DEVELOPMENT OF A PERSONALISED OSTEOPOROSIS MANAGEMENT SYSTEM

BY

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SUBMITTED
TO

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CERTIFICATION

This project titled, **DEVELOPMENT OF A PERSONALISED OSTEOPOROSIS MANAGEMENT SYSTEM** prepared and submitted by **OLAYEMI OREANU OLUWAPELUMI** in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE (Computer Science),** is hereby accepted

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DEDICATION

I dedicate this project to God almighty the giver of life.

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I am grateful to God Almighty, who in his infinite mercy has spared my life during this trying times and has been with me throughout my undergraduate journey.

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ABSTRACT

There is a large number of under treatment of Osteoporosis (a disease characterized by the loss of bone mass and the deterioration of the tissue) as report by the national osteoporosis foundation. Research shows that the cause of this under treatment is due to some factors such as high cost, fear of the adverse effect and lack of education or awareness among individuals.

The POMS was built on the basis that interaction of patients to the same treatment varies across various individuals due to different attributes that are unique to the individuals hence the need to personalise medicine to get a better health outcome.

The aim of the project was to solve some of the barriers that cause under treatment of Osteoporosis by personalizing the treatment and also educating and creating awareness among individuals on Osteoporosis related topics.

The POMS is a multi-platform system for both the health care providers and the patients, it helps the medical practitioners to keep track of patients in real-time and educate the patients.

It was developed with python, JavaScript and Dart

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Over the years, application of artificial intelligence (AI) has been largely beneficial in various ways ranging from image recognition, speech recognition, predictions,

sentiment analysis, and so on, leading to a massive reduction in a lot of manual processes. John McCarthy (1990) defined "artificial intelligence as the science and engineering of making intelligent machines, especially intelligent computer programs". Machine learning (ML), a subset of AI, enables computers to learn and interpret on their own when exposed to new data set, thus, resulting to various applications used in multiple industries today. ML has made doubtful ideas seen in fictional movies a reality today, playing a large role in our day to day activities (Attaran & Deb, 2018).

AI has been largely beneficial to the medical field, such as the development of medications, disease diagnosis, real-time patient flow optimization, AI assisted robotic surgeries etc. (Ahuja, 2019). AI has been used in various products and services including a clinical decision support system (CDSS). CDSS is a software related AI-based tools that help medical practitioners make optimize decisions (Sloanea & Silvab, 2019). It uses expert knowledge and also some models derived from statistical computations and the application of ML on available data (Wyatt & Spiegelhalter, 2020). Thus, by leveraging expert knowledge, it is able to analyse patients' data and make informed decisions while avoiding all human-related errors. It could be used to track patient's data before and after treatment making it possible to monitor how patients respond to the particular treatment administered (Kuperman, et al., 2007). Thus, this will help make the jobs of the medical practitioners to be more effective and seamless. Also, patients will have a better experience and a better health outcome. The development of CDSS has helped with reducing the risk of medication errors (Jia, Zhang, Chen, Zhao, & Zhang, 2016),

A survey that was carried out in 2015, on six European countries shows that 20 million people aged 50+ were estimated to be diagnosed with Osteoporosis (IOF, 2020). Most of these patients were unaware of the presence of this disease till they developed

fractures known as the Osteoporotic fracture. Stanford Health Care defines Osteoporotic fractures as fractures that are caused as a result of Osteoporosis, which is a bone condition that makes the bone more fragile resulting from loss of bone mass or deterioration of bone (Stanford, 2020). '

The micro-architectural deterioration of bone tissue increases the risk of bone fragility and bone fractures mainly in the spine and femur area. (Devikannigam, Joshua, & Raj, 2018). Bone Mineral Density test (BMD) is concluded to be the most functional diagnostic tools when identifying Osteoporosis patients while the use of fracture risk reduction remains the most pertinent to the outcome of Osteoporosis treatment (Small, 2005).

Some risk factors that greatly affect Osteoporosis, could be modifiable such as loss of weight, lack of physical activity, cigarette smoking etc. or non-modifiable advanced age, race, and disease occurrence in the family (Pouresmaeili, Kamalidehghan, Kamarehei, & Goh5, 2018). Globally, Osteoporosis is considered to occur predominantly in women than in men, the National Osteoporosis Foundation (NOF) reports reason why this happens which includes the reality that women tend to have smaller and thinner bones than men and also Estrogen, which protects the bone decreases sharply when women get to menopause. Proper diagnosis of Osteoporosis has been a big topic even among medical experts, knowing when to recommend a patient to be evaluated in Osteoporosis outside the classically targeted woman undergoing the postmenopausal stage is of great importance (Goode, Wright, & Lynch, 2019).

Although we have a lot of Osteoporosis cases, only a small number of individuals with high-risk fragility are treated (Fraser, et al., 2011). All lot of barriers have hampered the

effective management of Osteoporosis disease such as the unwillingness of patients to treat the disease, fear of the real and perceived side effects of the medication, high cost of treatment, lack of proper understanding of the disease and the complexity of medical management (Iversen, Vora, Servi, & Solomon, 2011). A lot of drugs that are effective in the treatment of Osteoporosis are available today but, minute effort has been made to systematically personalise the pharmacological approach for patients with osteoporosis on the basis of refined risk stratification (Khosla, Personalising osteoporosis treatment for patients at high risk of fracture, 2019).

Although people with Osteoporosis are best identified with BMD test while the fracture risk reduction is very relevant to the therapeutically related process as reported by (Small, 2015), thus the discrepancies in lifestyle, heritage etc. of patients plays a role in Osteoporosis treatment. Research carried by (Mathur & Sutton, 2017) explains how personalised treatment has the potential to improve the overall health outcome by reduction in cost of health.

Various literature explains how personalised treatment will help in reducing the adverse effects. Hence this could improve patient compliance thus breaking the barrier of patient's unwillingness to treat disease. Thus, the need for a Personalised Osteoporosis Support System (POSS) based on medical history.

1.2 Statement of Problem

International Osteoporosis Foundation (IOF) reports that Osteoporosis disease is under diagnosed and under treated, and we have a case where about 80% of people living with high risk or even had at least one Osteoporotic fracture are not given the necessary medical attention needed.

Survey carried out by (Simonelli, Mehle, & Swanson, 2002) shows that 61% of primary care physicians interviewed report that the potential adverse effects of medication is a major cause limiting treatment while 57% also confirmed that cost of therapy could be a major factor but when asked of the major problem of factor limiting treatment, 61% said it was the cost of treatment.

All these have a great impact on the economy, with the increasing cost of fragility fractures globally (Curtis, Moon, Harvey, & Cooper, 2017), CDSS can help in improving health i.e. decreased cost (Jacob, et al., 2017) thus, extra resources spent on Osteoporosis treatment could be used in other beneficial things in the industry and this tend to become a big problem for the society. However, to reduce these costs & improve the patient health outcomes, there is need for POSS to ensure a better treatment outcome by leveraging patients' medical records.

1.3 Aim and Objectives

The aim of this project is to develop a robust system for supporting a personalised management of Osteoporosis treatment.

The specific objectives are to:

1. To store and manage patient's information for effective monitoring/tracking
2. To automate the management process of Osteoporosis treatment
3. Build a personalisation system for Osteoporosis management
4. To build a multi-platform system, both mobile and web based system to support the management process.
5. To create datasets repository from Osteoporosis patients in real-time for further analysis.

6. To test the system.

1.4 Proposed Methodology

This project on the development of the personalised Osteoporosis management system would involve 3 steps. It describes the different steps that have been thoroughly taken in achieving the research objectives and the rationale behind the methods adopted.

1) Dataset collection: This stage involves the collection of dataset that would be used for this project. The variables will be based on the risk factors, type of medication and adverse effect of the medication.
2) Designing a classifier that would predict a medication with the least side effect based on patient's medical history.
3) Designing and implementing an AI based multi-platform system using various algorithms to achieve personalisation for the patient.

Requirements Elicitation

Techniques for gathering information for this project would include the following:

- A study would be carried out to ascertain the relevance of the system.
- Research would also be carried out to determine variables that influence the choice of medication by using the existing system available.

Requirements Analysis

All the functional requirements (expected functions to be performed by the system) and non-functional requirement (expected behavioral patterns of the system) would be stated.

Requirements Modelling

An activity diagram would be used to express the links between the activities within the system. A use case model would can be used to illustrate interactions between different actors and their mode of operation.

A class diagram can be used for data modeling to better describe the relationship between the various data objects in the system.

System Design

The following are the respective tasks and tools to be used in determining the system design:

- The overall system architecture modelling would be designed leveraging on the Subsystem Hierarchy Relationship Architecture.
- Algorithms (and flowchart or pseudo code if required) would clearly indicate the System Logical Design of health management system owing the conversion of inputs to outputs

Implementation

The proposed system would be implemented using the Python for building the ML model, JavaScript would be used for developing the web platform leveraging on the MERN stack (MongoDB, Express, React and NodeJS). While Dart programming language will be used in developing a cross platform mobile application.

1.5 Scope and Limitations of the Study

This study is for the creation of a system to enhance Osteoporosis management in patients, through personalized health care. A multi-platforms system for POSS will be developed to facilitate treatment of patient and to provide support to the patients throughout the entire process, providing them with a better understanding of Osteoporosis. A datasets repository will be created to facilitate further analysis to achieve higher accuracy in finding the right treatment plan with the least side effects and is cost effective. Testing and validation of the system will not be feasible due to the little time frame allocated to this research work.

1.6 Justification

With the high number of under treatment of people with Osteoporosis as reported by NOF there is a great need to solve this problem. Research carry out so far has pointed out some barriers to Osteoporosis, and there were some factors which stood out such as high cost of treatment, fear of the adverse effect of the medication and lack of education

and awareness among individuals and health care providers on Osteoporosis topics. Thus if there is a system that can solve some of this barriers, then there should be massive reduction in under treatment of Osteoporosis patients.

CHAPTER TWO

LITERATURE REVIEW

2.1 Preamble

Health management system (HMS) are coordinated systems which consists of several components that are solely intended to optimize different health care processes ranging from collection, storage, retrieval and exchange of patient data. Personal health systems were introduced to meet the need for solutions tailored to the unique needs of different people using platforms that supply a broad number of people while retaining high quality (Lewy, Barkan, & Sela, 2019).

Machine learning has aided so many medical processes over the years, the use of ML to support personalized medicine is increasing, i.e. Identifying treatment options that suitable for individuals based on those individual-specific characteristics (Davenport & Kalakota, 2019). The goal of the use of ML with real-time HMS data is to build a comprehensive platform to predict the most effective treatment options for patients with osteoporosis.

2.2 Health Management Information Systems

Before we proceed, it will be great to have a comprehensive understanding of what health management information (HMIS). HMIS is a system that facilitate the

collection, storage and retrieval of health data which can be processed to improve decision making (Endriyas, et al., 2019).

Considering the fact that there are multiple use cases when it comes to health information system, the overall goal is to deliver better care to the patients. The foundation of health management system is storing health records electronically which is commonly known as EHR

The electronic storage of patient medical records has been very helpful, such as less mistakes when storing data, allowing easy access to both doctors and patients (Menachemi & Collum, 2011)**.** Thus providing a better experience for both health-care providers and patients.

Better patient health safety is achievable with the use of clinical patient order entry (CPOE) which may have a feature that notify the medical personnel prescribing of any patient allergies, or the interaction of the patient to certain drug, thus influencing the decision to be taken (Alotaibi & Federico, 2017)**.** Thus this is only possible due to availability of data made available by EHR which is a major component of the HMIS.

Survey carried by (Nyamtema, 2020) explains the state of inadequate collection of health and lack of informed decision making, this problem is currently being solved tremendously in regions like Europe and America, unfortunately this problem is persistent in some areas in Africa owing to constraints in internet bandwidth, computing resources and numbers of qualified workers, trouble in malaria-endemic countries (Shaffer, et al., 2018).

2.2.1 Personalised Health Management System

Building a health care system for the in statistics, Naive Bayes classifiers are a family of simple "probabilistic classifiers" based on applying Bayes' theorem with strong (naive) independence assumptions between the features 21st century it paramount to evolve towards personal health management systems which optimizes patient treatment by using the full power of tech (Neupert & Mundie, 2009). A typical use case of using technology for personalised health management includes leveraging tech for real-time monitoring of individuals. This could aid the enhancement of disease management through data-driven personalized treatment recommendations (Ho, Quake, McCabe, Tan, & Yen, 2020). Surveys released from **(**ONC Data Brief, 2017**)** over 97 percent of hospitals in USA use electronic health record (EHR) data. In regions like Africa, taking Nigeria as a case study, where most of the hospitals, especially public-owned who still carry out most of their medical processes manually, do not make use of the EHR data.

Today EHR data forms the foundation for providing great medical care to individuals as there is improved quality of care, reduction of medical errors and most importantly bringing satisfaction to health care providers and patients (Menachemi & Collum, Benefits and drawbacks of electronic health record systems, 2011).

2.2.2 Personalised Medicine for Osteoporosis

To achieve a personalised treatment for a patient we have to consider the patient's drug response and several literature have shown the relationship of the drug response to certain genetic factors such as age, nutrition, weight etc. One of the main problem, that this project is trying to solve is the case of the adverse effect of the drug, as it has been

one of the major barrier to the treatment of Osteoporosis (Lindsay, Olufade, Bauer, Babrowicz, & Hahn, 2016).

Personalised medicine helps in the delivery of a better health care by making it possible for patients to receive earlier diagnoses, risk assessments and optimal treatment (Vogenberg, Barash & Pursel, 2010).

"To maximise the true value of the information about about health, we need bring together genomic, clinical and diagnostic, and lifestyle data"(NHS, 2020).

2. 2. 2. 1 Peculiar Data for Personalised Medicine

As reported by (NHS, 2020) to get the true value of the health care we need to bring to together the following list below

- Genomic data
- Clinical and diagnostic data
- lifestyle data

The risk factors in Osteoporosis, BMD test and preferred treatment can be categorised into the above listed groups. Proper collection, integration and analysis of this data, will aid us in getting the an accurate drug response of the patients. Thus, this will lead to the provision of an optimal treatment with the least adverse effect for the patient. It could also create room for the development of more optimal drugs.

2. 2. 2. 1. 1 Genomic Data

(Chesi et. al., 2019) pinpointed two genes which are ING3 and EPDR1, to have very strong effects on the human Osteoblast (cells that form new bones). So we are going to be collecting patient's data to check for the presence of the genes.

2. 2. 2. 1. 2 Clinical and Diagnostic Data

Clinical data is essentially a set of patient findings, this finding originate from various sources including diseases, follow up of therapies, preventive measure etc. clinical data form a large aspect of the patient's record. relevant clinical and diagnostic data will be collected from the patient.

2. 2. 2. 1. 3 Lifestyle Data

Various data ranging from nutrition, stress, alcohol intake, physical activity, smoking etc will be collected from the patients to effectively monitor the patient.

2.3 Clinical Decision Support Systems

Decision making over the years became more complex owing to two reasons, growing technology and so many feasible alternatives to choose from (Rashidi, Ghodrat, Samali, & Mohammadi, 2018). Thus there is a great to augment the decision making process to ensure optimum decisions are taken most of the time.

The decision support system is meant to assist in the decision making process rather than to replace the decision makers (Rashidi, Ghodrat, Samali, & Mohammadi, 2018).

A decision support system (DSS) is a basically an interactive based computer software that is made up of several components and processes aim at solving structure and unstructured business problems (Tripath, 2018)

A clinical decision support system CDSS is a software related AI-based tools that help medical practitioners make optimize decisions (Sloanea & Silvab, 2019). It uses expert

knowledge and also some models derived from statistical computations and the application of ML on available data (Wyatt & Spiegelhalter, 2020).

(Kronenfeld, 2013) describes clinical decision support as a variety of tools that aid information management both computerised and non-computerised. CDSS today, leverage on web applications and they are integrated with electronic health records which can be used on desktop, smart phones etc (Sutton, et al., 2020).

CDSS are classified into two main categories knowledge based (consist of three parts knowledge base, inference engine and mechanism to communicate) and non-knowledge based (uses ml to learn from past experiences and/or find patterns in clinical data), (Wikipedia, 2020).

2.3.1 Role of CDSS

CDSS provides support to medical practitioners in various ways, some of which includes:

- Suggestion for improved care
- Reminders, advice and critiques
- Massive decrease in medical error rate
- Improved clinical therapy

2.3.2 Factors that Influences Implementation of CDSS

(Scheepers-Hoeks, Grouls, Neef, Ackerman, & Korsten, 2011) described some that enhance the successful implementation of a CDSS

- Accurate and reliable message
- Inclusion of references in message

- ❖ High system speed to enhance time saving
- ❖ Electronic availability of data in the electronic medical record **(EMR)**

2.3.3 CDSS Limitation

One of the major limitation of CDSS is that computers do not completely capture scaffolding. It is difficult to incorporate the environmental, clinical and social limitations under which physicians work as inputs into a CDSS (Khairat, Marc, Crosby, & Sanousi, 2018)

2.4 Machine Learning Techniques

There are several algorithms that aid the computer to learn from an existing dataset without been explicitly been programmed, and the performance increased greatly as the sample size increases. Machine learning algorithms can be classified into four types: supervised learning, unsupervised learning, semi-supervised learning and reinforcement learning.

In supervised learning, this makes use of labeled dataset exclusively, the input data and output data are already known so the goal is the realisation of the mapping function that links input variable X to output variable Y, such that when a value is given for variable X, the generated model can predict the value of Y. Supervised learning involves two major processes: classification and regression. some examples of supervised learning algorithm include: linear regression, logistical regression, random forest, gradient boosted trees, decision trees, naive Bayes, k-nearest neighbor. One of the most common supervised learning task is the classification problem, where the model maps input to one of the several classes of the output, after studying several input-output

examples (Menachemi & Collum, Benefits and drawbacks of electronic health record systems, 2011)

In unsupervised learning, the desired results are unknown and yet to be defined unlike the supervised learning, it does not make use of labeled dataset, some use cases of supervised learning include detecting patterns, exploring valuable insights etc. The two of the main methods used in unsupervised learning are principal component and cluster analysis (Wikipedia 2020). Some examples of unsupervised algorithms include: k-means clustering; t-SNE (t-Distributed Stochastic Neighbor Embedding); PCA (Principal Component Analysis); association rule.

In semi-supervised learning this a combination of both labeled and unlabeled examples to create an appropriate model.

Reinforcement learning make use of a technique called exploration / exploitation, here the next action is based on the knowledge of the previous consequence. Reinforcement learning makes use of reward signals which occur upon completion of a task. Some example of reinforcement algorithms includes: Q-Learning, Temporal Difference (TD), Monte-Carlo Tree Search (MCTS), Asynchronous Actor-Critic Agents (A3C).

2.4.1 Linear Regression

This is mostly used to find out the relationship between variables and forecasting, where the predicted output is continuous and has a constant slope. It is a machine learning algorithm. It is used within a continuous range to predict values and is classified into simple regression and multivariate regression. The power of linear regression lies in its simplicity, meaning it can be used to solve problems across

multiple fields. The data gathered from the observations must first be gathered and plotted along a line.

2.4.2 Logistic Regression

A classification algorithm commonly used to assign observations to a discrete group of groups is the logistic regression. Mathematically, a logistic regression model predicts P(Y=1) as a function of X (TutorialsPoint, 2020). Logistic regression can be divided into: binary or binomial, multinomial, and ordinal. Logistic Regression is an effective machine learning algorithm because it has the ability to use continuous and discrete datasets to provide probabilities and classify new data.

2.4.3 Random Forest

A very precise definition of random forest would be the generation of multiple decision trees and then proceeding to merge them together to get an accurate and more stable prediction. unlike in decision trees, is that the process of finding the root node and splitting the feature nodes will run randomly. For both regression and classification, Random Forest may be adopted. The performance is very great although there are other algorithms with better performance but those take a longer time to build, thus random is suitable when you want to build a model quickly.

2.4.4 Gradient Boosted Trees

This is one most effective techniques for building predictive models, the principle of boosting came from the idea of whether it is possible to improve a poor learner to become better. Gradient boosting involves three elements: loss function, weak learner, and an addictive model. Also gradient boosting can be enhanced by tree constraints, weighted updates, stochastic gradient boosting and penalised gradient boosting. It is

known for its prediction and speed especially when working with large and complex set of data

2.4.5 Decision Trees

Here the main goal is to create a model that can make prediction of a class or value of the target variable by learning decision rules derived from the training data. It is a tree-structured classifier, where the characteristics of a dataset are represented by internal nodes, branches represent the rules of decision, and each leaf node represents the outcome. like gradient boosting they can be used to solve both regression and classification problems. Decision tree algorithms are important, well-established techniques for machine learning that have been used for a wide range of applications, particularly for classification problems. (Grajski, Breiman et al. 1986; get reference).

2.4.6 Naive Bayes

Naive Bayes classifiers are a set of Bayes' Theorem-based classification algorithms, with an inference between predictors of independence. A Naive Bayes classifier assumes, in simple terms, that the existence of a certain feature in a class is unrelated to the presence of any other feature. The Naive Bayes model is simple to create and especially helpful for very large data sets. Naive Bayes is considered to outperform even highly advanced classification strategies, along with simplicity. Naive Bayes classifiers are a family of simple " probabilistic classifiers "in statistics based on the application of Bayes ' theorem with clear (naive) assumptions of independence between the characteristics (Wikipedia 2020).

2.4.7 K- Nearest Neighbour

The k - nearest neighbor (KNN) algorithm assumes that in close proximity, similar items happen. Similar objects, in other words, are close to each other. It can be used for

both classification and regression problems. Two properties that helps in defining KNN algorithm very well includes: lazy learning algorithm (no specialised training phase, all dataset is used) and the non-parametric learning algorithm (does not assume anything about underlying data).

2.5 Osteoporosis

Osteoporosis can be seen as a deadly disease, common to old people, it is found mostly in old women after their menopause. Osteoporosis is described by the World Health Organization (WHO) as "a skeletal disease characterized by low bone mass and micro-architectural deterioration of bone tissue, resulting in increased bone fragility and fracture susceptibility." The micro-architectural deterioration of bone tissue increases the risk of bone fragility and bone fractures mainly in the spine and femur area. (D. Devikannigam, R. Joshua Samuel Raj, 2018).

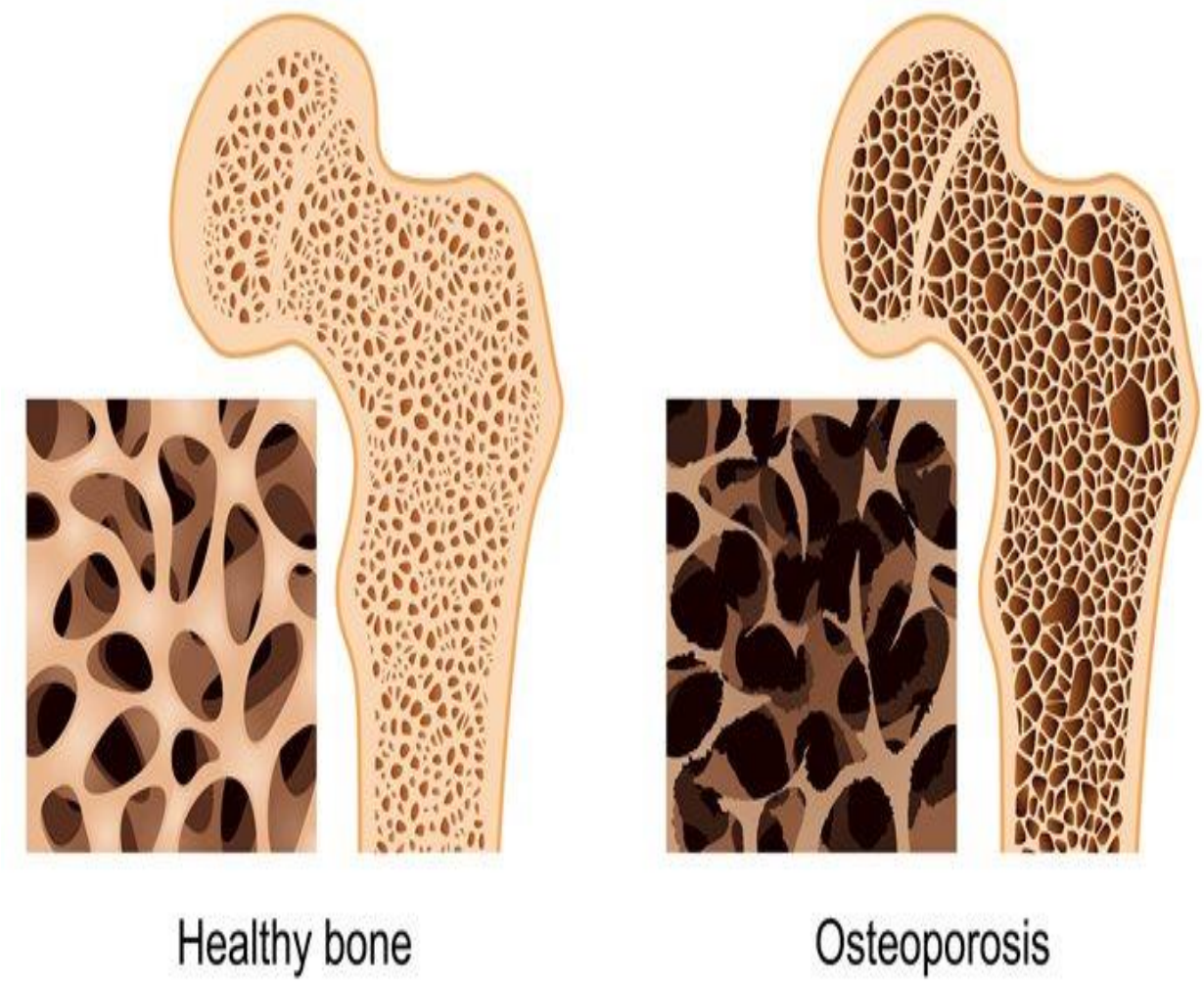


Figure 1 A healthy bone and an osteoporosis infected bone (Source: (MSFocus, 2020)

2.5.1 Classification of Osteoporosis

According to Mathew et al. (1999), Osteoporosis can be grouped into two: primary and secondary. The characteristic and occurrence varies among the patients.

Primary Osteoporosis

A correlation between the presence of two hormones, estrogen and progesterone, and the rate at which bone is lost is also correlated with normal aging processes here. Estrogen controls the osteoclasts that break down the bone and osteoblasts are regulated by progesterone, which helps to produce new bone (Khosla, Oursler, & Monroe, Estrogen and the Skeleton, 2012). Primary Osteoporosis is divided into idiopathic Osteoporosis and juvenile Osteoporosis. Juvenile osteoporosis typically occurs in children and young adult, mostly between the ages of 8 and 14 and is

characterized by abrupt bone pain and/or a fracture following trauma. Postmenopausal (type I) and senile (type II) are further categorised into idiopathic osteoporosis. Postmenopausal osteoporosis typically happens in women because of estrogen deficiency, while senile is due to skeleton ageing and calcium deficiency.

Secondary Osteoporosis

This is usually caused by particular clinical conditions, including a number of endocrinopathies and peak bone mass hereditary attainment, or by increasing involutionary bone loss rates. In addition, many medications are associated with bone re-modelling changes that may contribute to bone mineral loss. The primary processes that lead to osteoporosis can be superimposed on bone loss resulting from these diseases and medications, exacerbating normal bone loss in affected individuals (Damjanov, 2009).

2.5.2 Clinical Features of Osteoporosis

During the early stage of bone loss, patient's displays no symptoms prior to when they have Osteoporotic fracture. Over time, as the bones are weakened, we notice signs and symptoms such as loss of height, stopped posture, bone fragility resulting in rare fractures, etc. (Clinic, 2020)

2.5.3 Risk Factors of Osteoporosis

Results from (Zaidi, 2007) shows some risk factors for Osteoporosis which could categorised into modifiable and non-modifiable and also secondary causes. Table 1 shows some of the risk factors.

1. **Modifiable Risk Factors** Lack of physical activity or fall risk weight loss Inadequate nutritional absorption Cigarette smoking Alcohol consumption Air pollution
2. Non-Modifiable Risk Factors Older age Gender White ethnic background Prior fracture History of falls Reproductive factors (family history of Osteoporosis)
3. Secondary cause of Osteoporosis

Hypogonadism
Hyperparathyroidism
Chronic liver disease
Vitamin D deficiency
Renal disease (history of kidney stones)
Cardiovascular disease
Diabetes mellitus
Dementia
Chronic use of certain medications (prolonged use)

Table 1 Risk factors for osteoporosis (Source: (Zaidi, 2007))

Studies carried out by (Burke-Doe, Hudson, Werth, & Riordan, 2008) made hypothesis participant involved in their research who showed increased understanding of Osteoporosis fracture would reflect healthier bone habits and thus have less identifiable risk factors. Thus the need to have proper knowledge of these risk factors is paramount.

2.5.4 Diagnosis and Treatment of Osteoporosis

Presently, the gold standard technique for diagnosis of Osteoporosis is the Dual - energy X-ray absorptiometry (DXA), this measures the bone mineral density and shows the best predictive value for fracture risk (Società Italiana dell'Osteoporosi, 2016)**.** The result of a DXA are given as T-score and the Z-score. T score basically makes a comparison of your bone mass to that of an average 30 years old adult (Health, 2020).

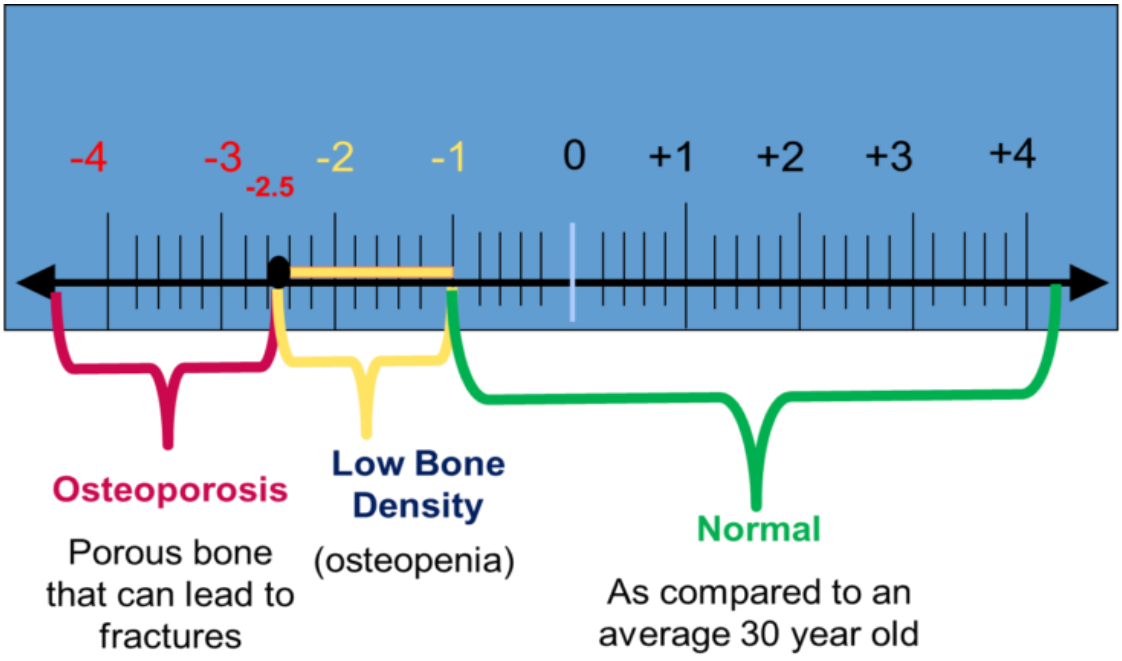


Figure 2 A healthy bone and an osteoporosis infected bone (Source: (MSFocus, 2020)

In a study carried out by (Burke-Doe, Hudson, Werth, & Riordan, 2008) they made a hypothesis that participants in their study who have shown better understanding of risk factors for osteoporosis would therefore reflect healthier bone habits and therefore have fewer identifiable risk factors. Thus if there is more awareness among individuals, they should reflect healthier bone habits.

while Z-score makes a comparison of the BMD to that of the same ethnicity and age. This is mostly done not because it is an indicator of bone strength, but to find out if the loss of bone mass is due to certain other causes, such as certain medical problems or drug treatment (Società Italiana dell'Osteoporosi, 2016) In a study carried out by (Burke-Doe, Hudson, Werth, & Riordan, 2008) they made a hypothesis that participants in their study who have shown better understanding of risk factors for osteoporosis would therefore reflect healthier bone habits and therefore have fewer identifiable risk factors. Thus the need for better understanding of Osteoporosis risk factors is highly beneficial.

Treatment of Osteoporosis

Once an individual has been diagnosed of Osteoporosis, a decision is made whether the treatment should be prophylactic (prevent measure) and/or curative (cure)**,** (Passini & Souza, 2010). The goal of both process is to prevent Osteoporotic fractures. Since Osteoporotic fractures can be prevented by pharmacological treatments, the available treatment includes bone forming (stimulating the Osteoblasts), anti-resorptive (inbiting the Osteoclats) or dual acting (simultaneously stimulating the osteoblasts and inhibiting the osteoclasts) (langdahl & Harslof, 2011) . Bisphosphonates, nuclear factor B ligand receptor activator (RANKL) antibody, and selective estrogen receptor modulators (SERMs) are anti-resorptive treatments that either induce osteoclast apoptosis (bisphosphonates) or inhibit osteoclast recruitment (RANKL antibody and selective oestrogen receptor modulators). Bone-forming drugs are teriparatide (parathyroid hormone [PTH], amino acids 1-34) and abaloparatide, for which abaloparatide is currently only available in the United States. (langdahl &

Harslof, 2011). Romosozumab is a dual-acting therapy that activates the formation of bones at the same time.

Treatment	Effect on Fracture Risk in Osteoporotic Women and Evidence Quality			Adverse Events and Evidence Quality	Fair Price for 1-Day Supply*
	Vertebral	Nonvertebral	Hip		
Bisphosphonates	Summarized individually below	Summarized individually below	Summarized individually below	As a class: atypical subtrochanteric fracture, osteonecrosis of the jaw (low-quality)	Summarized individually below
Alendronate	Improves; high-quality	Improves; high-quality	Improves; high-quality	Mild upper GI symptoms (high-quality)	Generic: $9 Brand-name (Fosamax): $130
Ibandronate	Improves; high-quality	Uncertain	Uncertain	Mild upper GI symptoms (high-quality); myalgias, cramps and limb pain	Generic: $60 Brand-name (Boniva): $588
Risedronate	Improves; high-quality	Improves; high-quality	Improves; high-quality	Mild upper GI symptoms (high-quality)	Generic: $136 Brand-name (Actonel): $337
Zoledronic acid	Improves; high-quality Improves in osteoporotic men; moderate quality	Improves; high-quality	Improves; high-quality	Mild upper GI symptoms, hypocalcaemia, influenza-like symptoms (high-quality); atrial fibrillation; arthritis and arthralgias, headaches, uveitis	Generic: $66 Brand-name (Reclast): $1105
Denosumab (injectable)	Improves; high-quality	Improves; high-quality	Improves; high-quality	Mild upper GI symptoms (high-quality), infection (moderate-quality); rash	Brand-name (Prolia): $1047
Teriparatide (injectable)	Improves; high-quality	Improves; high-quality	Unknown	Mild upper GI symptoms, headache, hypercalcemia (high-quality); hypercalciuria, renal adverse effects	Brand-name (Forteo): $2767
Raloxifene	Improves; high-quality	No effect	No effect	Hot flashes, thromboembolic events (high-quality); pulmonary embolism, cerebrovascular death	Generic: $2.40 Brand-name (Evista): $70
Calcium and vitamin D	Uncertain	Uncertain	Uncertain	Increased risk for hypercalcemia	NA
Menopausal hormone therapy	Improves in postmenopausal women (not selected for having osteoporosis in the studies); high-quality Does not improve in postmenopausal women with established osteoporosis; moderate-quality	Uncertain	Improves in postmenopausal women (not selected for having osteoporosis in the studies); high-quality	Increased risk for cerebrovascular accidents and thromboembolic events (high-quality)	NA

GI, gastrointestinal; NA = not available.
* Formulation and dosing vary. Generics are available where indicated. Data were obtained from the Healthcare Bluebook (www.healthcarebluebook.com).

Figure 3 Various osteoporosis medication for both men and women (Source: (Qaseem, Forciea, & Denberg, 2017))

2.6 Review of Related Works

This section gives us a little insight into projects that have been carried out previously based on the topic of disclosure.

2.6.1 A Clinical Decision Support System for the Diagnosis, Fracture Risks and Treatment of Osteoporosis.

Here, the researchers in this project developed a CDSS which they named osteoporosis advisor (OPAD). OPAD provided the physicians with a standard user interface to insert patient's data and get diagnostic comments, 10-year risk of fragility fracture, treatment options for the given case, and when to offer a follow-up DXA-evaluation. They had the opinion that patient potentially miss lifesaving therapeutic measure due to lack of proper diagnoses. Their goal was to design an expert system for diagnosis and treatment of Osteoporosis. To achieve this, they leverage on published country specific data using attributes like age, BMD, ethnicity, Gender, Parent hip fracture etc. (Gudmundsson, Hansen, Halldorsson, Ludviksson, & Gudbjornsson, 2019).

2.6.2 Development and Efficacy of a Computerized Decision Support System for Osteoporosis Management in the Community

Computerized primary care physician warnings, issued during visits to patients who complied with recommendations for treatment based on their electronic medical records. Their objective was to measure the efficacy of an automated real-time alert which was developed to assist osteoporosis management in the community. In a 2

million member Israeli health fund, the research population included treatment of naive patients with T-score <= -2.5 or hip or vertebral fracture. A pop-up screen reminded the caregiver to consider medication initiation on each outpatient visit to a primary care physician or endocrinologist (Goldshtein, et al., 2020).

2.6.3 Personalized Management of Hyperglycemia in Type 2 Diabetes

The researchers made emphasis on the need to develop tools to translate current recommendations into realistic clinical applications and, more importantly, to develop processes that promote coordinated patient co-management by primary care practitioners, consultants, educators, dietitians, and other HCPs as the specific needs and risks of patients require.

They also made emphasis on the differences among ethnic groups in pathophysiology, country-specific resources and infrastructure for medical care, level of provider training, and patient knowledge (Raz, et al., 2013).

2.6.4 Development of a clinical decision support system for diabetes care.

A diabetes-specific clinical decision support system (Diabetes Dashboard) interface for displaying glycemic, lipid and renal function results, in an integrated form with decision support capabilities, based on local clinical practice guidelines. A dashboard feature was included in the clinical decision support system that graphically summarized and displayed all applicable laboratory findings in a color-coded system that allowed easy understanding of the patients' metabolic control. (Sim, Ban, Tan, & Sethi, 2017)

2.6.5 Personalized Management of Bone and Mineral Disorders and Precision Medicine in End-Stage Kidney Disease

Here, researchers explain how personalised medicine may be used for the management of CKD-MBD and how it ultimately may lead to improved clinical outcomes. In this paper they highlighted that optimal management of CKD-MBD is critical for dialysis patients. It goes further to explained current ways used in individualising treatment giving special attentions to factors such as age, sex, race etc. (Nephrol, 2019).

2.6.6 Personalized Management of Cardiovascular Disorders

Personalized management of cardiovascular disorders (CVD), also referred to as personalized or precision cardiology in accordance with general principles of personalised medicine. The researchers expressed the relationship of bio-informatics to personalised medicine (Jain, 2017).

CHAPTER THREE

SYSTEM ANALYSIS AND DESIGN

3.1 Preamble

This chapter describes the workings and problems of the existing system, it also analyses the proposed system using various models and lastly gives us a sense of what

the system design would entail. In the analysis phase we determine the functional and non-functional requirements of the system, the data flow diagram show how data is transformed and moves between processes in the new system while the E-R diagram depicts the systems various entities and their relationships. In the system design phase the functional hierarchical diagram serves as a kind of organogram for the system, the logic model of the system uses pseudo code to model the systems association rules, an activity diagram is used to show the high level processes within the system and lastly prototypes of the various systems interfaces is described in the final sections of this chapter.

3.2 Description of Existing System

The current system is an Osteoporosis Advisor (OPAD) which provide physicians with standard user interface to insert patient's data and get diagnostic comments, 10-year risk of fragility fracture, treatment options for the given case, and when to offer a follow-up DXA-evaluation. The existing system does not take a personalised approach i.e. tailoring the treatment to the specific needs for the individuals, also education and awareness among patients and health care professionals is not covered by this system

3.2.1 Analysis of Existing System

Here we would look at the problems and benefits of the existing system

3.2.2 Problem of Existing System

The key problem with the existing system is that it does not take into account a patient feedback feature and real-time monitoring of patient information to see patient interaction at different times. It also has no feature(s) which ensure that individuals

and health care providers are more informed and aware of issues related to osteoporosis.

3.2.3 Benefits of the Existing System

The existing system has the benefit of improving the doctor's decision and also suggesting when to follow up patient, its knowledge base help to get the 10 years' risk of fragility fractures

3.3 Analysis of the Personalised Osteoporosis Management System

It aims to provide treatment recommendations that is tailored to the individuals by collecting real-time data and performing stream analysis on them. It also aims to educate and create awareness among patients and health care professionals. The existing system fails to collect real-time data from patients before and after treatment which can aid in making better treatment decision in future.

3.3.1 System Requirements of POMS

The requirement needed by the personalised Osteoporosis management system can be categorised into two namely: functional requirement and non-functional requirement.

3.3.1.1 Functional Requirements

The POMS' functional requirements are shown in the table below and it is further explained below the table:

No	Description
FR1	Collection of patient's data from historical data and real-time data containing their personal records, clinical records and their risk factor records.
FR2	Store data over time both from historical and real time collection of patient data.

FR3	Send notification to patient on treatment options, symptoms and also appointment schedules.
FR4	The web platform should be able to share data with the mobile platform in real time and vice versa via cloud sharing

Table 2 Functional requirement for POMS

1. Collection of patient's data from historical data and real-time data containing their personal records, clinical records and their risk factor records

   a. Input : patient's data corresponding to available variable fields is collected.

   b. Precondition: the patient must have been registered on the platform.

   c. Expected output: a view of all patient records.

   d. Post Condition: the data collected from the patient must be available at all times.

2. Store data over time both from historical and real time collection of data

   a. Input: patient data is stored in the cloud and updated from time to time

   b. Precondition: the patient data must have been collected

   c. Expected Output: a database containing the patient's data

   d. Postcondition: the database must be secure and accessible at all times

3. Send notification to patient on treatment options, symptoms and also appointment schedules

   a. Input: patient data is sent to the ML model for recommendation.

   b. Precondition: the patient data must have been stored on the platform.

   c. Expected Output: a recommendation for the patient is sent in form text.

d. Postcondition: the recommendation must be unique to patient and will also change while patient data is updated.

4. The web platform should be able to share data with the mobile platform in real time and vice versa via cloud sharing

a. Input: patient data is sent via cloud sharing from the mobile platform to the web and vice versa

b. Precondition: the web platform and mobile platform must be internet enable and all necessary security protocols must have been implemented.

c. Expected Output: data is sent and received on both the mobile and web platform

d. Postcondition: in a case where the connection is lost, data must be saved on the local storage of both platforms and uploaded once connection is restored

3.3.1.2 Non-Functional Requirement

The POMS' Non-functional requirements are shown in the table below and it is further explained below the table:

No	Description
NFR001	Encryption of data: database will be encrypted to patient's data to ensure security and patient's data confidentiality.
NFR002	Usability: the user interface will contain familiar components to enhance ease of use of the system.
NFR003	Reliability: Due to this critical nature of the system, there will be a big problem if the system ever goes down i.e. not online for a long time.
NFR004	The system should have backup for data to avoid loss of data.

Table 3 Non functional requirement for POMS

1. Encryption of data: personal data will be encrypted, data will only be granted to authorised users and also, threats such as connected devices threat will be mitigated.

2. Usability: The user interface will be developed following standard usability guidelines to ensure the users have a great experience.

3. Reliability: The system will be available at all times, leveraging on back up servers.

4. Maintainability: the system offers the efficiency for data backup.

3.4 Custom POMS Framework

A custom framework for personalising the recommendations, it was built to support the treatment process and to also serve as the working model that was used in the development of the system. In this framework the user interacts with the system and relevant patient data is captured. The captured data which is made of both historical data and specific data captured in real-time, is then stored in a cloud storage that is always accessible on the POMS. The database is then queried by the personalisation engine and various techniques are applied, the result of the weight of the technique is then analysed, fused and a recommendation is sent to the user.

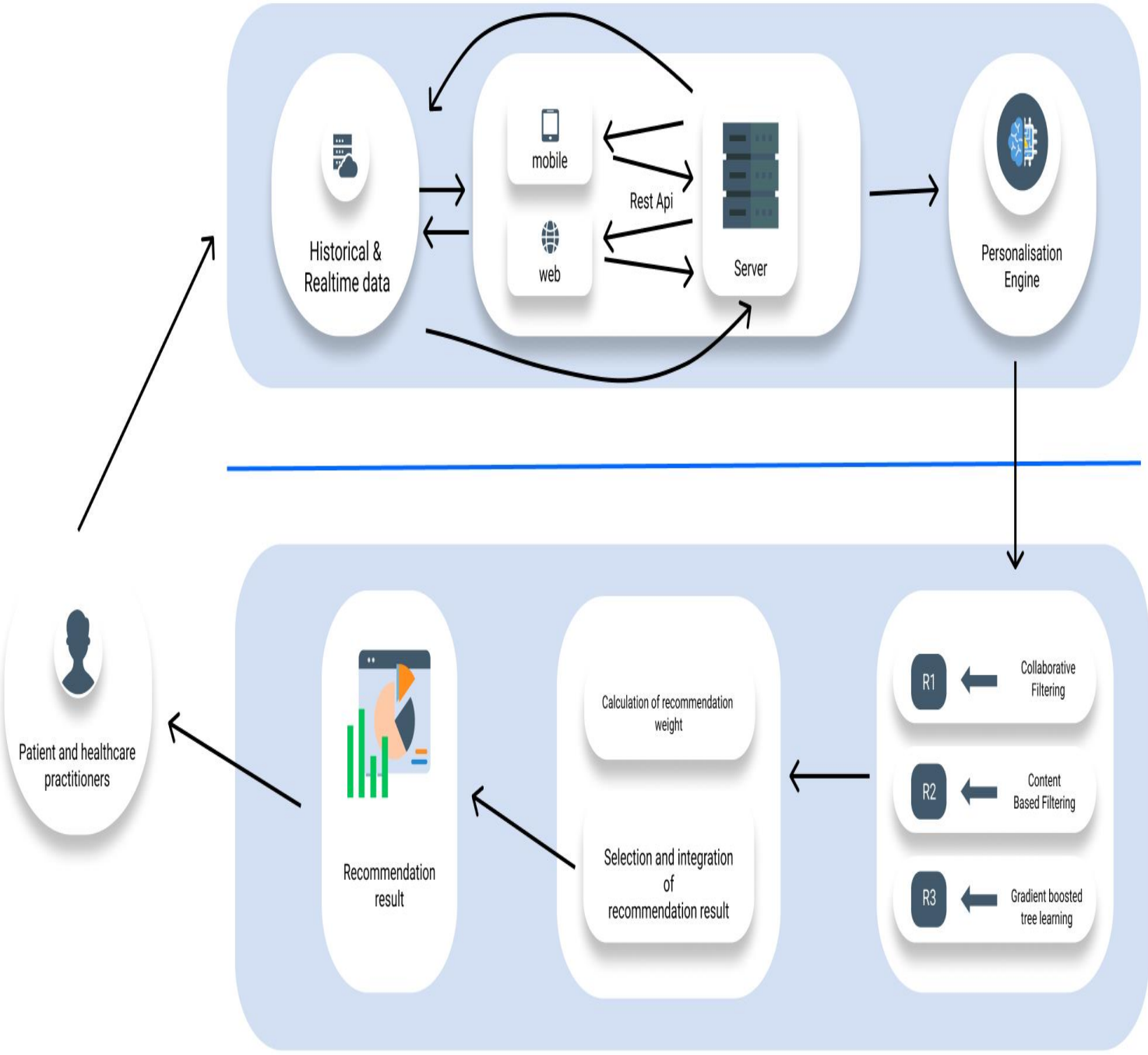


Figure 4 The custom POMS framework

3. 4. 1 **Multi-platform System Communication**

Here the two major platforms will be the web platform and the mobile platform. The web platform will be mostly used by the medical practitioners while the mobile platform will be used mainly by the patients. The web platform will aid in managing the entire process while data gotten subjectively from the patient can also be viewed.

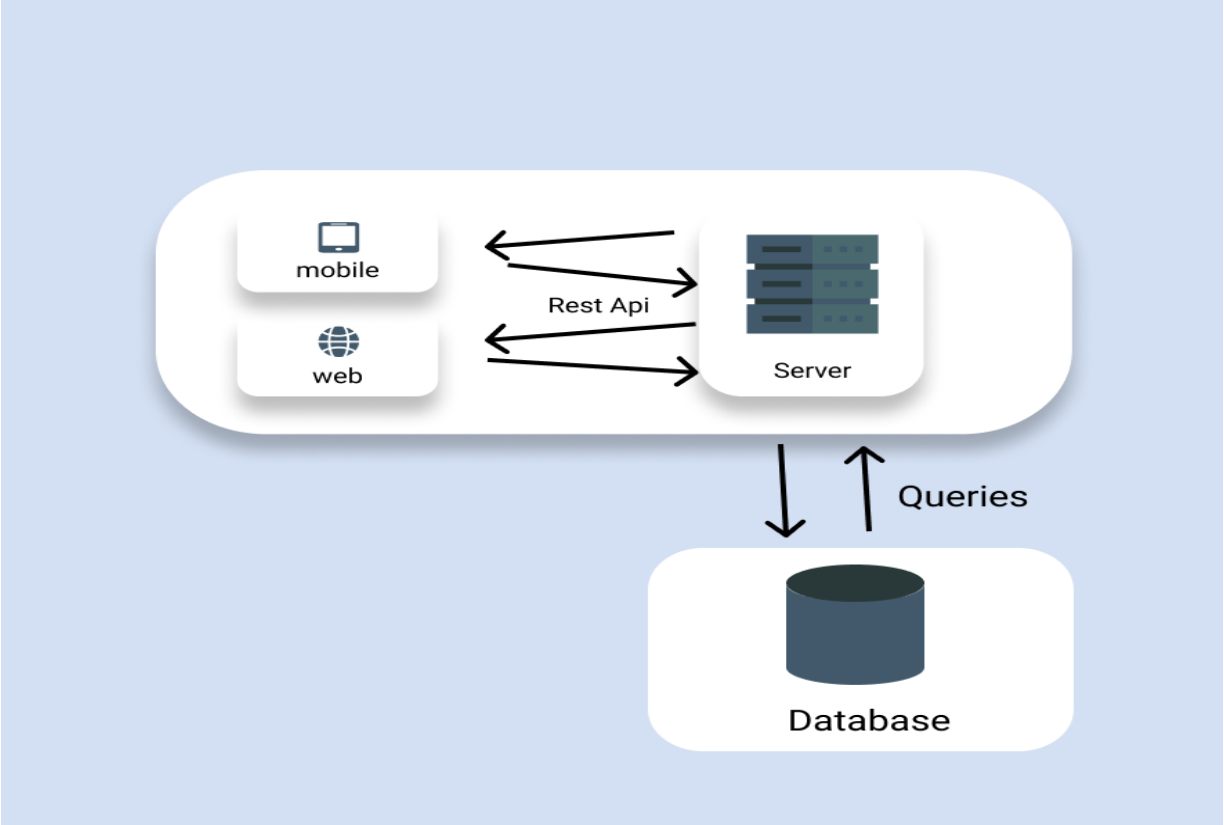


Figure 5 Communication between the web and mobile platform

3. 4. 2 **Dataset**

In this work primary data will be collected from the multi-platform for future analysis. The datasets would consist of bmd test result, risk factors and diagnosed treatment from already treated patients.

System Architecture

System Architecture is abstract, conceptualization-oriented, global, and focused to achieve the mission and life cycle concepts of the system. It also focuses on high-level structure in systems and system elements. It addresses the architectural principles, concepts, properties, and characteristics of the system-of-interest.

The Fig 3.1 below show the behaviour of the system, from the capturing of the patient and health care provider data via the multi-platform system through the Osteoporosis management system and how the data is stored in the data repository. The system now performs stream analysis on the data, by querying the data and analysing the data using machine learning techniques before information is displayed to the patient's and health care providers graphically.

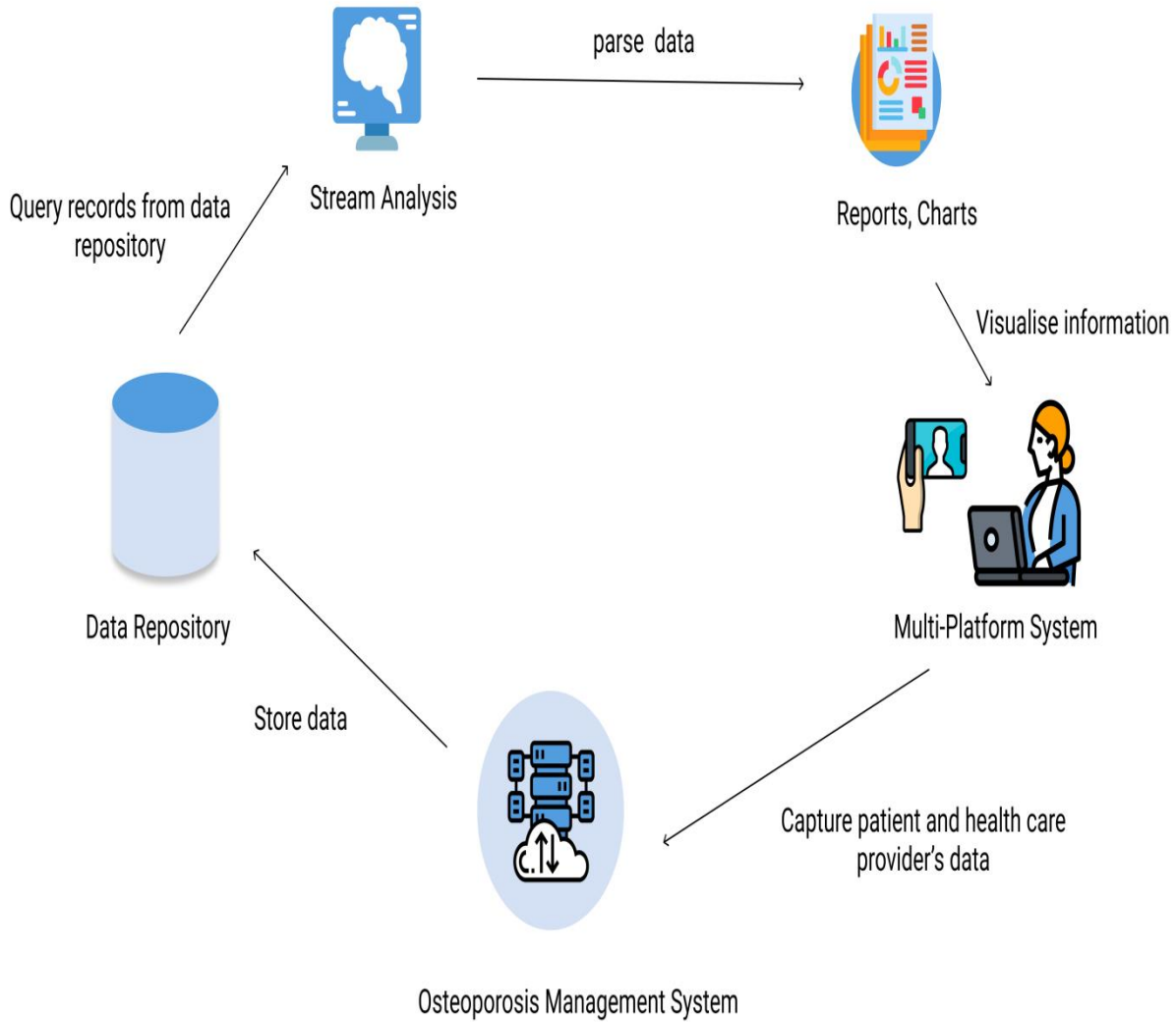


Figure 6 System Architecture for POMS

3.7.1 Use Case Model

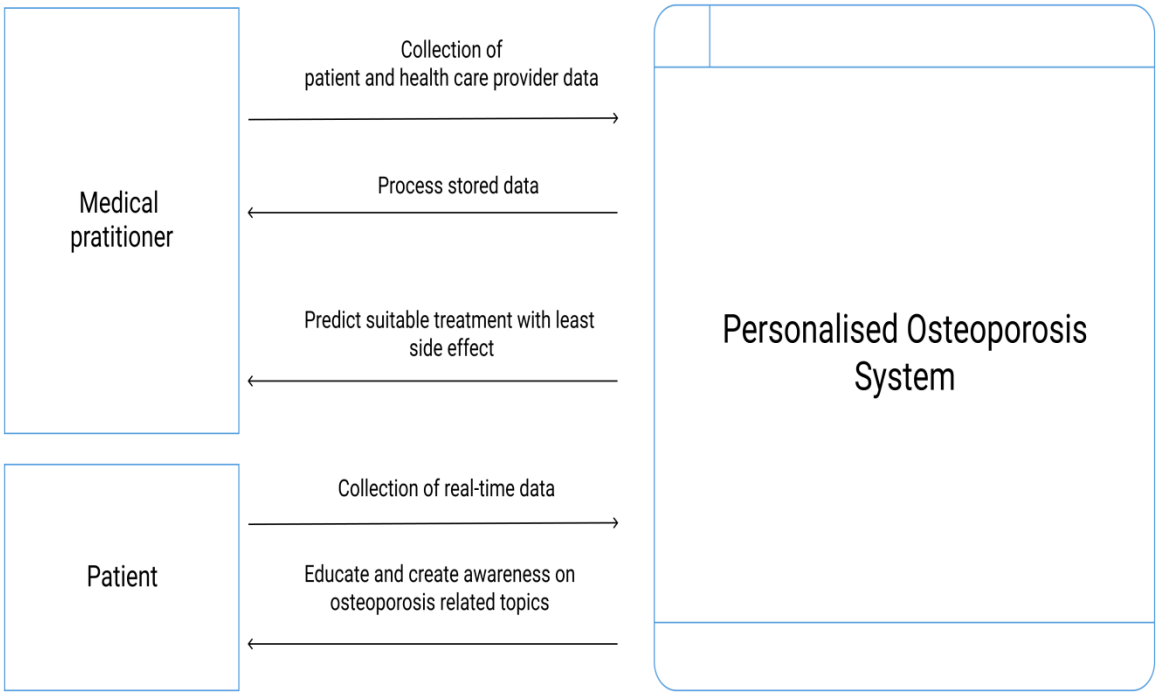
To solve a problem, a use-case model is a model that explains how various types of users communicate with the system. As such, the goals of the users, the interactions between the users and the system, and the system's necessary behavior in achieving these goals are defined.

The Fig 3 below shows how the user interacts with the system as whole. It helps in analysing the system and subsystems, which the systems analyst (actor) can interact with.

Figure 7 Use Case Diagram for POMS

3.7.2 Data Flow Diagram

DFD is the description of the data flow of a device or a process. It also offers insight into each entity's inputs and outputs and the mechanism itself. There is no control



flow for DFD and no loops or laws of judgment are present. A flowchart may illustrate particular operations based on the type of data. You can view the Data Flow Diagram in many ways. Structured-analysis modeling tools belong to the DFD. DFD is made up of four components: process, data flow, warehouse and terminator

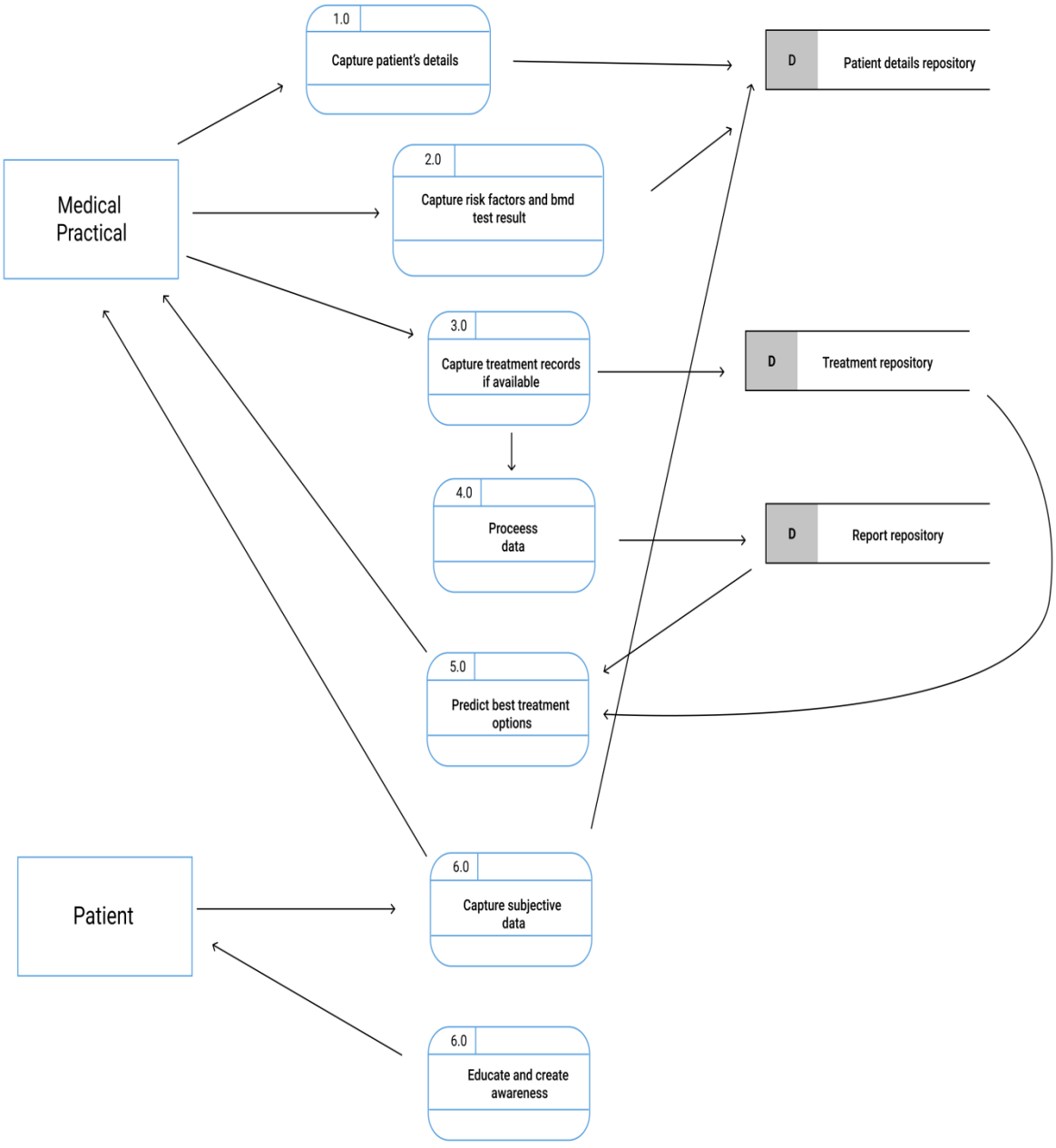
3.7.2.1 Context Flow Diagram

In fig 3.3, the diagram gives a general overview of the system with little detail unlike the level 0 DFD. The context DFD describes the system by showing the features that can be accessed by the primary entities (medical practitioner& patients)

Figure 8 Context Flow Diagram for POMS

3.7.2.2 Level 0 Data Flow Diagram

The fig 3.4 shows at a higher how data flows and its transformed within the system. It consists of five processes, a data repository (a store of medical records) and two



entities (medical practitioner and patients).

3.7.3 Data Model

The data model used for this system is shown below, all relationships and constraints are also defined explicitly

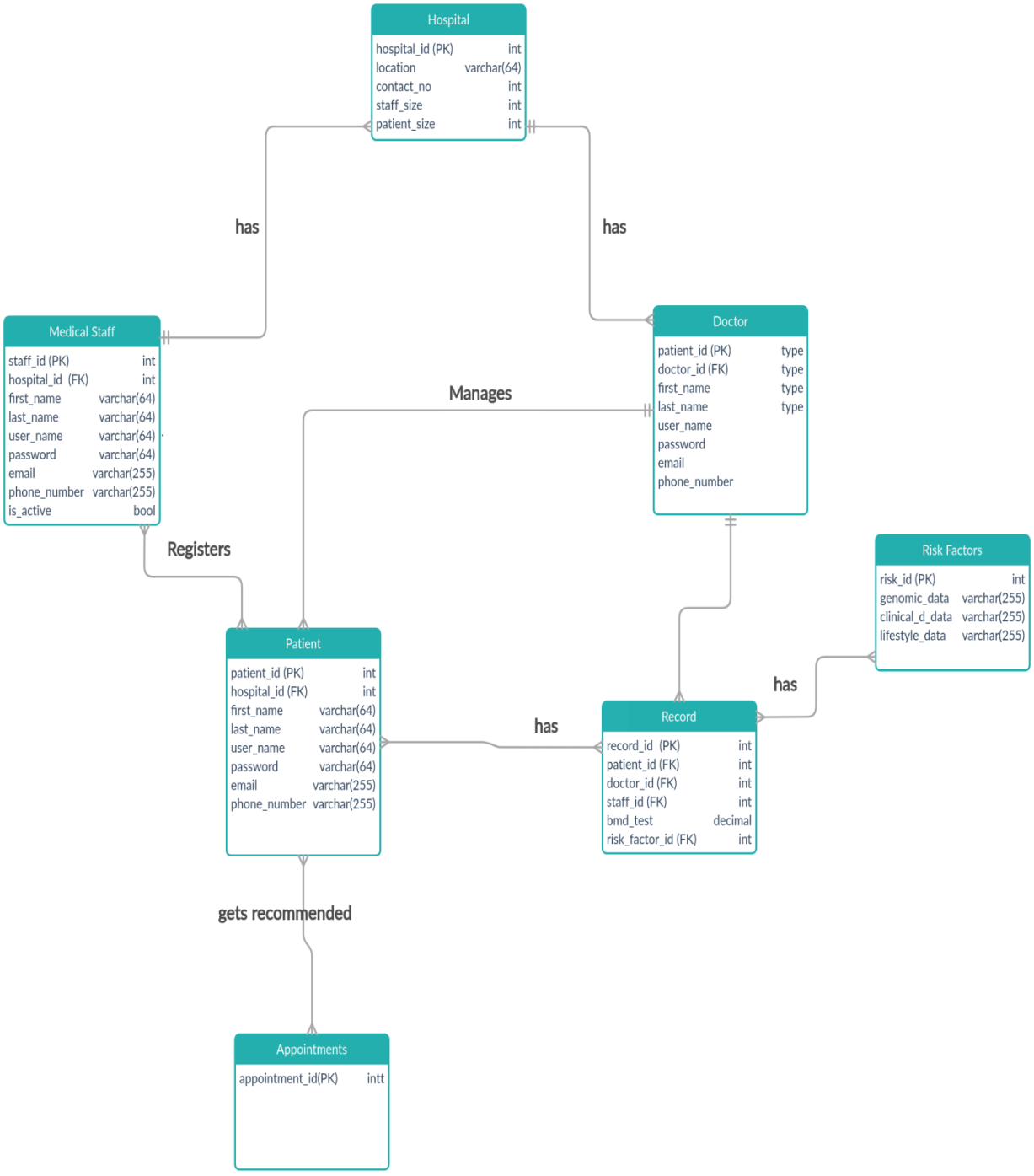


Figure 9 POMS data model diagram

3.7.4 Interface Design for POMS

This section shows the various interface design available to the users to interact with the personalised management system, the graphical interfaces used in displaying information for the admin using various visualisation methodologies.

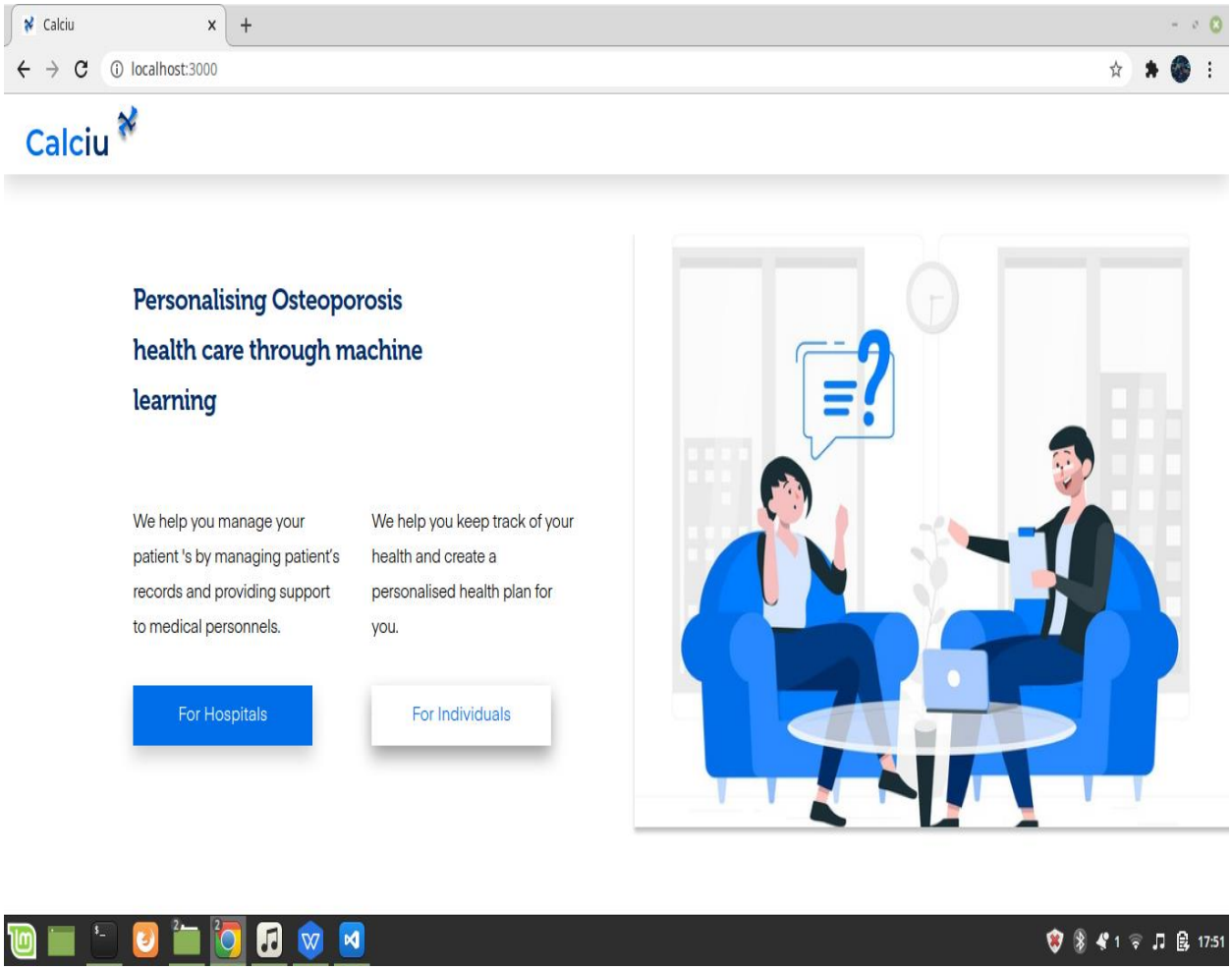


Figure 10 Landing Page of the POMS

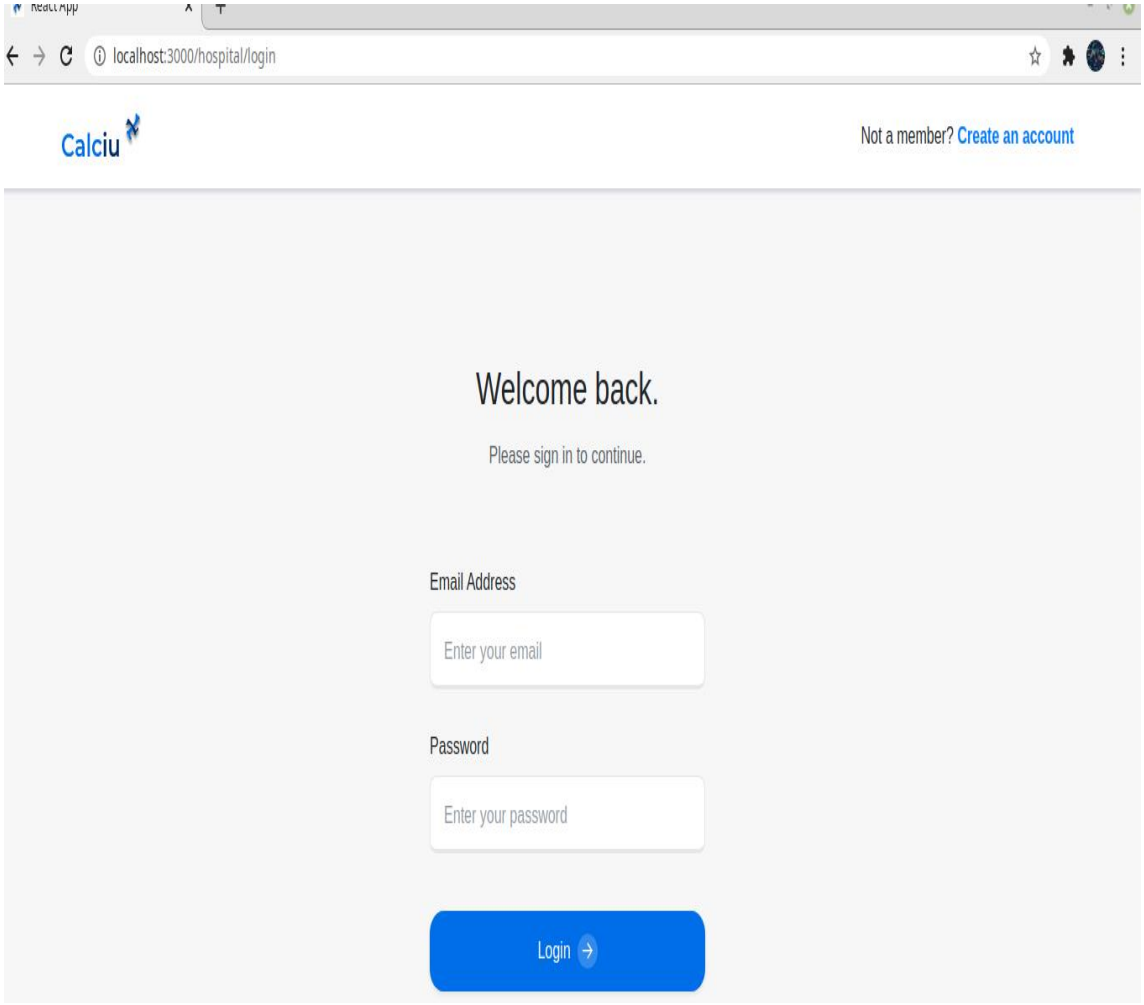


Figure 11 Login screen for the healthcare providers

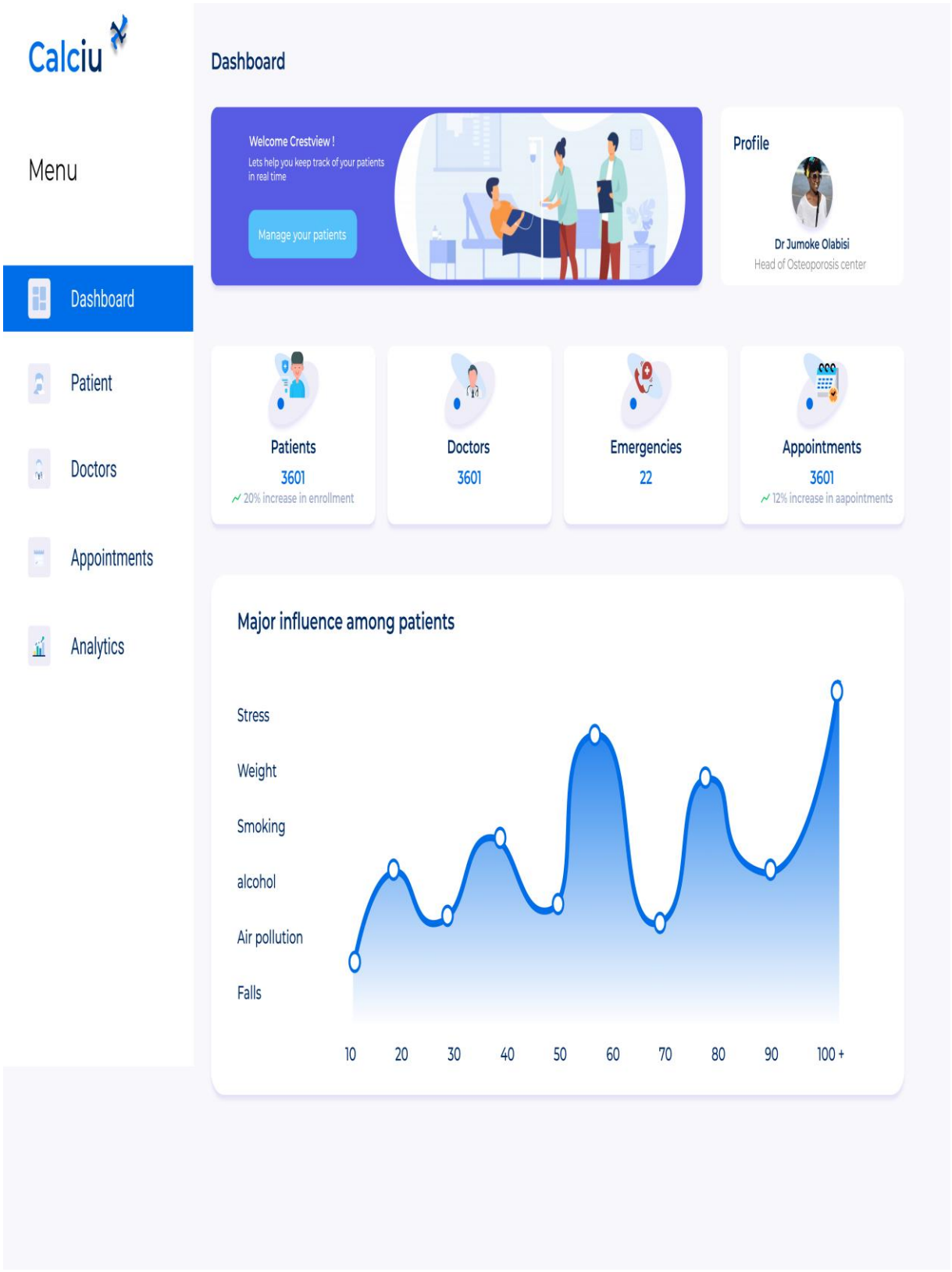


Figure 12 Dashboard of the POMS

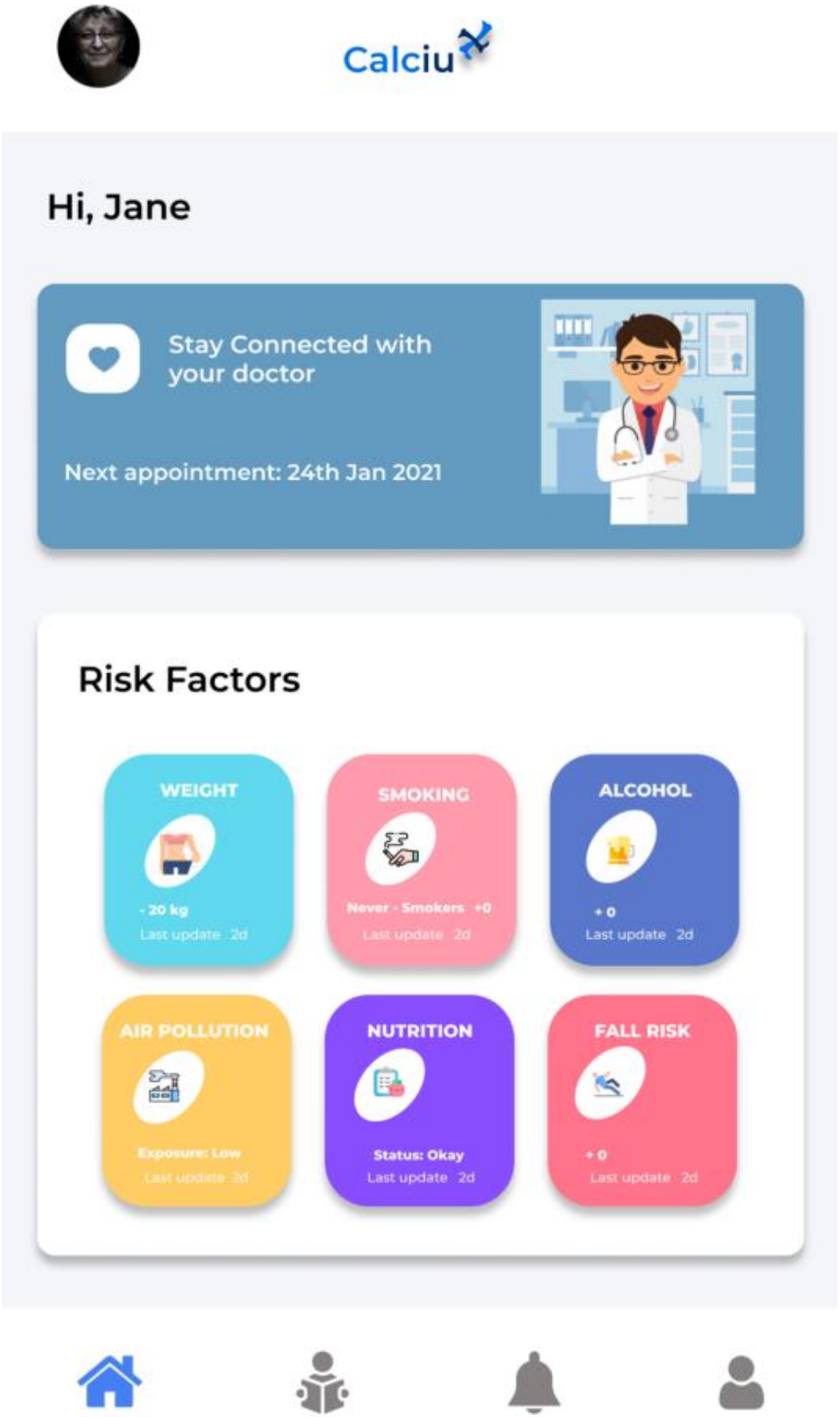


Figure 13 Dashboard of the mobile application for the patients

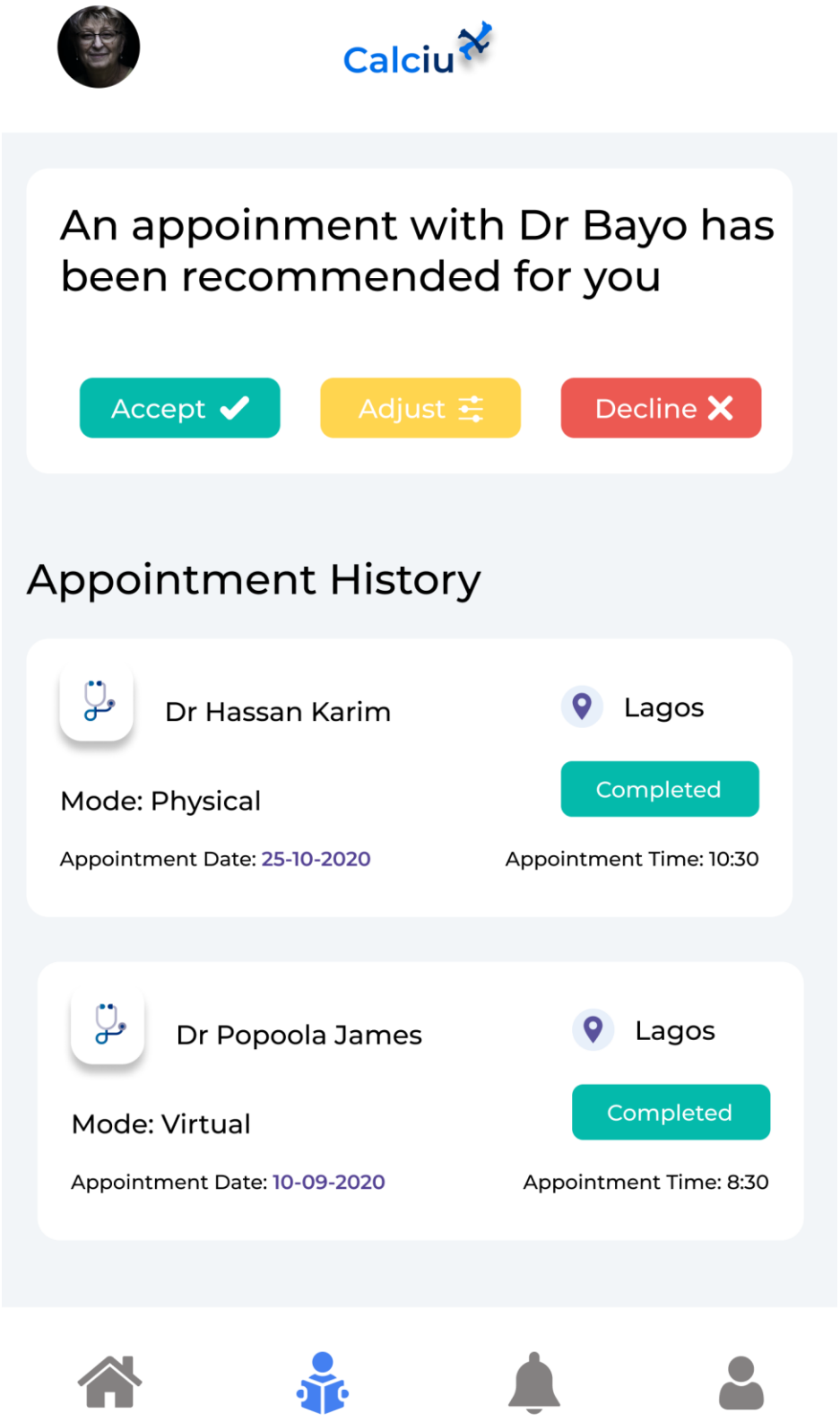


Figure 14 appointment screen showing recommended appointment for patients

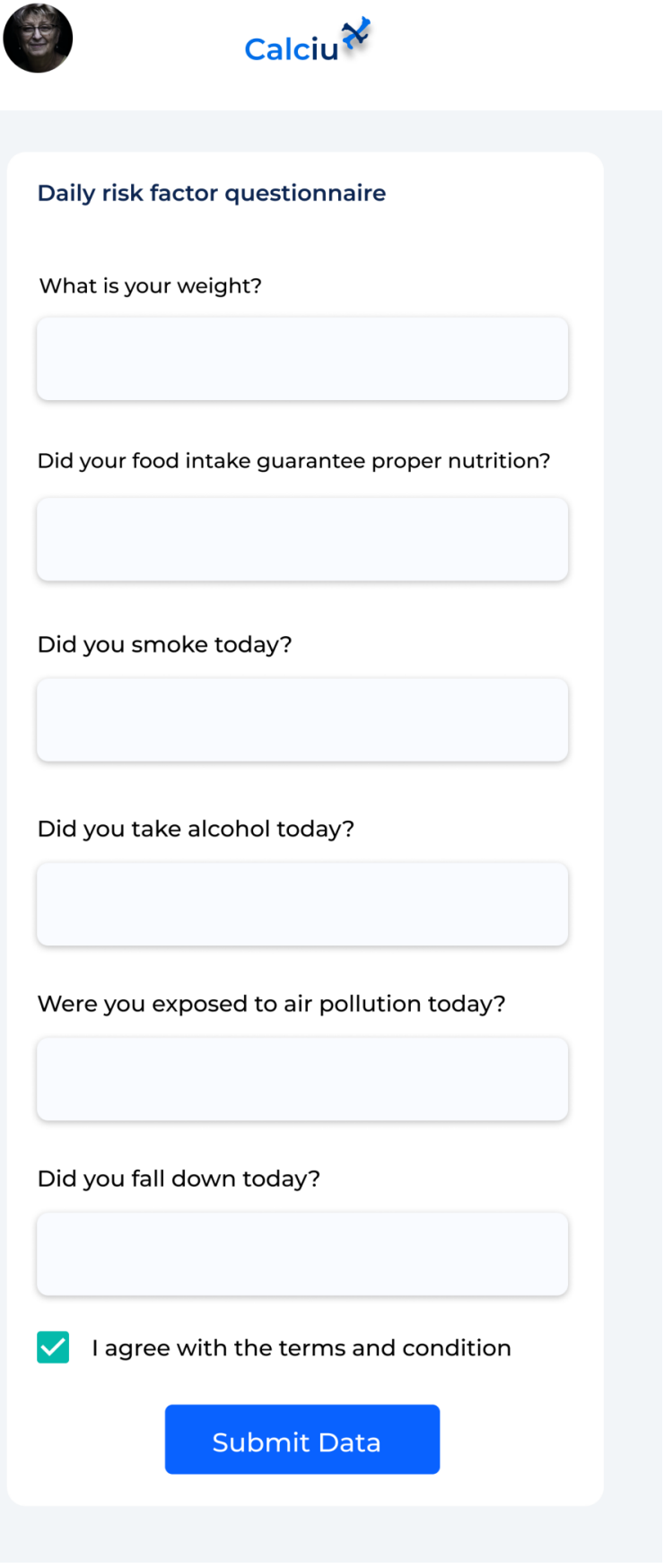


Figure 15 Daily data collection screen for patients

Calciu

Dr Popoola James

Lagos

Mode: Virtual

Completed

Appointment Date: 10-09-2020

Appointment Time: 8:30

Congrats you have recieved a treatment recommendation

View

CHAPTER FOUR

SYSTEM IMPLEMENTATION AND TESTING

4.1 Preamble

Based on the established personalisation framework, the system will be built, this chapter describes how the framework described in chapter 3 was implemented, the choice of programming language used, hardware and software requirements as well as user interfaces with the use of screenshot. The tools used in the design of the system and rationale behind the choice of tools will be evaluated in details, also measures for testing will also be discussed in detail. The purpose of this project is to address some of the barriers of the under treatment of Osteoporosis treatment by predicting treatments that are tailored to the needs of the individual based on certain unique attribute and also educating and creation of awareness for both the patients and the health care providers.

4.2 System Requirements

This sub section describes the necessary hardware and software needed for a successful deployment of the system. This system should could be used on both mobile and web platforms, the mobile platform is meant for the patients, while the web platform is meant for the medical practitioners.

The minimum device requirement will be specified for the best user interaction

4.2.1 Hardware Requirements

In order for the system to function efficiently the following hardware requirement would be required.

- A personal computer
- A Pentium 3 or equivalent microprocessor
- 512 MB RAM or more
- Up to 16GB of available disk space
- A (800 X 600) resolution VGA card

4.2.2 Software Requirements

- OS: Linux Mint
- Node v14
- Java Development Kit
- VS Code
- Google Chrome or any related browser
- Android Studio
- Geny Motion
- Flutter V2.1

4.2.3 Choice of Programming Language

JavaScript was used in building the web application leveraging on the PERN stack (PostgreSQL, Express, React, NodeJS. Python was used in building and deploying the model. The model was hosted as a RESTful API on Heroku with Python.

4.2.4 Implementation Tools

FlaskSpyder IDE and Jupyter Notebook were used to run all python programs, Android Studio IDE (4.0.1) was used to in developing the Flutter application, VS code was used in writing all JavaScript codes

4.3 Testing

The main aim of testing is to validate that user's requirement is met. It also ensures the provision of tests that are psychometrically accurate and reliable, as well as generalized and replicable outcomes. System testing is a fully functional method of testing the whole system to ensure that the system is bound to all the specifications provided by the client in the form of the documentation of the functional specification or system specification.

One of the central processes of software development is the software testing process, as any good software product is evaluated in one way or another. However, in terms of time, manpower, or funds, the testing process also has to function on minimal resources (Utting, et al., 2016).

Some of the major reasons why we test includes cost savings, security check and customer satisfaction. There are several reasons why people test systems

There are several types of testing, they include:

4.3.1 Recoverability Testing

Often disasters happen in a system, so therefore there is a great need to evaluate how systems operate when they experience such disasters, do the system continue operating after such disasters? For example, when trying to download a file and the connection is lost, what happens when the connection is restored? does the system restart the download or continue from where it stopped. All these above questions are answered using recoverability testing.

Recoverability testing is when you cause your program to fail. So both are possible in order to prove that recovery from the failure is possible. And they also worked well. The purpose, clearly, is to rapidly recover.

When performing recoverability testing we are measuring the following ((QAPlatforms, 2019):

- How long does it take for your system to resume normal operations?
- What percentage of scenarios can your system successfully recover from?
- Can the system recover all lost data?
- Can users reconnect successfully?

4.3.2 Integration Testing

The stage in the testing of software in which individual software modules are integrated and evaluated as a group. Integration testing is carried out to determine the compliance with stated functional specifications of a system or component (Wikipedia, 2020).

Some different type of integration testing includes:

- big-bang
- mixed (sandwich)
- risky-hardest
- top-down
- bottom-up.

4.3.3 Functional Testing

This is could done manually or automated, the main goal is to test to every function in the system, accurate are input are given to the system to verify if the system produces the right output. In them POMS functional testing was carried out

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

There is a large number of under treatment of Osteoporosis (a disease characterized by the loss of bone mass and the deterioration of the tissue) as report by the national osteoporosis foundation. Research shows that the cause of this under treatment is due to some factors such as high cost, fear of the adverse effect and lack of education or awareness among individuals.

The POMS was built on the basis that interaction of patients to the same treatment varies across various individuals due to different attributes that are unique to the individuals hence the need to personalise medicine to get a better health outcome.

The aim of the project was to solve some of the barriers that cause under treatment of Osteoporosis by personalizing the treatment and also educating and creating awareness among individuals on Osteoporosis related topics.

The POMS is a multi-platform system for both the health care providers and the patients, it helps the medical practitioners to keep track of patients in real-time and educate the patients.

It was developed with python, JavaScript and Dart

5.2 Conclusion

If some of these barriers that lead to the massive under treatment is curbed then more people can be treated and money wasted on fragility fractures can be used for other things, also the patients will have a better health outcome

5.3 Recommendation

Areas to be explored and improved upon in the project includes

- The use of sensor to get real-time data of the risk factor could be introduced
- There should be a program that reduce the cost of treatment

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Extract from react

```
/* eslint-disable jsx-a11y/img-redundant-alt */
import React from 'react';
import Header from './header';
// import { toast } from 'react-toastify';
import { useHistory } from "react-router-dom";
import './assets/css/styles.css';



const HomePage = () => {
    const history = useHistory();
    const DownloadPage = () => {
        history.push('/downloads')
    }
    return (
        <>
            <div className="fixed-top" >
```

```
                <Header />
            </div>
            <br />
            <br />
            <br />
            <div className="topContainer" >
                <div className="column" >
                    <h3 className="ltp1" >
                        Personalising Osteoporosis health care through machine learning
                    </h3>
                    <div className="topContainer" style={{ marginTop: 40 }} >
                        <div className="column" >
                            <h4 className="ltp2" >
                                We help you manage your patient 's by managing patient’s records and providing support to medical personnels.
                            </h4 >
                            <button className="talentBtn " >
                                For Hospitals
                            </button>
                        </div >
                        <div className="column" >
                            <h4 className="ltp3" >
                                We help you keep track of your health and create a personalised health plan
                                for you.
                            </h4>
                            <button className="talentBtn2 "
                                onClick={DownloadPage} >
                                For Individuals
                            </button>
                        </div >
                    </div>
                </div >
                <div className="column" >
                    <img src="/img/consultation_pic.png"
                        className="cPeople"
                        alt="consultation_pic" />
                </div>
            </div >
        </>
    );
}
```

```
export default HomePage;



import React from 'react';
import Clogo from './assets/img/clogo.svg';
// import './assets/css/homepage.css';

const Header = () => {
    return (
        <>
            <nav className="navbar navbar-expand-sm navbar-light shadow p-3 bg-white" style={{ height: 64 }}>
                <a href="/" className="navbar-brand ml-2">
                    <img src={Clogo} alt="logo" className="navbar-brand" style={{ width: "128px" }} />
                </a>
            </nav>
        </>
    );
}

export default Header;

import React from 'react';
import Header from './header';
import "./assets/css/notfound.css";
import Error404 from './assets/img/error.svg';

const NotFound = () => {
    return (
        <>
            <div className="pageBody">
                <div className="fixed-top" >
                    <Header />
                </div>
                <br />
                <br />
                <br />
                <div className="imgDiv">
                    <img src={Error404} alt="error4" className="img1" />
                </div>
                <p className="lt1">
                    Oops! We can't find the page.
                </p>
```

```
                        <p className="lt2">
                            <a href="/" className="lt2b">Go to Homepage</a>
                        </p>
                    </div>
                </>
        )
}



export default NotFound;

import React, { useState } from 'react';
import "./assets/css/form.css";
import { toast } from 'react-toastify';
import Header from './header';

const Login = ({ setAuth }) => {
        // localStorage.removeItem('userEmail');
        // localStorage.removeItem('adminToken');
        // localStorage.removeItem('fullName');
        // localStorage.removeItem('adminId');
        // localStorage.removeItem('userId');
        // localStorage.removeItem('token');

        // keeps track of the state of the data
        const [inputs, setInputs] = useState({
                user_email: " ",
                user_password: " "
        });

        // destructure
        const { email, password } = inputs;

        // basically just gets the current value of the state and assigns it to the name
        const updateFields = e => {
                setInputs({ ...inputs, [e.target.name]: e.target.value.trim() })
        }

        // this async function sends a post request to the backend
        const onSubmitForm = async (e) => {
                e.preventDefault();
                try {
```

```
            const body = { ...inputs }
            const requestOptions = {
                method: 'POST',
                headers: { 'Content-Type': 'application/json' },
                body: JSON.stringify(body)
            };

            const response = await fetch(`${process.env.REACT_APP_SERVER_URL}/auth/login`, requestOptions);
            const parseRes = await response.json();

            // if successfull user is authenticated, send a succesfull toast message and it stores token to localstorage
            if (parseRes.token) {

                localStorage.setItem('token', parseRes.token);

                setAuth(true);
                toast("Logged in Successfully!", {
                    className: "calcuRoll",
                    draggable: true,
                    position: toast.POSITION.TOP_CENTER,
                    autoClose: 2000
                });

                // User is not authenticated and sends the error message
            } else {
                setAuth(false);
                toast(parseRes, {
                    className: "payrollToast",
                    draggable: true,
                    position: toast.POSITION.TOP_CENTER,
                    autoClose: 3000
                });
            }


        } catch (err) {
            console.error(err.message);
        }
    }


    return (
```

```
<>
    <div className="pageBody">
        <div className="fixed-top" >
            <Header />
        </div>
        <br />
        <br />
        <br />
        <div>
            <h3 className="SgT1" >
                Login to Calciu
            </h3>
            <h5 className="SgT2">
                Welcome, please login to continue.
        </h5>
        </div>
        <div className="formBody">
            <div className="inputBody">
                <label className="leftLabel">Work Email Address</label>

                <input
                    className="form-control shadow-sm "
                    type="text"
                    name="user_email"
                    placeholder="Enter Email"
                    value={email}
                    onChange={updateFields}
                />
            </div>
            <div className="inputBody">
                <label className="leftLabel">Password</label>
                <input
                    className="form-control shadow-sm"
                    type="password"
                    name="user_password"
                    placeholder="Enter Password"
                    value={password}
                    onChange={updateFields}
                />
            </div>
        </div>
```

```
                    <div className="buttonDivS">
                        <button className="buttonWithIconS" onClick={onSubmitForm}>
                            Login To Calciu
                            <img src="/img/cArrow.png" className="imgInButton" alt="Calciu arrow" />
                        </button>
                    </div>


                </div>
            </>
        );
}




export default Login;


import React from 'react';
import "./assets/css/dashboard.css"

const VerificationMsg = ({ closeToast }) => {
    const userEmail = localStorage.getItem('userEmail');

    async function resendEvent() {
        const value = { user_email: userEmail }
        const requestOptions = {
            method: 'POST',
            headers: { 'Content-Type': 'application/json' },
            body: JSON.stringify(value)
        };

        const response = await fetch(`${process.env.REACT_APP_SERVER_URL}/auth/resend-verification`, requestOptions);
        const parseRes = await response.json();
        console.log(parseRes);

    }
    return (
        <div>
            Please verify your account
            <button className="resendBtn" onClick={resendEvent}>Resend</button>
        </div>
    )
```

```
}

export default VerificationMsg;




// Extract from flutter codes

import 'dart:async';

import 'package:calciu/onboardingscreen.dart';
import 'package:flutter/cupertino.dart';
import 'package:flutter/material.dart';



void main (){
    runApp(CalciuApp());
}

class CalciuApp extends StatelessWidget{
    @override
    Widget build(BuildContext context) {
      return MaterialApp(
          home: HomePage(),
          debugShowCheckedModeBanner: false,
      );
    }
}

class HomePage extends StatefulWidget{
    @override
    _HomePageState createState() => _HomePageState();
}

class _HomePageState extends State<HomePage>{

    // move to on boarding screen
    @override
    void initState() {
```

```
    super.initState();

    // splash screen count down
    Timer(Duration(seconds: 4), ()=> Navigator.push(context, MaterialPageRoute(builder: (context) => OnBoardingScreen())));
  }

  @override
  Widget build(BuildContext context) {
    return Scaffold(
      body: Column(
      mainAxisAlignment: MainAxisAlignment.center,
        crossAxisAlignment: CrossAxisAlignment.center,
        children: <Widget>[
          Center(
            // the calciu logo is aligned here
            child: Image.asset('assets/clogo.png', height: 65.0,),
          )
        ],
      )
    );
  }
}

class SliderModel{
  String imagePath;
  String title;
  String desc;

  // constructor
  SliderModel({
    this.imagePath, this.title, this.desc
  });

  void setImageAssetPath(String getImagePath){
    imagePath = getImagePath;
  }
  void setTitle(String getTitle){
    title = getTitle;
  }
  void setDesc(String getDesc){
    desc = getDesc;
  }
```

```
    String getImageAsset(){
      return imagePath;
    }

    String getTitle(){
      return title;
    }
    String getDesc(){
      return desc;
    }




}

List<SliderModel> getSlides(){

    List<SliderModel> slides = new List<SliderModel>();
    SliderModel sliderModel =     new SliderModel();

    //1
    sliderModel.setImageAssetPath("assets/on1.png");
    sliderModel.setTitle("Learn today");
    sliderModel.setDesc("We provide you tangible information on    the Osteoporosis related topics");
    slides.add(sliderModel);



    sliderModel =     new SliderModel();
    //2
    sliderModel.setImageAssetPath("assets/on2.png");
    sliderModel.setTitle("Track health");
    sliderModel.setDesc("We help you monitor the state of your health in real-time, giving you a better experience ");
    slides.add(sliderModel);

    sliderModel =     new SliderModel();

    //3
    sliderModel.setImageAssetPath("assets/on3.png");
    sliderModel.setTitle("Get help");
    sliderModel.setDesc("We provide the oppurtunity to talk to communicate with your doctor during a case of emergency");
    slides.add(sliderModel);
```

```
    return slides;
}



// import 'dart:html';

import 'package:calciu/data/data.dart';
import 'package:flutter/cupertino.dart';
import 'package:flutter/material.dart';



class OnBoardingScreen extends StatefulWidget {
    @override
    _OnBoardingScreenState createState() => _OnBoardingScreenState();
}

class _OnBoardingScreenState extends State<OnBoardingScreen> {

    List<SliderModel> slides = new List<SliderModel>();
    int currentIndex = 0;
    PageController pageController = new PageController(initialPage: 0);

    @override
    void initState() {
        // TODO: implement initState
        super.initState();
        slides = getSlides();
    }

    Widget pageIndexIndicator(bool isCurrentPage){
        return Container(
            margin: EdgeInsets.symmetric(horizontal: 3.0),
            height: isCurrentPage ? 10.0 : 6.0,
            width: isCurrentPage ? 10.0 : 6.0,
            decoration: BoxDecoration(
                color: isCurrentPage ? Colors.blue: Colors.grey,
                borderRadius: BorderRadius.circular(12)
            ),
        );
    }
    @override
```

```
Widget build(BuildContext context) {
  return Scaffold(
    body: PageView.builder(
      controller: pageController,
      itemCount: slides.length,
      onPageChanged: (val){
        setState(() {
          currentIndex = val;
        });
      },
      itemBuilder: (context,index){
        return SliderTitle(
            imageAssetPath: slides[index].getImageAsset(),
            title : slides[index].getTitle(),
            desc : slides[index].getDesc(),
        );
      }),
        bottomSheet: currentIndex != slides.length - 1 ? Container(
          height: 60,
          padding: EdgeInsets.symmetric(horizontal: 20),
          child: Row(
            mainAxisAlignment: MainAxisAlignment.spaceBetween,
            children: <Widget>[
              GestureDetector(
                onTap: (){
                  pageController.animateToPage(slides.length - 1 , duration: Duration(milliseconds: 400), curve: Curves.linear);
                },
                  child: Text("SKIP", style: TextStyle(
                    fontFamily: 'Eina',
                    fontWeight: FontWeight.w700,
                    color: Colors.black
                  ),)
              ),
              Row(
                children: <Widget>[
                  for(int i = 0; i < slides.length; i++)    currentIndex == i ? pageIndexIndicator(true): pageIndexIndicator(false)
                ],
              ),
              GestureDetector(
                  onTap: (){
                    pageController.animateToPage(currentIndex + 1 , duration: Duration(milliseconds: 400), curve: Curves.linear);
                  },
```

```
                        child: Text("NEXT", style: TextStyle(
                            fontFamily: 'Eina',
                            color: Colors.black,
                            fontWeight: FontWeight.w700,
                        ),)
                    ),
                ],
            ),
        ) : Container(
            alignment: Alignment.center,
            width: MediaQuery.of(context).size.width,
            height: 60 ,
            color: Colors.blue,
            child: Text("Get Started", style: TextStyle(
                color: Colors.white,
                fontFamily: 'Eina',
                fontSize: 20,
                fontWeight: FontWeight.w700
            ),)
        ),
    );
  }
}



//

class SliderTitle extends StatelessWidget{
  String imageAssetPath, title, desc;
  SliderTitle({this.imageAssetPath, this.title, this.desc});

  @override
  Widget build(BuildContext context) {
    return Container(
      padding: EdgeInsets.symmetric(horizontal: 30),
      child: Column(
        mainAxisAlignment: MainAxisAlignment.center,
        children: <Widget>[
          Image.asset(imageAssetPath),
          SizedBox(),
          Text(title, textAlign: TextAlign.center, style: TextStyle(
            fontSize: 40,
```

```
                    fontFamily: 'Museo',
                    fontWeight: FontWeight.w700,
                    color: Colors.black,

                  ),),
                  SizedBox(height: 12,),
                  Text(desc, textAlign: TextAlign.center, style: TextStyle(
                    fontSize: 16,
                    color: Colors.black,
                    fontFamily: 'Eina',
                    fontWeight: FontWeight.w500,
                  ),)
                ],
              ),
            );
        }
}



// extracts from python code
```