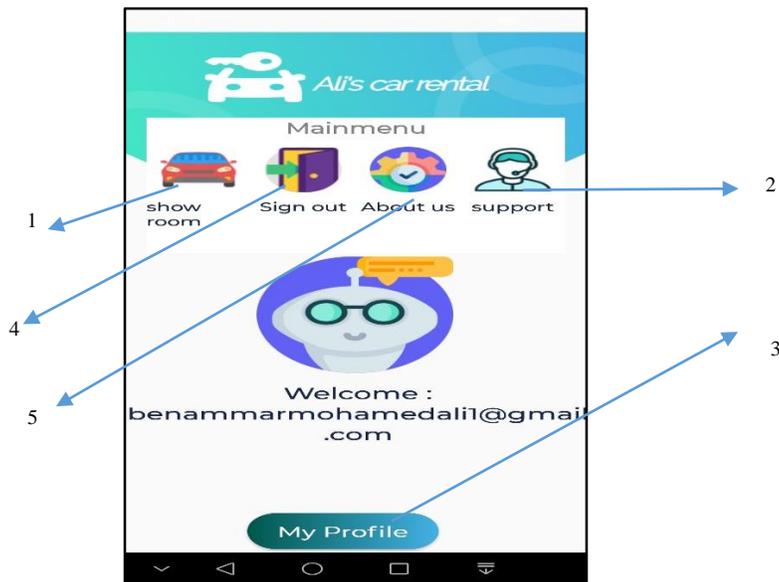
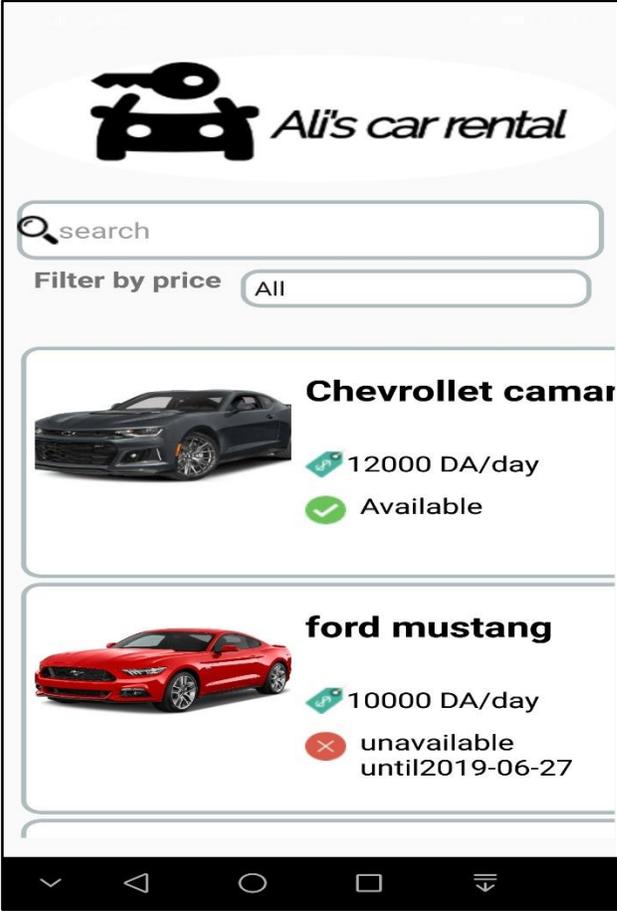


Figure 3. 38 Mobile dashboard activity.

The following table (Table 3.6) associates each element in our dashboard activity to where it leads in our application.

Element	Description
1	<p data-bbox="477 459 1211 491">Leads to the showroom: the list of our cars (Figure 3.39).</p> <div data-bbox="639 512 1256 1423" style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 300px;">  </div> <p data-bbox="729 1444 1164 1478">Figure 3. 39: Showroom activity.</p> <p data-bbox="477 1499 1419 1640">Users can search for car by a specific name or mark or even filter by price for example: show only cars that are between 4000da-6000da (Figure 3.40).</p>

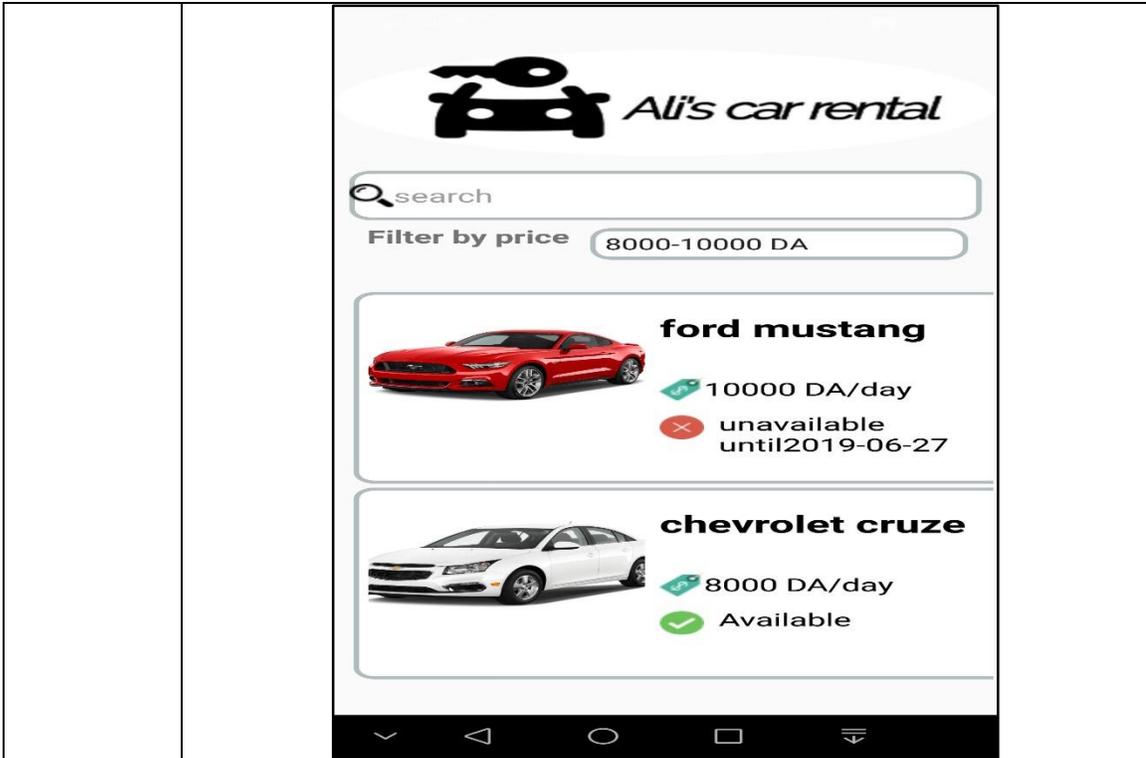


Figure 3. 40: Showroom activity filter by price.

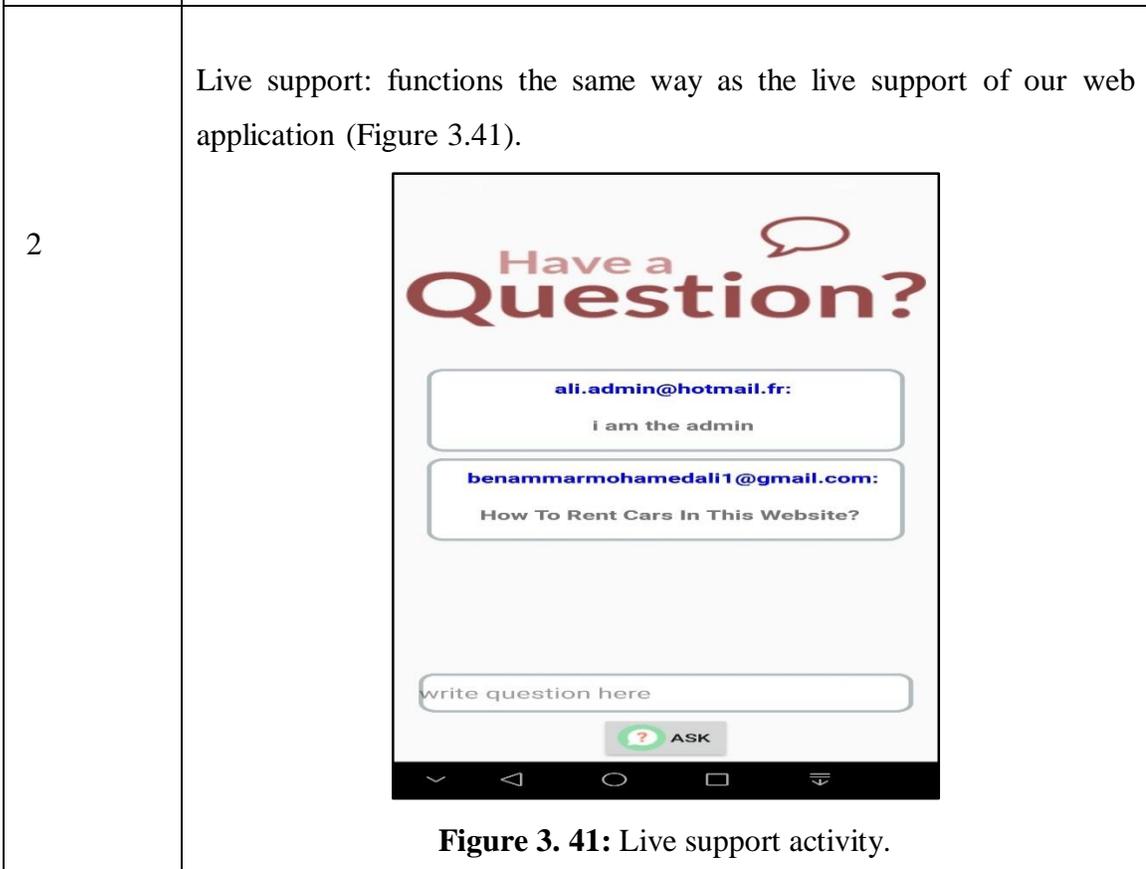
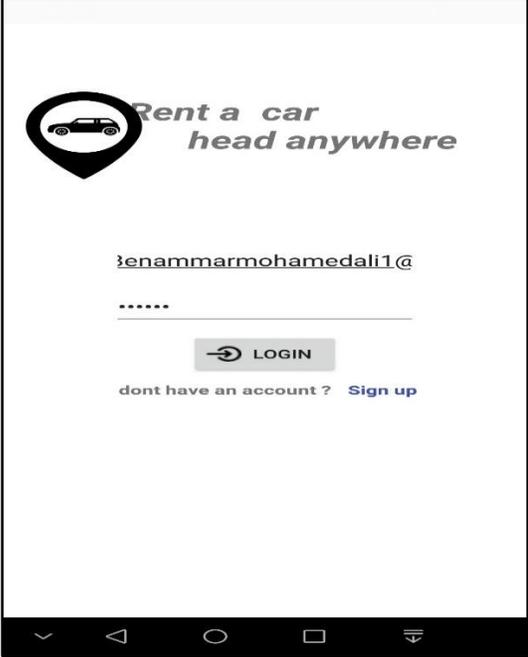


Figure 3. 41: Live support activity.

3	<p>Register activity (Figure 3.42) where guests can register.</p>  <p>The screenshot shows a registration form with the following fields: Full Name, Driver's License, Phone Number, City, Email, Password, and Password Confirmation. A SIGNUP button is located at the bottom of the form.</p> <p>Figure 3. 42: Register activity.</p>
4	<p>Leads to the login activity (Figure 3.43) where users login into their accounts.</p>  <p>The screenshot shows a login screen with the text "Rent a car head anywhere" and a car icon. The login form includes an email field with the text "benammarmohamedali1@" and a password field with six dots. A LOGIN button is present, along with a link that says "dont have an account ? Sign up".</p> <p>Figure 3. 43: Login activity.</p>

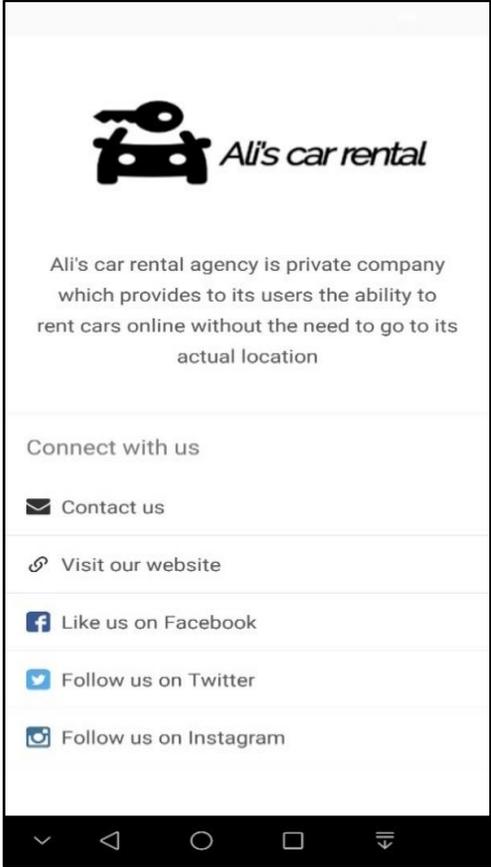
5	<p>Leads to about us activity. It is where we provide information about our agency and also ways to contact us (Figure 3.44).</p> <div data-bbox="701 304 1192 1171" style="border: 1px solid black; padding: 10px; margin: 10px auto; width: fit-content;">  </div> <p style="text-align: center;">Figure 3. 44: About us activity.</p>
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Table 3. 6: Mobile dashboard elements description.

B. Renting

The renting procedure is somehow similar to the one in the web application, the client first chooses a car from the showroom and clicks on it to see its details like shown in (Figure 3.45) below.

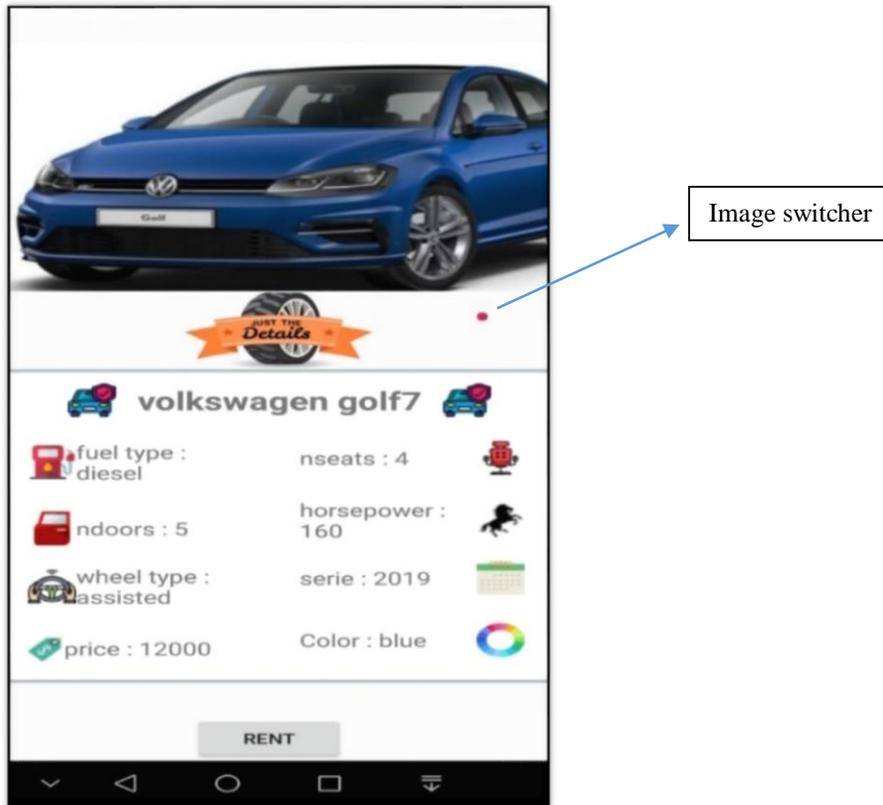


Figure 3. 45: Car details.

The image switcher in the (Figure 3.45) allows users to switch between the different images of the car by swiping left or right on the image. Rent button takes the user to the activity where he provides the renting information as presented in the (Figure 3.46) below.

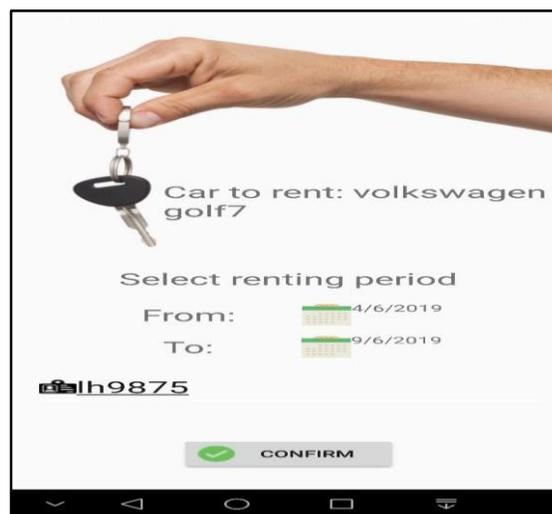


Figure 3. 46: Renting activity.

If all the renting conditions are met then the renting is complete he will be redirected to the final activity which is the bill activity and it is presented as follows (Figure 3.47).

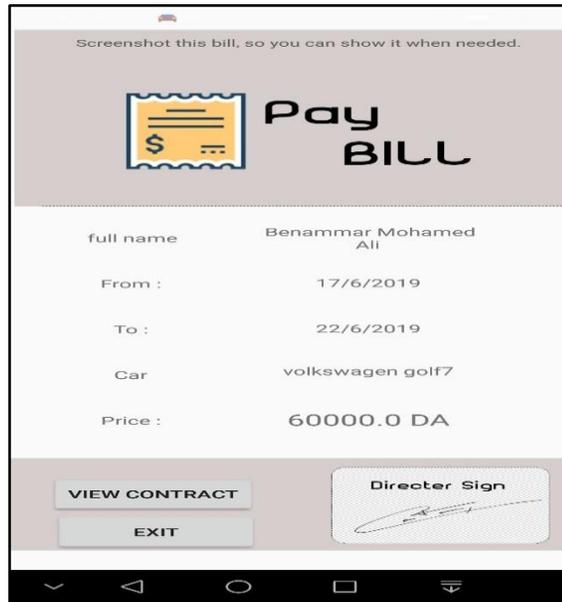


Figure 3. 47: Bill activity.

By clicking view contract in the (Figure 3.47) above, the client can see his contract as a pdf file containing information about the renting.

But to rent cars, a client needs to be logged in into the application using his email in the login activity (Figure 3.43), after the client is logged in, the home activity will look a bit different, see (Figure 3.48) below.

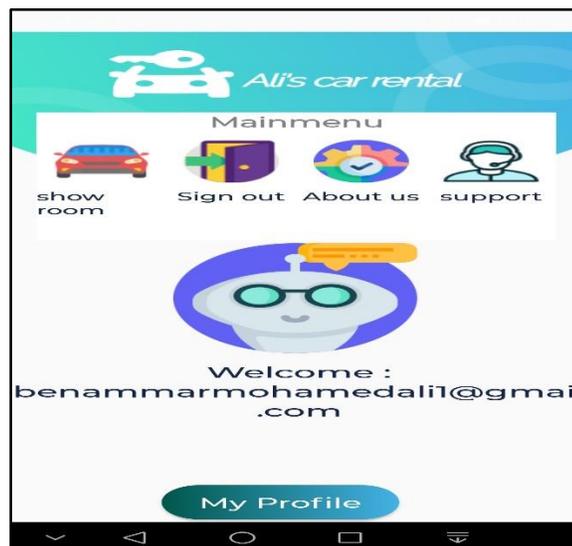


Figure 3. 48: Home activity after login.

A new button will appear “My profile”, when the client clicks on it, the client will be redirected to his profile, see (Figure 3.49) below.

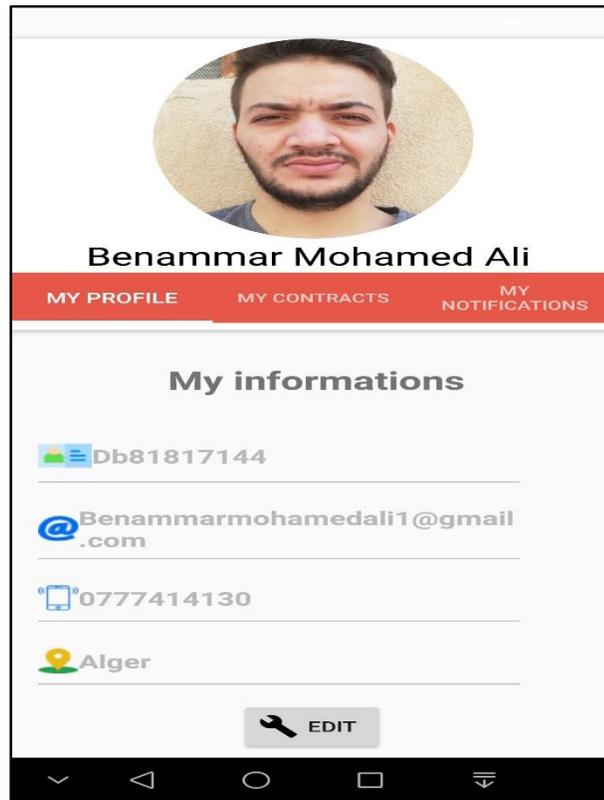


Figure 3. 49: Profile activity.

The client can see his information, he can edit them and he can see his contracts by clicking on “my contracts”, see (Figure 3.50).



Figure 3. 50: My contracts.

The client can also ask for a permission to extend his contract just like in the website by clicking on a contract and the following window appears (Figure 3.51).

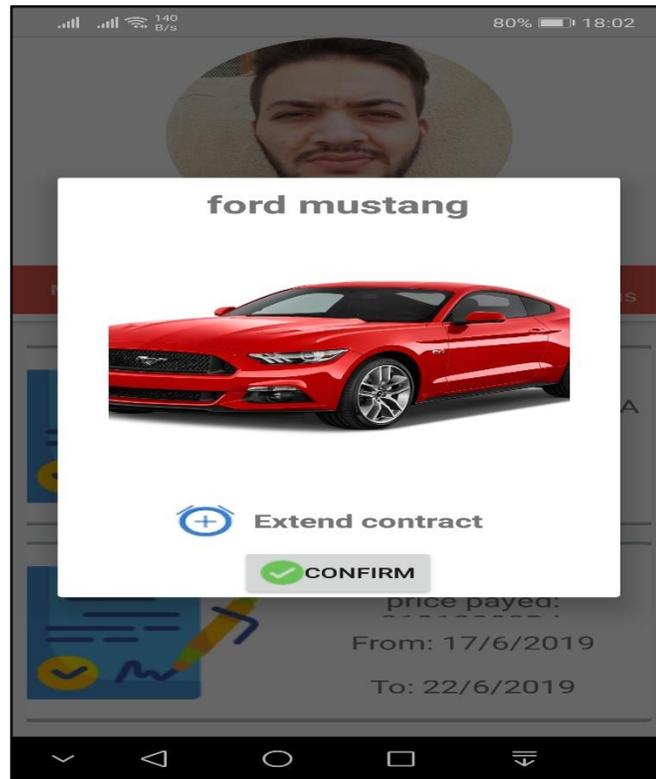


Figure 3. 51: Contract extend request.

The client can also see his notifications by clicking on “my notifications” in the profile activity (Figure 3.49) above, to see whether his requests to extend a contract are accepted or no.

4 CONCLUSION

In this chapter we have presented the programming languages and the development environments used to build our pervasive system of our car rental agency which consists of a web application and a mobile application. Then we illustrated and explained the different features and services of our system through GUIs that represent the main interfaces of both our mobile and web application in order to give a better idea of the work done.

GENERAL CONCLUSION

The objective of this work was to design and to implement a pervasive system based on business processes. We applied our contribution in a case study related to a car rental agency, since it provides a suitable set of internal and external business processes, in order to have a system that guarantees the best quality and the more availability of the car rental business.

The context of our work allows us to use in the design phase: firstly, semi-formal models such as UML, which combine both a structure description and a behavioral one, to understand problems, express and elaborate object models independently of any programming language by utilizing the following diagrams: Class diagram which represents the static structure of our system and helps us in the coding phase of our data base, Use case diagram which provides the functionality of our system from different views (user/visitor/administrator/manager) and then the sequence diagram and activity diagram where each diagram represented the dynamicity of our business process whether it is public or private.

Secondly, the implementation phase of our work also exploits different programming languages and assured a coherent matching of the previously made diagrams to build two kinds of applications and share the public business processes of the agency through them as: 1) A web application. 2) An android mobile application, so users can still be able to rent cars from anywhere at any time and to stay in touch with the agency.

In a future work, we plan to improve this project by adding the following features: first adding an actual online payment system using a credit card rather than the simulated one we are using right now. Secondly and since we are only available on android with our mobile application we plan to expand our availability to the IOS [iPhone Operating System] as well by building a suitable application to its users.

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