MEDICAL REPORT ANALYSIS AND ARCHIVING USING IMAGE PROCESSING AND OPTICAL CHARACTER RECOGNITION

By

Abdulla Ahmed Zahran
Ahmed Adel Ahmed
Remon Albear Filly
Mohammed Almotasem Mohammed

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
BACHELOR OF ENGINEERING
in
Systems and Biomedical Engineering

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Under the Supervision of

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Acknowledgments

For our work to reach its current state we had gone through many hard stages, which we wouldn't pass without the help of those great persons

First, we are grateful for our mentor professor Dr. Ahmed Kandil, who was always rectifying our perspective about what to do and when to do it

Second, we must specially thank Dr. Ahmed Ali, A consultant Pediatric, who was such a lifesaver by providing us with the needed medical report for us to complete our work

Finally, we have to thank our college for accepting us into the fund program with which we were able to afford the money we needed.

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Abstract

As a patient, you'll always struggle with your medical records. keeping track of each one carrying them around at every clinic and hospital. not to mention the fact of the time and money you consume waiting for an issued report to be received, or your analysis to be shown by your examining doctor. just too many difficulties facing you besides dealing with your sickness.

Monitoring that we decided that we use today's technology like Artificial Intelligence (AI) to solve as many as we can from those difficulties.

Our project -which has a friendly UI using React Native and Nodejs- is built on Optical Character Recognition (OCR) and Natural Language Processing (NLP) techniques to recognize and digitize the input report

The algorithm simply takes the report as a picture captured by its camera, rectifies, and enhances it, and converts it into a digital form to ease its understanding and storing it.

Given the previous is done the patient would have a full functionality editing, deleting, and assigning his report to a doctor of his own choice, while gets informed of his abnormal results and how to deal with them using our medical database until his analysis is done and sent by his doctor saving him time effort and money.

We sure hope that what we had created will help to notch our Biomedical society up and make a patient life easier

Chapter 1 : Introduction

As the population of the world increases and humanity's main perspective has become better health, no of medical reports issued every day is growing at an enormous rate.

Keeping tracking all that data in paper form would be an impossible task for any laboratory, doctor, or even patient.

So, the simple solution was to try harnessing the technology surrounding us and digitize those records, allowing retrieving and updating them anytime anywhere.

Another problem that had to be addressed is that the “medically” of any report or in other words the difficulty to understand the simplest information a report contains without any previous medical experience, leaving the patient ignorant with his/her medical condition and waiting for his appointment with a doctor to get an analysis, which in some conditions it didn’t happen fast enough can lead to severe problems harming the patient.

Going to another aspect is what could be done by some patients nowadays in taking medical consultations from the different platforms of social media or internet blogs.

Where anyone can post his/her own opinion without having any medical background endangering patients’ lives.

In An Attempt to exploit what we studied and learned all those past years to help people solving the above problems, we resorted to AI and its many specializations as OCR and NLP to come with an innovation that will allow the patient to digitize all paperwork, connect the patient directly to a medical consultation saving them money and effort and finally protecting him from any wronged opinion that could risk his/her life.

1.1. HIS (Healthcare Information System)

As a healthcare organization, you strive to offer top-quality care to your patients. One of the key challenges you are facing is how to provide your medical staff with convenient, on-demand, and cost-efficient access to patient medical records. Hospital Information Systems (HIS) cannot fully address this challenge if you have a backlog of medical records in paper format. These paper records, which are extremely costly to store and retrieve, need to be incorporated into your HIS to provide a unified view of each patient.

Figure 1: HIS Schema

1.2. EMR (Electronic Medical Record)

Our value proposition to you is to eliminate your dependency on paper records and associated physical storage and retrieval costs

allowing your healthcare professionals to access complete electronic medical records (EMR) for each patient with a press of a button and to focus on what they do best – take care of their patients.

1.3. Statistics

1- The NHS (National Health Service) reported that the estimated annual cost of maintaining an onsite medical records library is between £500,000 and £1 million for each Trust - which could be better spent on additional necessary resources, such as doctors or nurses.
2- Scanning patients' medical records could save the NHS £300 million a year.
3- It is believed to take 10,000 full-time staff to manage medical records, typically housed in 200,000 sq m of space that could be used for frontline clinical care.

Chapter 2 : Market Research

Our project is supposed to achieve the following:

- Applying the new AI developed techniques in improving the healthcare system.
- Provide the help that the patient needs in reading the test analysis and understanding the diagnosis of the condition.
- Prevent the wrong diagnosis from people from outside the medical system that sometimes happens on platforms like social media or unauthenticated websites.
- Save the patient lots of time and money.
- The system can be updated in the future after collecting enough data and adding more features, to help the doctors in verifying any type of diagnosis they need.

2.1. Targeted Audience

- Patients.
- Laboratories & Medical Units.
- Doctors.
- Curios Persons for Wellness.

2.2. SWOT Analysis

Figure 2: SWOT Analysis Items

2.2.1. Strengths

- On-cloud services (availability).
- Free services are available.
- On-demand consultations with verified doctors.
- Independent profile for each user.
- Ability to assign any report to a doctor immediately.
- Share/export features with many options (text or image formats).
- Storage of a huge number of reports.
- User-friendly application on android.
- Available online using website.

2.2.2. Weaknesses

- Needs internet for analysis and permanent storage.
- Some features are paid/ad-free.
- Limited access to the website.
- Not available on iOS.

2.2.3. Opportunities

- The only platform specialized in healthcare and wellness in medical records and laboratories market nationally.
- Ability to update and add more features.
- Integrations with any platform are possible.

2.2.4. Threats

- IOS development is a challenging mission and not available.
- User resistance for digitization.
- International competitors may enter the local market.

Chapter 3 : Data Acquisition

Due to different types and structures of the reports on each lab, patient privacy issues, and covid-19 pandemic it was hardly difficult to collect information, but we managed to gather information from local doctors specialized in hematology to collect different cases and CBC reports as starting point to our project to standardize and build a prototype.

Data Collection: Our methods of data collection will be best suited to the project at hand. Research methods will include:

- Focus groups.
- Collection of social media data.
- Surveys via the Internet, phone, or email.
- Long-range in-home consumer tests.
- Distribution of samples.
- In-person promotional.

The stage of collecting data is crucial before starting to work as it gives a conceptual view of how your future input would be like. For that our first step was to try and gather as many reports and lab templates as we can before going any further.

But, unfortunately, most of our attempts we are condemned to fail for two main reasons:

- Most of the medical centers and laboratories refused to help for the sake of keeping the secrecy of the patients' data.
- In the previous months and due to the COVID-19 pandemic, most hospitals were off-limits for us to visit and access any needed data.

To be able to continue our work, we were able to get help from local doctors specialized in Hematology, where they offered us the needed data and help that we need.

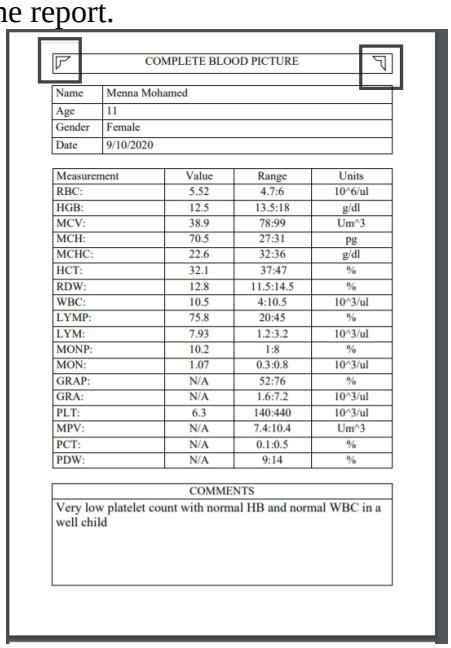
We decided that to be able to achieve the best results that we could, our work would be based on a certain design of a blood report, and later the idea would be generalized for all possible reports.

The second step was to try to expand our dataset by capturing the reports from many directions and using different effects on the same image which would eventually lead to different images.

3.1. Image Preprocessing

After having enough images for our report template, we were ready to move to the next step which was data preprocessing.

We walked through two different aspects in these criteria; the first was by modifying the template with some distinguishing marks at its corners to ease for the OCR model identifying the report.



COMPLETE BLOOD PICTURE

Name	Menna Mohamed
Age	11
Gender	Female
Date	9/10/2020

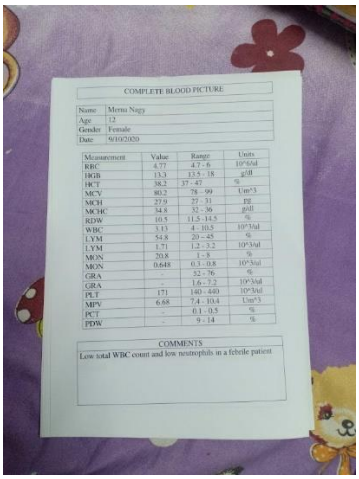
Measurement	Value	Range	Units
RBC:	5.52	4.7:6	10^6/ul
HGB:	12.5	13.5:18	g/dl
MCV:	38.9	78:99	Um^3
MCH:	70.5	27:31	pg
MCHC:	22.6	32:36	g/dl
HCT:	32.1	37:47	%
RDW:	12.8	11.5:14.5	%
WBC:	10.5	4:10.5	10^3/ul
LYMP:	75.8	20:45	%
LYM:	7.93	1.2:3.2	10^3/ul
MONP:	10.2	1:8	%
MON:	1.07	0.3:0.8	10^3/ul
GRAP:	N/A	52:76	%
GRA:	N/A	1.6:7.2	10^3/ul
PLT:	6.3	140:440	10^3/ul
MPV:	N/A	7.4:10.4	Um^3
PCT:	N/A	0.1:0.5	%
PDW:	N/A	9:14	%

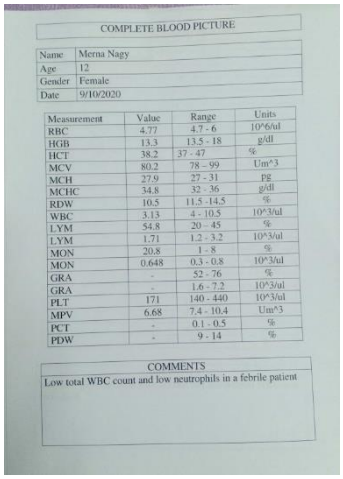
COMMENTS

Very low platelet count with normal HB and normal WBC in a well child

Figure 3: Example for corner marks used to detect and identifying.

The second one was by using computer vision and extracting the descriptors and the features of the template and comparing it with those of any input image to upright the input image and cut any unnecessary background which could affect the results.





COMPLETE BLOOD PICTURE

Name	Merna Nagy
Age	12
Gender	Female
Date	9/10/2020

Measurement	Value	Range	Units
RBC	4.77	4.7 - 6	10^6/ul
HGB	13.3	13.5 - 18	g/dl
HCT	38.2	37 - 47	%
MCV	80.2	78 – 99	Um^3
MCH	27.9	27 - 31	pg
MCHC	34.8	32 - 36	g/dl
RDW	10.5	11.5 -14.5	%
WBC	3.13	4 - 10.5	10^3/ul
LYM	54.8	20 - 45	%
LYM	1.71	1.2 - 3.2	10^3/ul
MON	20.8	1 - 8	%
MON	0.648	0.3 - 0.8	10^3/ul
GRA	-	52 - 76	%
GRA	-	1.6 - 7.2	10^3/ul
PLT	171	140 - 440	10^3/ul
MPV	6.68	7.4 - 10.4	Um^3
PCT	-	0.1 - 0.5	%
PDW	-	9 - 14	%

COMMENTS

Low total WBC count and low neutrophils in a febrile patient

Measurement	Value	Range	Units
RBC	5.13	4.7 - 6	10^6/ul
HGB	13.8	13.5 - 18	g/dl
HCT	41	37 - 47	%
MCV	80.0	78 – 99	Um^3
MCH	27.0	27 - 31	pg
MCHC	33.7	32 - 36	g/dl
RDW	10.8	11.5 -14.5	%
WBC	10.6	4 - 10.5	10^3/ul
LYM	7.44	20 – 45	%
LYM	0.791	1.2 - 3.2	10^3/ul
MON	2.34	1 - 8	%
MON	0.248	0.3 - 0.8	10^3/ul
GRA	-	52 - 76	%
GRA	-	1.6 - 7.2	10^3/ul
PLT	287	140 - 440	10^3/ul
MPV	5.10	7.4 - 10.4	Um^3
PCT	-	0.1 - 0.5	%
PDW	-	9 - 14	%

(a) (b) (c)

Figure 4: Example for CV extraction of data and background elimination. (a) original image captured using a mobile camera. (b) background elimination image. (c) desired part of the image.

Doing these steps wasn't easy. but after wrapping them up we were ready to move on to the next mission.

Chapter 4 : Materials and Methods

4.1. Optical Character Recognition (OCR)

OCR is a technique that converts digital images of text to a digital form which the machine can understand and process.

Our eyes read text by matching a pattern of light and dark, convert those patterns into characters and words then understand it, OCR technique attempts to mimic this technique of our visual system.

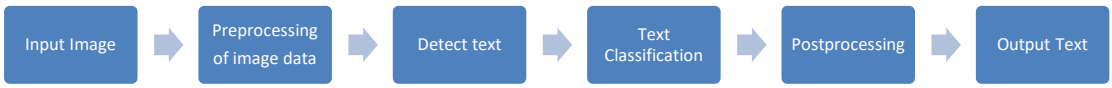


Figure 5: Flowchart for OCR system steps

4.1.1. Preprocessing

This step includes Noise reduction, binarization, de-skew, layout analysis, and more.

4.1.2. Detect text

Detect the location of the lines, text, and characters.

4.1.3. Text classification

There are two techniques used in this step, matrix matching and features detection.

The matrix matching technique matches the image pixel by pixel with a database of letters and finds the most similar letter, in the feature detection technique it tries to extract useful features from the image like lines, curves, and loops then match the image with a database of letters but with fewer dimensions than the first technique.

4.1.4. Postprocessing

To reduce errors in the classification, step a dictionary of words may be used, if the output word isn't in the dictionary, the word is getting replaced by the closest similar word.

In our project, we tried three different techniques to extract the text from the image,

- OCR for the whole image:
  In this technique, we apply the algorithm to the image directly and we used two APIs which are using AI algorithm to improve the performance of the text extraction:
  - Google OCR API
  - Tesseract OCR API
- OCR after cropping the locations of the data:
  In this technique, we crop exact areas from the image where the data are located, then apply the OCR algorithm to the cropped image and we used OpenCV and pytesseract packages in python to do this
- Nanonets:
  Is software that uses advanced OCR and Deep Learning to extract relevant information from unstructured text and documents
  We used this software to train a deep learning model to extract the interesting data from our template

4.2. Natural Language Processing (NLP)

NLP is a subfield of computer science and artificial intelligence concerned with the interaction between computer and human language and how the computer can understand, analyze and process natural language data.

In our project, we had a problem the result of the OCR step is unstructured data which is very hard to process to store, so to overcome this problem we used a technique from the NLP area called pattern matching, and we apply pattern matching using regular expression (regex).

4.2.1. Regex

Regex is a sequence of characters that specifies a search pattern, then using string-searching algorithms we can apply find or replace operations on the string.

4.3. Mobile Application

We use a mobile application framework for building Report Scanner Application to be used by smartphones running on Android or IOS systems. React Native is chosen to be our mobile application framework.

We use Redux for state management and manipulating data, use cross-fetch API to send and retrieve data to and from the server, use also react-native-camera to access the phone camera to capture pictures to the reports, and more and more packages to be able to do animation and properly show the pages.

4.4. Web Platform

As we all know the backend of any website is like its backbone that is responsible for all the routes and requests that are given to the server. We developed the back end using main JavaScript libraries such as NodeJS, expressJS, and MongoDB.

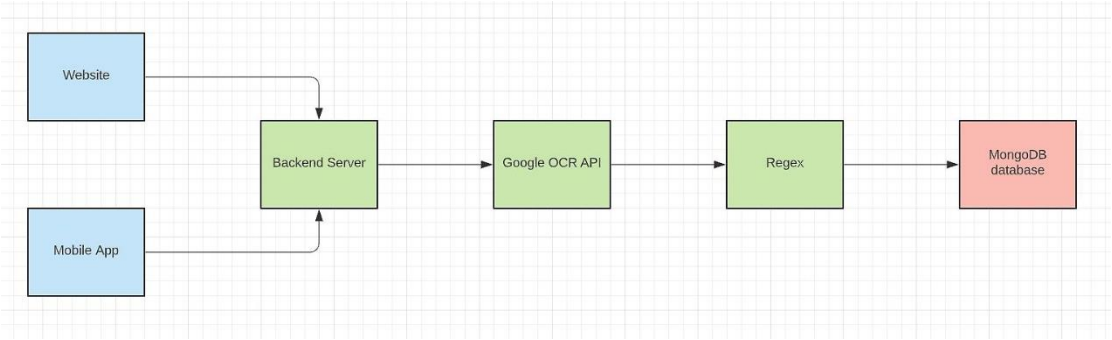


Figure 6: Block Diagram of the Project

4.4.1. NodeJS

NodeJS is an open-source, cross-platform, backend JavaScript runtime environment, that runs on the V8 engine which is the engine of Google chrome and executes JavaScript code outside a web browser. NodeJS gave us access to create a server that can run and listens to the requests handed to it.

4.4.2. Express.js

It’s an open-source backend web application framework for NodeJS, it's designed for building web applications and APIs, which make the development easier and more focused on the logic. expressJS makes your development easier as it connects the programmer in a more friendly way with the NodeJS library.

4.4.3. MongoDB

It’s an open-source cross-platform document-oriented database, classified as a NoSQL database that uses ISON-like documents with optional Schemas. and it also introduces the mongoose that we used during our work which is a library that eases handling the data, saving and modifying it.

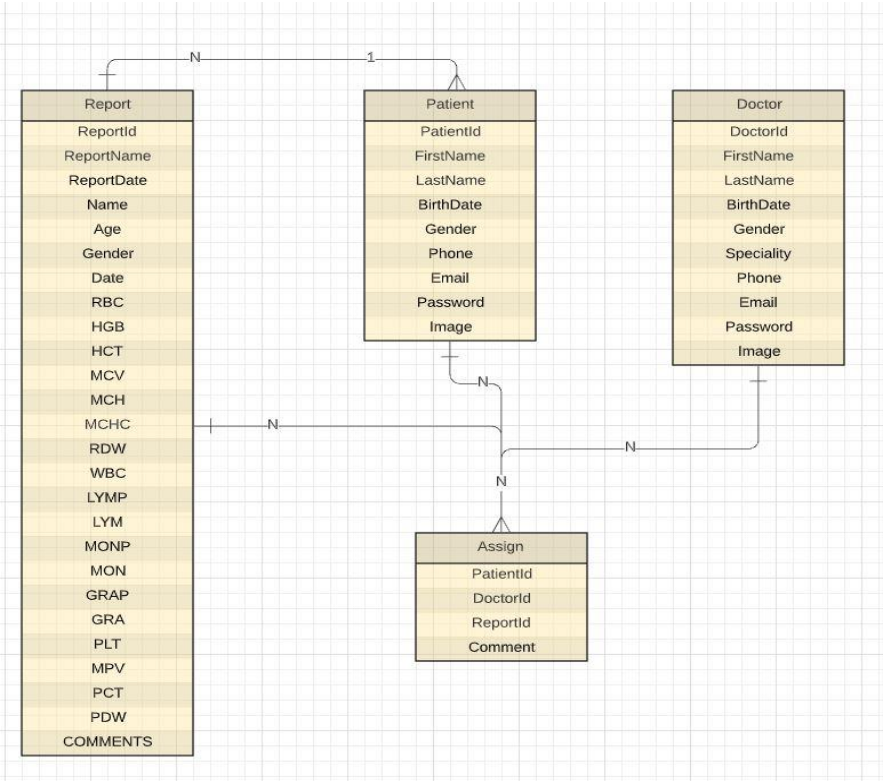


Figure 7: Relational Model of the Database

Chapter 5 : Results

5.1. OCR

5.1.1. Google API

Using Google API for the whole image gives us better results than the other techniques.

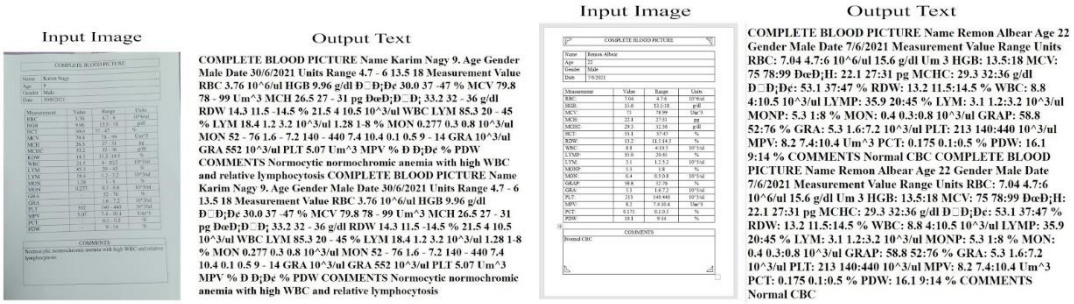


Figure 8: Google OCR comparing between input and output.

And as shown the output above was messy and not readable.

5.1.2. Tesseract OCR

By cropping the interesting part and using Tesseract OCR this technique gives us good results:

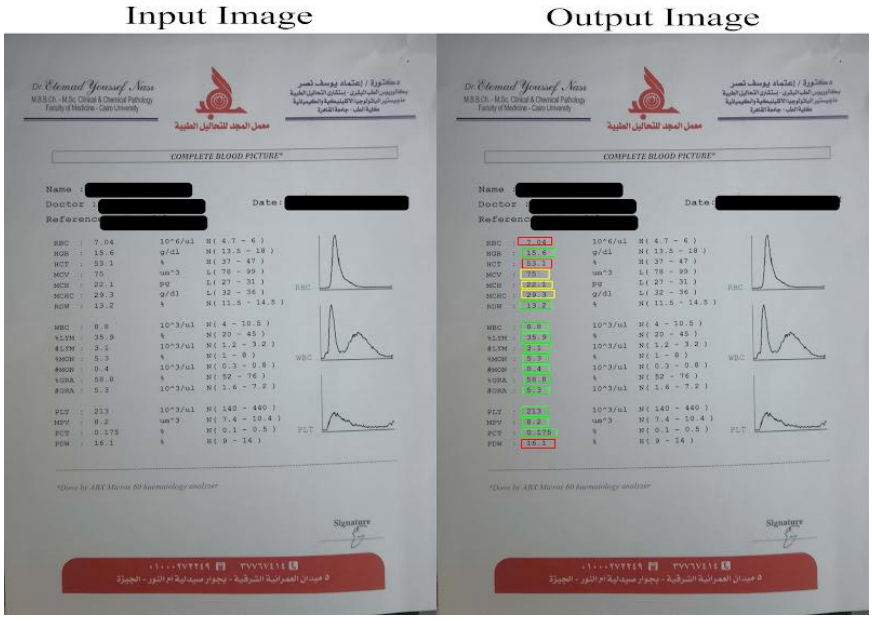


Figure 9: Tesseract OCR comparing between input and output.

as shown, we draw boxes around the data where the color indicates the level of the measurement, high(red), yellow(low), and green(normal)

5.2. Pattern Matching with regex

As shown previously the output of the OCR is very messy and in unstructured form so to be apple to store it we need to convert it to structured form and to do that we used pattern matching.

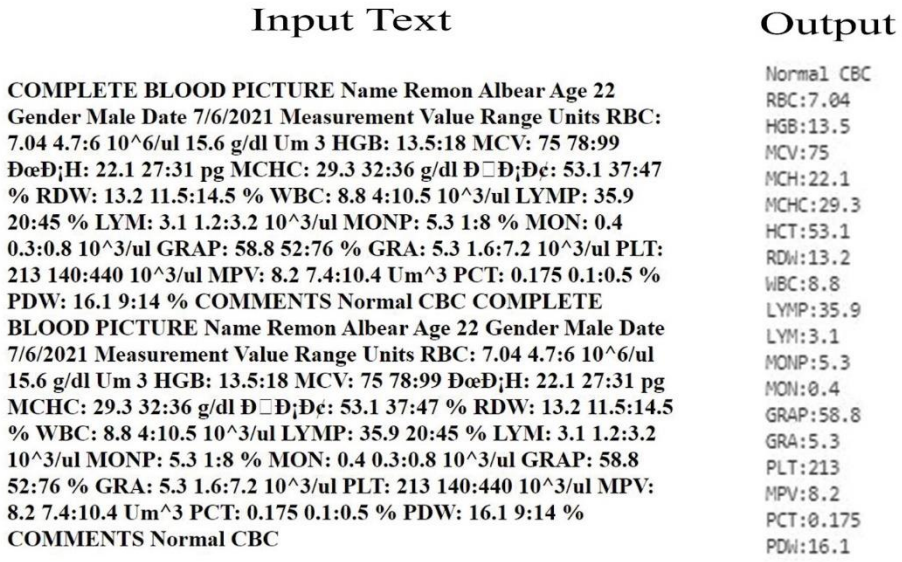


Figure 6: Reconstruction of the data using Regex.

5.3. Android Mobile Application

As the primary result of our project is required to be user-friendly and available for a wide range of users.

5.3.1. Report Scanner Functionality

Report Scanner will provide a lot of capabilities to the user (like Sign in/Up) and deliver our service to him (Scanning/Saving Reports and provide information) we will discuss briefly each features our app provides.

5.3.2. Sign-In and Sign-Up

It’s very easy to Sign Up in Report Scanner all it required is a phone number and password to have an account and a few other personal information and enjoy our services. If you are a doctor, we need to know your specialty.

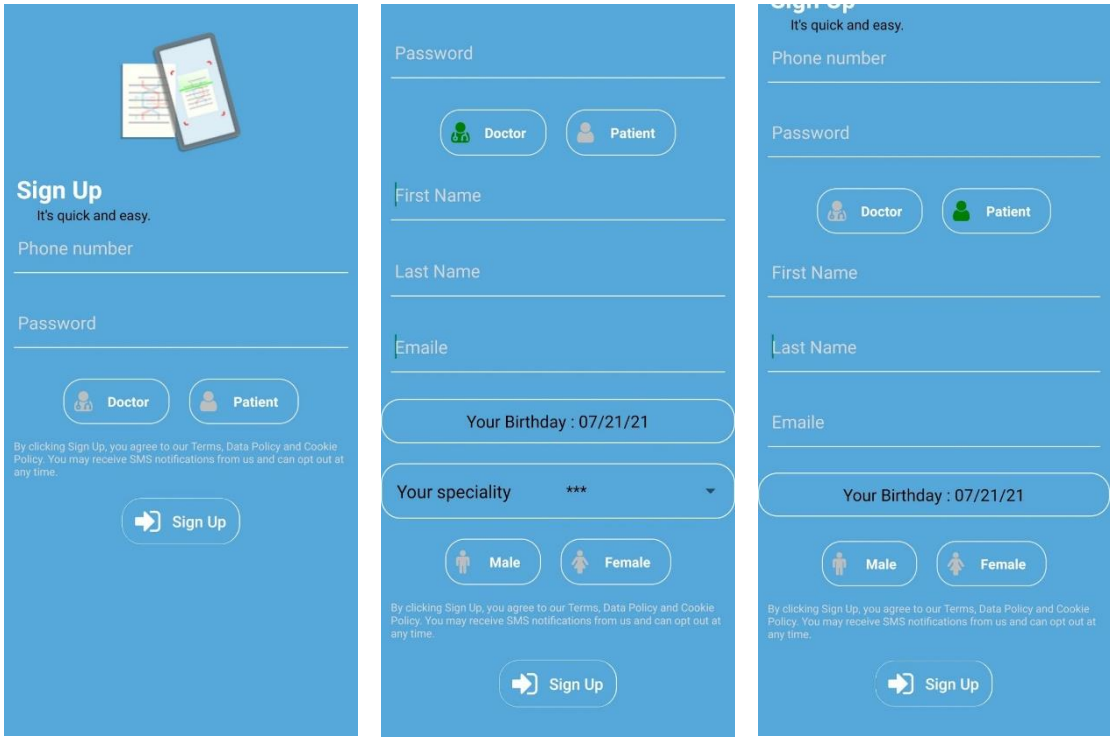


Figure 7: Mobile app - Sign-up for different modes.
(a) Main page (b) Doctor Sign-up (c) Patient Sign-up

After signing up you can go and sign in and be sure your data is safe and your password is hashing and no one can open your account except you.

Figure 8: Mobile app - Sign-in

5.3.3. Home Page

After signing in all your previous reports will appear to you if you want to check them again.

Shown below is the home screen which shows all reports and also has the other options to add a report from the mobile camera by scanning or even through filling a table as explained later.

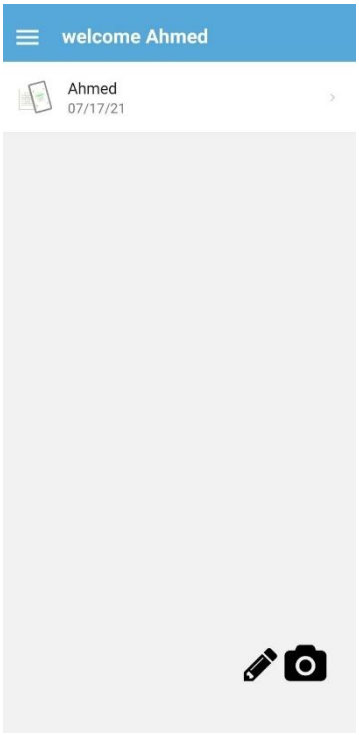


Figure 9: Mobile app - Home screen

5.3.4. Inserting the report/test

You can choose between two methods to enter your test by pressing on the pencil icon you will be asked to enter your test result by filling a table that will show to you.

But if you press on the camera icon you will use the app camera to capture your test result and we will do the rest for you.

5.3.4.1. Text Input

If you choose to insert it cell by cell a table will appear to you and you should fill in all the cell's values.

After filling all of them we will ask you to give a name to your test like the father test or my blood test. Enter the date that you made that test on, Enter the gender of the patient because it is sometimes necessary for the doctor to know the gender of the patient and the age too.

After that, you will notice that the report shows on your homepage you can check it.

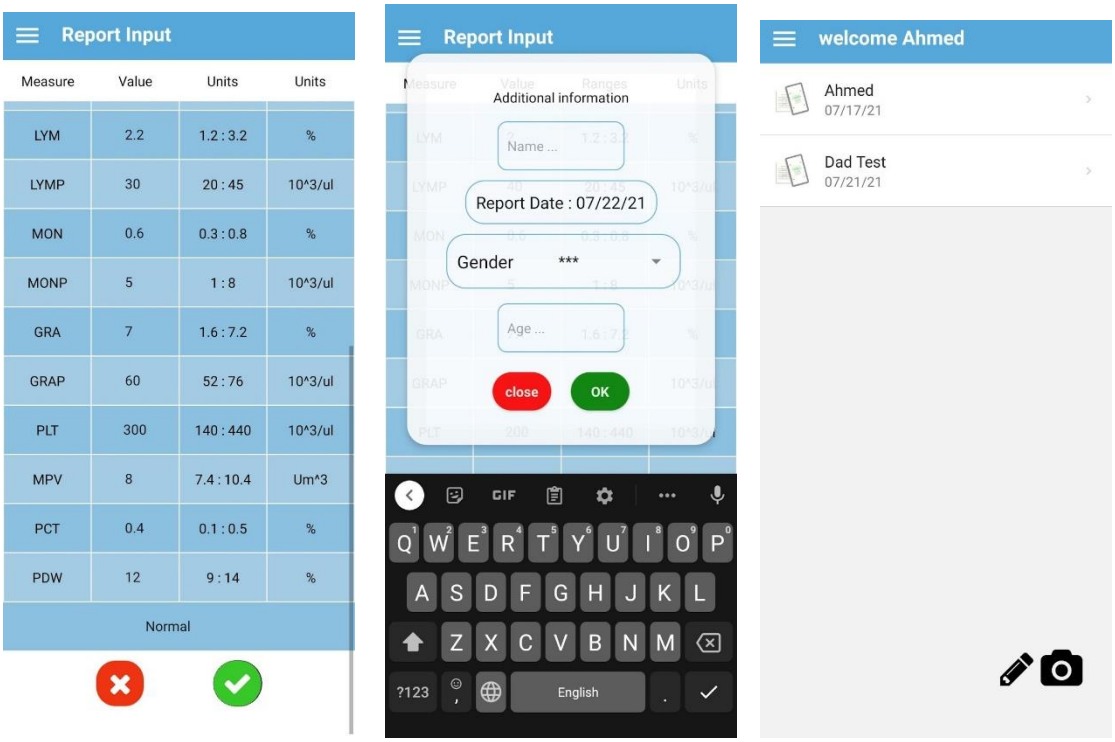


Figure 10: Mobile app - Manual input for reports and tests.

5.3.4.2. Camera Input

If you press on the camera icon you will be asked to take a picture of your test result then press the right icon the picture taken will show on the page by pressing on it you can see the whole picture to check if it's ok or not. Then press the right button to send the test result picture to the server to be processed. The loading animation will show waiting for the response from the server.

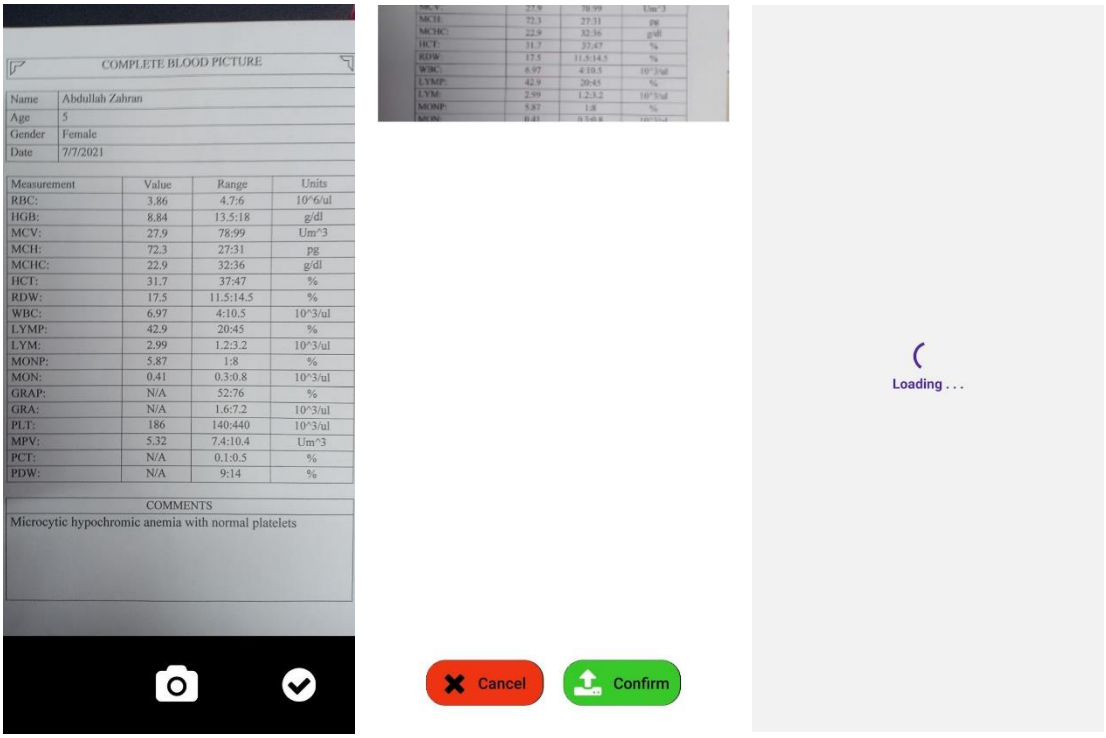


Figure 11: Mobile app - Automatic input for reports and tests.

When the server sends back the data of your test result we will fill the table for you, a table containing your result will show to you to check if any mistake happened by the algorithm. After you check it out you will be asked to fill the same data you entered with a text input form to save your test result on our platform.

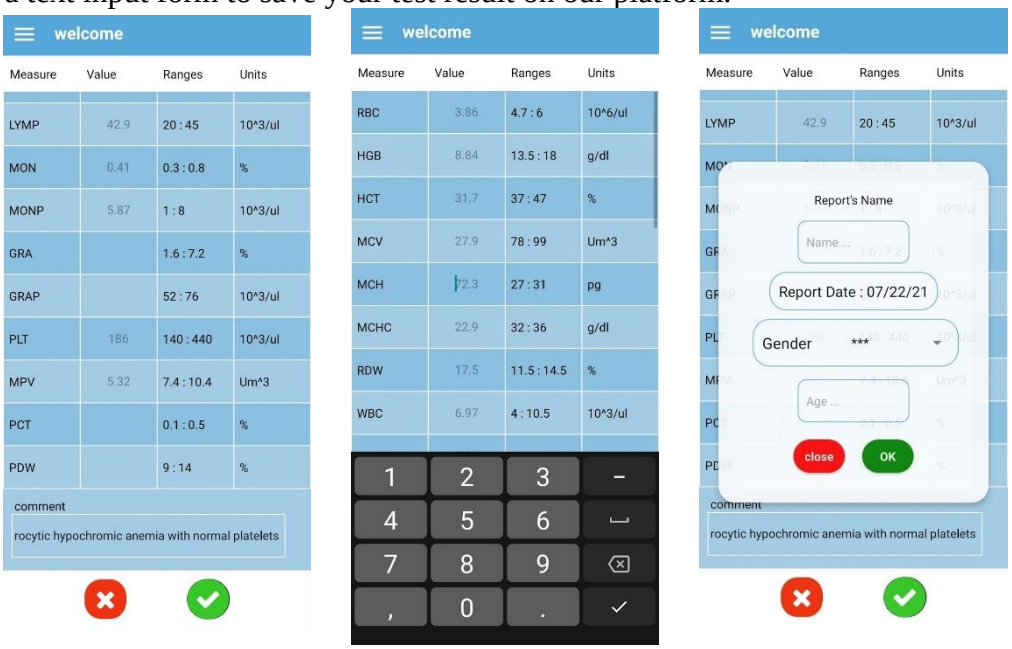


Figure 12: Mobile app - Validation step for automatic input for any manual modifications.

5.3.5. Report/Test Presentation

By pressing on the report page will show to present the report as the following:

Figure 13: Mobile app - Data preview.

5.3.6. Additional Information

At the end of the row, you can see an exclamation icon. e.g., If you want to know more about RBC you can press on the exclamation icon at the end of its row. that will take you to a page filled with information about RBC -what its meaning, why it's important to be measured, and more.

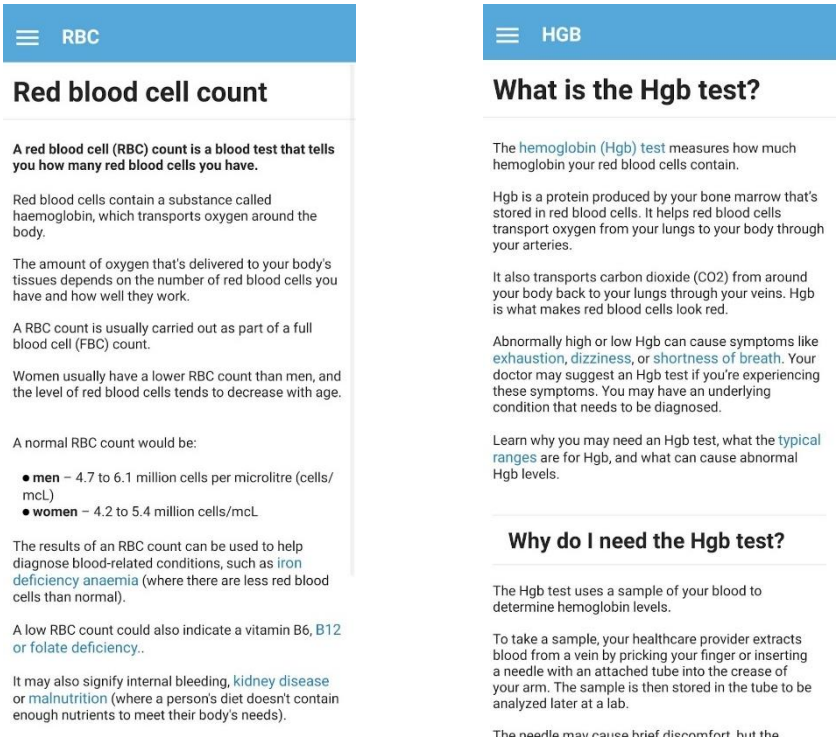


Figure 14: Mobile app - Additional information preview.

5.3.7. Reports Features

All shown tests have more capabilities. You can by swiping it lift to see two more features. Delete or share.

5.3.7.1. Deleting Report

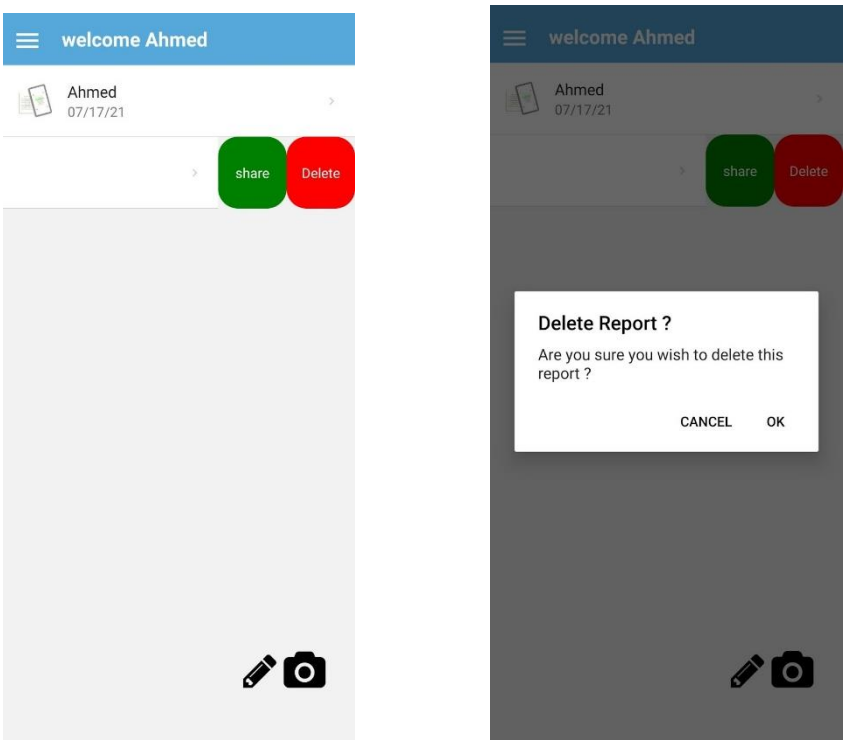


Figure 15: Mobile app - Delete report/test feature.

5.3.7.2. Sharing Report

By pressing the share button, you will be sent to another page that shows you all the doctors signed up in our app. You can see the profile of any of them and choose who you will send your test to.

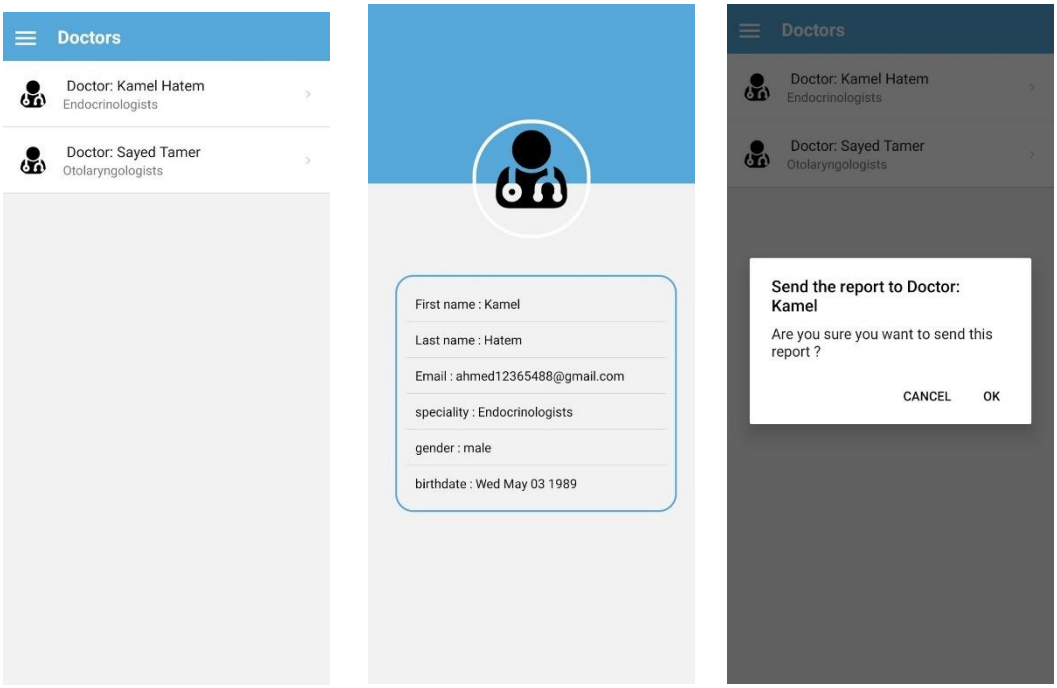


Figure 16: Mobile app - Assigning a report/test to a doctor.

When the doctor logs in he will see your test on his homepage and has the capabilities to see the whole test as you can and delete it if he wants.

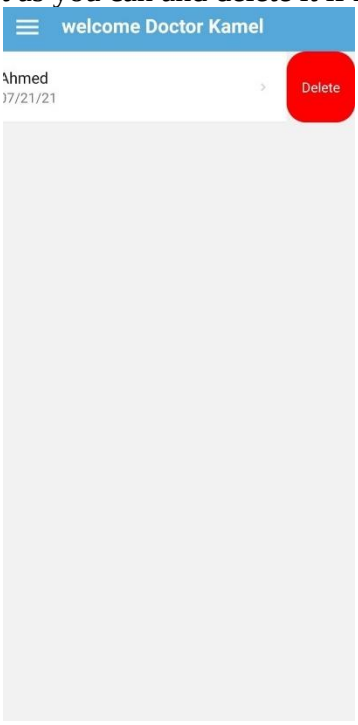


Figure 17: Doctor's side of our platform showing the assigned report.

5.4. Online Website

Although our initial plan was to implement only a mobile application, the idea of having a website that can serve the same functionality was at the back of our minds.

Having that website could be a very good impact to ease the usage of our idea by medical centers or medical laboratories where they keep all their data on systems that aren't related to IOS or mobile applications, but now they will be able to digitize all needed data and easily share it with their patients.

So, we started managing our way into implementing a user-friendly website and got the following:

Figure 18: Website - Home screen.

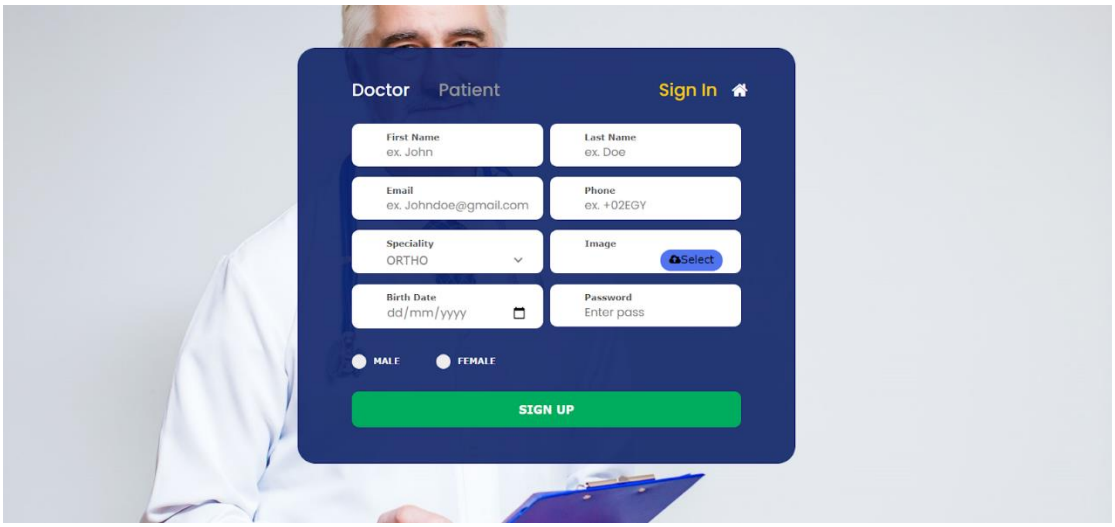


Figure 19: Website - Sign-up

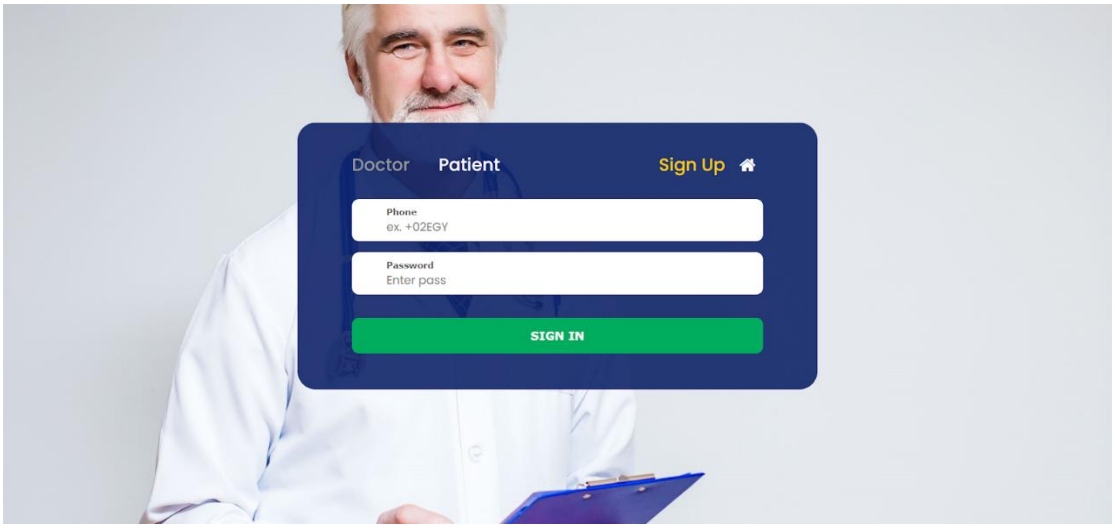


Figure 20: Website - Log-in

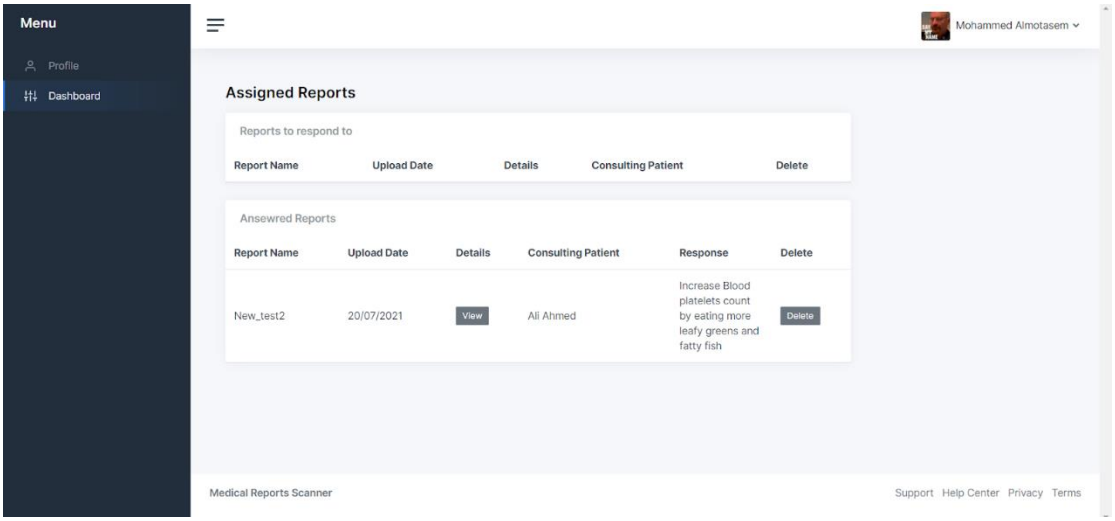


Figure 21: Website – Dashboard

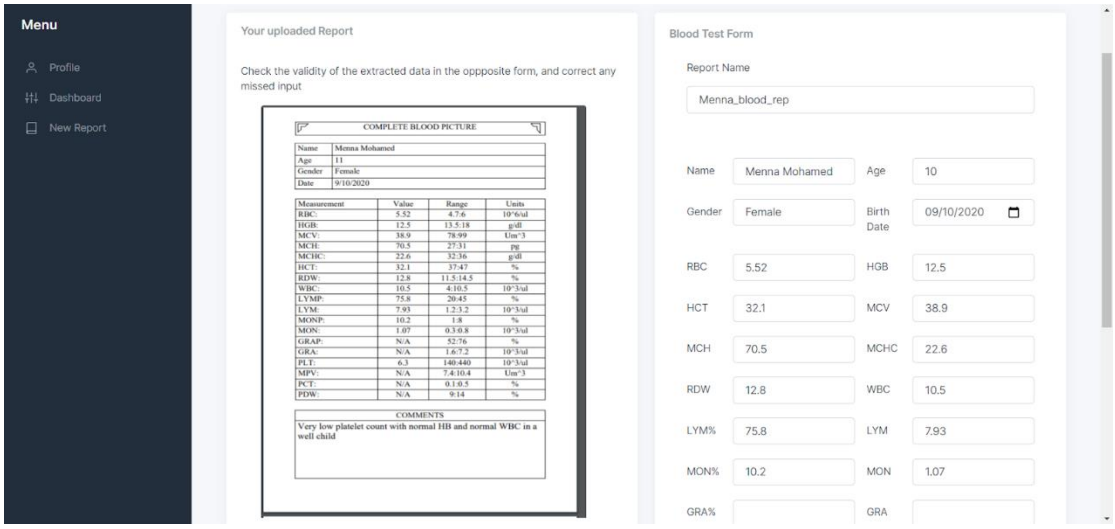


Figure 22: Website - Example of an uploaded report/test.

Chapter 6 : Discussion

6.1. Benefits

The most noticeable benefits of medical report scanning and archiving systems:

- Significantly reduce time spent looking for documents.
- Improved customer service and efficiency.
- More attention toward patient care and treatment.
- Reduce costs and increase productivity.
- Get more out of your EMR or EHR Systems.
- Eliminate bulky cabinets for more profitable use of space.
- Reduce office clutter and become more organized.
- Backup plan for disaster recovery or loss of medical charts.
- Compliance with HIPAA and HITECH legislation.
- Peace of mind that essential data is protected & compliant.

6.2. Problems

During research and development times we faced many problems.

The most significant problems in our project generally were:

- With medical documents in physical format, they are at risk of being misfiled or lost, which is potentially dangerous when they contain sensitive and private information.
- If a disaster occurs such as irreversible damage or loss, this can put healthcare organizations at risk of serious compliance violations.

6.3. Methods Discussion

6.3.1. Why React Native?

React Native is an open-source mobile application framework created by Facebook, Inc.[8] It is used to develop applications for Android,[9] Android TV,[10] iOS, macOS,[11] tvOS,[12] Web,[13] Windows,[11] and UWP[14] by enabling developers to use React's framework along with native platform capabilities.[15] We choose it because it’s using JavaScript language which is a powerful language making dealing with data and a lot of things around web and mobile development so easy. The community of react native is very wide we can find a lot of solutions for problems we met. React Native establish its standing by making a lot of powerful and very known apps like Facebook (the founder of React Native and use it in production for their Group App and their Ads Manager App)[17] Shopify, Discord, Skype Tesla, and Uber Eats and much more known apps using React Native. And it’s very required in the market.

6.3.2. Why Redux?

Redux is a Predictable State Container for JS Apps. It is most commonly used with libraries such as React[16] or Angular for building user interfaces. Similar to (and inspired by) Facebook's Flux architecture, it was created by Dan Abramov and Andrew Clark. We use it because it makes manipulating data very easy between different components and very safe from making any mistakes and changing the data. There are a lot of benefits to use redux.

- Predictability of outcome: there is always one source of truth, the store, with no confusion about how to sync the current state with actions and other parts of the application.
- Maintainability: having a predictable outcome and strict structure makes the code easier to maintain.
- Organization: redux is stricter about how code should be organized, which makes code more consistent and easier for a team to work with.
- Developer tools: developers can track everything going on in the app in real time, from actions to state changes.
- Server rendering: this is very useful, especially for the initial render, making for a better user experience or search engine optimization. Just pass the store created on the server to the client-side.

Cross-fetch API is very useful when the same JavaScript codebase needs to run on different platforms.[18] So, it’s a very nice choice for us because we use a JavaScript framework for building the app and use Nodejs for building a server.

react-native-camera API is used to access the camera of the smartphone giving us a lot of capabilities to do what we want without any difficulty or app crashing because of a lot of modifications in many files.[19]

we also use a lot of packages to make our app user-friendly by adding some animation and making it easier to use.

Chapter 7 : Conclusions and Future Work

7.1. Conclusion

A patient is filled up enough with his sickness, so our goal as biomedical engineers is to try helping him with the technical issues as hard as a doctor is helping to cure him.

And by our world prospective AI is the upcoming key for many locked solutions and knowing that fact we acted to find an innovation that will make our world better, draw a smile on patient's face and ease a doctor's job is taking care of his patients. We hope that the Medical Reports scanner would be the bridge that connects the patients with the healthcare system and make their journey easier.

7.2. Future Work

Innovation is a non-stopping process, and for it to progress, you'll always have to come up with new ideas and better features. and that is what we seek for our project.

We faced many problems during our journey, and our goal is to overcome each one of them soon.

Working our way to collect enough reports' templates so we can dispose of the standard form we are using giving more luxury for our users.

We also gathering a full function medical database that will depend on the NLP technique to fully analyze and diagnose a patient medical state offering him the proper treatment and hence ease the doctor's role and save time and money for the patient

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