Tracking people with AD: Overview and architecture proposal of an integrated solution

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Abstract

Alzheimer is a disease that has aroused the interest of several researchers around the world for decades, and so far, no cure has been found to end its proliferation. One of the critical symptoms of AD is memory loss, something that puts the patient at great risk and puts his family in pain. This research aims to resolve this problem, it focuses on the development of an integrated solution, which will help Alzheimer's patient to have a certain autonomy and to create a certain peace of mind among their relatives. This project is divided into two main parts an electronic bracelet and an informatic platform. Hence, the electronic bracelet, which is mainly based on a GPS technology, will allow a real-time monitoring of the movements of the patient wearing it, and the informatic platform will allow the people taking care of the patient to visualise his actual position. This smart solution will reduce the risk of patients to get lost in the streets, and can gather information form patient all over the world to study their behaviour, and consequently have more comprehensibility of this disease. In this article, we will present the core concept of the electronic bracelet, and the architecture of the informatic platform.

Keywords
Alzheimer disease, Emergency Medical Tags, Electronic Data Processing, Geographic locations and Real-time monitoring.

1. Introduction
Alzheimer Disease (AD) is a progressive neurological disorder that causes the brain to shrink and brain cells to die. It is the most common cause of dementia; a continuous decline in thinking, behavioural and social skills that affects a person's ability to function independently. AD is a brain disorder that slowly destroys memory and thinking skills and eventually, the ability to carry out the simplest tasks. Worldwide, at least 50 million people are believed to be living with AD or some type of dementia. The most dangerous part is that these patients lose control and if they escape, it would be so hard to find them. To avoid the risk of losses in people with AD, several studies have been done. In a study, a researcher developed an electronic tracking system that is a mobile GPS receiver-shaped, including function of telephony and data transfer via GSM / GPRS (Faucounau et al. 2009). This system aims to explore the needs and perceptions of wandering persons and their caregivers towards existing tracking devices as well as their acceptability and usability. In another related research the author tried to answer the growing number of people suffering from AD by offering a low-cost, easy-to-deploy technological solution (Bettahar et al. 2013). The goal is to perform a continuous and automated monitoring of the patient in his living environment. It is a multisensory surveillance system consisting of a network of sensibly distributed motion

sensors, associated with a wireless electronic tag carried by the person allowing its location and the detection of falls. Another researcher build an Android application based assistive toolkit for person affected by AD (Pirani et al. 2016). This application provides various functionalities such as tracking movements of patient through GPS, providing medicine and food timing notifications, daily routine tracker and quiz to increase cognitive functioning of the patient. In another article, the authors have presented a poster titled behavioural manifestations of disorientation of persons with AD dementia in outdoor way finding tasks: towards a situation aware assistance (Heine et al. 2016). This poster aims to characterize disoriented behaviour in people with AD dementia during outdoor navigation in a complex urban environment. Other researchers have used the Radio Frequency IDentifcation (RFID) technique to locate people with AD (Chowdhury et Khosla 2007; Raad et Sheltami 2016; Raad et al. 2018). Based on the start of the art, a researcher builds a tracking system of a patient who suffers from AD, from a GPS receiver and a NodeMCU ESP8266 board that captures the current coordinates and sends them to a server at the same time using an HTTP request, then from a server to a mobile / web application (Adardour et al. 2021). The Web / Mobile application also resides on the server, and the data exchange will be via a Wi-Fi wireless communication protocol. Another researcher also conducted a study to assess the use of a geolocation system by people with dementia of AD type and related (Sablier et al. 2011). This system is made up of bracelets equipped with GPS, connected to a remote assistance service. In an article, a researcher proposed an approach based on location technology (UWB ToF) to facilitate the use of the location of a connected object used in everyday life (Dalcé et al. 2021). In the first phase, a localization system was imagined, designed and developed and its output adapted to a user with visual impairment or cognitive impairment to help him find a lost object. Ultimately, the work carried out will make it possible to conceptualize interactive and support systems that are more natural and adapted to the capacities and activities of users. In another article, a researcher presented an outdoor monitoring system that relies on a in review transmitter worn by the AD patient and a portable receiver used to search for the patient (Altus et al. 2000). They developed the Mobile Locater, which aims at providing caregivers with a tool to locate a lost person. The authors conducted a 6-month pilot study involving users, healthcare professionals and caregivers. They concluded to be a great acceptance on the use of the device that proved to be effective and helpful to caregivers as they could have some piece of mind regarding the AD patient's whereabouts. The high cost was pointed out as a potential drawback. Then, other researchers found in the literature another outdoor system for the same purposes which is ComfortZone (www.alz.org/comfortzone), presented by the Alzheimer Association (Paiva et Abreu, 2012). This system relies on a GPS device that sends location position to the Comfort Zone Web application, which can be accessed by caregivers. The monitoring level can be configured, for instance to determine the type of alerts received. Like with Mobile Locater, ComfortZone has a cost. The monthly plan chosen determines the frequency that the application communicates with the device to register a location. There are currently two monthly plans: frequency of 15 minutes or frequency of 30 minutes. This can be looked at as another drawback of ComfortZone, other than the cost itself, as it might be important to have shorter monitoring time frames. Additionally, not much flexibility in the system configuration is provided. Other generic outdoor monitoring systems exist such as 3DTracking (http://3dtracking.com.pt/), GpsGate Server (http://gpsgate.com/), GPS-Trace Orange (http://gps-trace.com/) or OpenGTS. Considering the information, they gathered from the literature review, the authors of an article present a low-cost GPS tracking system focused on AD patients which relies in a mobile device with GPS functionality allowing to track and locate patients in near real-time (Paiva et Abreu 2012). The choice for this equipment was based on its GPS functionality, its low cost and on the possibility to develop an application that can easily provide the ability to configure the system's usage. Furthermore, in their article (Javed et al. 2020) it said that Modern inventions can be even more automated by using the Internet of Things (IoT) and Artificial Intelligence (AI). In this work, (Dawadi 2013) showed that machine-learning algorithms can be designed to perform automated assessment of task quality based on smart home sensor data that is collected during task performance. His results indicate that smart homes and ubiquitous computing technologies can be useful for monitoring complex everyday functions and to automate assessment of daily activities. As part of this research work, we focused on articles containing a better illustration and a better description of the various devices that enable communication between caregivers and elderly people, their assistance, and their geolocation. There are several devices, but we have chosen to work on bracelets and watches. Below, we illustrate the tables with some existing devices adapted from an article about Alzheimer devices (Retmi 2012).

1.1 Features description of the relevant developed Bracelets and watches

Based on the features described above, we have established a comparison between the existing solutions in the market for both bracelets and watches (Table 1).

Table 1. Comparison of the different existing bracelets and watches

	Bracelets				**Watches**			
	Vega	**Bracelet B2**	**Saver Life**	**Columb**	**Freedo m GPS**	**Kéruvé Pro**	**Limmex**	**Num8+**
Type	Bracelet	Bracelet or Medallion	Bracelet	Bracelet	Watch	GPS watch and portable receiver	Watch	Watch
Geolocation technology	GPS / AGPS	GSM / GPS	GPS	GPS, GSM, GPRS	GSM / GPS	SBAS-GPS, Vision-indoor, Vision CellIDy, T-GSM	N/A	GPS, GPRS
Followed the route in real time	No but it is possible to perform every 4 minutes outside monitoring of displacements	Yes	No	No	Yes	No, the watch turns on his GPS at the location request or alarm triggered. to save the battery, Kéruvé turn off his GPS.	No	No
Information when the person leaves the safe zone	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Right of caregivers to manage the secure zone	No	Yes	N/A	Yes	N/A	Yes	N/A	Yes
Launch a voice call from the device	No	Yes	Yes	No	No	No	Yes	No
Number of programmable numbers	1	5	4	N/A	It allows to send text messages to any mobile phone	N/A	Up to 10	N/A
Direct call	No	No	Yes	No (an	No	No	Yes (In	No
Direct call of the caregiver	No	No	Yes	No (an alert is sent electronically by the device for medical help desk who sent it to the caregivers and family).	No	No	Yes (In normal operation, it is not possible to call a watch Limmex. Exception: after the wearer activated an emergency call, the watch can be called for 30 minutes to ensure that the help was organized well. During this time, the watch automatically accepts incoming calls.	No
Sensitivity and access keys	Very insufficient	Good	Acceptable	Acceptable	Good	Acceptable	Acceptable	Acceptable

1.1.Comparison of all devices

After studying how all these devices work, we focused on advantages and disadvantages of each solution, then, we compared all of them in order to design our own system. In review the comparison that we have made above, has allowed to us to define the common advantages (Table 2) and disadvantages (Table 3) of each solution.

Table 2. Common advantages of current solutions

Battery
a. Simplicity and quick charge b. Long autonomy (life time battery is 7 days) c. Sensor inside which puts the device to sleep after one minute of no movement (to save battery)
Design
a. Status indicators and illuminated buttons. b. Good design which is small and not heavy c. The device cannot be cut as it incorporates a wire; and it has an attachment system that requires a special key in order to remove it
Monitor of location
a. Real time monitoring
Help desk assistance
a. High availability of support service in the case of emergency call after waiting of 30 second
Secure area
a. Unlimited numbers of security zones b. Caregivers defining zones
Others
a. The wearer must press each key for a long time in order to avoid unintentional calls b. Dermatologically tested to ensure safe wearing c. Change of caregiver's number is simple d. Contract is terminable at any time e. Warning if the elderly people fall f. Watertight g. No installation technique required h. Very low power consumption i. The caregivers have a touch screen to take with them when they go in search of the elderly people, the screen will include the location as and when it progresses. j. Historic journey available to show all displacements k. Encrypted data sharing to ensure no unauthorized access of location l. Alert button which can operate both inside and outside providing caregivers a precise alert notification that can be monitored on laptops or PDA. m. Device automatically answers after two rings n. Customer portal for family and professional caregivers to manage secure zones, programmable numbers, real time tracking, history of events

Table 3. Common drawbacks of Current Solutions

	Battery
a.	It is difficult to see the level of battery charge when the wearer is outside
b.	Autonomy is poor (battery lifetime is 2 hours)
c.	Installation and charging require the assistance of third party
d.	Unexpected sounds are heard when charging and switching on the device
Design	
a.	The size of the device

b. Complex c. The plastic cover is not strong d. Bracelet uncomfortable e. Screen unreadable f. Heavy g. No locking mechanism h. Instructions tinkered with gaps, complex manual and not clear i. The touch screen can be disadvantage for caregivers who are not comfortable with j. The board buttons are very small
Monitor of location
a. Not real time GPS tracker
Coverage
a. Poor GSM coverage
Help desk assistance
a. Helpline does not respond to every alert call
Secure area
a. No secure area
Precision
a. High imprecision in calculating the position of the person
Others
a. The wearer cannot launch a voice call from the device b. Location requires internet connection c. The remaining credit is unknown, so the monitoring of consumption is impossible d. When the device answers automatically, the person can be spied on without knowing it. e. When the device is stopped, an incoming call leads to an answering machine offering to leave a message that can never be heard f. Programming numbers through service providers (the device should be returned for change) g. History and setting require expensive software h. The location is impossible when there is no credit i. Changing the setting are not always taken into account j. Many alert calls fail k. The device is stopped via a long press (device appeared to be off but it is not) l. The caregiver must stop the alarm by sending an SMS, else he receives series of SMS every 5 min until the completion of credit

2. Materials and methods

2.1 Methodology

2.1.1 SCRUM Method

The choice between one method and another depends on the nature of the project and its size. For projects of small size and domain under control, for example, a cascading lifecycle is more than sufficient. When it comes to a project where the data is not gathered from the start, where the needs are incomplete or even fuzzy, we must move towards an iterative or prototype-oriented method. Among the iterative methods, we can distinguish the AGILE methodology widely used nowadays around the world. A method AGILE is carried out in a collaborative spirit and adapts to incremental approaches. It generates products of high quality while taking into account the changing needs of the customer. An AGILE methodology ensures better communication with the customer and better visibility of the deliverable. It also allows you to manage continuous quality and to detect problems as early as possible, thus making it possible to undertake corrective actions without too many penalties in costs and delays. There are several AGILE methodologies, which leads to select the most suitable one for this project. The nature of the project which must be scalable and not all of the needs have yet been fully identified, directed us to an AGILE type of methodology and more specifically SCRUM.

Scrum is an agile form of project management framework with iterative release cycles. In a project flowering scrum methodology, there is a fixed short duration release cycle called ‘Sprint’, at end of which a potential releasable part of the product is released. Duration of scrum may range from 1 week to 4 weeks; however, the

ideal case is 2 weeks. The criteria defining whether the product is 'potentially releasable' will be there in the 'Definition of Done'. In other words, the definition of done will list the conditions on satisfying which a 'story' or statement defining a feature of the product is considered complete and ready for release. Definition of done is agreed upon by the scrum team at the beginning of the project. A scrum team is members participating in the project and what they do is defined by three 'Scrum Roles'. The Scrum team Participates in certain scrum ceremonies which form part of the scrum framework resulting in the creation of certain artifacts at the end of each sprint.

The software product releases are planned based on the following variables:

- Customer requirements: how the current system needs enhancing.
- Time pressure: what time frame is required to gain a competitive advantage.
- Competition: what is the competition up to, and what is required to best them.
- Quality: what is the required quality, given the above variables.
- Vision: what changes are required at this stage to fulfil the system vision.
- Resource: what staff and funding are available.

These variables form the initial plan for a software enhancement project. However, these variables also change during the project. A successful development methodology must take these variables and their evolutionary nature into account.

2.1.2 Implementation of SCRUM method in Tracking people solution in AD

The methodology section is too vague and presents only well-known information on AGILE and SCRUM techniques. However, the practical implementation of such approaches is missing.

In this project, three personnel collaborate to develop the application with the following tasks:

- Project Manager who is in charge to supervise, track, control, and is responsible for the overall project
- Systems Analyst who is on a mission to prepare a feasibility study, analysis the requirements of the patients, and specify the features of the solution
- Programmer who is in charge to present the conceptual design and coding the program and internal testing of the program to support the application system.

Regarding the main principles of the method, we have:

- The team: we focus on people and their interactions rather than processes and the tools
- The application: the most important thing is to have a functional application rather than having complete documentation.
- Collaboration: this method is based on collaboration with the client.
- Acceptance of change: we do not follow a fixed plan but we react to each new change.
- The Product Backlog: The Backlog consists of a list of features to be performed. These features, expressed in the form of tasks and research, are prioritized by the Product Owner, which makes it possible to establish an order to be followed in order to achieve the proposed objective.

Table 4. Product Backlog

Story	Time estimated	Status	Sprint
Starting by interviews	The whole day	Done	Sprint1
Check in sessions to present the advancement	10 minutes	Done	Sprint2
Mentoring sessions to discuss the customers interviews	1 hour	Done	Sprint3
Flutter application to collect positions from phone to firebase	2 hours	Done	Sprint4
Web application to collect data from firebase	5 hours	Done	Sprint5
Display the date from firebase to the view	2 hours	Done	Sprint6
Preapring the final presentation	1 hour	Done	Sprint7
Sandbox presentation to discuss the product to customers	2 hours	Done	Sprint8

2.2 Requirement analysis and specification

This part will present the analysis phase of the project, to dissect the specifications of the application we started with this phase, more precisely the use cases diagram to study the needs of the actors and the expected functionalities of the system.

We proceed in this part to the identification of all the functionalities of the system for each type of user and this by listing the functional needs and apprehending the list of requirements translated by the non-functional needs and finally studying the different cases of uses that the system offers.

2.2.1 Specification of functional requirements

The main actors and their roles:

- Administrator: After authentication, we can choose one of the patients and follow his/her location through a marker that points to their current position on Google maps.
- Patient: The person with Alzheimer's, that the administrator must track its position. This patient is supposed to be wearing a bracelet that will be connected to the web application.

2.2.2 Specification of non-functional requirements

After having determined the functional needs, we present below all the constraints to be respected to guarantee the performance of the system, to reduce the number of risks of failure or non-operation.

- Performance: To be accepted by the customer, the application must meet this criterion while ensuring minimum response time and smooth operation.
- The Ergonomics of Computer Interfaces: Interfaces must be simple and user- friendly, and the application must ensure information security.

2.2.3 Cases description

In order to properly study the needs of the actors and the expected functionalities of the system, we built the diagram of use cases. To do this we started by defining the different use cases that the system offers.

- Retrieve the patient's last position
  - **Description:** The administrator retrieves the patient's last position stored in Firebase whichis represented as a GeoPoint (latitude, longitude). The last position stored in the database isthe current position.
- Track the patient's location every five seconds
  - **Description:** The administrator after login, choose one of the patients and must track their positionsby a marker pointing in Google maps

2.2.4 Use case diagram

The analysis is therefore completed by the construction of the use case diagram which allowed us to properly present the actors and their expected needs of the system.

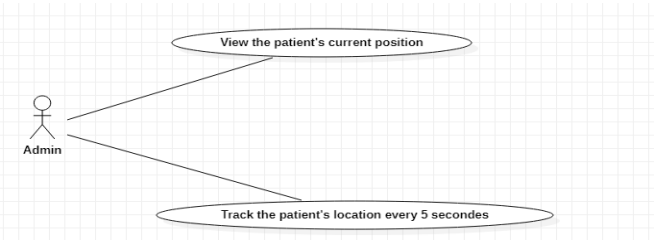

Figure 1. Use Case diagram

2.2.5 Conception

After we defined the use cases, the next step goes for dissecting each system functionality. This part has been devoted to detail the scenarios by first showing the sequence diagram to follow the patient's current position. Then we will start the classes, attributes as well as associations between classes and classpaths to finally build a class diagram.

a. Sequence Diagram

First of all, the administrator who is responsible for the patient with Alzheimer's connects to the application. Then follows any patient's positions every 5 seconds, and finally tracks the position history.

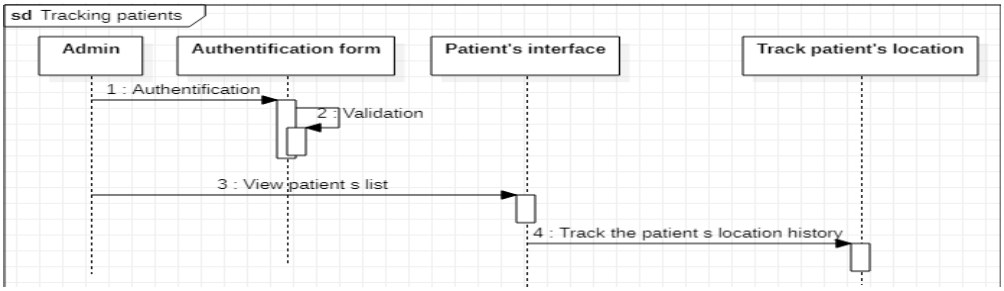

Figure 2. Sequence diagram

b. Class diagram

The third step is to build the class diagram, which is very important in object-oriented modelling. It is used for general conceptual modelling of the application's structure and detailed modelling, translating the models into programming code. While the use case diagram is used to gather the requirements of a system including internal and external influences.

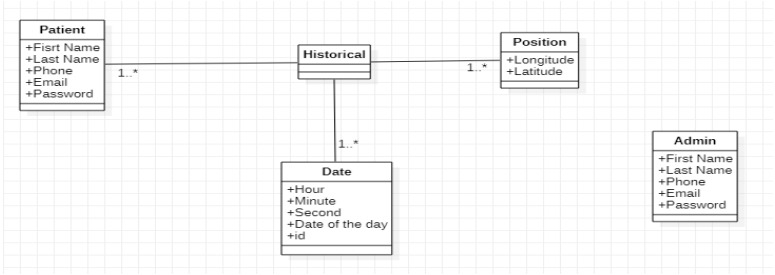

Figure 3. Class diagram

In this part we have defined the different use cases of the application, resulting in the construction of the use cases diagram. We have modelled the website by providing answers to the modelling and design issues based on the needs analysis of the application. We were able to model there in the form of case diagrams of use then of sequence, then design the application in the form of class diagrams.

2.2.6 Architecture of an integrated solution for tracking patients with AD

The architecture of the solution was designed following a modularized approach to effectively trace in real time patients, identify them and show their current geographical position and other information associated to them. This modularized approach allows to have a decoupled architecture that allows future extension and improvement, also it makes easy the maintenance of solution.

There are three main components constituting this architecture (Figure 4):

- The bracelet: represents the patient side of the solution, it allows to send permanently the geographical position of the patient, and it's designed to have a better reliability and battery autonomy.
- Web application: represents the caregiver side of the solution, can be deployed on computer, tab and smartphone, it permits to visualize in real time the patient position. Furthermore, the web application is conceived to integrate a deep learning module, in order to analyse the saved data, and hence, have more understanding of the behaviour of Alzheimer's patients.
- Data storage: it's a storage which run on the cloud and allows to save, for future treatment, all information about the patient.

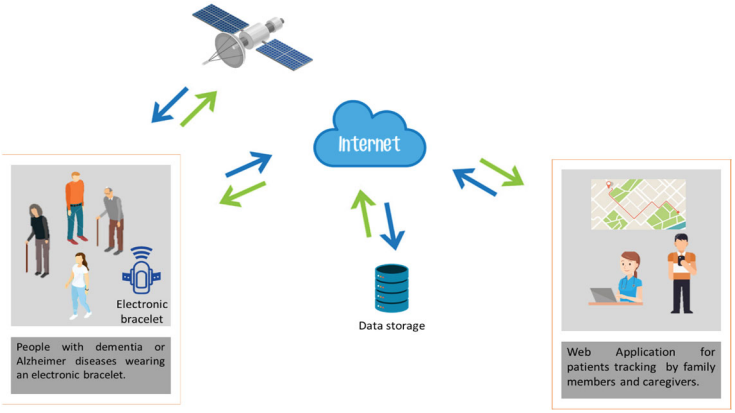

Figure 4. The solution architecture

3. Results: Tools used for the Web application and the bracelet development

3.1 Bracelet

Within the bracelet component (Figure 5), three units are conceived:

- The GPS unit implements the required functionality for real-time monitoring.
- GSM unit handles the connectivity to the web application and the transference of information from the bracelet and to the application.
- Internal memory unit to save the static data related to the bracelet.

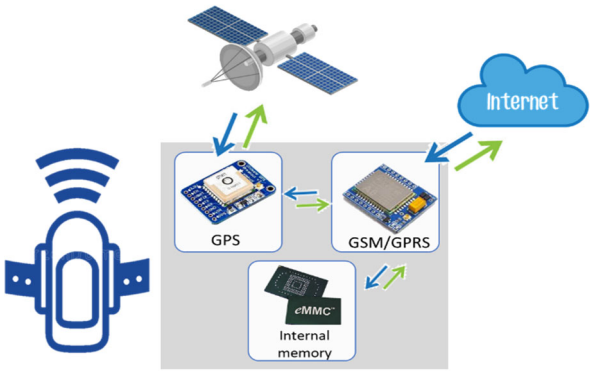

Figure 5. Bracelet units

3.2 The solution « WearYouNow»

3.2.1 Required software and web application deployment model

Models represent approximatively the target system, and they can be under different forms. During the software development evolution, it was also an evolution of software modelling approaches. Software evolution can be viewed as a process of stepwise changes in a feedback-loop to adjust to the environment. Hence, the model is representing the software assets and their relationships (Obermeyer et Emanuel, 2016). In this case the development of the web application is based on multiple software and programs (Figure 6), described as follow:

- The JavaScript programming language and Reactjs the JavaScript library are used to create the web application.
- The Flask is a lightweight Web Server Gateway Interface and a web application framework in Python, is used to quickly and easily develop the web application.
- The Marshmallow is an ORM/ODM/framework-agnostic library for converting complex datatypes, such as objects, to and from native Python datatypes.
- The SQLAlchemy is the Python SQL toolkit and Object Relational Mapper is used to gives us the full power and flexibility of SQL.
- The NGINX is a web server and reverse-proxy
- The Gunicorn "Green Unicorn" is a Python Web Server Gateway Interface (WSGI), an HTTP server which interface between the web application and NGNIX
-

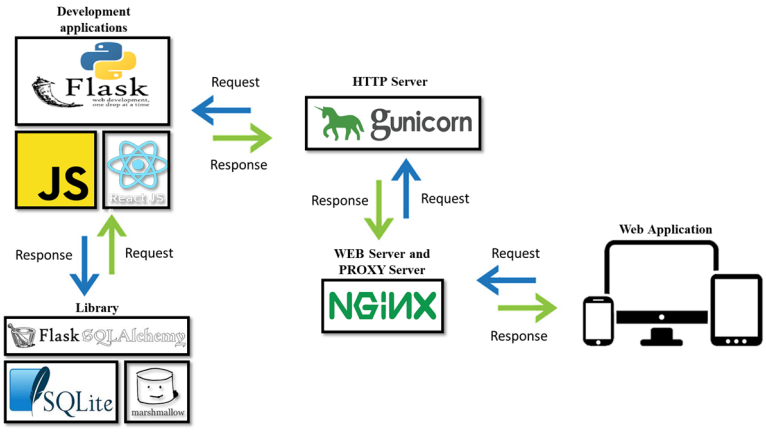

Figure 6. Web application deployment model

4. Discussion and conclusion

As we mentioned above AD is a complex progressive brain degenerative causing cognitive and functional decline. So, the big challenge for scientists is to find a cure to recover the cognitive ability of Alzheimer's patient. Unfortunately, till now there is no medical solution for this illness, but because of the current technological and software advances, we can reduce the bad effect of AD. In fact, the existing technological solutions have the ultimate goal to make the patients more independent, so they can handle autonomously their daily activities.

The integrated solution that we propose has many features once implanted correctly, it will make it a prominent solution comparing to the already existing solutions in the market. By using geolocating technics, we propose to establish a distant monitoring of the Alzheimer's patient, more explicitly the patient will wear a bracelet which has a GPS module and a permanent internet connection, so the web application already developed can monitor continuously the real time position of the patient. This web application has a confidential access by the caregivers and the responsible family members of the patient.

Based on the need analysis that we have done, we have taken into consideration all necessary features that this solution must have, in order to work properly, for instance the long battery autonomy, the GPS position accuracy, internet coverage, water resistance, shock resistance, etc. But for us, the most ambitious goal, is to integrate a machine learning module, that can process a data collected from a several patients wearing the bracelets. This data is related to the patient health like his body temperature, blood pressure, heartbeat and the walking distance, and also this data contain the environmental conditions like the exterior temperature, the humidity, the noise, etc. Hence, the study of this data might guide us to understand more the eventual factors that affect positively or negatively the health situation of the Alzheimer's patients.

In this paper, we presented the outline of our solution especially, the choice of the bracelet and watches devices and the global features compared with anther solutions. We identified the methodology and methods. After a conceptual model has been presented. We finally identified the architecture of an integrated solution for tracking patients with Alzheimer's disease and discussed the study's contributions.

In the future, we intend to integrate a machine learning module, that can process data collected from patients wearing our bracelets. This module will recommend environmental conditions like the exterior temperature, the humidity, the noise, etc.

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Biography

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