UNIVERSITY OF SALERNO

DEPARTMENT OF COMPUTER SCIENCE

Master Thesis of Computer Science in Internet of Things

Save time to save lives:

Improving UX and UI on ambulance emergency system

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Acknowledgment

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A Raffaele pilastro portante della mia esistenza, consigli preziosi nei quali rintanarsi e farne tesoro, non sarei la persona che sono oggi senza aver avuto la fortuna di conoscerti.

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Abstract

This thesis discusses the optimization of user experience (UX) and user interface (UI) design for a smart ambulance system, which uses advanced technologies to enhance emergency medical services. The study aims to improve the usability, efficiency, and effectiveness of the system by addressing issues related to UX and UI design. The paper reviews relevant literature on UX and UI design principles as well as smart healthcare systems on board and identifies specific challenges related to designing for emergency medical services. The paper proposes a set of design guidelines based on these principles, and these guidelines are evaluated through user testing with emergency medical services providers. The results of the user testing indicate that the proposed design guidelines are effective in improving the usability, efficiency, and effectiveness of the system. The study concludes that UX and UI design can play a critical role in the success of a smart ambulance system, and that careful attention to these design principles can lead to better outcomes for the patient and reduced healthcare costs and response time.

Keywords: User experience, user interface, smart ambulance.

Table of Contents

Acronyms

AI	Artificial Intelligence.
ECG	Electrocardiogram.
EMS	Emergency medical service.
EMSIS	Emergency medical services information system.
GPS	Global positioning system.
GUI	Graphical User Interface.
HCI	Human Computer Interaction.
IDE	Integrated development environment.
IoT	Internet of Things.
LiFi	Light Fidelity.

RFID	Radio Frequency Identification.
UI	User interface.
UX	User experience.

1 Introduction

1.1 Current state of EMS

Emergency medical service (EMS) play a critical role in providing immediate care to patients in need. However, the delivery of prompt and efficient care by ambulance systems can be challenging due to several factors.

One significant challenge faced by EMS is the increasing demand for their services. With the aging population, the prevalence of chronic diseases, and the rise in emergencies caused by accidents or natural disasters, the demand for EMS continues to grow. This demand puts a strain on EMS resources, making it difficult for them to respond quickly to all calls.

Another challenge is the shortage of trained and qualified EMS personnel (Figure 1.1). EMS workers require specialized training to provide life-saving care to patients in emergency situations. However, there is a shortage of qualified EMS personnel, making it difficult for ambulance services to recruit and retain skilled workers.

Figure 1.1: EMS personnel of Red Cross

Additionally, there is a lack of standardized protocols and guidelines for EMS care. Different regions may have different protocols and guidelines for responding to emergencies, which can lead to confusion and inconsistencies in care delivery. This can also cause delays in response times and impact the quality of care provided.

1.2 Smart Ambulance System

A smart ambulance system (Figure 1.2) is an innovative approach to emergency medical services that aims to improve the efficiency and quality of patient care. It is a comprehensive system that integrates advanced communication technologies, medical equipment, and data analytics tools to provide timely and effective emergency medical services.

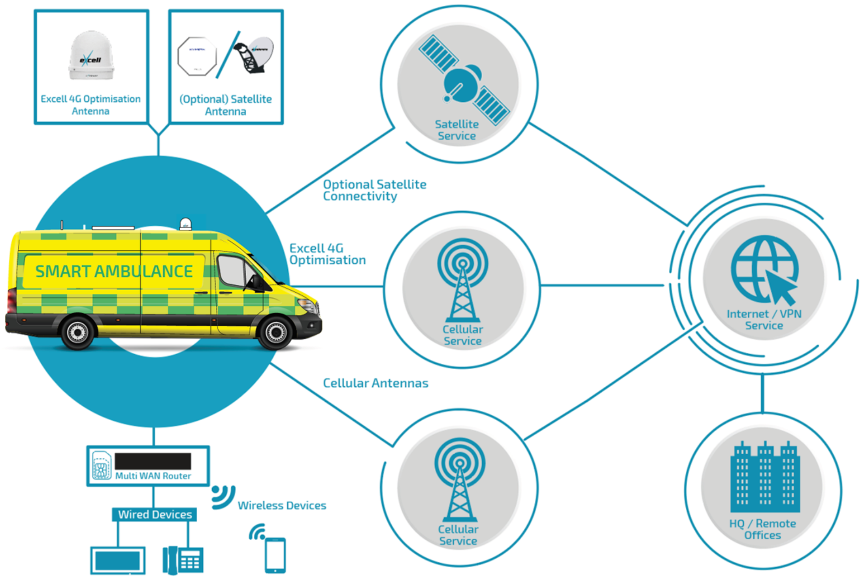

Figure 1.2: Smart Ambulance System

The key components of a smart ambulance system include:

Advanced Communication Technologies: A smart ambulance system uses state-of-the-art communication technologies to ensure seamless communication between the ambulance crew and the hospital staff. This includes real-time video conferencing, high-speed internet connectivity, and advanced GPS tracking systems.

Medical Equipment: A smart ambulance system is equipped with advanced medical equipment that allows the ambulance crew to provide life-saving interventions and treatments. This includes defibrillators, ventilators, ECG machines, and other medical devices that are necessary for emergency medical care.

Data Analytics Tools: A smart ambulance system uses data analytics tools to monitor and analyze patient data in real-time. This allows the ambulance crew to make informed decisions and provide targeted treatments based on the patient's condition. Data analytics tools also enable hospitals to track ambulance performance and optimize their emergency medical services.

Automated Dispatch System: A smart ambulance system uses an automated dispatch system to ensure that the ambulance crew reaches the patient's location in the shortest possible time. This system is designed to optimize routing and dispatch based on real-time traffic data and other factors such as the severity of the patient's condition.

Electronic Medical Records: A smart ambulance system uses electronic medical records to maintain a comprehensive record of the patient's medical history and treatment. This enables hospitals to provide better follow-up care and ensure continuity of care.

Overall, a smart ambulance system is designed to provide timely and effective emergency medical services using advanced communication technologies, medical equipment, and data analytics tools. By leveraging the latest technological advances, EMS providers can provide better care to patients in need, ultimately saving lives and improving quality of life for all.

1.3 The important role UX and UI in emergency systems

The User experience (UX) and User interface (UI) are crucial elements in designing smart ambulance systems. In emergency situations, every second counts, and the usability and efficiency of the system can have a significant impact on patient outcomes. Here are some of the ways in which UX and UI play an important role in smart ambulance systems:

Quick access to information: The UI design should allow for quick and easy access to essential information, such as patient data, medical history, and emergency protocols. This information should be organized in a way that is easy to understand and navigate, even in high-stress situations.

Clear and concise communication: The UX design should enable clear and concise communication between ambulance staff, hospital staff, and emergency responders. This can include features such as in-app messaging and audio/visual alerts that provide real-time updates and feedback.

Intuitive navigation: The UI design should be intuitive, making it easy for ambulance staff to access the features they need quickly. The system should also be customizable, allowing ambulance staff to personalize their workflows and access the features they use most frequently.

Mobile compatibility: The UX and UI should be designed to work seamlessly on a range of mobile devices, including smartphones and tablets. This can enable ambulance staff to access information and communicate with hospital staff even while on the move.

Accessibility: The UX and UI should be accessible to users with disabilities, including those with visual or hearing impairments. This can include features such as text-to-speech and high-contrast modes.

UX and UI play a critical role in smart ambulance systems by ensuring quick access to information, clear communication, intuitive navigation, mobile compatibility, and accessibility. By designing a user-centered system, ambulance staff can provide faster and more effective care to patients in emergency situations. A user-centered design approach can help in identifying the specific needs of ambulance personnel, dispatchers, and patients, and create intuitive and easy-to-use interfaces. The UX and UI design should consider the context in which ambulance services are delivered, including high-stress situations, limited resources, and diverse user groups. Designers should focus on simplifying the workflow, reducing cognitive load, and providing clear and concise information to facilitate quick decision-making. A well-designed UX and UI can also reduce errors and improve efficiency, leading to better patient outcomes. Therefore, investing in improving UX and UI on ambulance emergency systems is not only important for the well-being of patients but also for the success of emergency services as a whole.

1.4 Smart ambulance systems in the world

Smart ambulance systems have emerged as a promising solution to improve emergency medical services by utilizing technology to enhance communication, data exchange, and medical response. Here are some case studies of successful implementations of smart ambulance systems in different parts of the world and their impact on emergency medical services:

United Kingdom - GoodSAM (Figure 1.3): GoodSAM is a UK-based smart ambulance system that uses a smartphone app to alert nearby first-aid trained volunteers and emergency services in case of cardiac arrest or other medical emergencies. The system was first launched in 2014 and has since been adopted by several ambulance services across the UK. According to a study published in the Journal of Medical Internet Research, GoodSAM has significantly reduced the response times for cardiac arrests, resulting in higher survival rates and better outcomes for patients.

Figure 1.3: GoodSAM System

United States - Priority Ambulance (Figure 1.4): Priority Ambulance, a private ambulance service provider based in the US, implemented a smart ambulance system in 2018 to improve the quality of care and communication between ambulance crews and hospitals. The system includes a tablet-based software that allows paramedics to share real-time patient information with hospital staff and receive medical guidance from specialists. According to a case study by the National Institute of Standards and Technology, the system has helped reduce the time it takes to transfer patients from ambulances to hospital care, resulting in faster treatment and better outcomes.

Figure 1.4: Priority Ambulance's Tablet

South Korea - Emergency medical services information system (EMSIS) (Figure 1.5): EMSIS is a smart ambulance system developed by the Korean Ministry of Health and Welfare to improve the coordination and response time of emergency medical services. The system includes a centralized database that collects real-time data from ambulances, hospitals, and emergency call centers to facilitate information sharing and decision-making. According to a study published in the Journal of Medical Systems, the implementation of EMSIS has significantly reduced the response time for emergency calls, resulting in improved patient outcomes and reduced healthcare costs.

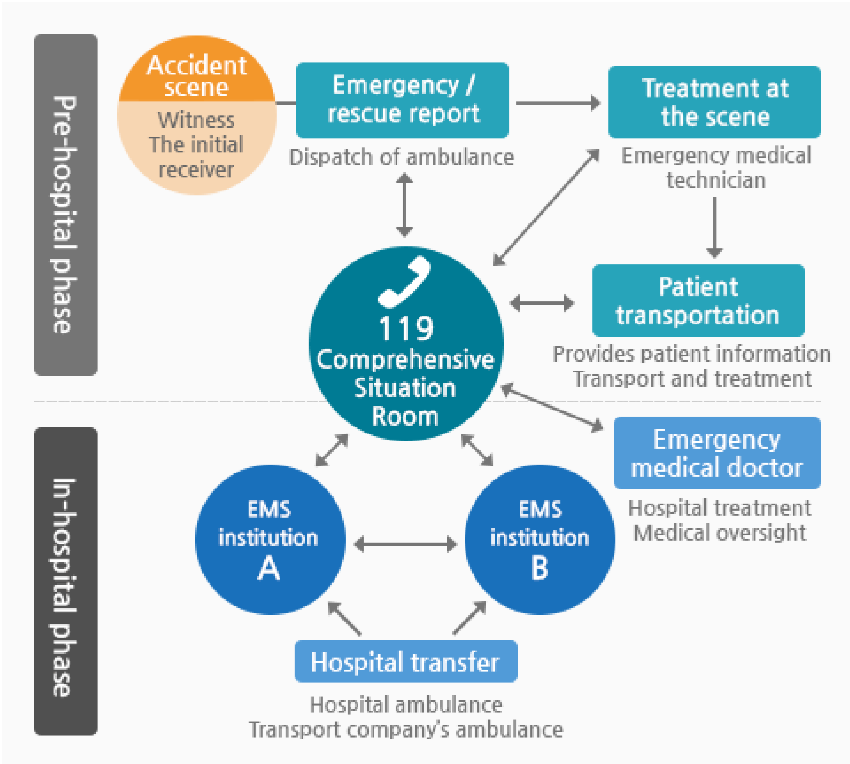

Figure 1.5: EMSIS operational phases

India - Dial 108 (Figure 1.6): Dial 108 is a smart ambulance system implemented by several state governments in India to provide quick and efficient emergency medical services to rural and remote areas. The system includes a toll-free number that people can call to request emergency medical assistance, and a fleet of ambulances equipped with GPS tracking and medical equipment. According to a report by the World Health Organization, the implementation of Dial 108 has significantly improved the accessibility and quality of emergency medical services in India, resulting in reduced morbidity and mortality rates.

Figure 1.6: Dial 108 Ambulance

These case studies demonstrate that the implementation of smart ambulance systems integrating adequate UX and UI has resulted in better patient outcomes, reduced healthcare costs, and improved access to emergency medical services.

2 State of the art

The purpose of this section is to present the most recent principles of the smart ambulance vehicles. Furthermore, it will address the incorporation of their technologies to reach out their critical goals. Smart ambulances play a significantly important role in modern healthcare systems. These vehicles are equipped with advanced technology and medical equipment that can help save lives in emergency situations.

2.1 Automatic Ambulance System using IOT

The paper [1] proposes a system that leverages Internet of Things (IoT) technology to improve the response time of ambulances by automating the dispatch process. The authors describe the current scenario of emergency response systems in India, where delays in ambulance dispatching can result in loss of life. The paper presents an intelligent ambulance dispatch system that uses real-time data from sensors and GPS to automatically identify the nearest available ambulance and dispatch it to the emergency site. The system is designed to work in three phases: detection, communication, and dispatch. In the detection phase, the system uses various sensors to detect an emergency situation, such as a heart attack or an accident. The sensors include an accelerometer, a heartbeat sensor, and a temperature sensor. These sensors continuously monitor the patient's vital signs and send data to the cloud server. In the communication phase, the data from the sensors is analyzed, and if an emergency is detected, the system sends an alert to the nearest ambulance station. The alert includes information about the patient's location and the nature of the emergency. The ambulance station can then dispatch the nearest available ambulance to the location. In the dispatch phase, the system provides real-time updates to the ambulance driver about the patient's condition and the quickest route to the location. The system also sends updates to the hospital, informing them about the patient's condition and estimated time of arrival. The authors claim that this system can significantly reduce the response time of ambulances, which can be critical in emergency situations. The system can also help in optimizing the ambulance dispatch process, reducing the workload of the dispatchers, and improving the overall efficiency of the emergency response system. This paper presents an innovative approach to using IoT technology in emergency response systems. While there have been several studies on ambulance dispatch optimization, most of them rely on traditional methods such as static allocation of ambulances based on geographical areas or a fixed number of ambulances allocated to each area. The proposed system, on the other hand, leverages real-time data and advanced algorithms to dispatch ambulances automatically, which can significantly improve the efficiency of the emergency response system. Overall, the paper presents a promising solution to the challenges of ambulance dispatch optimization, and it can be a valuable contribution to the field of emergency response systems. However, the authors did not provide any empirical evidence of the system's effectiveness, and more research is needed to evaluate its performance in real-world scenarios.

2.2 5G-Network-Enabled Smart Ambulance

An other interesting study conducted by Yunkai Zhai et al. [2] presents an innovative approach for improving emergency medical services using 5G network-enabled smart ambulance technology. The authors propose an architecture that integrates various components, such as smart sensors, wearable devices, video cameras, and a communication system, to provide real-time patient monitoring, diagnosis, and treatment during transportation to the hospital. The paper presents a detailed description of the proposed architecture, which is composed of four main components: the vehicle component, the sensor component, the communication component, and the healthcare provider component. The vehicle component comprises the ambulance and its equipment, while the sensor component includes various sensors, such as Electrocardiogram (ECG), blood pressure, and temperature sensors. The communication component consists of a 5G network, which enables high-speed data transmission and low-latency communication between the ambulance and the hospital. Finally, the healthcare provider component comprises the hospital staff who receive and analyze the patient data transmitted by the ambulance. The paper also discusses the application of the proposed system, highlighting how it can improve ambulance services by enabling real-time monitoring and diagnosis of patients, remote consultation with medical professionals, and faster transportation to hospitals. Finally, the paper evaluates the proposed system's performance using various metrics such as data transfer rate, latency, and energy consumption. The results show that the system can achieve high data transfer rates, low latency, and energy-efficient operation, making it a viable solution for improving ambulance services. Overall, the paper provides an insightful perspective on how 5G network technology can be leveraged to improve emergency medical services. The proposed architecture has the potential to revolutionize the way emergency medical services are provided by enabling real-time monitoring and diagnosis of patients during transportation to the hospital.

2.3 Improving the performance of Ambulance Emergency Service

Mohammad Abdeen et al. study [3] proposes a smart health system that aims to enhance the performance of ambulance emergency services. The authors suggest using smart technologies, such as Internet of Things (IoT) sensors, cloud computing, and data analytics, to improve the overall ambulance emergency service performance. The authors begin by discussing the current challenges faced by ambulance emergency services, such as the difficulty in locating patients in emergency situations, long response times, and inadequate medical equipment. They then propose a solution that utilizes smart health systems to address these challenges. The proposed system consists of four main components: an IoT-based patient tracking system, a cloud-based data management system, a real-time communication system, and a data analytics module. The IoT-based patient tracking system is designed to locate and track patients using sensors and GPS technology. The cloud-based data management system stores patient data and can be accessed in real-time by medical personnel. The real-time communication system enables efficient communication between medical personnel and the ambulance control center. Finally, the data analytics module is used to analyze the data collected by the system, identify patterns, and provide insights to improve the overall performance of the ambulance emergency service. The authors claim that their proposed system has several advantages over traditional ambulance emergency services. These include faster response times, better patient tracking, improved communication, and more efficient use of medical resources. The authors also provide a case study to demonstrate the effectiveness of the proposed system. Overall, the paper provides a comprehensive overview of the challenges faced by ambulance emergency services and proposes a smart health system that utilizes IoT, cloud computing, and data analytics to improve their performance. While the proposed system is promising, further research is needed to address any potential issues or limitations.

2.4 Ambulance vehicle routing in Smart Cities

Finally, an other useful study [4] proposes a method to optimize ambulance routing using neural networks in smart cities. The method selects eight features, such as time, location, type of accident, and number of injured people, to decide the shortest route for the ambulance from the health center to the accident site. The paper evaluates the performance of the ambulance management system by considering two criteria, the effectiveness of the system's response and the service level. The authors also conduct simulation experiments on a dataset based on a GPS road map. The paper provides a comprehensive review of ambulance routing methods used in the past few decades. Previous studies have used algorithms such as Dijkstra's algorithm and the star algorithm to determine the shortest path. The paper also highlights the use of communication technology, video image processing, RFID-based traffic congestion control, miniature smart traffic light system, and LiFi model in emergency vehicle routing. The authors claim that their method can capture past accident conditions and analyze previous accident risks and road data corresponding to policies. The paper concludes by presenting the obtained outcomes from the simulation experiments and discussing future research directions. Overall, the paper presents an innovative approach to optimizing ambulance routing in smart cities. The use of neural networks and the selection of relevant features make the proposed method promising. The paper also highlights the importance of evaluating ambulance management systems to ensure effective emergency response in cities.

3 Case of study

3.1 Overview

The chapter is organized as follows:

- the description of functionalities and lacks of the system;
- representation of the quality of the system through the analysis of the response times of a specific task;
- how data was extrapolated, managed and the organization of the final results
- used technologies.

3.2 Ambulance Navigator System

During this work has been studied the navigator system on board of the Red Cross Ambulances of the Local Committee in Salerno; describing its functionalities, the operators response time for critical tasks and lastly some potential lacks of the system are being discussed.

The navigator on board an ambulance is a critical component of a smart ambulance system providing a centralized control point for monitoring and managing critical data in real-time. It provides through GPS tracking the emergency medical services EMS team with accurate information about the location of the ambulance, the quickest route to the emergency site, the status of traffic and weather conditions; communicate with the health operations centre at the hospital through satellite communication; enables critical functions such as emergency lights and sirens through the Graphical User Interface (GUI) on board of the ambulance.

3.2.1 Gps Navigation

Figure 3.1: System's Navigation GPS

The GPS navigation function on board of the ambulance is a feature that uses satellite signals to provide the ambulance with real-time location information about the location of the vehicle and the surrounding traffic conditions. This feature utilizes Global positioning system (GPS) technology to determine the precise location of the ambulance to calculate the fastest and safest route to the destination, this allows the ambulance crew to quickly and accurately navigate to the location of the patient, as well as the hospital or medical facility where the patient needs to be transported. The GPS navigation system is integrated with a computer or tablet device on board, which displays the route and provides turn-by-turn directions to the driver. The navigator can automatically reroute the ambulance if the crew deviates from the planned route or encounters unexpected road closures or traffic. The system include a voice prompt feature that provides audible instructions to the driver, so that they can keep their eyes on the road. In addition to providing directions, the GPS navigation system in the ambulance also offer other features such as real-time traffic updates, accident alerts, and alternative route suggestions in the event of road closures or other obstructions. This information is critical for ambulance drivers who need to reach their destination quickly and safely, as it allows them to avoid traffic congestion and other potential delays. The GPS navigation function on board is an essential tool that helps emergency responders reach their destination efficiently and effectively, enabling them to provide the best possible care to patients in need.

3.2.2 Radio Communication

Figure 3.2: Radio Communication System

Radio communication is a method of sending and receiving information using radio waves. In the context it connects the ambulance with a health operations center, so radio communication is a crucial technology that enables the ambulance team to communicate with the center in real-time. The ambulances are equipped with a radio transmitter that broadcasts information such as the ambulance's location, first evaluation code of the patient, and other relevant data. This information is transmitted in the form of radio waves that travel through the air and can be picked up by radio receivers. The health operations center has a radio receiver that is tuned to the same frequency as the smart ambulance's radio transmitter. When the radio waves carrying the information from the smart ambulance reach the receiver, the information is decoded and displayed on a screen or other device. The health operations center can then communicate with the ambulance team by sending a signal back through the radio system, this signal is transmitted as radio waves and picked up by the radio receiver in the ambulance; the ambulance team can then receive and respond to the message, completing the communication loop. This communication allows the ambulance team and the health operations center to exchange important information about the patient's condition, the ambulance's location, and any necessary medical treatments. It also allow the ambulance crew to communicate with the health operations center if they need assistance or have questions about patient care. The use of radio communication in this context is critical for enabling a fast and efficient response to emergencies and can ultimately help save lives.

3.2.3 GUI on board

A Graphical User Interface (GUI) is a type of interface that allows users to interact with a computer or other electronic device through graphical elements such as icons, buttons, and windows (Figure 3.4). A GUI makes it easier for users to interact with complex software applications by providing a visual representation of the software's features and functions. The strengths of a GUI include:

- User-friendly: GUIs are designed to be intuitive and user-friendly, making it easy for users to navigate through software applications without requiring specialized technical knowledge.
- Visual representation: GUIs provide a visual representation of data and processes, making it easier for users to understand and interact with complex information.
- Accessibility: GUIs can be designed to be accessible to users with different abilities and disabilities, making software applications more inclusive.
- Interactivity: GUIs allow users to interact with software applications in real-time, providing immediate feedback and allowing users to make changes or adjustments on the fly.
- Customization: GUIs can be customized to suit the needs and preferences of individual users, allowing them to personalize their software experience.

Figure 3.3: Ambulance front compartment

Having an easily understandable Graphical User Interface (GUI) on the ambulance's navigator leads to have several essential utilities, on top must be easy to use. During an emergency situation, time is of the essence so an easily understandable GUI helps the ambulance driver navigate through traffic and find the quickest route to the destination, thereby reducing response times and saving lives.

3.3 Analysis of the current system

Following the analysis of the fundamental principles of Human Computer Interaction (HCI) of the system (Figure 3.4), closely related to the user experience and user interface of the latter.

Figure 3.4: Home Navigator

3.3.1 Learnability

Learnability refers to the ease with which users can learn how to use a new software or system. It is a key factor in determining the usability of a product, and it is important because users are more likely to adopt and continue using a product that they can learn quickly and easily. There are mainly five principles of learnability: predictability, synthesizability, familiarity, generalizability, consistency.

- Predictability refers to the ability of users to anticipate the outcome of their actions in a given system. From the tests done by the users on the current system it was found that the degree of predictability was quite high. For example, when the users clicked on the “Go to...” (button “Vai a...” in

Figure 3.4) button they expected to insert the address into the system on the successive screen.

- Synthesizability refers to the ease with which users can understand and interpret the information presented in a system. The system was found to have low synthesizability since the interface is the same for all the functions but the buttons are clearly labeled with simple words, as well as visual symbols. For example the button “Go to..” (button “Vai a...” in Figure 3.4) has the symbol of an arrow and is labelled with a text.
- Familiarity refers to the extent to which users are familiar with the design and functionality of a system. Users found themselves quite familiar with the system. For example, the use of a grid of icons on the home screen (Figure 3.4) is a familiar convention that is present on the current system.
- Generalizability refers to the support for the user to extend knowledge of specific interaction within and across applications to other similar situations. Users easily found the settings of the system since it has the symbol of a wheel (button “Impostazioni” in Figure 3.4), which is often used also in other systems to label the “settings” button.
- Consistency refers to the degree to which different elements of a user interface behave in the same way across different contexts and situations. In the case of the current system, the buttons of the home screen are always placed in the same order.

3.3.2 Flexibility

Flexibility refers to the ability of an interface to adapt to the needs and preferences of individual users. A flexible interface can accommodate a wide range of user goals, tasks, and preferences, allowing users to customize the interface to fit their needs. There are five principles that contribute the flexibility: dialog initiative, multi-threading, task migratability, substitutivity, customizability.

- Dialog initiative refers to which party, the user or the system, is in control of the conversation or interaction. In the current system users are in control, for the most part, of the dialog initiative, for example when they have to insert the address into the text box.

- Multi-threading refers to the ability of an interface to support multiple concurrent activities or tasks. Users were able to start the GPS navigator and turn the sirens on while the navigator was executing in the background of the system.

- Task migratability refers to the ability of users to move tasks or activities between different devices or platforms seamlessly. This principle was not found in the current system. A possible solution could be the use of the system on multiple devices, for example on smartphone and tablets, in order to execute different tasks on the go, for example turning the lights on in the rear compartment while approaching the vehicle rather than reach first the ambulance and turns the lights on, so as to reduce the execution time and reach the necessary devices sooner.

- Substitutivity refers to the ability of users to switch between different input modalities or devices seamlessly. It was found that there was only one type of input: the touchscreen. There was no voice assistant to insert the commands into the system without using the touchscreen. Time consumed typing the commands is much more than time used with voice assistant. The wasted time could be very precious in case of an emergency.

- Customizability refers to the ability of users to personalize or modify the interface or functionality of a system or application to better suit their needs or preferences. Users were able to modify the order of the icons on the home menu and also to change the color of the map in the settings (Figure 3.5).

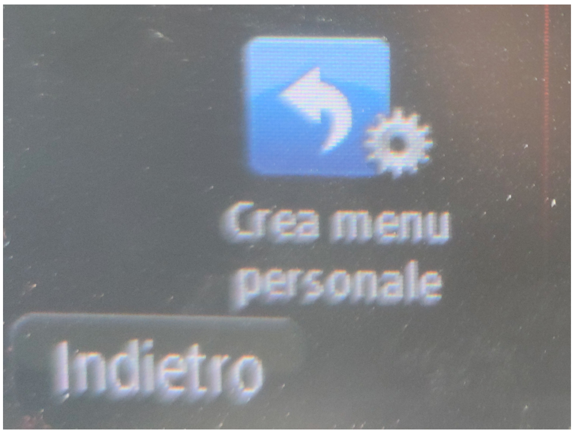

Figure 3.5: Menu customization settings

3.3.3 Robustness

Robustness refers to the ability of a system or application to continue functioning properly even in the face of unexpected or erroneous inputs or actions from the user. There are mainly four principles that affect the robustness: observability, recoverability, responsiveness, task conformance.

- Observability refers to the ability of users to understand the current state or status of a system or application, including its internal processes and operations. This principle was found in the "Help" section of the system (Figure 3.6). In fact, when a user presses a button, it lights up.

- Recoverability refers to the ability of a system or application to recover from errors or failures and return to a usable state. Users who made errors when interacting with the system were given the option to cancel the action they had done.
- Responsiveness refers to the ability of a system or application to quickly and efficiently respond to user input. Responsive times were quite immediate during the tests.
- Task conformance refers to the degree to which a system or application enables users to complete their tasks effectively and efficiently. Task conformance was found to be quite low in the current system due to the outdated software.

3.3.4 Lacks

The current system as previously analyzed encounters some shortcomings on the Graphical User Interface starting from the essential function of "Help" section (Figure 3.6) that are all represented with the same size and the same colors, decreasing its usability and, in case of emergency, the visual impact of the critical and essential functions (such as turning on or off emergency lights and sirens).

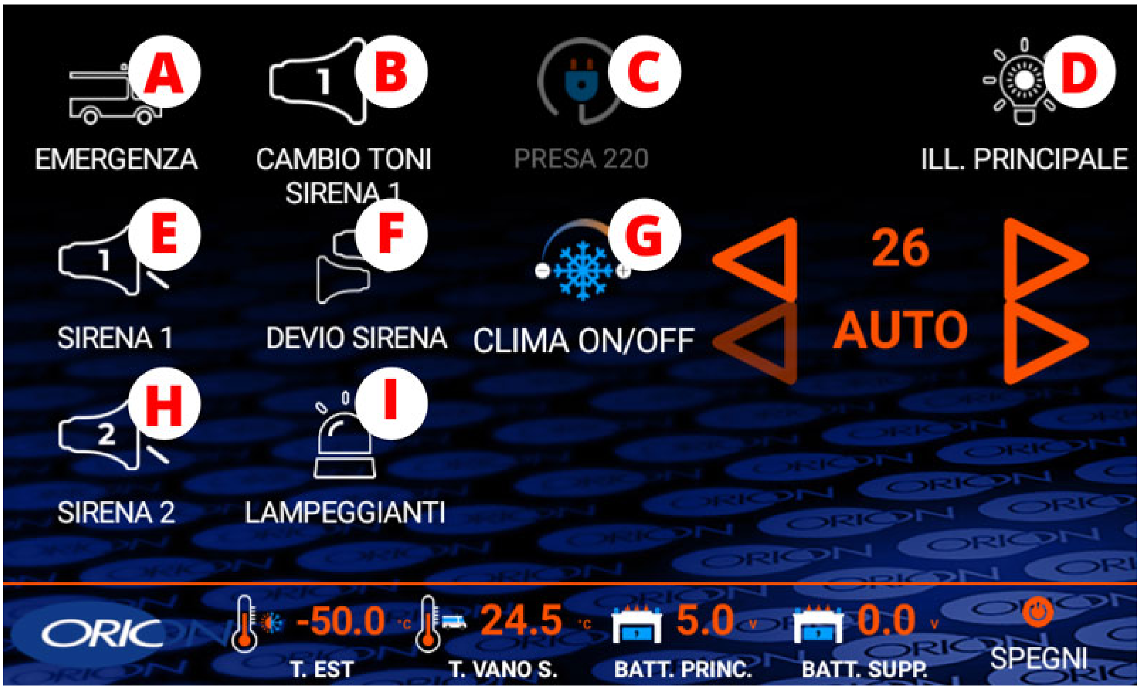

Figure 3.6: “Help” Section Dashboard

A further weak point of the on-board system is the inevitable use of different ambulances that have completely independent and different systems, thus reducing the “learnability” 3.3.1 and increasing the gap between the regular users of the system compared to those who use it sporadically and maybe they inevitably change the ambulance (and therefore the system) (Figure 3.7).

(a) New Ambulance System (b) Old Ambulance System

Figure 3.7: Different Emergency Systems

3.4 Quality of the service

The proposed system is functional but not easy for all the volunteers that uses it since the medical interface (Figure 3.6) is the same for all the functions and not even for the emergency one there is a visual impact for the user and this affects the synthesizability 3.3.1. During this study has been considered so the response time of individuals using the system, dividing them into three categories having so an objective point of view to analyze the system and its efficiency.

During this study, 41 people belonging to the Italian Red Cross volunteered to test the current system and develop an objective report on the quality of the current emergency service, most of whom are volunteers and only a small part of the "ambulance drivers" category carries out the activity as employees. Volunteers and non-volunteers were divided as follows:

- N. 9 - "Ambulance Drivers" between three of whom offer medical service as employees, the remaining six are volunteer rescuers; this category has been labeled as "employees" since they considered themselves experienced users of the system and they use it everyday.
- N. 20 - "Expert Rescuers" between six of whom are drivers too but they considered themselves rescuers since they play more often this role rather than drivers one. This category has been labeled as "experts" since they have more than 1 year of experience on ambulances and used at least 2 different systems (every ambulance has its own independent system).
- N. 12 - "Inexpert Rescuers" this category has been labeled as "inexperts" since they have less than 1 year of experience.

Each of the participants was asked to perform a specific and randomly generated task among 5 essential actions such as:

- "Emergenza" that allows to turn on the emergency lights and sirens at the same time
- "Sirena1" that allows to turn on the principle sirens connected to the loudspeakers
- "Sirena2" that allows to turn on the secondary sirens that blare at the rear of the ambulance
- "Lampeggianti" that allows to turn on the emergency lights
- "DevioSirena" that allows to change the selected type of siren between the principle and the secondary

The response times inherent to the single task and single user have been transcribed in an .xls file and then converted into a .csv file so that they can be managed using Jupyter 3.5.1 for data analysis.

In [15]:
```
import pandas as pd
```

In [16]:
```
data_original = pd.read_csv('C:/Users/Antonio/Desktop/Response_time1.csv')
```

In [17]:
```
data_original
```

Out[17]:

	Ruolo	Emergenza	Sirena1	Sirena2	Lampeggianti	DevioSirena
0	autista1	10.76	10.63	8.77	11.48	9.22
1	vol_esp1	11.55	11.87	9.34	10.74	12.16
2	vol_inesp1	10.47	12.41	12.93	17.32	13.03
3	autista2	11.34	11.87	12.18	10.64	8.94
4	vol_esp2	12.56	13.22	12.65	11.45	10.54
5	vol_inesp2	16.30	14.74	15.64	13.26	16.12
6	vol_inesp3	12.43	10.74	13.08	11.44	12.13
7	vol_esp3	9.65	11.39	12.11	9.78	10.24
8	vol_esp4	12.73	11.56	11.73	10.34	11.40
9	autista3	11.20	10.53	12.57	9.93	12.19
10	vol_inesp4	13.56	11.47	13.53	11.18	12.79
11	vol_esp5	11.22	11.72	10.40	9.63	12.54
12	vol_esp6	10.76	11.54	9.56	8.24	11.85
13	autista4	9.47	10.27	8.71	9.39	7.83
14	vol_esp7	12.30	10.84	10.90	10.32	12.70
15	vol_esp8	11.59	12.86	11.34	8.72	10.60
16	autista5	8.44	9.32	7.63	10.38	8.47
17	vol_esp9	10.27	11.61	9.53	11.79	10.12
18	vol_esp10	11.43	12.51	9.29	11.87	10.50
19	vol_inesp5	9.46	9.83	11.69	11.17	9.85
20	vol_inesp6	11.51	12.75	10.74	11.74	8.73
21	vol_inesp7	13.86	14.37	12.46	13.78	12.75
22	vol_esp11	9.78	10.43	11.60	10.39	12.72
23	vol_inesp8	11.64	12.87	9.64	10.43	11.37
24	vol_esp12	12.13	14.53	10.49	11.27	9.63
25	vol_inesp9	11.91	9.63	12.49	12.34	11.67
26	vol_esp13	11.57	10.29	12.45	9.69	10.82
27	autista6	8.93	7.88	11.37	11.16	9.62
28	autista7	9.85	10.71	10.64	8.21	8.77
29	autista8	11.07	10.46	10.56	12.31	9.66
30	vol_esp14	9.65	10.39	12.10	11.37	12.40
31	vol_esp15	11.71	8.27	9.54	9.21	11.76
32	vol_inesp10	9.56	10.34	10.56	11.94	8.77
33	vol_inesp11	13.63	12.17	13.38	12.95	11.78
34	vol_esp16	10.61	12.57	12.40	11.37	11.83
35	vol_esp17	11.92	13.56	10.29	11.61	10.54
36	autista9	9.73	8.26	10.46	7.35	8.44
37	vol_esp18	11.16	12.34	10.29	12.45	10.39
38	vol_esp19	9.61	8.67	8.08	10.83	9.16
39	vol_inesp12	12.94	13.11	10.79	12.53	11.24
40	vol_esp20	9.31	9.74	11.18	10.23	9.82

Figure 3.8: CSV dataset

Then the three categories have been divided into subgroups so as to analyze the reaction times for the single category closely related to the user experience:

```python
import csv

# Open the CSV file
with open('C:/Users/Antonio/Desktop/Response_time1.csv', mode='r') as csv_file:
    csv_reader = csv.reader(csv_file)

    print("\033[1mRuolo\t\tEmergenza\tSirena1\t\tSirena2\t\tLampeggianti\tDevioSirena\033[0m")

    # Iterate over the rows in the CSV file
    for row in csv_reader:
      if row[0].startswith('autista'):
        print(row[0],'\t',row[1],'\t\t',row[2],'\t\t',row[3],'\t\t',row[4],'\t\t',row[5])
```

Ruolo	Emergenza	Sirena1	Sirena2	Lampeggianti	DevioSirena
autista1	10.76	10.63	8.77	11.48	9.22
autista2	11.34	11.87	12.18	10.64	8.94
autista3	11.2	10.53	12.57	9.93	12.19
autista4	9.47	10.27	8.71	9.39	7.83
autista5	8.44	9.32	7.63	10.38	8.47
autista6	8.93	7.88	11.37	11.16	9.62
autista7	9.85	10.71	10.64	8.21	8.77
autista8	11.07	10.46	10.56	12.31	9.66
autista9	9.73	8.26	10.46	7.35	8.44

(a) Drivers Category

```python
import csv

# Open the CSV file
with open('C:/Users/Antonio/Desktop/Response_time1.csv', mode='r') as csv_file:
    csv_reader = csv.reader(csv_file)

    print("\033[1mRuolo\t\tEmergenza\tSirena1\t\tSirena2\t\tLampeggianti\tDevioSirena\033[0m")

    # Iterate over the rows in the CSV file
    for row in csv_reader:
      if row[0].startswith('vol_esp'):
        print(row[0],'\t',row[1],'\t\t',row[2],'\t\t',row[3],'\t\t',row[4],'\t\t',row[5])
```

Ruolo	Emergenza	Sirena1	Sirena2	Lampeggianti	DevioSirena
vol_esp1	11.55	11.87	9.34	10.74	12.16
vol_esp2	12.56	13.22	12.65	11.45	10.54
vol_esp3	9.65	11.39	12.11	9.78	10.24
vol_esp4	12.73	11.56	11.73	10.34	11.4
vol_esp5	11.22	11.72	10.4	9.63	12.54
vol_esp6	10.76	11.54	9.56	8.24	11.85
vol_esp7	12.3	10.84	10.9	10.32	12.7
vol_esp8	11.59	12.86	11.34	8.72	10.6
vol_esp9	10.27	11.61	9.53	11.79	10.12
vol_esp10	11.43	12.51	9.29	11.87	10.5
vol_esp11	9.78	10.43	11.6	10.39	12.72
vol_esp12	12.13	14.53	10.49	11.27	9.63
vol_esp13	11.57	10.29	12.45	9.69	10.82
vol_esp14	9.65	10.39	12.1	11.37	12.4
vol_esp15	11.71	8.27	9.54	9.21	11.76
vol_esp16	10.61	12.57	12.4	11.37	11.83
vol_esp17	11.92	13.56	10.29	11.61	10.54
vol_esp18	11.16	12.34	10.29	12.45	10.39
vol_esp19	9.61	8.67	8.08	10.83	9.16
vol_esp20	9.31	9.74	11.18	10.23	9.82

(b) Expert Rescuers

```python
import csv

# Open the CSV file
with open('C:/Users/Antonio/Desktop/Response_time1.csv', mode='r') as csv_file:
    csv_reader = csv.reader(csv_file)

    print("\033[1mRuolo\t\tEmergenza\tSirena1\t\tSirena2\t\tLampeggianti\tDevioSirena\033[0m")

    # Iterate over the rows in the CSV file
    for row in csv_reader:
      if row[0].startswith('vol_inesp'):
        print(row[0],'\t',row[1],'\t\t',row[2],'\t\t',row[3],'\t\t',row[4],'\t\t',row[5])
```

Ruolo	Emergenza	Sirena1	Sirena2	Lampeggianti	DevioSirena
vol_inesp1	10.47	12.41	12.93	17.32	13.03
vol_inesp2	16.3	14.74	15.64	13.26	16.12
vol_inesp3	12.43	10.74	13.08	11.44	12.13
vol_inesp4	13.56	11.47	13.53	11.18	12.79
vol_inesp5	9.46	9.83	11.69	11.17	9.85
vol_inesp6	11.51	12.75	10.74	11.74	8.73
vol_inesp7	13.86	14.37	12.46	13.78	12.75
vol_inesp8	11.64	12.87	9.64	10.43	11.37
vol_inesp9	11.91	9.63	12.49	12.34	11.67
vol_inesp10	9.56	10.34	10.56	11.94	8.77
vol_inesp11	13.63	12.17	13.38	12.95	11.78
vol_inesp12	12.94	13.11	10.79	12.53	11.24

(c) Inexpert Rescuers

Figure 3.9: Categories

Of each category has been considered the response time of the single task and has been extrapolated the average response time for the single task between all the users of the same category, to summarize, only the phases of the first category will be displayed briefly.

Similarly to drivers category has been extrapolated the average time of the single tasks for the other two categories that produced the following average time:

.

Ruolo	Emergenza
autista1	10.76
autista2	11.34
autista3	11.2
autista4	9.47
autista5	8.44
autista6	8.93
autista7	9.85
autista8	11.07
autista9	9.73

Media: 10.087777777777779

(a) "Emergenza" task and average for drivers

Ruolo	Sirena1
autista1	10.63
autista2	11.87
autista3	10.53
autista4	10.27
autista5	9.32
autista6	7.88
autista7	10.71
autista8	10.46
autista9	8.26

Media: 9.992222222222225

(b) "Sirena1" task and average for drivers

Ruolo	Sirena2
autista1	8.77
autista2	12.18
autista3	12.57
autista4	8.71
autista5	7.63
autista6	11.37
autista7	10.64
autista8	10.56
autista9	10.46

Media: 10.321111111111113

(c) "Sirena2" task and average for drivers

Ruolo	Lampeggianti
autista1	11.48
autista2	10.64
autista3	9.93
autista4	9.39
autista5	10.38
autista6	11.16
autista7	8.21
autista8	12.31
autista9	7.35

Media: 10.094444444444443

(d) "Lampeggianti" task and average for drivers

Ruolo	DevioSirena
autista1	9.22
autista2	8.94
autista3	12.19
autista4	7.83
autista5	8.47
autista6	9.62
autista7	8.77
autista8	9.66
autista9	8.44

Media: 9.237777777777776

(e) "DevioSirena" task and average for drivers

Figure 3.10: Driver's category average time

Expert Rescuers

- “Emergenza” avarage time: 11.07
- “Sirena1” avarage time: 11.49
- “Sirena2” avarage time: 11.76
- “Lampeggianti” avarage time: 10.57
- “DevioSirena” avarage time: 11.18

Inexpert Rescuers

- “Emergenza” avarage time: 12.27
- “Sirena1” avarage time: 12.78
- “Sirena2” avarage time: 13.06
- “Lampeggianti” avarage time: 13.61
- “DevioSirena” avarage time: 12.94

3.4.1 Data results

Once obtained the various average times of all three different categories has been plotted a graph, as final result, that highlight the gap in terms of response time between the experienced users and novice ones:

```
import numpy as np
from matplotlib import pyplot as plt
plt.style.use("ggplot")
indexs = np.arange(5)
width = 0.3
x = ["Emergenza","Sirena1","Sirena2","Lampeggianti","DevioSirena"]
y1 = [10.08, 9.99, 10.32, 10.09, 9.24]
y2 = [11.07,11.49,11.76,10.57,11.18]
y3 = [12.27,12.78,13.06,13.61,12.94]
plt.bar(indexs,y1, label="Drivers", width=width, color="white")
plt.bar(indexs+width,y2, label="Expert Rescuers", width=width, color="#212121")
plt.bar(indexs+width+width,y3, label="Inexpert Rescuers", width=width, color="red")
plt.title("Categories")
plt.xlabel("Tasks")
plt.ylabel("Response time (sec)")
plt.legend()
plt.xticks(indexs+width/3, x)
plt.show()
```

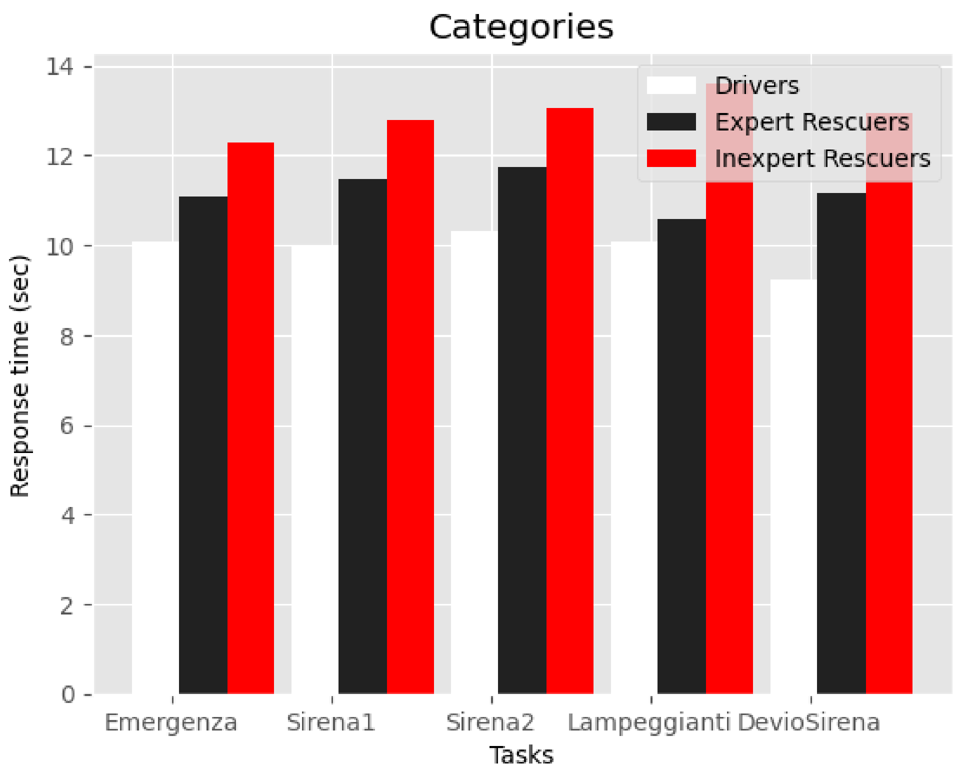

Figure 3.11: Final Graph

3.5 Used technologies

3.5.1 Jupyter Notebook

Jupyter Notebook [5] is a web-based Integrated development environment (IDE) used for data analysis, scientific computing, and machine learning. It was originally developed as the IPython Notebook by Fernando Perez in 2011 and has since become a popular tool among data scientists and researchers worldwide. In this essay, we will discuss the key features of Jupyter Notebook, its benefits, and how it has transformed data analysis and scientific computing.

Jupyter Notebook has several features that make it an attractive option for data scientists and researchers. Firstly, it provides an interactive computing environment that allows users to create and share documents that contain live code, equations, visualizations, and narrative text. This makes it easy for users to explore data, experiment with algorithms, and communicate their findings with others. Users can run code cells individually, which enables them to test and debug their code quickly.

Secondly, Jupyter Notebook provides a wide range of tools and libraries that facilitate data analysis and scientific computing. This includes popular libraries such as NumPy, Pandas, Matplotlib, and TensorFlow, which are essential for data manipulation, analysis, and visualization. Jupyter Notebook also has built-in support for various programming languages, including Python, R, and Julia, which enables users to choose the language that best suits their needs.

Another essential feature of Jupyter Notebook is its ability to create reproducible research. This means that users can share their code and data with others, and others can reproduce their results using the same code and data. This is particularly important in scientific research, where reproducibility is essential for verifying results and ensuring that they are accurate and reliable.

Jupyter Notebook offers several benefits to users, including increased productivity and efficiency. Its interactive computing environment enables users to work more efficiently by automating several tasks that would otherwise be time-consuming. For instance, users can quickly visualize data using Matplotlib or explore data using Pandas, without having to write additional code. Additionally, Jupyter Notebook's ability to create reproducible research reduces the time required to share and reproduce research results, thus increasing productivity.

Another significant benefit of Jupyter Notebook is the vast community of users and resources available. The Jupyter community is active and supportive, with several resources available online, such as forums, blogs, and tutorials. This makes it easy for users to find solutions to problems and to learn new skills. Furthermore, Jupyter Notebook's website provides several resources, including documentation, videos, and sample code, to help users get started with the IDE.

Used Libraries

Pandas Pandas is a Python library that provides an extensive set of functions and data structures for working with structured data. Pandas is an open-source library for data manipulation and analysis that was developed by Wes McKinney in 2008. It is built on top of the NumPy library and provides a high-level interface for working with structured data. The library is designed to handle data in tabular form, such as CSV or Excel files, and provides functionality for cleaning, merging, and reshaping data. The two primary data structures provided by Pandas are the Series and DataFrame. A Series is a one-dimensional array-like object that can hold any data type, while a DataFrame is a two-dimensional table-like structure that consists of rows and columns. The columns in a DataFrame can be of different data types, such as strings, integers, or floating-point numbers.

NumPy NumPy is a powerful Python library that is widely used for scientific computing and data analysis. NumPy stands for Numerical Python. It provides a powerful set of tools for working with large, multi-dimensional arrays and matrices, as well as a large collection of high-level mathematical functions to operate on these arrays. NumPy is an essential library for data scientists, statisticians, engineers, and researchers.

Matplotlib Matplotlib is a powerful Python library that is widely used for data visualization. It provides a wide range of options for creating high-quality visualizations of data. The library was first released in 2003 by John D. Hunter and has since become one of the most popular data visualization libraries in the Python ecosystem. In this essay, we will explore the key features of Matplotlib and how it can be used to create various types of plots.

4 Conclusions

After conducting an extensive study, it has been proven that users with more experience (3.10) of the system have a significantly higher response time compared to users who are less experienced (3.4). This study was conducted by observing and measuring the response time of different users when interacting with the system. The study was conducted using a medium sample size, and the results were statistically significant, suggesting that the findings are reliable and valid. The results showed that users who had more experience with the system had a higher response time, indicating that familiarity with the system did not necessarily lead to quicker responses. This could be due to a number of factors, such as the user becoming complacent with the system, or relying too heavily on their prior knowledge rather than relying on the information provided by the interface. These findings have significant implications for the design and development of systems and applications. It suggests that developers should not assume that familiarity with a system will necessarily lead to better performance. Instead, they should focus on creating user interfaces that are intuitive and easy to use, regardless of the user's prior experience. Furthermore, the study highlights the importance of ongoing training and support for users of complex systems. While experienced users may be able to navigate the system effectively, they may not be using it to its full potential. By providing ongoing training and support, users can continue to develop their skills and optimize their performance. In conclusion, the results of this study indicate that experience with a system does not necessarily lead to faster response times. Developers should focus on creating user interfaces that are intuitive and easy to use adding for example speech recognition AI to interact with the system and simplify the tasks to all users whether they are experts or novice, and ongoing training and support should be provided to ensure that users can optimize their performance and utilize the system to its full potential.

List of Figures

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