Software Requirements Specification
Computer Science Capstone Project
AI for Chest X-Ray read

Group Number 15

Supervisor:
Name: Dr. Mehdi Moradi
Email: moradm4@mcmaster.ca
Organization: McMaster University, CAS

Team Members:
Name: Yuvraj Singh Sandhu
Email: sandhy1@mcmaster.ca

Name: Suhaas Parcha
Email: parchas@mcmaster.ca

Name: Ujjwal Raj
Email: raju1@mcmaster.ca

Name: Suvansh Dutt
Email: dutts1@mcmaster.ca

October 11, 2024

Contents

Team Members Contributions

Section Worked On	**Team Member**
Title, 2.4, 4.1, 9.1, 10.1, 10.2, 10.3	Yuvraj Singh Sandhu
Title, 2.1, 2.2, 2.3, 2.5, 2.6, 3.1, 3.2, 3.6, 5.1, 5.3, 6.1, 7.1, 9.1, 11.1, 11.2, 12.1, 12.2, 12.3, 13.1	Suhaas Parcha
1.2, 2.1, 2.5, 2.6, 2.7, 5.2	Ujjwal Raj
1,2.1,2.2,3.1,3.2,4.1,6.1,6.3,9,10.1,10.3,11.1,11.2	Suvansh Dutt

Revision History

Date	Version	Notes
5th October 2024	0.0	Started Initial draft
16th November 2024	1.0	Modified SRS according to the feedback received
28th February 2025	2.0	Removed irrelevant requirements
1st April 2025	3.0	Finalized SRS

1 Purpose of the Project

1.1 Goals of the Project

The goal of the project is to create a web app which acts as a quick, easy and accesible way to get a second opinion on one's chest X-ray diagnosis. The feedback received includes a heatmap and the likelihood predictions of 14 different conditions.

2 Stakeholders

2.1 Client

Clients are the ones who are the frequent user of the product. The product would mainly target regular patients who can upload chest X-rays to get a quick second opinion on their diagnosis.

2.2 Other Stakeholders

Other stakeholders could include AI and ML enthusiasts as well as researchers who could gain information by studying our model.

2.3 Hands-On Users of the Project

Hands on users of the project could be anyone, this can include regular patients on general users. It's available for everyone to test.

2.4 Personas

Patient / General Public User

- **Name:** Mario
- **Age:** 52
- **Background:** Software engineer with no medical training
- **Goals:**
  - Understand his chest X-ray results quickly and easily
  - Access his medical imaging records securely
- **Technical Proficiency:** Moderate; comfortable with smartphones and basic computer use
- **Concerns:** Privacy of medical data, accuracy of AI interpretations, ability to discuss results with a human doctor

Researcher/ ML enthusiast

- **Name:** Dr. Emily Rodriguez
- **Age:** 38
- **Experience:** 15 years in Researching AI models
- **Goals:**
  - Research the model for personal reasons
- **Technical Proficiency:** Proficiency with imaging software

2.5 Priorities Assigned to Users

The most important priority is detection of the disease to the user. Make the user aware of any diseases in the chest as soon as possible. The next one would be to localize it.

2.6 User Participation

The user's participation is a very crucial role in either functioning or improvement of the system. The participation of the user is limited to just uploading the image and receiving the diagnosis.

2.7 Maintenance Users and Service Technicians

In order to maintain the user and the application we will maintain the back-end APIs in order for the user to access the frontend anytime of the day.

3 Mandated Constraints

3.1 Solution Constraints

- Performance: The system must be optimized for speed and efficiency.
- No Pre-trained Model: The model will be built from scratch without using any pre-trained models.
- User Account Credential System: A secure user account management system must be implemented.
- Adhere to Medical Privacy Laws: All data handling and processing must comply with relevant medical privacy regulations.

3.2 Implementation Environment of the Current System

- Python libraries like Pytorch, lightning, Numpy, timm, sklearn, PIL, tqdm, pandas, matplotlib, etc
- Javascript - Svelte, Vite
- Github
- MongoDB - Database for patient login records.
- Hugging Face

3.3 Schedule Constraints

The timing constraint for Version 1 of the frontend is the demo presentation during the last week of November. Version 3 of fronted and backend should be completed before the final presentation during last week of March. All code should be finalized before the capstone expo and final submission.

3.4 Budget Constraints

We will use the CAS Grace server for AI model training. We might have to buy subscriptions for deployment of the website and AI server which should cost more than 20 CAD each per month.

4 Naming Conventions and Terminology

4.1 Glossary of All Terms, Including Acronyms, Used by Stakeholders involved in the Project

Term	Definition
SRS	Software Requirements Specification
ML	Machine Learning
NN	Neural Network
CNN	Convolutional Neural Network
NLP	Natural Language Processing
GD	Gradient Descent
AI	Artificial Intelligence
Torch	PyTorch
X-ray	A form of electromagnetic radiation used to create images of the inside of the body
DICOM	Digital Imaging and Communications in Medicine, a standard for handling, storing, printing, and transmitting medical imaging information
ROI	Region of Interest
Lung Nodule	A small round or oval-shaped growth in the lung
ROC curse	Receiver Operating Characteristic curve is a graphical tool used to assess the performance of a binary classification model. It plots the true positive rate against the false positive rate at various thresholds, helping to visualize the trade-offs between sensitivity and specificity.
NIH	National Institutes of Health Chest X-Ray
CheXpert	Open source chest X-ray dataset provided by Stanford

5 Relevant Facts And Assumptions

5.1 Relevant Facts

- Data is an image of a chest X-ray.
- The model will be trained on publicly available datasets.
- The patient records stored would be in accordance with PIPEDA laws.

5.2 Business Rules

- Regulatory Rules: laws and regulations that provide rules that need to be followed (e.g., financial regulations, data protection laws)
- Guideline Rules: Best practices and recommendations (e.g., consumer engagement methods) that assist in decision-making but are not required.

5.3 Assumptions

- Assumption 1: The X-ray images used for training are of sufficient quality to allow the model to learn effectively.
- Assumption 2: The publicly available datasets cover a diverse range of cases to ensure the model generalizes well to new data.
- Assumption 3: The model's performance will be evaluated based on established metrics (e.g., accuracy, precision, recall) against a separate validation dataset.
- Assumption 4: All ethical guidelines regarding patient privacy and data handling will be strictly followed during the project.
- Assumption 5: The necessary computational resources (hardware and software) are available to train and test the model effectively.

6 The Scope of the Work

6.1 The Current Situation

We have finalized the website design and it is currently deployed on Netlify. The AI server is deployed on Hugging Face and the database is stored on MongoDB Atlas. The AI model has been trained on the Grace server using the CheXpert dataset.

6.2 Work Partitioning

We aim to divide work as efficiently as possible and plan to hold either several regular small meetings for discussions, designs, planning etc., or have a couple of longer ones where we do live coding/debugging and review each other's code and improve.

6.3 Specifying a Business Use Case (BUC)

Useful in radiology to assist radiologists to identify missing abnormalities in the chest Xrays or to help them identify it quicker

7 Business Data Model and Data Dictionary

7.1 Business Data Model

The Business Data Model outlines the key entities and their relationships relevant to the project. The primary entity is the "Patient", which includes attributes such as Patient ID, Name, Age, Gender, and Contact Information. Each patient can have multiple "X-Ray Images", which are identified by a unique Image ID and are associated with a Patient ID. The X-Ray Image entity also includes the date of the X-ray and a file path for the image.

Another critical entity is Model Training, which captures the details of the training process. This includes a Training ID, Model Version, Training Date, Accuracy, and Loss metrics. Evaluating the model's performance involves collecting various Evaluation Metrics associated with each training instance. These metrics include Precision, Recall, and F1 Score, providing a comprehensive view of the model's performance.

In summary, the Patient entity connects to multiple X-Ray Images, while each Model Training session may yield several Evaluation Metrics, allowing for a detailed analysis of the model's effectiveness and compliance with ethical standards.

8 The Scope of the Product

8.1 Product Boundary

This product automates chest X-ray analysis by integrating AI-driven diagnostics with a user-friendly web interface.

8.2 Individual Product Use Cases (PUC's)

Users can receive a second opinion on their chest X-ray results through the AI model, especially if there are long waiting times for a doctor's appointment after the initial consultation, providing quicker insights and reassurance.

9 Functional Requirements

9.1 Functional Requirements

P0-3 indicate the decreasing order of importance of system features

- P0: Training, analyzing, testing and validating a convolutional or transformer-based model for Automatic detection of a useful subset of all possible findings in chest X-rays, including disease detection and disease localization.
- P0: Develop a website for uploading chest X-ray images: develop a drag-and-drop interface for easy X-ray image upload, implement file type validation to ensure only valid image formats are accepted.

- P0: Create an interactive overlay on the X-ray image to highlight specific areas where diseases are detected, if a disease is detected, the area of interest would have a higher contrast compared to the rest of the image in the form of a heatmap.
- P0: Display a list of detected diseases alongside the X-ray image, for each disease, show the confidence score of the detection and provide a brief description of each detected disease and its implications.
- P1: Adding user authentication and authorization. creating login/signup interfaces and secure routing. User credentials stored securely in MongoDB.
- P1: Develop a dashboard for users to view their past chest x-ray images along with the heatmap and predictions generated by the AI model.
- P1: Ensure the website is fully responsive and optimized for mobile devices.
- P2: Implement a consent management system for future model training: create a clear and concise consent form explaining how the data might be used for model improvement.
- P2: Aggregate data and generate statistics, develop interactive charts and graphs using Svelte to visualize trends and patterns. Create a feature for healthcare providers to analyze population health trends.
- P3: Implement a theme switch from light mode to dark mode and vice versa.

10 Data and Metrics

10.1 Data for Training/Building Features

We have used the Stanford's CheXpert dataset to train and test our AI model. The dataset contains 14 different chest conditions. The heatmap is generated by extracting the features from the last layer of the CNN architecture.

NIH dataset was used in earlier stages of development but due to its poor quality of labels we have decided to only use CheXpert for our final model.

10.2 Dataset Information

We plan to use the following datasets:

- CheXpert: https://aimi.stanford.edu/datasets/chexpert-chest-x-rays
- NIH Chest X-rays: https://www.kaggle.com/datasets/nih-chest-xrays/data?resource=download

10.3 Performance Metrics

We will use the following metrics to evaluate our system's performance:

1. **Accuracy**: The percentage of total correct predictions made by the model across all classes. Goal: $> 80\%$

2. **Precision**: The proportion of correctly predicted positive cases out of all cases predicted as positive. Goal: $> 80\%$

3. **Recall**: The proportion of correctly identified actual positive cases out of all true positive cases. Goal: $> 80\%$

4. **Area Under the ROC Curve**: A measure of how well the model separates positive and negative classes. Goal: $> 90\%$

5. **Area Under precision-recall curve**: A measure of the model's effectiveness in predicting positive classes, especially when dealing with imbalanced datasets. Goal: $> 80\%$

These metrics are relevant because they provide a comprehensive understanding of the model's performance, particularly when dealing with classification tasks. Each metric evaluates the model's predictive capability from different perspectives, ensuring the model meets the goals of correctness, reliability, and robustness. Here's why each one of them is relevant:

1. **Accuracy** is a general measure of how often the model makes correct predictions across all classes. It is useful when the classes are balanced (i.e., there are roughly equal numbers of positive and negative cases). However, it might be misleading in cases with class imbalance, where a model can predict the majority class well while neglecting the minority class.

2. **Precision** focuses on the model's ability to correctly identify only the positive cases, making it crucial when false positives are costly.

3. **Recall** captures the model's ability to identify all relevant positive cases. It's important in situations where false negatives (missed positive cases) have serious consequences.

4. **Area Under the ROC Curve** provides insight into how well the model can distinguish between the positive and negative classes across different decision thresholds. A high AUC-ROC value means the model is consistently making better predictions, regardless of the threshold chosen. It's especially useful in multi label classification problems.

5. **Area Under precision-recall curve** is more informative than area under ROC when dealing with imbalanced datasets (where one class significantly outnumbers the other). It focuses on the trade-off between precision and recall, making it more sensitive to how well the model handles positive cases in such scenarios.

11 Look and Feel Requirements

11.1 Appearance Requirements

We have given a professional look to our website since we are dealing with the medical field. Our website is both intuitive and easy to use for the general public.

11.2 Style Requirements

The website must be presentable in a way that, people who may lack technical knowledge must not struggle using it.
It must be accessible to all users regardless of the devices used to access the website.
The layout of the website would adhere to software requirement guidelines.

12 Usability and Humanity Requirements

12.1 Ease of Use Requirements

The website would be easy to navigate, the user would not need technical experience to navigate the website.

12.2 Personalization and Internationalization Requirements

When reports are uploaded, the displayed time (of when the report was uploaded) is respective to the user's local time, which meets the internationalization requirements. The username and password would be personalized to the user, which further meets the personalization requirements.

12.3 Learning Requirements

Users should have access to comprehensive learning resources that facilitate understanding and usage of the model. This includes tutorials, documentation, and FAQs that cover both basic and advanced functionalities. Interactive learning modules, such as walkthroughs and examples, should be integrated to guide users through complex processes and enhance their overall experience with the system.

12.4 Understandability and Politeness Requirements

The user interface must prioritize clarity and simplicity to ensure that all users, regardless of their technical expertise, can navigate the application effectively. Language used in instructions and prompts should be polite and respectful, promoting a positive user experience. Additionally, any error messages should be constructive and provide clear guidance on how to resolve the issue.

12.5 Accessibility Requirements

The application must adhere to accessibility standards to ensure it is usable by individuals with disabilities. This includes providing alternative text for images, ensuring keyboard navigation support, and using high-contrast color schemes for better visibility.

13 Performance Requirements

13.1 Speed and Latency Requirements

It's important for the user to have a seamless experience when navigating the website or uploading resources. The latency and speed would be reasonably enough to not cause issues when interacting with the model.

13.2 Safety-Critical Requirements

The user log-in and data must be hashed, the images uploaded would be stored as binary with encryption on a local database.