UAB
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Data Management
Laboratory Report

Pocket Doctor

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1 Abstract

This paper introduces an innovative mobile application designed to revolutionize patient interactions with the public health system. Our device, accessible from any location worldwide with an internet connection, functions as a digital doctor. Users can consult the application by describing symptoms, providing photos, and answering questions for a more detailed analysis. The application will then deliver diagnoses, recommendations, and treatments, effectively performing the tasks of a doctor during a typical consultation. However, for procedures requiring specialized physical equipment, such as X-rays, blood tests, or CT scans for example, users will need to visit a healthcare facility. The results of these tests will be available in the app, allowing the digital doctor to explain them and provide a diagnosis to the user.

The primary aim of this innovation is to reduce waiting times, enhance diagnostic accuracy, and empower patients by providing immediate access to medical consultations. By streamlining the diagnostic process and making healthcare more accessible, this device addresses critical inefficiencies in the public health system. Furthermore, the application has significant social implications, including improving healthcare equity, reducing the burden on healthcare professionals, and potentially transforming how healthcare services are delivered and perceived by the public. These implications will be explored in detail throughout the paper.

2 Keywords

Digital Health; Mobile Health Applications; Artificial Intelligence; Healthcare Accessibility; Patient Empowerment; Diagnostic Automation; Machine Learning; Natural Language Processing; Telemedicine; Health Equity; Public Health Innovation; Remote Medical Consultation; AI-Powered Diagnostics; Health System Efficiency; Privacy and Data Security in Health Tech.

3 Introduction

The public health system faces significant challenges, including long waiting times for medical appointments, limited access to healthcare services, and an overwhelming burden on healthcare professionals. These issues are exacerbated by the growing demand for medical care and the shortage of healthcare providers. As a result, patients often experience delays in receiving diagnoses and treatments, which can lead to deteriorating health conditions and increased healthcare costs.

To address these challenges, innovative solutions are needed to streamline the healthcare delivery process and improve patient access to medical services. This paper presents a novel mobile application, designed to function as a digital doctor, providing users with immediate access to medical consultations from anywhere in the world with an internet connection. The application uses advanced artificial intelligence (AI) algorithms to simulate interactions with a healthcare provider, enabling users to describe symptoms, provide photos, and receive detailed analyses, diagnoses, and treatment recommendations.

The primary objective of this digital doctor application is to reduce waiting times, enhance diagnostic accuracy, and empower patients by offering a convenient and accessible alternative to traditional in-person consultations. By automating the diagnostic process and integrating it with the public health system, the application aims to alleviate the workload on healthcare professionals and improve the overall efficiency of healthcare delivery.

Moreover, the implementation of this technology has far-reaching social implications. It has the potential to democratize access to healthcare, particularly for individuals in remote or underserved areas, and to reduce disparities in healthcare access based on geographic, economic, and social factors. This paper will explore these implications in depth, analyzing the potential benefits and challenges associated with the widespread adoption of the digital doctor application.

In the following sections, we will provide a detailed overview of the current context of the public health system, review previous approaches to addressing similar challenges, describe the methodology used in developing the application, and present the key features and benefits of the device. We will also discuss the potential social impact, biases, and important issues to be addressed during the implementation of this innovative solution. Finally, we will conclude with a summary of our findings and recommendations for future research and development.

4 Context

4.1 Context Without the device

Understanding the landscape of the public health system without the implementation of innovative tools like the proposed mobile application is essential for appreciating the challenges it faces and the potential impact of such solutions.

Currently, accessing medical care within the public health system involves a series of steps that can be tedious and time-consuming for patients. When individuals suspect they have a medical issue requiring attention, they typically initiate the process by contacting a healthcare facility, often a hospital. This initial contact involves describing their symptoms, scheduling an appointment, and awaiting a consultation with a healthcare provider. However, due to the overwhelming demand for services, waiting times for appointments can extend for days or even weeks, particularly in primary care settings.

Once patients secure appointments, they must physically visit the healthcare facility for their consultation. This often involves travel, time away from work or other responsibilities, and potential logistical challenges, particularly for individuals with limited mobility or resources.

During the consultation, patients present their symptoms to the healthcare provider, who then conducts an assessment and provides a diagnosis. However, the limited time available for consultations and the high volume of patients can result in rushed assessments and potentially overlook certain symptoms or nuances in the patient's condition.

Overall, the current process of accessing medical care within the public health system is marked by inefficiencies, long waiting times, and challenges in delivering personalized care to patients. Addressing these issues requires innovative approaches that streamline the diagnostic process, reduce waiting times, and empower patients to take control of their health.

The introduction of tools like the described app represents a significant opportunity to transform the healthcare landscape by leveraging technology to improve access, efficiency, and quality of care within the public health system.

4.2 Previous approaches to the problem

Similar devices to ours have been made by some countries within and outside the European Union. It is crucial to gather information about previous experiences in order to successfully integrate this kind of device in the Catalan public health system.

- **Babylon Health (UK):** Babylon Health was a London-based startup that aimed to revolutionise healthcare by putting an AI-powered doctor in your pocket. This app was developed by a start-up which was heavily funded by the NHS, the public health system in the UK. The more revolutionary feature of this app is a chatbot which performs a triage and assesses the users symptoms. This was aimed to reduce pressure on doctors' time. This was intended to reduce waiting lists and cut costs. (The Week, 2023)

  But the Babylon chatbot didn't perform as expected. The project failed in the economic and technical sense. It turned out that patients asked for far more appointments than typically, encouraged by the ease of use of the app, this ended up meaning that Babylon would lose more and more money for each user they were getting because of the deal they had with the NHS. In the technical side, the chatbot raised concerns from the beginning. Various medical experts were amazed by the so basic implementation, the so-called chatbot consisted of a series of if - else statements which fail to spot a wide range of medical problems. It is important to note that this was released in 2017, before the GPT era. The project ended up failling completely and the start-up went bankrupt on August of 2023. (Wired, 2023).

- **Successfull cases:** The success of digital health solutions significantly relys on the robustness of the underlying AI technology and the continuous monitoring and maintenance of these systems. Some examples of succes are netherlands based SkinVision's AI-driven (SkinVision, 2024) app for skin cancer detection, boasting high accuracy rates for identifying malignant melanomas. This success is attributed to the rigorous training of its AI models on extensive datasets and ongoing refinement to improve diagnostic accuracy. Similarly, Germany's Ada Health's (Ada Health, 2024) symptom assessment tool leverages advanced AI algorithms and a vast medical knowledge base, continually updated and optimized to ensure precise health assessments. This robust AI foundation, coupled with regular updates and maintenance, ensures these applications provide reliable, up-to-date information, thereby gaining user trust and achieving integration into public health systems. In contrast, solutions lacking in AI robustness and ongoing maintenance often fall short in accuracy and reliability quickly lead to lower user adoption and eventual failure. Is it difficult for humans to trust in machines and if those are proven to not be accurate, users quickly stop using the app.

5 Methods

5.1 Interview with a health care professional

The interview was conducted with a healthcare professional, specifically a nurse, who is currently working in a healthcare facility. It covered various aspects regarding the integration of AI in the healthcare sector, its utility, how these technological changes would impact medical professionals, patients, and the healthcare system in general, and the nurse's personal perspective on the matter.

Our main objective in developing this device was to acelerate the diagnostic process, increment the efficiency of the healthcare system, and reduce the medical professionals' workload. The nurse affirmed that we were moving in the right direction, emphasizing that AI could be very beneficial to the healthcare system. Iff AI were to handle entire diagnoses, waiting lists would end, addressing a critical issue that affect healthcare systems today. "The most pressing problem in healthcare right now is the long waiting lists, both in social security and private insurance," she remarked. However, she raised a valid point regarding the substantial investment required for AI implementation, suggesting that resources could also be allocated to hiring additional professionals. "AI would be an investment of a lot of money. Just as it could be invested in AI, it could also be invested in hire 50.000 professionals more". With the current shortage of doctors, AI would be a valuable tool that would really help them (but not substitute).

The nurse discussed how AI could be incorporated into the medical field. She first thought that "being in urgency may not be that helpful because immediate actions have to be taken in the sense of having to bandage an arm". Then, she recognized its potential in diagnostic processes, particularly in areas like dermatology, "train machines for example for dermatology, injuries that are very difficult to know whether it is a fungus or a bacterium...", she said. Following this topic, We remarked that in fact our application's intent is to do this by allowing AI to analyze images of pigments on the skin, distinguishing between benign and malignant conditions. She emphasized the importance of specialist verification for all diagnoses. "It already happens with electrocardiograms, that the results can be normal, can be an arrhythmia, a heart attack... but they always say at the end that this have to be verified by a specialist. And it should be the same with diagnosis made by an AI."

Furthermore, she mentioned existing AI applications in healthcare, such as the e-CAP computer program, which uses AI to calculate sintrom dosages based on blood test results. She also mentioned that in the UVI of Igualada, there are beds that monitor patient weight and sweating losses daily.

In conclusion, the nurse expressed skepticism regarding people's trust in AI-driven diagnosis, emphasizing the value of human interaction in medical care. "People are get used to go to the doctor, which explores them and make a decision based on this exploration". Despite AI's potential accuracy, she pointed out the necessity of doctor supervision, as she mentioned earlier, and doubted its ability to fully replace human compassion and empathy. She is not afraid of AI substituting doctors and nurses, "no matter how much AI there is, it will never substitute a real person who hugs you or comforts you". To that statement, we asked what if we could make an empathic AI. She responded that

human contact remains irreplaceable. “Human contact makes it everything. If that were to happen, which right now I see that very difficult, I would still prefer to be comforted by a real person instead of a machine”, she ends up saying.

5.2 Interview with an AI expert developer

The second interview was to an AI expert, Fernando, who has worked on numerous medical imaging projects. We talked about the diverse perspectives there are on the application of AI in the healthcare sector, particularly in the domain of medical imaging and diagnostics, and covered many aspects during the intervew, including the objectives of medical imaging research, the challenges of data collection, the integration of multimodal models, the complexities of patenting innovations, and the acceptance of AI by healthcare professionals and patients from a developer’s perspective, offering a comparison with a healthcare proffessional’s opinion.

To start with, we discussed how AI contributes to the medical imaging field. And Fernando emphasized that the primary goal of medical imaging research is not to provide direct diagnoses but to support and improve the diagnostic process performed by healthcare professionals. This distinction is crucial, he said, and insisted that AI as an assistive tool rather than a replacement for human expertise. The AI systems are designed to provide evidence that help doctors make more accurate and informed decisions. To clarify his point, he provided an example from a project he once worked on. He explained that when working with endoscopic capsule technology, the AI system doesn’t directly diagnose but analyzes the intestinal contractions, providing valuable data that supports the diagnostic process.

We then asked about challenges we might encounter when collecting data, especially because health-related data seems to be more difficult. He highlighted one significant challenge, which is collecting and integrating data from different hospitals. Each hospital may follow slightly different procedures, leading to systematically biased data. This variation can significantly impact the training and performance of AI models. The key is to ensure that the AI models are robust and generalizable across different settings and not dependent on specific data from particular hospitals. However, at the moment, integrating such diverse data from different sources and cleaning it to be unbiased is still a complicated task.

Additionally, discussing multimodal models, Fernando explained that these types of models involve integrating various types of data, such as CT scans, X-rays, MRI images, and ultrasound images. Each modality provides different information and has its own complexities. For instance, ultrasound images can be particularly challenging due to their discontinuous nature, resembling radar images. Integrating these diverse data types into a coherent model that can assist in tasks like locating a catheter during a procedure requires sophisticated algorithms. The goal is to create a comprehensive view that enhances diagnostic accuracy and procedural planning.

After that, we were also interested in knowing a little bit about the process involved in patenting innovations in the medical field.

He said that the process is highly regulated and time-consuming, especially in Europe. Researchers face a problem because publishing their findings can stop them from patenting these findings, as the novelty has been lost. In contrast, in the United States, there are conditions under which innovations can still be patented after publication. These regulations often cause that companies will not pubish research results to secure patents, postponing the circulation of new knowledge and slowing down the overall progress in the field.

Subsequently, as we did with the previous interview, we wanted to know, from a developer's point of view, what he thinks about the acceptance of AI by healthcare professionals and patients.

On the topic of adoption by healthcare professionals, Fernando pointed out that successful implementation of AI in clinical practice requires stable, collaborative partnerships between public and private entities, as well as clinical research spaces. Such collaborations ensure that all stakeholders are aligned and invested in the project's success. Without this alignment, projects may struggle to achieve real-world impact.

Regarding the acceptance of AI by patients, he stated that this is another significant barrier. Despite high accuracy rates, patients will always prefer human interaction and the reassurance it provides.

And finally, a crucial point we discussed is the importance of minimizing false negatives, as these can have severe consequences. Although false positives may need additional checks, they do not pose the same level of risk. If we focus on reducing these false negatives, the doctors can concentrate on classifying those cases marked as positives, even if they turn out to be false positives, reinforcing this concept of AI supporting doctors and reducing their workload rather than replacing them.

6 The Device

Our device is a smartphone application that can be used anywhere in the world with an internet connection. It functions as a digital doctor, allowing users to consult it, describe symptoms, provide photos, and answer questions for a detailed analysis. The app then provides diagnoses, recommendations, and treatments, performing all the tasks a doctor would normally do during an in-person consultation. However, for procedures requiring specialized physical equipment, such as X-rays, blood tests, or CT scans, users will need to visit a healthcare facility. The results of these tests will be available within the app, allowing the digital doctor to explain them and provide a diagnosis.

This device is an integration into the existing CatSalut application, maintaining the familiar interface while enhancing it with advanced diagnostic capabilities. Users will have 24/7 access to a digital doctor (AI chatbot) that can address their concerns at any time and from any location. The application includes two models based on Vision Transformers, which offer high accuracy in diagnosing diseases. Additionally, the app features a section where users can view the results of their physical tests and request a diagnosis, among other functionalities.

By leveraging state-of-the-art AI algorithms, our device aims to streamline the diagnostic process, reduce waiting times, and improve healthcare accessibility. This innovation not only enhances patient care but also eases the burden on healthcare professionals, ensuring a more efficient and effective healthcare delivery system.

6.1 End Users

The device can be used for the whole population, but may have a primary focus on the following groups who can be benefited the most:

- **Users with Limited Access to Medical Services**: This includes individuals residing in remote areas or facing challenges in accessing medical services due to geographic, financial, or time constraints.
- **Individuals with Chronic Conditions:** This category comprises people with chronic diseases requiring regular monitoring and management. The app serves as a convenient tool for daily tracking and self-management. Allowing, when necessary, to reduce the amount of visits to the health center.
- **People Interested in Prevention and Wellness:** Individuals seeking a proactive approach to their health can benefit from the immediacy on getting a result that the device offers without having to schedule an appointment and enlarging the waiting lists.
- **Those with Busy Lifestyles:** Individuals with hectic schedules find it challenging to schedule regular doctor visits. The app offers a convenient solution for inquiries and guidance without the need for physical travel and the subsequent time loss.
- **Specific Demographic Groups:** Depending on the application's features, it may cater to specific demographic groups such as seniors, pregnant women, or individuals

with unique health needs. Basically those who more often make use of these public services.

- **General Users:** The application is designed to be accessible and beneficial to anyone interested in effectively managing their health and obtaining personalized wellness information.

The application must be designed in an inclusive and user-friendly way so that it is accessible to a wide audience. Additionally, data privacy and security should be critical considerations, especially in the health information space.

6.2 App Design

The app will be a mobile application accessible on various platforms (Android and iOS). It will consist of the following key components:

- **Symptom Input Module:** Users can input their symptoms by interacting with a virtual doctor (GPT chat bot).
- **Diagnostic Engine:** The core of the app, powered by artificial intelligence algorithms. This engine will analyze the inputted symptoms and utilize state-of-the-art techniques to identify potential medical conditions. There are several specialized algorithms, experts in a single diagnostic.
- **Medical Database:** The app will access a comprehensive database containing medical records, symptoms associated with various diseases, past medical data of the user and it will keep updating with new information about the user, making the app more personal as time advances.
- **Recommendation Module:** Based on the analysis, the app will provide a list of possible diagnoses along with their severity and risk factors. In addition to this, it will suggest the next steps that need to be followed according to the result of the diagnosis.
- **Risk Assessment:** The app will also offer recommendations for further medical tests or consultations based on the identified risk factors.
- **Diagnostic Results Display:** Once the diagnostic engine analyzes the symptoms, the results will be displayed in a clear and organized manner. The app will present the possible diagnosis that the model has predicted.

6.3 Benefits

Among the myriad advantages offered by the innovative app, the most significant identified benefits are:

- **Increased Efficiency:** Automates the diagnostic process, reducing the time required for diagnosis.
- **Patient Empowerment:** Provides patients with self-diagnostic tools and facilitates communication with healthcare professionals.

- **Reduced Costs:** By automating diagnosis, the app can potentially lower healthcare costs and improve access to care. This results in more public money allocated in other areas of the public health system.
- **Early Disease Detection:** The app's ability to analyze symptoms promptly and accurately increases the likelihood of detecting diseases in their early stages. Early detection allows for timely intervention and treatment, leading to better patient outcomes and potentially lower healthcare costs associated with advanced-stage treatments.

6.4 User Interface Design

The user interface (UI) of the app is designed to be intuitive and user-friendly. This section explores the UI design for the app's home page and screens. Through intuitive navigation, users can engage with the chatbot, input diagnostic information, and receive analysis results, enhancing accessibility and usability.

- **Initial home page:** The home page serves as the main interface for users to access various functionalities of the app, organized as icons, and including the chatbot interaction option, mentioned in *4.3 App Design* section. When the user clicks on the chatbot icon, it will be opened a new screen, transitioning to the chatbot interface.
- **Chatbot interface:** When the chatbot interface is displayed, the users can interact with the virtual doctor (GPT chatbot) to input their symptoms. Once the chatbot identifies the user's need for a specific diagnostic task, for example, the analysis of a mole, it directs the user to another screen for inputting the required information.
- **Input screen for diagnostic information:** Once the user has reached this screen, he/she will have to provide the required information in order to analyze it. In the case of a mole, the user will have to upload or capture a photo directly within the app interface. After inputting the necessary information, the app initiates the diagnostic analysis.
- **Diagnostic result tab:** Another screen shows up, displaying the diagnostic result in a clear and understandable format.

6.5 Regulatory Compliance

Ensuring regulatory compliance is crucial for the app to meet legal requirements and maintain user trust, especially when talking about health-related topics. Here are the key aspects of regulatory compliance:

- **Medical device regulations:** It is essential that the application adheres to medical device regulations established by the European Union, including the Medical Devices Regulation (MDR), or national legislations that the Spanish Agency of Medicines and Medical Devices (AEMPS) may apply, which is an agency responsible for ensuring the quality, safety and accurate information of medicines and health products from its research to use.

- **Data protection regulations:** The app must comply with data protection regulations such as the General Data Protection Regulation (GDPR) and the Organic Law on Data Protection (LOPDGDD). This involves ensuring the confidentiality, and availability of user data and obtaining explicit consent for data collection and processing.
- **Ethical guidelines:** The app should adhere to ethical guidelines for healthcare apps, including principles of beneficence, non-maleficence, autonomy, and justice. This involves ensuring that the app's design and functionality prioritize patient safety, privacy, and informed decision-making.
- **Security standards:** Implementing robust security measures is essential to protect sensitive user data from unauthorized access or breaches. This includes encryption of data transmission, secure storage of user data in compliance with GDPR requirements, and regular security assessments to identify possible vulnerabilities.
- **Compliance documentation:** Maintaining documentation of regulatory compliance efforts, including risk assessments and quality assurance processes, is essential for demonstrating compliance to regulatory authorities and stakeholders.

6.6 Data Privacy and Security

Data privacy and security are fundamental considerations for the app to protect user confidentiality and comply with regulations. Here are the key aspects of data privacy and security:

- **User Consent:** Obtain explicit consent from users for the collection, processing, and sharing of their personal and health-related data. Clearly communicate how their data will be used and provide options for users to manage their privacy preferences.
- **Encryption:** Implement encryption for data transmission and stored data. This ensures that sensitive user information remains secure and protected from unauthorized access or interception.
- **Access Controls:** Implement robust access controls to limit access to user data only to authorized individuals.
- **Data Minimization:** Collect and retain only the minimum amount of data necessary for the app's functionality. Minimize the collection of personally identifiable information and anonymize or pseudonymize data whenever possible to reduce privacy risks.
- **Regular Audits and Assessments:** Conduct regular security audits and risk assessments to identify and address vulnerabilities in the app's infrastructure and data handling processes. This includes code reviews and vulnerability scanning to mitigate security risks.

More concretely, as this device is developed inside the European Union jurisprudence, all legal aspects conserning data are set by European level law. In this case, the General

Data Protection Regulation (GDPR). So when implementing the app it is necessary to comply with this law in the matters of data protection. The GDPR classifies health data as a **special cattegory** of personal data which requires more protections due to its sensitive nature. It defines "data concerning health" as: data related to the physical or mental health of a natural person, including the provision of health care services, which reveal information about his or her health status. (European Union, 2016)

The GDPR states in which cases health data can be used:

- Explicit Consent (Article 9(2)(a)): The data subject has given explicit consent to the processing of their personal data for one or more specified purposes.
- Employment, Social Security, and Social Protection Law (Article 9(2)(b)): Necessary for carrying out obligations and exercising specific rights of the controller or of the data subject.
- Vital Interests (Article 9(2)(c)): Necessary to protect the vital interests of the data subject or another person where the data subject is physically or legally incapable of giving consent.
- Public Health (Article 9(2)(h) and (i)): Necessary for public interest in the area of public health, such as protecting against serious cross-border threats to health or ensuring high standards of quality and safety of health care.
- Medical Diagnosis and Treatment (Article 9(2)(h)): Necessary for the purposes of preventive or occupational medicine, medical diagnosis, provision of health or social care, or treatment.

So, health data will be able to be processed for our device if and only if it can be argued that one of the conditions above holds. In order to be able to have a functional device, two different types of health data are being processed:

- Data used to train the models. In order to be able to have accurate AI models lots of data is needed. This data, according to the definition given by the GDPR, has to be considered health data as in most cases it has a label which states wether there is a health problem or not. It can be argued that it complies with the last two cases. That it is a metter of public health, as the device will help the majority of the citizens, thus it is of public interest and also that is being used for medical diagnosis and treatment.
- Data input from the user. This kind of data is less trickier. As the use of the app is voluntary, there isn't any obligation, users would have to give explicit consent to the processing of the app. Of course, then the fundamental aspects of data privacy mentioned above should be followed.

By prioritizing data privacy and security measures, the app can build trust with users, maintain compliance with regulations, and safeguard sensitive health information effectively.

6.7 Simulation Device

To demonstrate how the application would function in real-life scenarios, we have created a simulation. This involved developing an application using Android Studio, aimed at mimicking the interface of the La Meva Salut application. The conversation with a doctor is simulated using the OpenAI API, where user input is sent and responses are received from a virtual doctor (ChatGPT-4). For analysing user data such as images and audio files, we deployed a Flask server connected to Hugging Face repositories containing models trained on these data types. User data is sent to these models, which then return the analysis results.

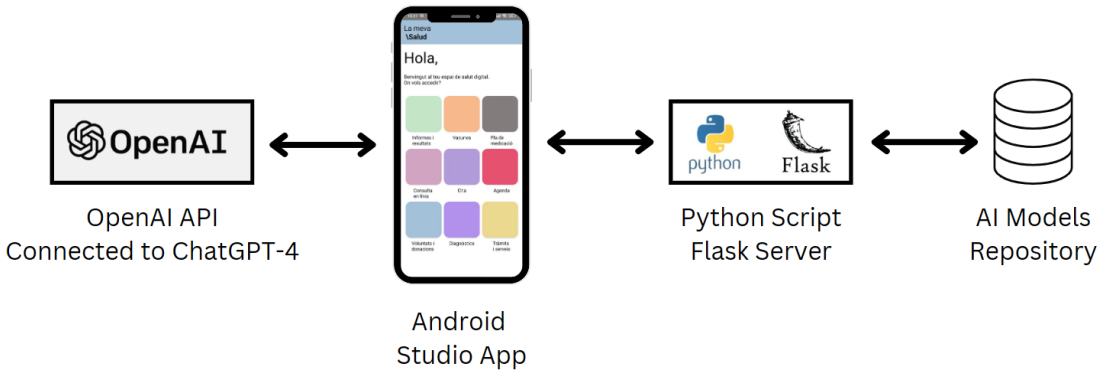

Figure 1: Simulation Workflow

6.7.1 Android Studio: Application Interface

The application was developed using Android Studio with the Kotlin programming language. We carefully replicated the interface to enhance the simulation experience. Below is a comparison of the interfaces:

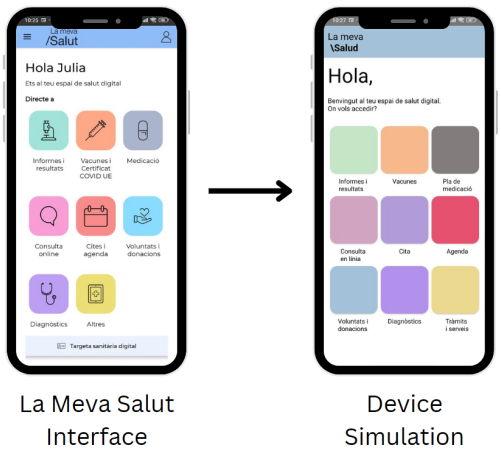

Figure 2: Home Interfaces Comparation

This coding environment allowed us to implement various functionalities within our application. We focused on two main buttons on the home interface:

1. **Diagnostics:** Where users can chat with the virtual doctor and receive their diagnoses.
2. **Informes I Resultats:** Where patients can view the results of their medical tests (e.g., radiographs) and ask questions about them to the virtual doctor.

6.7.2 OpenAI: Chat Implementation

The chat feature was implemented using the OpenAI API. When a user inputs a message, it is sent to ChatGPT along with a personalized prompt specifying the chat's behavior as a medical doctor. The response is then displayed to the user. This process continues until the diagnostic is completed.

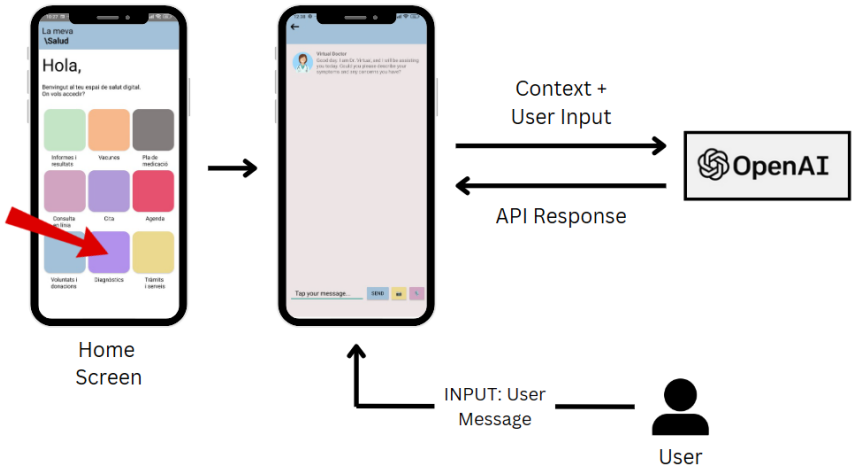

Figure 3: Chat Workflow

This method is both simple and efficient, with the added benefit of being multilingual, as ChatGPT-4 understands many languages. Below is an example of a possible conversation:

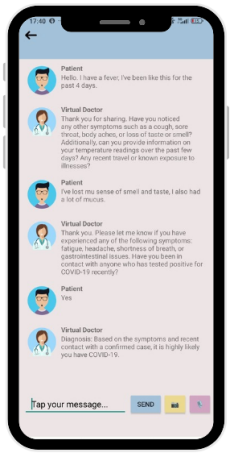

Figure 4: Conversation Example

6.7.3 Flask Server: Connection to the models

To allow users to upload data for diagnostic purposes, we used a Flask server. In this case, the data input is sent to the Flask server, analyzed by the respective model, and the result is sent to OpenAI along with the input text and previous conversation. This approach makes the virtual doctor more akin to a real one.

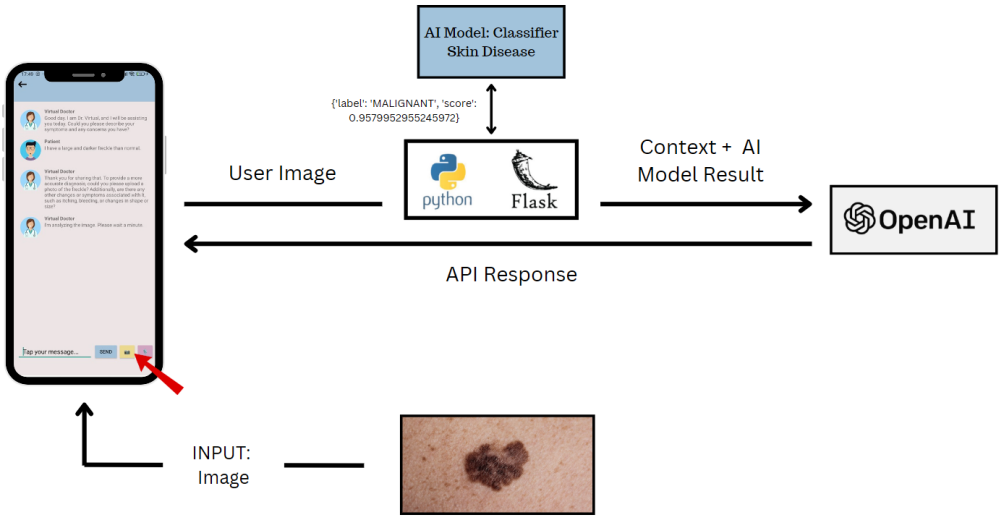

Figure 5: Application Final Cycle

As mentioned earlier, patients can also review their medical tests and ask the virtual doctor questions about them. The workflow remains the same, but it occurs in a different section of the application. To enhance realism, we randomly select different test results from a folder. Below are two examples, one where the patient is healthy and another for a pneumonia case:

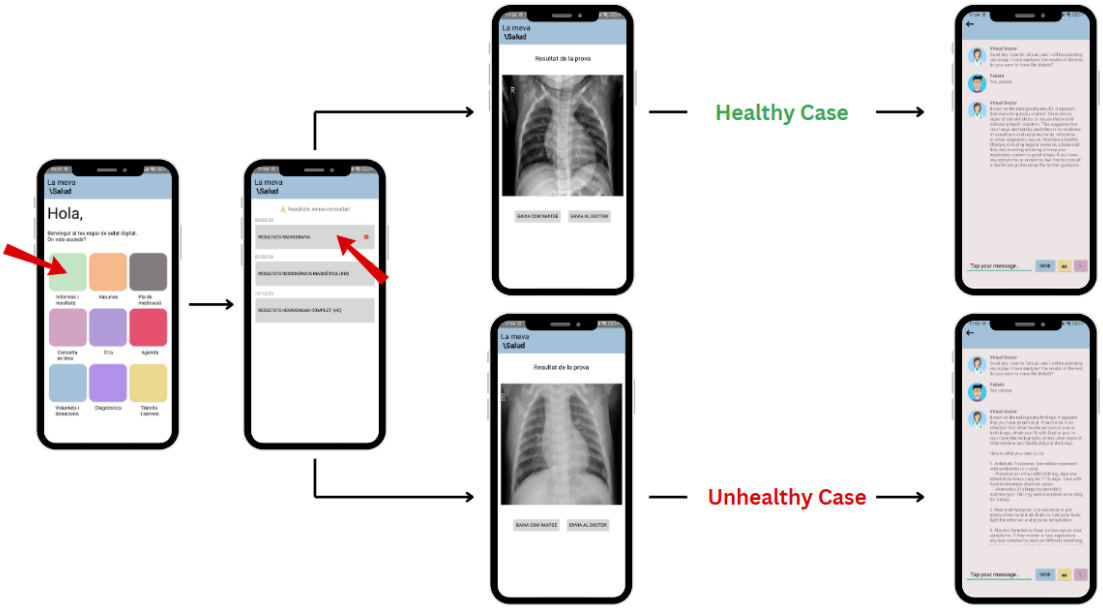

Figure 6: Example

For more information on the code, visit the project's GitHub repository: GitHub Link

6.8 Model Overview for Detecting Melanomas and Pneumonia (ViT) Overview

A Vision Transformer (ViT) is a type of deep learning model specifically designed for image recognition tasks. Unlike traditional convolutional neural networks (CNNs), which use convolutional layers to process images, ViTs apply the transformer architecture, originally developed for natural language processing (NLP), to images.

The ViT architecture consists of the following key components:

1. **Patch Extraction**: The input image is divided into fixed-size patches (e.g., 16x16 pixels). Each patch is then flattened into a vector.

2. **Linear Projection**: These vectors are linearly projected to a higher dimension and combined with positional embeddings to retain positional information, resulting in patch embeddings.

3. **[Class] Token**: An extra learnable embedding ([class] token) is prepended to the sequence of patch embeddings. This token is used to aggregate information across the patches for classification tasks.

4. **Transformer Encoder**: The sequence of patch embeddings (including the [class] token) is fed into a transformer encoder, which consists of multiple layers of multi-head self-attention and feed-forward neural networks. The encoder learns relationships between patches and generates a representation of the image.

5. **MLP Head**: The output corresponding to the [class] token is passed through a multi-layer perceptron (MLP) head to produce the final classification output.

6.8.1 Explanation of ViT Components

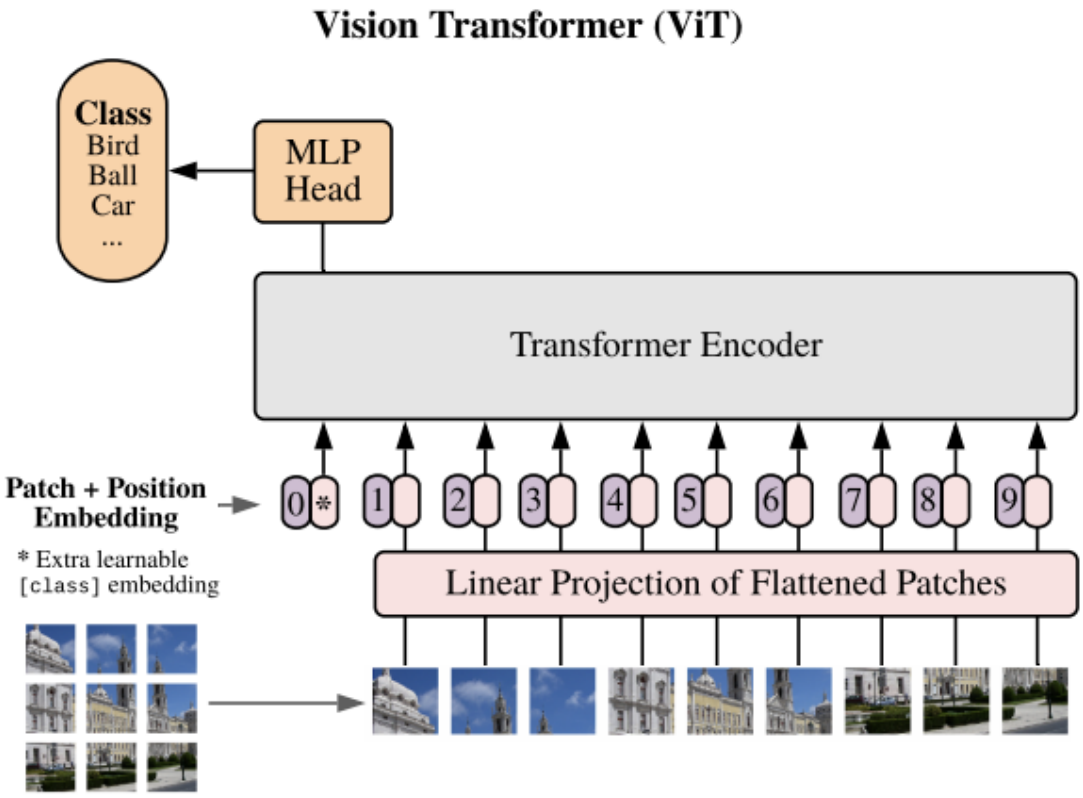

Figure 7: ViT Architecture

1. **Patch + Position Embedding**: The input image is split into patches, each patch is flattened and projected linearly. Positional embeddings are added to retain spatial information.

2. **Transformer Encoder**: The sequence of patch embeddings, along with the extra [class] embedding, is processed by the transformer encoder, which learns the interactions between different patches.

3. **MLP Head**: The encoded representation is fed into an MLP head that outputs the class probabilities for the given image.

6.9 Models Used in the App Device for Detecting Melanomas and Pneumonia

6.9.1 Melanoma Detection Model: sergiocannata/prove_melanomaprova_melanoma

This model utilizes the Vision Transformer (ViT) architecture to classify images of skin lesions. It is trained on a dataset of melanoma images and non-melanoma images. The model follows these steps:

1. **Patch Extraction**: The input skin lesion images are divided into smaller patches.
2. **Linear Projection and Positional Embedding**: Each patch is flattened and linearly projected, and positional embeddings are added.
3. **Transformer Encoder**: The sequence of patch embeddings is processed by the transformer encoder.
4. **Classification**: The output from the [class] token is passed through the MLP head to classify the image as melanoma or non-melanoma. Accuracy obtained: 0.8467

6.9.2 Pneumonia Detection Model: lxyuan/vit-xray-pneumonia-classification

This model also employs the Vision Transformer (ViT) architecture but is designed to classify chest X-ray images to detect pneumonia. The process is similar to the melanoma detection model:

1. **Patch Extraction**: Chest X-ray images are divided into patches.
2. **Linear Projection and Positional Embedding**: The patches are flattened, linearly projected, and combined with positional embeddings.
3. **Transformer Encoder**: The sequence of patch embeddings is processed by the transformer encoder.
4. **Classification**: The output from the [class] token is passed through the MLP head to classify the image as either showing pneumonia or not. Accuracy obtained: 0.8273

7 Discussion

As mentioned in previous sections of this paper, this device would mean a big change on how people relate to their own health, this of course brings up a series of points for discussion that need to be adressed.

The app significantly improves the amount of time needed to access healthcare. Even though this app can be used by all the population who have access to the catalan public healthsystem, during the development of the device several target groups have been identified as the ones who would beneffit the most from the proposed solution. One of the biggest improvements we aim to achieve is to make access to medical diagnosis more agile and time efficient. This is why, those groups of people for whom time is a major factor when deciding wether or not they will go to the doctor, this app can have a more significant impact on how they relate to health services. The identified target groups are:

- People living in rural or remote areas.
- People who lead a life with little free time.
- People with disabilities.
- Travelers
- People with a difficult access to transportation

These are just some examples of groups who would be impacted the most with our device. What all these have in common is that they beneffit from the two main advantages that the device offers, having a diagnosis from anywhere and with very little time. In this way, a largest rate of early detection can be achieved, providing better health equity.

Empowering individuals with information about their health is a profound social impact of the app. Users can gain insights into their symptoms and potential diagnoses without waiting for a doctor's appointment. Acheiving a significant number of people who are gaining an active consciousness about their health status can improve the overall health of the whole population, being able to attack the problems when it starting and easier to mitigate. This proactive approach encourages people to take charge of their health, fostering a more health-conscious society.

The app has the potential to reduce healthcare disparities by providing uniform diagnostic capabilities regardless of socioeconomic status. This means that even those with limited financial means can access high-quality preliminary diagnostic services, contributing to more equitable healthcare outcomes. One of the fundamental aspects of the device is the context within it is operating, which is the public health system. Thi means that anyone (who has access to the public health system) can use the app without any added cost. Here it arises another important target group, which wasn't mentioned before in this discussion, Individuals from low-income backgrounds. This comprises a big group of people, who appart from the time and convinience, they can have access to a higher quality health system without having to pay for a private insurance.

By triaging patients effectively, the app alleviates the burden on healthcare systems, particularly in overstressed environments. In the current system it takes too many steps and time to get a first opinnion on the health issue. First, the patient has to contact the health center, talk to administration, then an appointment is set (usually in weeks time). When the first visit happens, the doctor makes directly a diagnosis or it may relate the patient to a specialist on the matter, making the process even longer. With the introduction of the device, the patient would have a result in minutes (from the AI system) and then the triage process would be much more efficient as the result can be directly revised by the right specialist and ana appointment to him could directly be set. In most cases, an opinion from a human is necessary but the doctor would have a first opinion given by the AI model, has some pre hand information about the health issue (for example a photograph) and could give a final diagnosis in less time than with the current system. This can lead to more efficient use of healthcare resources, reduced wait times, less crowded emergency rooms and mst importantly, it enables for a better organiation of time slots for visits, ultimately enhancing the quality of care for all patients.

For individuals with chronic conditions, the app offers a valuable tool for regular monitoring and self-management. This can lead to better health outcomes and reduced need for frequent healthcare visits, which can be both time-consuming and costly. Enhanced self-management can also improve patients' quality of life and reduce the incidence of complications.

The app encourages preventative healthcare by allowing users to quickly check their symptoms and get advice on when to seek medical attention. This proactive approach can lead to early detection of illnesses, which is often associated with better treatment outcomes and lower healthcare costs.

For individuals with hectic schedules, the app offers a convenient solution that fits into their lives without the need for physical travel and lengthy waiting times. This can reduce stress and improve overall well-being by making healthcare more accessible and less time-consuming.

The app can be tailored to cater to specific demographic groups such as seniors, pregnant women, or individuals with unique health needs. This targeted support can ensure that these groups receive appropriate care and attention, addressing their specific health concerns more effectively.

The app can lead to significant cost savings for both patients and healthcare systems by reducing unnecessary visits to primary care physicians and emergency rooms. This can result in more efficient allocation of healthcare funds and potentially lower healthcare costs for individuals. When lavereging this aspect, it is very important to have in mind that this is the public health system, so all cost savings that can be made here are of general interest for the whole society. How the saved money is managed would be up to the polititians criterion but it would be fair that these extra resources are used to improve other areas within th epublic health system that are in great need of attention.

While the app offers many benefits, it also raises important considerations regarding

data privacy and security. Ensuring robust measures to protect users' health information is critical to maintaining trust and compliance with regulations such as GDPR or HIPAA. Addressing these concerns proactively can enhance user confidence and encourage widespread adoption. Failing in this aspect could put an end to the project, both for legal issues and for the lack of trust from the potential users.

The widespread adoption of such an app could lead to cultural and behavioral changes in how people approach healthcare. By normalizing the use of digital health tools, it can foster a more tech-savvy and health-aware society. However, it is important to ensure that the app is designed inclusively to accommodate users with varying levels of digital literacy. It also changes how people relate to their phones. More and more they are becominng an essential tool, with this, it would add an extra feature as a diagnostic tool.

The app holds the potential for profound social impact by democratizing access to healthcare, empowering individuals with health information, reducing disparities, and alleviating the burden on healthcare systems. While there are important considerations around data privacy and security, the benefits of such an innovative tool could lead to significant improvements in public health and well-being.

7.1 Potential negative impact on the society

Of course, all big changes have positive but also negative consequences. So it is important to have the negative ones in mind in order to mitigate or at least minimize them as much as possible.

- **Overreliance on Technology:** There is a risk that patients may become overly reliant on the app, potentially neglecting the need for in-person consultations when necessary.
- **Digital Gap:** Individuals without access to smartphones or the internet may be excluded from the benefits of this technology, exacerbating existing health disparities. As the device can only be used with an smartphone, it is another service that pepople without one couldn't use. There isn't any possible solution to this problem.
- **Disconfort from health professionals:** Health professionals could see this new technology as a threat to their jobs. Also, administrative jobs can be lost if the implementation of the devicce is succesful and it achieves the efficiency gains it aims to. As for health professionals, lots of pedagogy should be done in order to make clear that this does not aim to substitute doctors and nurses but making their jobs easier. It is a partnership and not a substitution. But, if this task is not done with enough effort, the implementation of the dvice could be met with a boycott from this health professionals.
- **Potential Misdiagnoses:** Although the app leverages advanced AI algorithms, there is still a possibility of misdiagnoses, which could have serious health implications for patients. This fact could have a huge negative impact on the implimentation of our device in the society. People can accept humans making mistakes but not machines. If the number of unhappy users is big, due to a faulty diagnose, it could raise concerning voices against the device. As has already happened in past

experiences, this has a very big impact on the adoption of this kind of technologies and it could put the hole project in jeopardy.

- **Patients feeling lack of humanity:** As health is a very personal and delicate aspect of a persons life, getting result from a chatbot and not from a real person can cause a mental disconfort, added to the potential health problems. If not cared with sensibility, this could have a big negative impact on mental health.

7.2 Possible Biases

AI systems can inadvertently perpetuate biases present in the data they are trained on. Possible biases in our digital doctor application include:

- **Data Bias:** If the training data is not representative of the diverse patient population, the AI models may perform poorly for certain demographic groups, leading to inaccurate diagnoses. For example, if the dataset primarily consists of images of lighter skin tones, the algorithm may not perform as well on darker skin tones, which could be considered discriminatory.
- **Algorithmic Bias:** The design of the algorithms themselves may introduce biases, especially if they are not rigorously tested and validated across different populations. This could result in the AI making inaccurate recommendations for specific groups.
- **User Bias:** Users' interactions with the app may be influenced by their own biases, such as their trust in digital healthcare solutions or their willingness to follow the app's recommendations. This could affect the outcomes and effectiveness of the AI's advice.

To mitigate these biases, it is crucial to use diverse and representative training data to ensure the AI models are robust and perform well across various demographics. Additionally, continuously monitoring and evaluating the AI's performance is essential to identify any disparities in accuracy and reliability for different demographic groups. Incorporating feedback mechanisms allows both users and healthcare professionals to report any issues or biases in the app's recommendations, which can then be addressed and corrected.

Moreover, transparent communication with users about the AI system's limitations and potential biases is vital. For instance, if the AI is known to perform better on certain skin tones, this information should be disclosed to users along with advice to seek additional medical consultation if necessary. Recognizing that AI models have an inherent error rate, there should be protocols for managing these errors, including addressing misdiagnoses and providing users with options for recourse.

Besides, regular updates and refinements of the AI models are necessary to improve performance and reduce biases. This involves incorporating new data, retraining models, and adjusting algorithms based on the latest research and user feedback. It is also important to ensure that the AI does not engage in profiling or discriminatory practices, which includes avoiding any actions that could lead to the unfair treatment of users based on their demographic characteristics.

By addressing these considerations, we can create a more equitable and reliable digital doctor application that effectively serves all users.

7.3 Important issues to be addressed once the device is implmented

Regulatory Compliance: Ensuring the app complies with medical device regulations and data protection laws like GDPR and the AI ACT, which are EU laws, is essential for user trust and legal operation.

Data Privacy and Security: Robust measures must be in place to protect sensitive health information from unauthorized access and breaches.

Integration with Existing Healthcare Systems: Seamless integration with existing healthcare infrastructure, such as electronic health records (EHRs), is necessary to provide comprehensive patient care.

User Education and Training: Educating users about the app's capabilities and limitations is crucial to prevent misuse and ensure they understand when to seek in-person medical attention.

Continuous Improvement: Regular updates and improvements based on user feedback and advancements in AI technology will be necessary to maintain the app's effectiveness and relevance.

Ethical Considerations: Addressing ethical issues related to AI in healthcare, such as informed consent, transparency, and accountability, is vital for maintaining public trust.

8 Social Dimensions

8.1 Map of actors

There are many actors that make this project possible. Without them, this application would not exist.

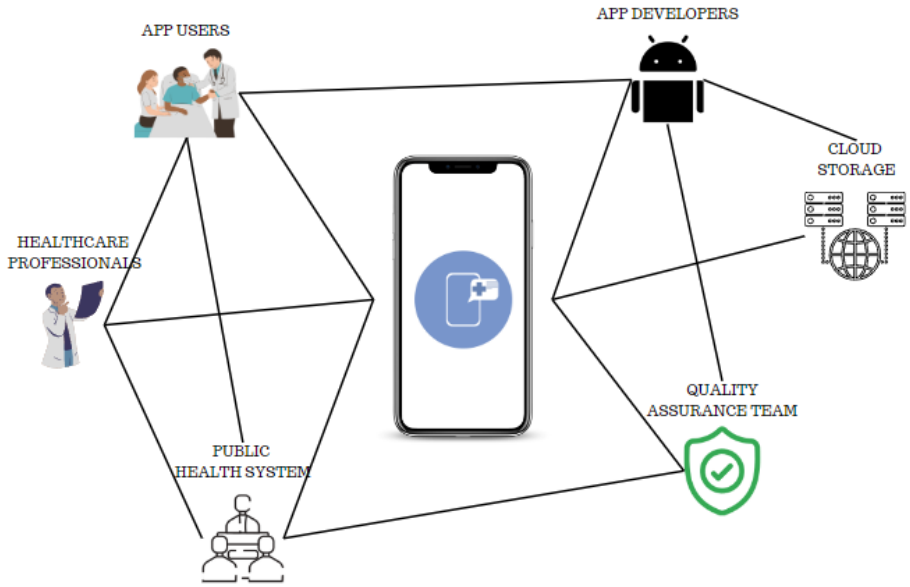

Figure 8: Map of actors

- **Application Developers:** Application developers play a crucial role as they are responsible for the final outcome of the device. Throughout the app development process, they must prioritize the needs of the end users, ensuring engagement and attraction. They collaborate closely with cloud storage managers to access and utilize stored data effectively, and with the quality assurance team to meet specific quality standards.

- **Cloud Storage:** Refers to the database administration team responsible for managing the stored data, especially sensitive health-related information. With such kinds of data, there are lots of regulatory concerns that need to be addressed and taken very carefully. It's crucial to choose a secure option with robust security measures to address regulatory concerns effectively. This team is responsible for ensuring compliance with regulatory requirements related to data security and privacy.

- **Quality Assurance Team:** This team will be in charge of imposing some quality measures and doing the corresponding reports, in order to ensure the accuracy of the model and high performance. These reports are crucial for regulatory approval by the public health system. Furthermore, they will be in charge of any regulatory issues that can arise with the matters this application is dealing with.

- **App Users:** Those who will be the most benefited by the application. They will be engagin with the app to access healthcare services, receive diagnoses, and obtain advice on various health-related concerns.

Their engagement involves providing personal health information, symptoms, and concerns to the app to receive personalized recommendations and guidance. Users are also engaged through features such as appointment scheduling, medication reminders, and access to educational resources aimed at improving health literacy.

Note that the device targets diverse users, particularly those with limited healthcare access, chronic conditions, interest in preventive care, busy lifestyles, specific demographics, and general health management needs.

- **Healthcare Professionals:** Healthcare professionals are not only key contributors to the development and oversight of the app but also the primary beneficiaries and directly impacted stakeholders.

  They are integral to the development and oversight of the app, contributing expertise in algorithm design, and treatment protocols, and ensuring the accuracy of medical information. Also can review user-generated data, offering additional insights or recommendations based on their expertise. Their involvement ensures the app's adherence to medical standards and enhances its efficacy in providing comprehensive healthcare support. Also, they will have to be able to adapt to this new reality of Human-AI collaboration by assessing the results given by the algorithms, they will be able to correct the results and will always prevail the opinion of the doctor before the one given by the algorithm.

- **Public Health Systems and Government:**Public health systems and government agencies are involved in regulating and overseeing the app to ensure compliance with healthcare standards and regulations and they may collaborate with developers to establish guidelines for data privacy, security, and ethical use of healthcare information within the app.

  Government agencies may also promote the app as part of broader initiatives aimed at improving the public health system and its digitization. These promotion can be done via marketing campaigns to increase health awareness or initiatives to expand access to telemedicine services. Additionally, public health systems may leverage data collected by the app to monitor population health trends, identify emerging health threats, and inform public health policies and interventions.

  Also for access to public health data, the permission of government instances and figures is needed for the model training, note that for different countries different regulations and compliance must be followed, the idea is to leverage the app to be globally available.

8.2 Citizen Engagement

Make it Simple: The application must be intuitive and easy for everyone but above all and most importantly is old people who might not be used to using technology, this is a critical point as it is not acceptable that anyone is demotivated to use this service because does not understand well the interface or its use. So our goal is to provide a good-looking interface with big images and letters so it is easy to read and clearly shows what is the use of each option offered.

Make it Visible: We must ensure that the app is known to all potential users and they have access to it, also we must ensure that the users know how they may benefit from using this service like avoiding waiting time, displacements to a health center, and getting quick responses for health-related questions. This would be done mainly using the tools that the Government already uses for health purposes like Cat salute.

Make it Playful: To engage users with the use of the application we could implement polls from time to time in order to know what to upgrade or change so the users feel they have an active role in controlling the way the application evolves, another way to

Make it Personal: There are several ways to make the device personal, in the one hand the application interface itself and in the other hand the algorithms that are running in the back-end. As for the application interface, it should be very customizable so each user can make it a little bit their own way (of course with some limitations). An example of that would be that if they are actively using a specific diagnostic tool a lot, this would be shown in the first slots of the app. As for the algorithms which are behind the diagnostic tools it is a good idea that they are updated with the data that each patient is providing to the app when running it. This results in algorithms which improve based on the peculiarities of each patient, making them more personal.

Make it Practical: As the usage of the application is very straightforward, we have to put some effort into communicating this aspect to the potential users. We can tackle various aspects here. First the application is easy to use, providing clear examples for first-time users and putting special efforts on groups who may not be so technology-friendly. In addition to this, it is crucial to make clear that this application is beneficial for the public health system for the reasons that we have already mentioned, a good idea for this would be to include charts showing the amount of total waiting time that the usage of the application has saved or the number of successful detection.

8.3 Ethical Considerations

The implementation of our digital doctor application raises several important ethical considerations that must be carefully addressed to ensure the technology is used responsibly and benefits all stakeholders involved.

- **Privacy and Data Security:** Protecting patient privacy and securing personal health data are essential. The application must comply with data protection regulations such as GDPR in Europe and HIPAA in the United States, as explained before in sections 6.5 and 6.6. Ensuring robust encryption, secure data storage, and strict access controls are essential measures to prevent unauthorized access and data breaches.

- **Informed Consent:** As discussed earlier in section 6.6as well, users must be fully informed about how their data will be used, stored, and shared. Clear, understandable consent forms should be provided, detailing the purpose of data collection and the rights of the users. It is crucial that consent is obtained in a transparent manner, allowing users to opt-in or opt-out freely.

- **Bias and Fairness:** AI algorithms can inherit biases present in the training data, leading to unfair or inaccurate diagnoses for certain demographic groups. It is essential to use diverse and representative datasets during the development phase to minimize biases. Regular auditing and updating of the AI models are necessary to maintain fairness and accuracy in diagnoses.
- **Accountability and Liability:** Determining accountability in case of misdiagnoses or technical failures is critical. Clear guidelines must be established regarding the liability of developers, healthcare providers, and users. Mechanisms for reporting and addressing errors or adverse outcomes should be in place to ensure accountability and continuous improvement.
- **Transparency:** Transparency in how the AI makes decisions is crucial for building trust among users and healthcare professionals. Providing explanations for the AI's recommendations and decisions helps users understand and trust the technology. Open communication about the capabilities and limitations of the AI system is necessary to manage expectations.
- **Accessibility and Equity:** Ensuring equitable access to the application is vital, particularly for underserved and remote communities. Efforts must be made to make the application user-friendly and accessible to individuals with varying levels of digital knowledge and those with disabilities. Addressing potential disparities in access to technology and internet connectivity is essential to prevent exacerbating existing health inequalities.
- **Human Oversight:** Despite the advanced capabilities of AI, human oversight remains crucial. The application should be designed to support, not replace, healthcare professionals. AI-generated diagnoses and recommendations should always be reviewed by qualified healthcare providers to ensure accuracy and provide a human touch, particularly in complex or sensitive cases.

These ethical considerations align well with the basic standard principles to take into account when developing any AI model to ensure responsible AI, which are fairness, reliability and safety, privacy and security, inclusiveness, transparency and accountability. Ethical review boards and continuous ethical assessments should be integrated into the development and deployment processes to ensure the technology aligns with these ethical standards. By addressing them, we can ensure that our application is developed and deployed in a way that respects patient rights, promotes equity, and enhances the overall quality and accessibility of healthcare services.

8.4 Accessibility and Inclusivity

Accessibility and inclusivity are critical considerations for this app. In the context of public health, it inheritely aims to make it available to the whole population. However, like with all new technologies, several challenges may arise regarding its accessibility and inclusivity.

Firstly, the app's reliance on smartphone technology excludes individuals who do not

own one, potentially leaving out significant portions of the population, especially in underserved or economically disadvantaged areas and elderly people. This digital divide can exacerbate existing healthcare disparities, as those without smartphones may not have alternative means to access the diagnostic tool.

Moreover, while the app is designed to be user-friendly and very easy to use, varying levels of technical literacy among users can impact its effectiveness. Individuals who are not comfortable with modern technology, such as the elderly or those with limited exposure to digital tools, might find it difficult to navigate the app, even if it is intuitive. This could result in incorrect usage or abandonment of the app altogether, thereby limiting its intended benefits.

Additionally, users with disabilities, such as visual or hearing impairments, might face difficulties if the app does not offer adequate accessibility features, like screen readers or audio cues.

These issues highlight the importance of considering diverse user needs in the design and deployment of our app interface. Without addressing these potential barriers, the app could not reaching its full potential in providing equitable healthcare solutions to all segments of the population.

9 Conclusion

In summary, our digital doctor application aims to revolutionize the public health system by providing immediate access to medical consultations through advanced AI algorithms. This innovation addresses critical issues such as long waiting times, limited access to healthcare services, and the heavy workload and high stress levels experienced by healthcare professional due to the high demand for medical services. By automating the diagnostic process and integrating it with existing healthcare systems, our application seeks to improve efficiency and patient outcomes. As it has been remarked several times through this paper, this AI pretends to give support to the healthcare professionals rather than replacing them.

When deploying this application, it is essential to ensure the accuracy and reliability of the AI models. This includes using diverse and representative training data to avoid biases and continuously monitoring the performance of the system across different demographic groups. Additionally, robust security measures must be implemented to protect patient data and maintain user trust. It is also crucial to involve healthcare professionals in the validation process to ensure that the AI recommendations are accurate and safe.

Looking ahead, our application has the potential to be integrated into various aspects of healthcare delivery. Future developments could include expanding the range of diagnosable conditions, incorporating more sophisticated AI algorithms, and enhancing user interface features to improve accessibility and usability. To start with, a gradual implementation of the application in stages could be carried out, to test and refine the system in a smaller and controlled environment before expanding to a broader audience. By starting with a pilot program in a specific region or healthcare facility, any issues would be identified and addressed early, ensuring a smoother and more successful wider deployment later on. Gathering user feedback and iteratively improving the application will be very important to successful scaling and broader adoption.

Throughout the development of this project, we have learned a several things. Firstly, the importance of collaboration between AI developers and healthcare professionals is extremely important to ensure the successful development and implementation of AI systems in healthcare. Their expertise and insights are invaluable in creating a practical and effective tool. Besides, we have come to recognize that AI will likely never be able to replace healthcare professionals. Despite achieving high accuracy, patients will always maintain tehir trust in human professionals. Additionally, addressing ethical considerations and potential biases early in the development process is essential to ensure fairness and equity in healthcare delivery.

In conclusion, our digital doctor application represents a significant step forward in leveraging AI technology to enhance public health systems and make a meaningful impact on healthcare accessibility and efficiency.

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