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**A Unified Medical Information System**

**based on Machine Learning for Patients, Doctors, Pharmacists and Policy Makers**

A Thesis By

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for the degree of Master of Science in Information Technology

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Date: 22/09/2023

# EXAMINER DECLARATION

The undersigned have examined the thesis entitled **‘A Unified Medical Information System based on Machine Learning for Patients, Doctors, Pharmacists and Policy Makers’** presented by **Mr. Jashnil Kumar**, a candidate for the degree of Master of Science in Information Technology, Department of Computer Science and Mathematics, The University of Fiji and at this moment certify that it is worthy of acceptance.

Supervisor: **Professor A B M Shawkat Ali**, The University of Fiji, Fiji Signature:

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# ABSTRACT

Machine learning has the potential to revolutionize healthcare by providing a unified medical information system that benefits patients, doctors, pharmacists, and policymakers. The development of a unified medical information system based on machine learning has the potential to revolutionize healthcare by providing benefits to patients, doctors, pharmacists, and policymakers. Machine learning algorithms have demonstrated their effectiveness in analyzing big healthcare data and generating algorithms that perform on par with human physicians. These algorithms can extract valuable information and knowledge from Electronic Medical Records (EMRs), enabling physicians to make more accurate diagnoses and treatment decisions. Machine learning techniques can also assist in improving hospitalization prediction, mortality prediction, and clinical text classification.

Machine learning in a unified medical information system can benefit patients by improving the accuracy and efficiency of diagnoses and treatment plans. By analyzing large amounts of patient data, machine learning algorithms can identify patterns and trends that may not be apparent to human physicians, leading to more personalized and effective care. This can ultimately improve patient outcomes and reduce healthcare costs.

For doctors, a unified medical information system based on machine learning can provide decision-support tools that enhance their analysis and decision-making processes. Machine learning algorithms can improve feature ranking and classification accuracy by leveraging the knowledge captured in knowledge graphs and the taxonomical structure of the Unified Medical Language System (UMLS). This can help doctors identify relevant features and passages in clinical text, enabling them to make more informed decisions. Machine learning algorithms can assist doctors in making more accurate diagnoses, predicting disease progression, and personalizing treatment plans based on individual patient characteristics.

Pharmacists can also benefit from a unified medical information system by leveraging machine learning algorithms to improve drug discovery and personalized medicine. Machine learning techniques can analyze large datasets to identify potential drug candidates and predict their efficacy and side effects. This can accelerate the drug discovery process and lead to the development of more effective and personalized treatments.

Policymakers can utilize a unified medical information system to make data-driven decisions and improve healthcare policies. Machine learning algorithms can identify trends, patterns, and correlations that inform policy decisions and resource allocation by analyzing large-scale healthcare data. This can lead to more efficient and effective healthcare systems.

However, deploying machine learning algorithms in healthcare also raises ethical considerations. The opacity and uncertainty associated with machine learning algorithms can undermine the epistemic authority of clinicians and raise concerns about paternalism, moral responsibility, and fairness. Therefore, it is crucial to carefully consider the ethical implications and potential pitfalls of algorithmic decision-making in healthcare.

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# STATEMENT OF ETHICS

# Regrettably, due to the project's limited timeframe and the intricate challenges of managing extensive datasets, collecting personal data was an unfeasible endeavor. To address this, an anonymized dataset was used, a necessary step to ensure the utmost confidentiality of the information. By substituting sample names, the integrity of patient data was meticulously safeguarded. It's important to note that this standardized dataset was utilized across all proposed algorithms, yielding outcomes of noteworthy statistical significance. The body of the project encompasses a comprehensive 25,000-word count, exclusive of references and supplementary materials.

# Author: Jashnil Kumar

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# LIST OF ACRONYMS

Covid-19 - Coronavirus

EMRs - Electronic Medical Records

UMLS - Unified Medical Language System

SVM – Support Vector Machine

LR – Linear Regression

DT – Decision Tree

RF – Random Forest

EHR - Electronic Health Records

CHT - Computerized History-Taking

VAE - Variational Autoencoder

ANN - Artificial Neural Networks

SVR - Support Vector Regression

KRR - Kernel Ridge Regression

ePHRs - Electronic Personal Health Records

GIS - Geographic Information System

GBM - Gradient Boosting Machine

LASSO - Regularized Regression

HCHN - high-cost, high-need

RNN - Recurrent Neural Network

EMS - Emergency Medical Services

COPD - Chronic Obstructive Pulmonary Disease

XGBoost - Extreme Gradient Boosting

SGD - Stochastic Gradient Descent

AI - Artificial Intelligence

ML – Machine Learning

RMSE – Root Mean Square Error

MLP - Multilayer Perceptron

MARS - Multivariate Adaptive Regression Splines

# DEFINITIONS

**Algorithm** - An algorithm is a step-by-step set of instructions, or a systematic process designed to solve a specific problem or perform a particular task in a well-defined and efficient manner.

**Regression** - Regression is a statistical analysis method used to model and analyze the relationship between a dependent variable (the outcome or response) and one or more independent variables (predictors or features) to understand and predict the value of the dependent variable based on the values of the independent variables.

**Dataset**- a collection of information comprising different elements.

**Experiment** - An experiment is a systematic and controlled process used to test a hypothesis or gather data to better understand a specific phenomenon or answer a scientific question.

**Machine learning** - a computer science technique that enables computers to learn and make predictions or decisions without being explicitly programmed, by using patterns and data to improve their performance over time.

**Split**- the process of dividing something into two or more components

**Pre-processing** - series of steps and techniques used to clean, transform, and prepare raw data into a structured and meaningful format that can be used for analysis or training machine learning models.

**Information system** - a structured and organized set of components that collect, store, process, and distribute data to support decision-making and other organizational activities.

**Forecasting** – the process of predicting future events or trends based on historical data and analysis.

**Analysis** – the process of examining something carefully to understand its components, structure, and meaning.

# CHAPTER 1: Introduction

## Background

Data has become an indispensable part of our modern society and economy, exerting a substantial influence across multiple domains. Its availability and effective utilization have instigated remarkable transformations in various industries, fostering innovation and enhancing decision-making processes. Data is crucial in various fields, including science, technology, business, healthcare, and social sciences. It is used to make informed decisions, gain insights, and understand patterns and trends. In mathematics education, data is used to study the effectiveness of different teaching methods and interventions. For example, a study by Karatas-Aydin and Bostan [56] explored the views of gifted students on integrating the history of mathematics-embedded videos into mathematics classrooms. The study's findings revealed that the history of mathematics could be used both as a tool and as a goal in mathematics education. In the field of biodiversity, data is used to understand the distribution and abundance of different species and ecosystems. Bölling *et al*. [57] discussed the robust integration of biodiversity data using a representation based on object histories. This approach provides a coherent structure for documenting individual processes and states for any given object and linking this documentation. In healthcare, data is used to improve the quality of care and clinical decision-making. Zakim *et al*. [58] conducted a study comparing the completeness and accuracy of medical history data collected by physicians in electronic health records (EHR) with data collected through computerized history-taking (CHT). The study found that CHT improved the data quality for clinical decision-making, suggesting that methods to improve the completeness and accuracy of medical history data could have clinical value. The emergence of big data and advanced analytics techniques has further magnified the significance and potential of data [1]. Izhar and Shoid [59] highlight the importance of trustworthy organizational data for achieving organizational goals. The availability of reliable and accurate data enables organizations to make informed decisions and align their strategies with their objectives. Data also plays a significant role in interpreting and understanding models and frameworks. As data becomes more abundant, insight into models and frameworks becomes increasingly important [60]. The analysis and interpretation of data allow researchers and practitioners to gain a deeper understanding of complex systems and phenomena. The quality and reliability of data are crucial for its effective utilization. Merendino *et al*. [61] emphasized the importance of using multiple data sources to enhance the findings' reliability and validity. By incorporating diverse data sources, the risk of common method bias can be minimized, ensuring the accuracy and robustness of the data.

## Evolution of Data Analysis

The use of data has expanded with advancements in technology, allowing for the collection, storage, and analysis of vast amounts of information. Data is also vital in artificial intelligence (AI) and machine learning. Feature relevance and selection have been active research areas for years [62]. The evolution of data analysis has seen significant advancements in recent years, driven by technological developments and the increasing availability of large and complex 0s. Researchers and practitioners have explored various approaches and techniques to analyze data and extract meaningful insights. The analysis of data and identification of relevant features contribute to the development of effective AI models and algorithms. Data analysis techniques, including machine learning and statistical methods, have become essential for extracting insights and making informed decisions. These techniques enable the identification of patterns, trends, and correlations within large datasets [3,4]. In fields such as drug discovery, bioinformatics, and environmental monitoring, data analysis plays a pivotal role in identifying potential targets, predicting outcomes, and optimizing processes [5-7]. Nevertheless, the utilization of data also presents challenges. Data privacy and security is of utmost importance, particularly when dealing with sensitive information such as patient health records or personal identifiers [8]. Additionally, data quality and integrity are critical factors that need to be addressed to ensure the reliability and validity of analysis results [9,10]. Moreover, the data's sheer volume and complexity require advanced computational infrastructure, robust storage capabilities, and effective data management strategies [11,7].

## Data & Information Systems in Healthcare

One area where data proves particularly valuable is in healthcare, however, there are significant drawbacks associated with manual record-keeping compared to the utilization of medical information systems. Manual methods, such as paper-based systems, are susceptible to errors, loss, and damage. Retrieving and sharing paper records can be time-consuming and inefficient, impeding timely decision-making and care coordination. Moreover, manual record-keeping cannot generate real-time reports and analytics, making identifying patterns, trends, and potential cost-saving opportunities challenging. Additionally, the security and privacy of data are compromised with manual record-keeping, increasing the risk of unauthorized access and breaches. Medical information systems, such as electronic health record (EHR) systems, accumulate and store extensive patient data encompassing medical history, diagnoses, treatments, and medication usage. This data can be leveraged to monitor medication expenses and control healthcare costs [2]. By analyzing patterns in medication usage, healthcare organizations can identify areas of excessive spending and implement cost-saving measures such as promoting generic medication usage or negotiating better pricing with pharmaceutical suppliers [1]. Furthermore, data from medical information systems enables forecasting future medication expenditures. By analyzing historical medication usage data and applying predictive analytics models, healthcare organizations can estimate future demand for specific medications and allocate resources accordingly [2]. This forecasting capability facilitates improved strategic planning, budgeting, and resource allocation, ultimately leading to more efficient and cost-effective healthcare delivery. Moreover, integrating data and information systems has the potential to enhance the resilience of healthcare organizations, as demonstrated during the COVID-19 pandemic.

## Types of Record-Keeping in Healthcare

In healthcare, record keeping can be broadly categorized into two methodologies: automated information systems and manual record keeping. Each approach presents unique attributes concerning efficiency and data security, with the selection often guided by the healthcare establishment's contextual demands and technological framework.

## 1.4.1 Automated Information Systems

Automated information systems, also known as electronic health records (EHRs), involve using digital technology to store and manage patient information [46]. EHRs allow for the electronic capture, storage, and exchange of patient data, including medical history, diagnoses, medications, and test results. These systems offer numerous advantages over manual record keeping, including improved accessibility, efficiency, and accuracy of patient information [46]. EHRs can be accessed by authorized healthcare providers across different locations, facilitating seamless communication and coordination of care. They also support decision-making by providing real-time access to patient data and clinical decision-support tools [46].

## 1.4.2 Manual Record

Manual record keeping involves using paper-based systems to document and store patient information. This traditional method requires healthcare providers to physically write, file, and retrieve patient records [47]. Manual record keeping can be time-consuming and prone to errors, such as illegible handwriting or misplaced documents. It also limits the accessibility and sharing of patient information, as records need to be physically transported or faxed between healthcare providers [47].

## 1.5 Covid–19 Pandemic vs Manual Records

The COVID-19 pandemic has significantly impacted various aspects of society, including healthcare and record-keeping practices. While most developed nations harnessed the benefits of readily available technological resources for data management during the pandemic, certain developing countries, such as Fiji, faced limitations that necessitated the adoption of manual systems to track information [48]. During the COVID-19 pandemic, manual record-keeping in healthcare has posed several disadvantages. One of the main challenges is the time-consuming nature of manual record-keeping, which can lead to delays in accessing and retrieving patient information [49]. This can be particularly problematic during a fast-paced and rapidly evolving crisis like the pandemic, where timely access to accurate patient data is crucial for effective decision-making and patient care [49]. Another disadvantage of manual record-keeping during the pandemic is the increased risk of contamination and transmission of the virus. Paper-based records can act as potential fomites, facilitating the spread of infectious diseases [50]. In healthcare settings, where infection control measures are of utmost importance, handling and storing physical records can pose a risk to patients and healthcare workers [50].

## 1.6 The Problem

Manual health record keeping has several disadvantages that can impact the efficiency and effectiveness of healthcare systems. One major drawback is the time-consuming nature of manual record-keeping, which can lead to delays in accessing and retrieving patient information [53]. This can hinder timely decision-making and patient care, especially in urgent situations like the COVID-19 pandemic [54]. Manual record-keeping also increases the risk of errors and inaccuracies in data entry and documentation [52]. Illegible handwriting, incomplete information, and misplaced or lost records can compromise the quality and reliability of patient data [52]. In the context of the pandemic, accurate and up-to-date information is essential for contact tracing, monitoring disease progression, and ensuring appropriate treatment and care.

Furthermore, manual record-keeping can hinder efficient communication and coordination among healthcare providers, especially when remote collaboration and telemedicine are necessary [51]. The lack of real-time access to patient information can impede timely decision-making and continuity of care, particularly when healthcare professionals are working remotely or in different locations [51].

Another disadvantage of manual record keeping is the limited accessibility and sharing of patient information [55]. Physical records must be transported or faxed between healthcare providers, which can be time-consuming and prone to errors [55]. This can impede the seamless exchange of information and collaboration among healthcare professionals, particularly in emergencies or when remote access to patient data is necessary.

## 1.7 Research Questions

This thesis aims to examine and evaluate a range of machine learning algorithms employed in healthcare forecasting. Furthermore, it seeks to propose an optimally suited algorithm for predicting spending in the medical sector. The mini-thesis will thoroughly analyse diverse algorithms within this domain to identify the most effective approach for forecasting. The research will address the following key research questions:

i. Which algorithm is the most suitable for forecasting expenditure on medicine?

ii. What are the top three algorithms for forecasting healthcare expenditure?

## 1.8 Aims

This research aims to test, analyze, and forecast top forecasting algorithms and identify the best algorithm that can be used for forecasting medical spending. The relevant authorities can use the best algorithm to forecast spending each year for budgeting and other purposes that may concern them.

## 1.9 Motivation

There are several compelling reasons for conducting a thorough analysis of different forecasting algorithms in the healthcare domain. Firstly, it is crucial to acknowledge that existing algorithms for healthcare forecasting often lack comprehensive testing and validation. While some algorithms may show promise in other domains or general forecasting tasks, their effectiveness and suitability for healthcare forecasting remain uncertain. Therefore, it is essential to critically evaluate and compare multiple algorithms to identify the most reliable and accurate approach.

Another significant reason for scrutinizing forecasting algorithms in healthcare is the need for continuous updates and improvements. As the healthcare industry generates increasingly complex and diverse data, algorithms must regularly update to accommodate these evolving trends. Outdated algorithms may not effectively capture the intricacies of modern healthcare data, resulting in suboptimal forecasting performance. Researchers can identify areas where algorithmic enhancements are necessary by assessing and analyzing different algorithms and propose innovative solutions to achieve more accurate and precise healthcare forecasts.

Furthermore, it is important to note that while there is a considerable body of literature on forecasting spending, not all papers focus specifically on healthcare. Healthcare presents unique challenges and characteristics that require specialized algorithms and methodologies. Therefore, relying solely on algorithms developed for other domains may not yield optimal results in healthcare forecasting. By narrowing the scope of analysis to algorithms specifically tested and evaluated in the healthcare context, researchers can gain insights into the performance, limitations, and potential of these algorithms in addressing the specific challenges of healthcare forecasting.

In summary, conducting an in-depth analysis of various forecasting algorithms in healthcare is essential due to the limited testing of existing algorithms, the need for continuous updates to adapt to complex healthcare data, and the unique requirements of the healthcare domain. By delving deeper into these algorithms, researchers can identify the most effective approaches and contribute to advancing healthcare forecasting by proposing innovative algorithmic solutions and improving overall accuracy and reliability in this critical field.

This thesis is dedicated to the comprehensive analysis of algorithms used for healthcare expenditure forecasting. Its central objective is to determine the algorithm that provides the highest level of accuracy in predicting healthcare spending. The study will thoroughly examine various algorithms proposed in the literature, considering their strengths, limitations, and performance metrics. In addition to identifying the best algorithm, the research aims to propose improvements and enhancements to optimize their forecasting capabilities. This may involve incorporating novel data sources, refining algorithmic techniques, or leveraging advancements in machine learning and forecasting methodologies. The intent is to develop more robust and reliable algorithms to generate precise and actionable forecasts for healthcare expenditure. By achieving accurate and reliable forecasts, the research contributes to the effective planning and allocation of resources in healthcare management. Decision-makers can use these forecasts to optimize budgeting, strategic planning, and operational decision-making processes. Furthermore, the study's findings and proposed improvements can serve as a foundation for future research and development in healthcare expenditure forecasting. Overall, this mini-thesis endeavors to provide a detailed and comprehensive examination of algorithms for healthcare expenditure forecasting, aiming to identify the best algorithm and propose enhancements that enable more informed decision-making and efficient resource allocation in healthcare management.

## 1.10 Objectives

The research endeavors are directed towards achieving the following objectives:

1. Testing five algorithms with available data and forecast expenditure; and
2. Analyzing the top 3 algorithms that will be best suited for forecasting expenditure.

## 1.11 Methodology

Research Methodology of the research is divided into the following sections:

## 1.11.1 Literature Review – Phase 1

The initial stage of the data collection method involves conducting a comprehensive literature review, where the works of various researchers will be examined and compared. Additionally, a survey of relevant studies conducted by other researchers will be reviewed to determine the algorithms utilized in previous research on medical spending. Once the suitable algorithm for forecasting expenditure is identified, the next step will be to select the top three algorithms based on the findings from the related works. The below steps were followed:

## 1.11.1.1 Information Extraction

This process involves methodically searching for, carefully selecting, and thoroughly analyzing relevant research papers that focus on predicting healthcare expenses and revenue using machine learning techniques. Both scholarly journal articles and conference papers were utilized for this research, ensuring the application of suitable methodologies to extract meaningful insights and conclusions.

## 1.11.1.2 Literature Source

A limited but trusted set of digital databases was utilized to gather research papers, focusing on discovering the latest machine learning algorithms employed for forecasting healthcare spending and revenue within a five-year timeframe. The digital platforms accessed for this study include:

i. IEEE Xplore

ii. ScienceDirect

iii. Wiley

iv. Springer

v. Google Scholar

These platforms were carefully chosen to provide a well-rounded insight into recent developments in this field.

## 1.11.1.3 Search Strategy

This research utilized different features to filter out and acquire the most appropriate papers.

*Table 1. Shows the search strategy techniques used in the research.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Search Terms | Techniques | Boolean Operators | | Results |
| 1. Medical Information system 2. Machine Learning 3. Forecasting 4. Predicting | Truncation search (\*) | AND | OR | Medical Information System AND Machine Learning\* AND Forecasting OR Predicting |

A collection of search terms was pinpointed relevant to the research theme, including phrases like "medical information system," "machine learning," and "algorithm/forecasting." Truncation was applied to the search terms to widen the scope of the search and encompass a broader range of papers with pertinent insights. For instance, "forecast\*" was utilized to encompass related terms like "forecasting," "forecasted," or "forecasts." A blend of Boolean operators, specifically "AND" and "OR" was employed to connect the terms in the search query, for example: "Medical Information System AND Machine Learning\* AND Forecasting OR Predicting." This approach aimed to gather relevant information from various angles comprehensively.

## 1.11.1.4 Study Selection Conditions

Several relevant previous studies were identified concerning Information Systems and machine learning algorithms, contributing to the complexity of the selection process. Consequently, this investigation employed specific inclusion and exclusion criteria to navigate this challenge.

The inclusion criteria encompassed:

* + 1. The prior work should extensively address machine learning algorithms about healthcare expenditure or revenue;
    2. The prior work should be authored in English, enhancing accessibility and comprehension; and
    3. The prior work should fall within 2018-2023.

Conversely, the exclusion criteria comprised:

1. Literature that did not pertain to machine learning was excluded.
2. Works that appeared in multiple databases were disregarded, ensuring a focused selection process.

## 1.11.1.5 Research Results

## 

A sum of 20 suitable research papers, comprising both journal articles and conference papers, were unearthed in the literature. While this tally fell slightly below initial expectations, it remains congruent with the essential criteria and proves adequate for the research, especially considering the confined five-year scope of prior work.

## 1.11.2 Data Source – Phase 2

The data source for this study will be provided by an anonymous medical clinic, ensuring the protection of patient information. To maintain confidentiality, the names of individuals and their visit dates will be altered and extracted from a separate sample dataset. The data will be divided into two sets: 95% will be allocated as training data, and the remaining 5% will be designated as testing data.

## 1.11.3 Development of Unified Information System – Phase 2

Develop a comprehensive and unified information system. This system will cater to patients, doctors, pharmacists, and policymakers' needs. We will conduct an extensive scoping exercise involving all relevant stakeholders to ensure its effectiveness. Through this process, we will gather valuable insights and requirements. Based on these inputs, we will design a mockup showcasing the information system's envisioned functionalities and user interface. The Entire development study is discussed later in the chapter.

## 1.11.4 Experimental Testing – Phase 4

The dataset will be used to test the top 5 algorithms identified through the literature review, and based on their accuracy scores, the best three algorithms will be determined. The model development process will take place using Google Collaboratory, where the experimental testing involves training the model with the training data and evaluating its performance using the testing data. Upon completion of the training and testing phase, the accuracy scores of each algorithm will be calculated and compared. This comparison will enable the selection of the three best algorithms based on the obtained results. The entire experimental study is discussed in later chapters.

# CHAPTER 2: Literature Review

## 2.1 INTRODUCTION

## 2.1.1 Machine Learning

Due to its potential in forecasting and decision-making tasks, machine learning has gained significant attention in various fields, including marketing, finance, healthcare, and environmental sciences. Machine learning techniques have been applied to improve forecasting models, leading to better decision-making in direct marketing campaigns [13]. Similarly, in the context of COVID-19, machine-learning models have been used to forecast infection rates and predict the evolution of infectious diseases [14]. In finance and accounting, machine learning has been employed to enhance financial decision-making. Studies have explored the application of machine learning in predicting stock market trends, forecasting financial distress, and analyzing financial statement information [15-17]. These applications have demonstrated the potential of machine learning in providing valuable insights for informed decision-making in the financial sector. Machine learning has also been utilized in the energy sector to forecast energy commodity prices, supporting policymakers and decision-makers in the international energy market [18]. In addition, machine learning has been applied to predict health insurance premiums, enabling more accurate pricing and decision-making in the insurance industry [19]. In the healthcare sector, machine learning has shown promise in forecasting healthcare spending, predicting patient outcomes, and assisting in resource allocation. Machine learning algorithms have been used to identify high-cost patients, estimate hospitalization costs, and forecast healthcare expenditures. These models can potentially improve decision-making by providing insights into patient risk profiles and resource needs. Machine learning has also been applied to other domains, such as supply chain management, stock market analysis, and environmental sciences. In supply chain management, machine learning has been used to predict supply chain financial risks and enhance decision-making in logistics and operations [20,21]. Machine learning techniques have been employed in stock market analysis to forecast stock prices and identify trading entry points [22,23]. In environmental sciences, machine learning has been utilized to predict rainfall patterns and analyze ecological data [24]. While machine learning offers significant potential in forecasting and decision-making, some challenges need to be addressed. These challenges include data quality, privacy concerns, interpretability of models, and the need for skilled personnel with expertise in both machine learning and the specific domain of application [25,26]. Additionally, the interpretability of machine learning models is crucial, particularly in high-stake domains where decision-makers need to understand the rationale behind the recommendations [27,28].

## 2.1.2 Forecasting Techniques

Forecasting is crucial in various domains, such as smart grids, geology, medicine, and economics. Machine learning techniques have been widely employed to improve the accuracy and efficiency of forecasting models. Deep learning has gained significant attention in forecasting due to its ability to capture complex patterns and relationships in data. Akhtaruzzaman *et al*. [63] proposed a distributed deep-learning model for load forecasting in smart grids using the HSIC bottleneck technique. They demonstrated that incorporating deep learning techniques can provide higher accuracy in load forecasting. Harrou *et al*. [64] developed a deep learning framework for forecasting emergency department overcrowding, showing the superior performance of the variational autoencoder (VAE) compared to other algorithms. Ridge regression is a powerful regression technique used for forecasting. Li *et al.* [65] employed ridge regression-based predictors to forecast daily crude oil prices. They enhanced the accuracy of ridge regression by using differential evolution (DE) to optimize the regularization item and weights. Additionally, Li *et al.* [65] highlighted the effectiveness of kernel ridge regression (KRR) in wind forecasting, where KRR outperformed other methods, such as support vector regression (SVR) and artificial neural networks (ANN). Support vector regression is a popular machine-learning technique used for forecasting. Pourmousavi *et al*. [66] evaluated the performance of feature selection techniques and machine learning algorithms, including SVR, for future residential water demand forecasting. They found that implementing the feature selection method improved the accuracy of SVR in forecasting water demand. Other forecasting techniques are available, such as Linear Regression, Decision Tree Regression, and Random Forest model, which offer a wide range of forecasting methods that can be applied to various domains. Deep learning models, such as neural networks and autoencoders, have shown promising results in capturing complex patterns. Ridge regression and support vector regression are effective techniques for forecasting, while ensemble methods and federated learning can improve accuracy and robustness. The choice of the appropriate forecasting technique depends on the specific domain and characteristics of the data.

## 2.1.3 Medical Information System

Information systems play a crucial role in healthcare by facilitating managing and storing patient health information, improving access to healthcare services, and supporting decision-making processes. Various types of information systems in healthcare include electronic personal health records (ePHRs), laboratory information system databases, electronic medical records (EMRs), and geographic information systems (GIS). ePHRs are patient-centric systems allowing individuals to manage and store their health information [29]. They can be categorized into three types: untethered or stand-alone ePHRs, tethered ePHRs, and integrated or unified ePHRs [29]. Laboratory information system databases collect routine individual-level biomarker data from general practitioners and hospital encounters [30]. EMRs are computerized patient records that aim to organize, secure, complete, and improve the quality of patient healthcare records [31]. GIS is a tool to assess healthcare accessibility and identify optimal locations for healthcare services [32]. Information systems in healthcare offer numerous benefits. They empower healthcare consumers by providing them with easy access to their health information, enabling them to participate in the management of their health actively [33]. This increased engagement can lead to improved health outcomes and reduced healthcare expenditure [33]. Information systems also enhance the efficiency of healthcare processes by facilitating information sharing between healthcare providers and improving the quality of care and patient safety [34]. They can support effective decision-making, aid in identifying hidden patterns in data, and provide decision support for medical professionals [35]. Additionally, information systems can contribute to the resilience and sustainability of healthcare systems [36]. During pandemics, information systems in healthcare play a crucial role in managing and responding to the crisis. The COVID-19 pandemic, for example, has led to decreased healthcare utilization due to mobility restrictions, social distancing measures, and fears of contracting the virus within healthcare facilities [37]. Information systems can help mitigate the impact of the pandemic by facilitating telehealth services, remote monitoring of patients, and disseminating accurate and timely information [38]. They can also support contact tracing efforts and assist in resource allocation and decision-making processes [37].

## 2.2 Prior Work - Forecasting Medical Expenditure

Literature review played a critical role in this research endeavor, serving as a crucial foundation in acquiring previously published research by various scholars. This process yielded a comprehensive understanding of the chosen subject matter, along with the identification of the most robust supporting algorithms. Through this rigorous exploration of existing literature, five distinct algorithms emerged as noteworthy contenders. These forecasting machine learning algorithms, discovered through our thorough review, have demonstrated their prominence as the most extensively employed predictive tools within the medical sector. They have proven their effectiveness in forecasting a diverse array of critical variables, including but not limited to revenue, expenditure, and disease prevalence. The following have been unveiled as our significant findings:

## In a study conducted by a researcher [68,69], four predictive models were employed to predict patients' expenditures based on historical periods. These models encompassed ordinary least squares linear regression (LR), regularized regression (LASSO), gradient boosting machine (GBM), and recurrent neural networks (RNN), which represent a deep learning approach. The research paper delves into a comprehensive investigation of the temporal consistency within healthcare expenditures observed in a sizeable state Medicaid program. The study unveils a prevalent and robust temporal correlation pattern within these expenditures. Advanced machine learning models were harnessed to enhance the precision of forecasting healthcare costs, particularly for high-cost, high-need (HCHN) patients. Notably, the study underscores the potential efficacy of machine learning models, such as the recurrent neural network (RNN), in providing highly accurate predictions of healthcare expenditures, aligning them more closely with actual rankings [68]. The research adopted a meticulous three-step approach for prediction, which included employing an E-dimensional vector to ascertain the significance of elements within each embedding. Furthermore, the study showcased that healthcare expenditures exhibit substantial inter-period correlation, underscoring their pronounced temporal consistency. Overall, the findings from the study underline the capacity of machine learning methodologies to serve as valuable tools for the precise forecasting of healthcare expenditures, particularly for high-cost and high-need patient populations. This, in turn, can contribute to informed preventive care strategies, reducing overall healthcare expenditures, and optimising care delivery efficiency. Importantly, the researcher utilized a dataset from a prominent state Medicaid program as the foundation for its analysis. Healthcare empirical insights into the temporal aspects of healthcare spending and the potential for machine learning-driven forecasting in this critical domain [68].

## Another research by [70] focused on employee machine learning models such as Artificial Neural Networks, Support Vector Machines, Moving Average, and Linear Regression to predict the necessity for pre-hospital emergency medical services (EMS) and to improve operational efficiency. The author noted that integrating a Geographic Information System (GIS) allows for the visualization of the spatial distribution of forecast demand and error, aiding in emergency planning and decision-making. The author [70] also emphasizes the importance of response time in emergency cases and aims to study how to shorten the response time to improve efficiency and provide timely pre-hospital EMS. The authors used a Geographic Information System (GIS) to manage and visualize the spatial distribution of forecast demand and error. The research also built a flexible model that organizes demand data based on user-defined area and time. The model developed in the research organizes demand data based on user-defined area and time step sizes, making it adaptable to different scenarios. Compared to other models, the study focused on the regression capabilities of Support Vector Machines (SVMs) for predicting EMS call volume. The data used in this paper was collected from the New Taipei City EMS, which was used for training and validating machine learning models. The authors used four temporal factors in their research, without the year attribute, to capture the demand change over time for the forecasting models. The study [70] presented preliminary results of daily forecasts using 34 months of training data and the last two months for validation. The research outcome has the potential to be applied to the current practice, as it offers an easy-to-use model with acceptable prediction performance. The study [70] also mentioned that Further research could explore the integration of online training for the forecast of EMS demand, as it produces close to optimal solutions relatively fast and is more appropriate for real-time or efficient forecasting. The study also provided a positive and research-worthy remark that the potential of Support Vector Machines (SVMs) regression capabilities in EMS demand forecasting can be further investigated, as previous studies have mainly focused on SVMs for classification problems.

## Kan *et al*., [71] proposed research to determine the performance of the two linear regression models namely standard linear regression and penalized linear regression in terms of forecasting the future healthcare costs in older adults. The study focused on predicting future healthcare costs in older adults, using the comorbidity indicators from 2009 to 2012 to predict costs in 2013, it also demonstrated the advantages of using transparent and easy-to-interpret penalized linear regression for predicting future healthcare costs, providing a practical and incremental step forward in risk adjustment. The use of longitudinal data increased prediction accuracy, highlighting the potential of penalized regression models for improving risk adjustment and population health management in healthcare insurance providers and policymakers. The paper utilized a retrospective cohort study design, analyzing data from the IMS LifeLink Health Plan Claims Database containing fully adjudicated and de-identified medical and pharmaceutical claims from health insurance plans. For the study, the author [71] utilized data from the IMS LifeLink Health Plan Claims Database, which contains fully adjudicated and de-identified medical and pharmaceutical claims from health insurance plans; it included 81,106 Medicare Advantage patients with 5 years of continuous medical and pharmacy insurance from 2009 to 2013. The comparison of standard linear regression and penalized linear regression models, including lasso regression, was carried out in the experiment. The performance of the models was evaluated using metrics such as R2 (coefficient of determination) to assess prediction accuracy. The study [71] further examined the prediction ratios generated by the different models across different levels of predicted risk. Penalized regression models offer transparency and interpretability within the familiar regression framework, making them easier to train and scale than other machine learning techniques. Using longitudinal data in the models also increases prediction accuracy, further enhancing their practical utility in predicting healthcare costs. Ordinary least squares (OLS) performed poorly, with an R2 of 16.3%. Penalized linear regression models, particularly lasso regression, performed better, with R2 ranging from 16.8% to 16.9%. The researcher [71] also noted that Further research is needed to confirm the findings in larger and more diverse samples, which would enhance. In generalizability of the results, further studies should be conducted to establish the external validity of the findings by using test data drawn from a different period or a different health plan. This would help validate the effectiveness of the penalized regression models in predicting future healthcare costs in older adults.

## A study [84] claimed that Healthcare costs are a significant and growing portion of GDP, making it challenging to predict their growth due to complex time trends and dependencies on economic measures. Machine learning techniques are shown to improve forecast accuracy by 30% compared to realized costs [84]. The study also used a random forest approach to estimate the impact of the 2018 TARMED revision on aggregate costs, resulting in savings of 0.36 billion CHF, less than the proposed target of 0.47 billion CHF. The study further proposes a novel, tractable, and flexible prediction approach for healthcare costs, which increases the accuracy of predictions compared to existing forecasts by 20%. For experimental purposes, the machine learning techniques utilized were the Random Forest model, to improve the accuracy of healthcare cost forecasts compared to realized costs. The study utilized physician data provided by SASIS AG for the analysis. The data used in the analysis covers services provided in the outpatient sector. Machine learning techniques, particularly the Random Forest model, improved the accuracy of healthcare cost forecasts by 30% compared to realized costs. The Post-Lasso model performed the best among the models considered, although the difference in performance was marginal. The Pruned Tree, Random Forest, and Post-Lasso models were selected for growth predictions and were compared to the KOF prediction. The Random Forest model outperformed the KOF prediction, with an average deviation of 2.3 compared to KOF's 3.3. The author also mentioned Further exploration of machine learning techniques for healthcare cost prediction, including the evaluation of other models and algorithms. Investigation of additional factors that may impact healthcare costs, such as demographic changes, technological advancements, and policy reforms, and Consideration of the potential for incorporating more complex data, such as time series data, to improve the accuracy of cost predictions.

## Yang *et al*., [88] applied various machine learning techniques to predict healthcare expenditures for high utilizers in a large public health program. This shows promise in identifying individuals who may require targeted preventive care. The study focused on improving interpretability by quantifying the contributions of influential input variables to the prediction score, which helps advance the field toward lowering healthcare costs. The study [88] applied and developed machine learning techniques, including linear models, tree-based models, and deep neural networks, to forecast healthcare expenditures for high utilizers in a large public health program. The results show promise in predicting healthcare expenditures for high utilizers, which can aid in identifying individuals who may require targeted preventive care. The study also focused on improving interpretability by quantifying the contributions of influential input variables to the prediction score, providing insights into the factors that contribute to high healthcare costs for certain individuals. The findings contribute to advancing targeted preventive care, helping to lower overall healthcare costs by identifying and addressing the needs of high utilizers. The quantification of influential input variables in the prediction score enhances interpretability insights into the factors contributing to high healthcare costs for certain individuals. The study also mentioned that information can guide decision-making in developing preventive care strategies. The quantification of influential input variables in the prediction score enhances interpretability, providing insights into the factors contributing to high healthcare costs for certain individuals. The information can guide decision-making in developing preventive care strategies. The authors [88] also quantified the contributions of influential input variables to the prediction score, aiming to improve interpretability. The study also concludes that machine learning techniques, including linear models, tree-based models, and deep neural networks, show promise in predicting healthcare expenditures for high utilizers in a large public health program.

## Another study by [85] aimed to contribute to the interpretability of deep learning models in predicting healthcare costs, comparing their performance with traditional machine learning methods and proposing a novel interpretation method. The study proposed a novel interpretation method to examine how the deep learning model performs differently from other methods when facing fluctuations in monthly costs. It found out that while most traditional prediction models worsen with greater fluctuation in the data, the deep learning model can incorporate the fluctuation information and improve prediction accuracy. The study aimed to provide a better understanding of the performance of deep learning models in predicting future costs of patients. It incorporates a time series of information about members' healthcare costs and key variables summarizing their healthcare services utilization for precise cost prediction. The study [85] used a long short-term memory (LSTM) based recurrent neural network as the deep learning approach for predicting healthcare costs. It compares the performance of this deep learning model with traditional machine learning methods, including linear regression, lasso regression, ridge regression, and random forest. The study incorporates time series information about members' healthcare costs and key variables summarizing their healthcare services utilization for precise cost prediction. It focuses on the fluctuation in the time series of healthcare costs and uses the monthly costs in the past 48 months to calculate the fluctuation. The study [85] uses claims data of 1,434,912 members from the greater Rochester area. The dataset includes information on 62,406,379 encounters over seven years. It contains standard claims information, including medical and pharmacy claims, as well as demographic information such as age, gender, and payer type. The goal of the study is to provide accurate future individual cost predictions. The deep learning model incorporated sequential information and accurately predicted healthcare costs, outperforming other methods. The deep learning model demonstrated the ability to incorporate fluctuations in monthly costs and improve prediction accuracy, while most traditional prediction models performed worse with greater fluctuation in the data. The study [85] also reported that the deep learning model had significantly lower absolute error than the regression models, and the random forest model improved prediction over the baseline.

## Another study based in China by [72] aimed to identify and predict potential high-cost Chronic obstructive pulmonary disease (COPD) patients using machine learning approaches, which can help address the economic burden of COPD in China. results of this study said to be utilized by healthcare data analyst, policymakers, insurers, and healthcare planners to improve the delivery of health services. The study compares the predictive performance of different variable sets using logistic regression, random forest (RF), and extreme gradient boosting (XGBoost) models. Machine learning approaches, including logistic regression, random forest (RF), and extreme gradient boosting (XGBoost), were used to estimate the medical costs of COPD patients in a large city in western China. The authors [72] utilized the Medical Insurance Data of a large city in western China to estimate the medical costs of Chronic obstructive pulmonary disease (COPD) patients. The study stated that machine learning approaches in healthcare data analysis can provide reliable and correct results for predicting high-cost patients and optimizing healthcare resource allocation. After completing the experimental parts, it was noted that all three models (logistic regression, RF, and XGBoost) demonstrated good predictive performance however XGBoost model outperformed the others, achieving an area under the ROC curve of 0. 801. The areas under the ROC curve for logistic regression, RF, and XGBoost were 0.787, 0.792, and 0.801, respectively. The author [72] mentioned that the use of machine learning approaches in healthcare data analysis can provide reliable and correct results for predicting high-cost patients and optimizing healthcare resource allocation; it was also noted in the study that further research can be conducted to explore additional variables that could improve the predictive performance of the machine learning models in identifying high-cost Chronic obstructive pulmonary disease (COPD) patients in China.

## Engaging in pre-admission financial planning can be a demanding and anxiety-inducing task. To counter the issue, Kulkarni *et al*., [73] based a study on a group of the New York Population which aims to predict hospital charges for patients before admission, helping them plan their finances and allowing insurance companies to forecast potential claims. The study [73] addresses the concern of increasing healthcare costs by developing a machine learning model to predict hospital charges before admission. It allows patients to plan their finances and insurance companies to forecast potential claims. For experimental purposes, the study utilizes secondary data from patient discharges in New York State in 2017 and employs feature engineering and regression techniques to predict the target value of "total charges”. The length of stay was found to have a linear relationship with the total cost, and the "age group" was identified as the most important predictor among the features considered. A stratified sampling technique was employed to sample the data from the population. Feature engineering was performed on categorical variables to enhance the model's predictive power. Different regression techniques were tested to predict the target value of "total charges," including random forest, stochastic gradient descent (SGD) regressor, K nearest neighbors regressor, extreme gradient boosting regressor, and gradient boosting regressor. Among the algorithms considered, the random forest regressor demonstrated the highest accuracy, with an R2 value of 0.7753. The study [73] further mentioned that further research could explore the application of machine learning techniques to predict hospital charges in different geographical regions or healthcare systems, beyond the scope of New York state's patient discharges, and future work could investigate the inclusion of additional variables such as patient demographics, comorbidities, or specific medical procedures to enhance the accuracy of the predictions.

## A study [86] examined personal health data to estimate insurance premiums and compares the effectiveness of different machine learning regression algorithms in predicting the cost of health insurance. It focuses on using regression analysis techniques such as Linear, Ridge, Lasso, and Polynomial regression to estimate the insurance amount. The study [86] provides insights into the factors that influence the cost of health insurance and highlights the importance of accurate predictions in helping individuals plan for their medical expenses. The study [86] employs the dataset "insurance" from Kaggle, which contains attributes such as age, gender, BMI, children, smoker status, and medical expenses. Data pre-processing involves deleting duplicate values and using label encoding to transform categorical values into numerical ones. The dataset is divided into training and testing sets, with 80% used for training and 20% for testing. The study [86] evaluates the performance of Linear, Ridge, Lasso, and Polynomial regression techniques and identifies polynomial regression as the most effective in predicting health insurance costs. The study [86] highlights the significance of predicting health insurance costs in helping individuals manage their medical expenses and pay their bills more easily. Regression techniques, such as linear regression, ridge regression, lasso regression, and polynomial regression, are identified as valuable tools in the field of prediction for estimating insurance amounts.

## Kaushik *et al.,* [90] discuss the use of artificial intelligence (AI) and machine learning (ML) in healthcare to predict health insurance premiums. It highlights the benefits of AI and ML in improving the efficiency and accuracy of health insurance coverage. The study [90] proposes a machine learning-based regression framework to predict health insurance premiums, using an artificial neural network model trained on various parameters such as age, gender, body mass index, number of children, smoking habits, and geolocation. The authors [90] trained an artificial neural network (ANN) model using a machine learning-based regression framework to predict health insurance premiums. The model achieved an accuracy of 92.72% in predicting the health insurance cost incurred by individuals based on various parameters such as age, gender, body mass index, number of children, smoking habits, and geolocation. The performance of the trained ANN model was evaluated using key performance metrics such as RMSE, MSE, MAE, r2, and adjusted r2. The evaluation metrics of the trained model were found to be better than those of the linear regression model, indicating the effectiveness of the machine learning approach in predicting health insurance premiums. The experimental results demonstrate the effectiveness of the proposed approach in accurately and efficiently predicting health insurance premiums, showcasing the potential of machine learning in the insurance industry. The machine learning-based regression framework proposed in this paper has practical implications for the health insurance industry. By accurately predicting health insurance premiums based on various parameters such as age, gender, body mass index, number of children, smoking habits, and geolocation, insurance businesses can provide clients with more accurate, quick, and efficient health insurance coverage. The author commented that the ability to predict health insurance costs can also benefit consumers by allowing them to make more informed decisions when selecting insurance plans. They can better understand the potential costs they may incur based on their characteristics, helping them choose the most suitable and cost-effective coverage. The authors suggest that future research can focus on improving the accuracy of the machine learning-based regression model for predicting health insurance premiums. The authors also recommend conducting further analysis to evaluate the model's performance on a larger and more diverse dataset, to ensure its generalizability and robustness. Additionally, future studies could investigate the potential integration of real-time data, such as wearable device data or electronic health records, to enhance the accuracy and timeliness of health insurance premium predictions.

## In response to the growing prevalence of unforeseen epidemic outbreaks, there is an imperative demand for the development of accurate predictive models. These models play a crucial role in elucidating the intricate factors that underlie the persistent upward trend in healthcare insurance costs. To challenge the issues, a study was done by [74], which focused on predicting medical insurance costs using regression algorithms and a dataset with 24 relevant attributes, aiming to reduce manual work and improve accuracy in the medical field. Various regression algorithms, including Linear Regression, Decision Tree Regression, and Random Forest Regression, were implemented and evaluated using metrics such as Mean Squared Error. The dataset includes attributes such as age, sex, BMI, children, smoker, region, charges, and more. The study [74] utilized a sample dataset from Kaggle, as it includes more attributes for a more comprehensive prediction of insurance costs. After the completion of the experiment, it was discovered that Random Forest Regression outperformed other algorithms with an R-squared value of 0.9533. The author also mentioned that further research could explore other regression algorithms or machine learning techniques to improve the accuracy of medical insurance cost prediction in the healthcare sector. The dataset used in this paper includes 24 features, but future studies can consider incorporating additional relevant attributes that may contribute to better prediction models. The author [74] also noted that future work can focus on incorporating real-time data and updating the prediction system to adapt to changing trends and patterns in the healthcare industry.

## Another study [80] explores using machine learning algorithms, specifically Linear Regression, Decision Tree Regression, and Gradient Boosting Regression, to predict healthcare insurance costs. The study utilizes a medical insurance cost dataset from the KAGGLE repository and compares the accuracies of the different regression models. The study [80] specifically highlights the high accuracy of the Gradient Boosting Regression model, with an r-squared value of 86. 7853%. The dataset is processed before training the regression models with training data. The research approach presented in the study provided a computational intelligence approach for predicting healthcare insurance costs, which can make insurance more effective in the healthcare industry. The study [80] highlighted the limitations of machine learning in predicting medical insurance costs and emphasized the need for further investigation and improvement in this area. Further investigation and improvement are needed in predicting medical insurance costs using machine learning approaches in the healthcare industry. The study [80] highlights the limitations of machine learning in this area, indicating the need for future research to address these limitations and enhance the accuracy of cost prediction models. The researcher also mentioned that including more diverse and comprehensive datasets could also be explored to improve the generalizability and robustness of the prediction models.

## The issue of health insurance fraud represents a critical challenge within the healthcare industry, posing significant financial and ethical concerns for insurers, healthcare providers, and policyholders alike. To counter this issue a study by [75] was carried out, the author [75] discusses that Health insurance fraud accounts for 3–10% of total medical expenditures every year. If the growth of fraud activities is allowed, it will cause irreversible consequences to the medical system. However, medical-related data is too large and complex, and it is difficult to process such a large amount of data with traditional statistical methods. Therefore, machine learning algorithms have become one of the important solutions. Whether the learning method can maintain its stability and give a more appropriate answer is a big question when faced with different data. Many related studies focused on medical insurance fraud and assessment, but few attempts to discover the important factors of medical fraud and find optimal machine learning methods. Therefore, this study used two unpublished datasets that might discover novel knowledge, and four machine learning methods, including Support Vector Machines (SVM), Decision Trees (DT), Random Forest (RF), and Multilayer Perceptron (MLP) to find the best machine learning method that can effectively detect medical fraud. From the results of DT, we also extracted 19 crucial characteristics of medical insurance fraud and grouped them into 4 categories, which are medical service providers, applied insurance claims amount, Healthcare Common Procedure Coding System (HCPCS), and beneficiary. The author [75] further commented that the results of experiments could provide valuable suggestions for insurance management to establish an automatic audit mechanism to eliminate medical fraud.

## A study [76] aimed to assess the applicability of machine learning tools in predicting healthcare costs for patients with acute coronary syndrome (ACS) using known risk markers. The study identifies the primary variable, higher depression scores, forecasting healthcare costs in 1-year follow-up among ACS patients. The research [76] highlights the potential of machine learning methods in optimizing the utilization of treatment strategies and decision-making for healthcare resource allocation. Healthcare costs were collected from electronic health registries for a 1-year follow-up period. The Cross-decomposition algorithms were used to rank the considered risk markers based on their impacts on variances. Regression analysis was performed to predict costs by entering the first top-ranking risk marker and adding the next-best markers, one by one, to build up 13 predictive models. It identifies higher depression scores as the primary variable forecasting healthcare costs, followed by low-density lipoprotein cholesterol and left ventricular ejection fraction. The study [76] highlights the potential of Machine Learning methods in optimizing the utilization of treatment strategies and resources in healthcare settings. It emphasizes the importance of considering known risk markers in predicting healthcare costs for patients with acute coronary syndrome. The findings contribute to understanding cost factors in this patient population and provide insights for decision-making in healthcare planning. Additionally, the study [76] also mentions the economic burden of cardiovascular diseases in the European Union, emphasizing the relevance of predicting and managing healthcare costs in this context. The average annual healthcare costs for patients with a recent acute coronary syndrome were €2601 ± €5378 per patient. The Depression Scale showed the highest predictive value (r = 0.395), accounting for 16% of the costs. When the next two ranked markers, LDL cholesterol (r = 0.230) and left ventricular ejection fraction (r = -0.227), were added to the model, the predictive value increased to 24% for the costs. The study demonstrates the potential of machine learning tools in predicting healthcare costs and highlights the importance of considering known risk markers, such as depression scores, in forecasting costs for patients with acute coronary syndrome. The findings suggest that higher depression scores are the primary variable in predicting healthcare costs for this patient population.

## Another study [81] aimed to predict the factors that affect medical expenses in patients who have undergone coronary artery bypass grafting (CABG) surgery, using machine learning algorithms. The study used data from the National Health Insurance Research Database (NHIRD) in Taiwan, focusing on patients who had their first CABG surgery between January 2014 and December 2017. The key factors identified were surgical expenditure, 1-year medical expenditure before the CABG operation, and the number of hemodialysis sessions. The XGBoost and SVR methods were found to be the best predictive models. The study [81] suggests the need to enhance healthcare management for patients with kidney-related diseases to prevent costly complications and reduce health insurance burdens in the future. The researchers [81] analyzed factors such as surgical expenditure, 1-year medical expenditure before the CABG operation, and the number of hemodialysis sessions to determine their impact on the 1-year medical expenses of CABG patients after discharge. The research provides valuable references for medical management with specific diseases, enabling effective control measures to reduce expenses and alleviate the burden on the government. By identifying key factors such as surgical expenditure, 1-year medical expenditure before CABG operation, and the number of hemodialysis, healthcare providers can focus on managing these factors to reduce medical expenses and improve patient outcomes.

## Navarro *et al.* developed a machine-learning algorithm using preoperative big data to predict length of stay (LOS) and inpatient costs after primary total knee arthroplasty (TKA) and propose a tiered patient-specific payment model that reflects patient complexity for reimbursement. It also proposes a tiered patient-specific payment model that reflects patient complexity for reimbursement, based on the algorithm's predictions [82]. The machine-learning algorithm developed in this study can predict the length of stay (LOS) and inpatient costs after primary total knee arthroplasty (TKA), which can help healthcare providers plan and manage resources efficiently. The model considers factors such as age, race, gender, and comorbidity scores to determine the payment amount, with higher complexity patients receiving higher reimbursement [82]. The algorithm and payment model have broad value-based applications, as they can contribute to the development of patient-specific care and value-based reimbursement models in orthopedic surgery. The study utilized a predictive naive Bayesian model to develop a machine-learning algorithm for predicting length of stay (LOS) and inpatient costs after primary total knee arthroplasty (TKA) using preoperative big data. The algorithm was created and trained using an administrative database that included 141,446 patients who underwent primary TKA from 2009 to 2016 [82]. Algorithm performance was evaluated using the area under the receiver operating characteristic curve and the percentage accuracy. The machine-learning algorithm required inputs such as age, race, gender, and comorbidity scores ("risk of illness" and "risk of morbidity") to predict LOS and cost. A proposed risk-based patient-specific payment model was derived based on the algorithm's outputs, with cost add-ons increasing in tiers of 3%, 10%, and 15% for moderate, major, and extreme mortality risks, respectively [82].

## As the global obesity epidemic continues to expand, it is becoming increasingly evident that the associated healthcare costs are on an alarming upward trajectory. This issue stands at the intersection of health, economics, and policy, demanding immediate attention and innovative solutions. To counter this, a study by [77] highlights the importance of estimating and predicting healthcare costs, particularly related to obesity prevention strategies, a global health concern. The use of genetic variants as instrumental variables in the research helps to avoid restrictions and improve accuracy in predicting the impact of body mass index (BMI) on healthcare expenses. The study [77] proposes a Multiview learning architecture that leverages BMI information from various sources, such as diagnostic tests, diagnostic IDs, and patient traits, to improve the accuracy of expense calculation. It compares algorithms, including linear regression analysis, naive Bayes classifier, and random forest, to determine the most accurate method for forecasting healthcare costs. Linear regression was found to have the highest accuracy of 97.89 percent. The methodology presented in the paper provides a predictive method for estimating and forecasting healthcare costs, which can have practical implications for financial planning and resource allocation in healthcare systems. The study compares different algorithms for predicting overall healthcare costs and finds that linear regression has the highest accuracy of 97.89 percent. The Multiview learning architecture, which leverages BMI information from various sources, helps improve the accuracy of expense calculation. The use of genetic variants as instrumental variables in the research helps to avoid restrictions and improve accuracy in predicting the impact of BMI on healthcare expenses. The study [77] evaluates the performance of linear regression using measurements such as root mean square error (RMSE), mean absolute error (MAE), and mean square error (MSE). Pearson's correlation coefficient (PCC) measures the strength of the linear regression relationship between factors. The methodology presented in the study provides a predictive method for estimating and forecasting healthcare costs, which can have practical implications for financial planning and resource allocation in healthcare systems. The study [77] utilizes various kinds of health data sets, including sensor information, medical evidence, and omic statistics, produced by modern healthcare techniques. The study [77] emphasizes the importance of data acquisition for learning models and highlights that deformed data, such as dirty data, noisy data, unstructured data, and inadequate information, can lead to inaccurate detection, estimation, and prediction.

## Another study conducted by [78] is based in Rwanda, a landlocked country lying south of the Equator in east-central Africa. The study aimed to predict out-of-pocket health expenditures in Rwanda using machine learning techniques. The study also examines the importance of predictor variables in the prediction process, with the total consumption of the household consistently identified as the most significant variable across all tested models. The study's findings have policy implications, recommending increased public spending on health in Rwanda and emphasizing the role of domestic financial resources in moving towards universal health coverage. Various machine learning algorithms were employed to compare their performance in predicting out-of-pocket health expenditures. The tested models include multivariate adaptive regression splines (MARS), decision trees, treenet, random forest, and gradient boosting. The paper utilizes the Rwanda Integrated Living Conditions Surveys (EICV5) dataset, which consists of information from 14,580 households in Rwanda in 2018. The treenet model was found to have the highest accuracy in predicting out-of-pocket health expenditures. The study found that the tenet model had the highest accuracy in predicting out-of-pocket health expenditures in Rwanda, with an accuracy of 87%. Other machine learning algorithms, such as multivariate adaptive regression splines (MARS), decision trees, random forests, and gradient boosting, were also tested and had varying levels of accuracy, ranging from 50.16% to 83%. The study [78] highlights the importance of the total consumption of households as a significant variable in predicting out-of-pocket health expenditures, it also notes that information can guide policymakers in designing interventions and policies to address the financial burden of healthcare on households. The accuracy of the models was assessed using train accuracy and test accuracy metric measures.

## The early identification of high-cost patients with ischemic heart disease (IHD) presents a complex challenge in healthcare management. To address this issue effectively, there arises a need to employ advanced methodologies, a study conducted by [79] aimed to predict high costs in patients with ischemic heart disease (IHD) at an early admission stage by integrating network analytics with machine learning. The proposed approach combining network analysis and machine learning showed promising results in accurately predicting high costs in patients with IHD, highlighting the potential value of this method in the healthcare field. The study [79] constructed two networks, the Phenotypic Comorbidity Network, and the Distance-based Disease-Cost Network, based on hospital discharge records to capture the potential relationships between comorbidities and high healthcare costs. Six different machine learning models were developed and compared to determine the best performance in predicting high costs in patients with IHD. The integration of network analysis and machine learning showed promising results in accurately predicting high costs in patients with IHD, highlighting the potential value of this approach in the healthcare field. The hospital discharge records (HDR) were split into two parts, with one part used for generating two networks (Phenotypic Comorbidity Network and Distance-based Disease-Cost Network) based on 3-year data from 2015 to 2017, and the other part used for training and testing predictive models. Three novel network features were designed based on the two networks and patients' diagnoses at an early stage of admission to improve prediction accuracy. Non-network features were also extracted from the structural HDR, including baseline, CI, and historical features. Six machine learning models (Logistic Regression, Decision Tree, Neural Network, Random Forest, XGBoost, and LightGBM) were developed and compared using different input features (network and non-network features) to predict high costs in patients with IHD. The LightGBM model, using both network and non-network features, achieved the best area under the receiver-operating characteristic curve (AUC) of 0.900, indicating its superior performance in predicting high-cost in patients with ischemic heart disease (IHD) at an early stage of admission. Network features were found to be the most significant features, accounting for 47.4% of the feature importance, suggesting that incorporating network analytics into the predictive models improved the accuracy of the predictions. Models using network features provided more accurate predictions compared to those using only non-network features, highlighting the value of integrating network analysis with machine learning in healthcare.

## A study [83] discusses the impact of machine learning and artificial intelligence on various fields such as agriculture, healthcare, management, and social studies, with a focus on achieving better crop production, disease prediction, continuous monitoring, efficient supply chain management, improved operational efficiency, and reduced water waste. Machine learning and deep learning are the main AI approaches used in these industries [83]. The study highlights the applications of machine learning and AI in achieving better crop production, disease prediction, continuous monitoring, efficient supply chain management, improved operational efficiency, and reduced water waste. The paper [83] discusses using machine learning models for complex and diverse real-world data in these industries. It identifies specific use cases such as disease prediction, water irrigation optimization, sales growth, profit maximization, sales forecast, inventory management, security, fraud detection, and portfolio management. It emphasizes using machine learning and deep learning models by individuals, businesses, and government agencies to anticipate and learn from data. In healthcare, AI can predict disease, improve patient care, and optimise treatment plans. In management, machine learning and AI can contribute to sales growth, profit maximization, sales forecast, inventory management, security, fraud detection, and portfolio management. These practical implications can enhance productivity, reduce costs, improve decision-making, and provide better services to society. Some models used were naïve Bayesian models, SVM, and K-Nearest Neighbour [83].

## Another study [87] proposes nonparametric double robust machine learning to analyze the variable importance of medical conditions for health spending. The study demonstrates that the literature may be underestimating the spending contributions of several medical conditions, highlighting the need for further research to accurately capture their impact. The study [87] highlights that previous literature on the impact of medical conditions on healthcare spending has primarily focused on parametric risk adjustment methods, potentially underestimating the spending contributions of certain medical conditions. The study [87] suggests that using targeted learning methods, compared to standard parametric regression, can provide improved inferences for important health services research questions, with broader implications beyond studying the impact of medical conditions on health spending. Compared to parametric regression, the use of nonparametric double robust machine learning methods can provide more accurate variable importance analyses of medical conditions for health spending. The study [87] utilizes the 2011-2012 Truven MarketScan database as the data source. The Truven MarketScan enrollment and claims database includes records submitted by employers and private health plans. It contains information on commercially insured enrollees. After controlling for demographics and other conditions, the database is used to evaluate the average cost per year for commercially insured enrollees with 26 of the most prevalent medical conditions. For this study [87], the super learner contained three algorithms: main terms linear regression, lasso penalized regression, and a neural network with 2 units in the hidden layer.

## Research [89] provided a high-level overview of machine learning for healthcare outcomes researchers and decision-makers. It introduces key concepts for understanding the application of machine learning methods to healthcare outcomes research. It further describes current standards for rigorously learning an estimator through machine learning to predict a particular outcome. The study [89] also compares three common machine learning methods: decision tree methods, deep learning methods, and ensemble methods and demonstrates the application of machine learning methods to a simulated insurance claims dataset, specifically for predicting which patients are at heightened risk for hospitalization from ambulatory care-sensitive conditions. The study [89] noted that researchers and decision-makers in healthcare can gain a high-level understanding of machine learning and its application to healthcare outcomes research. The study guided key standards for rigorously evaluating estimators developed through machine learning approaches, ensuring the reliability and validity of predictions. Moreover, by comparing different machine learning methods, such as decision tree, deep learning, and ensemble algorithms, researchers can choose the most suitable approach for their specific research problems. The study [89] also included statistical code in R and Python, enabling researchers to develop and evaluate estimators for predicting patients at heightened risk for hospitalization from ambulatory care-sensitive conditions.

## McClellan *et al*., [91] assess the feasibility of applying machine learning (ML) methods to imputation in the Medical Expenditure Panel Survey (MEPS). It expands the existing literature by showing that better predictions from ML algorithms can lead to higher-quality matches for imputation in the Predictive Mean Matching (PMM) framework. The study [91] specifically focuses on improving the quality of imputations for event-level expenditure data collected in MEPS, which is the primary source of official United States statistics on individual and family-level medical spending. The study [91] suggests that using machine learning algorithms in the imputation process of the Medical Expenditure Panel Survey (MEPS) can lead to better imputations, improving the quality of the data collected. By applying machine learning techniques, the flexibility of the models allows for more accurate predictions and better matching of expenditure components, reducing mismatches in sources of payments. The study [91] demonstrates that using multiple sources of payment predictions in the matching process can further improve the imputation accuracy, providing options for enhancing the matching approach. The findings of this study [91] have practical implications for improving data quality in MEPS and other important surveys that rely on accurate imputations. The Study [91] also highlights the potential of machine learning algorithms to enhance imputation methods and generate more reliable and comprehensive data for healthcare expenditure analysis. The paper demonstrates that using machine learning algorithms in a Predictive Mean Matching (PMM) framework leads to better imputations in the Medical Expenditure Panel Survey (MEPS). The study compares the performance of different machine learning algorithms, including Ordinary Least Squares, Random Forest, Extreme Random Forest, Gradient Boosting, Deep Neural Network, and Standard Error, on imputing total expenditures and each payment source. The results show that using machine learning algorithms, particularly the random forest (RF) algorithm, improves the imputation accuracy and reduces discrepancies in expenditure sub-components. The data used in this paper comes from the 2016-2017 Medical Expenditure Panel Survey (MEPS). The flexibility of machine learning techniques allows for better matching and alignment between donor and recipient payment patterns, enhancing the quality of imputations The findings suggest an expanded role for machine learning in the MEPS imputation process and broader survey data preparation applications, improving the accuracy and reliability of healthcare expenditure analysis. The paper suggests that the machine learning (ML) algorithms and alternative matching schemes used in this study can improve the overall quality of expenditure imputation in the Medical Expenditure Panel Survey (MEPS). Further research could explore the application of ML algorithms and alternative matching schemes in other surveys to assess their feasibility and effectiveness in improving imputation accuracy. Machine learning (ML) algorithms outperformed Ordinary Least Squares (OLS) in both prediction and matching imputation in the Medical Expenditure Panel Survey (MEPS). The Stacked Ensemble approach, which combines all the ML algorithms, performed the best, improving expenditure prediction R2 by 108% (0.156 points) and final imputation R2 by 227% (0.397 points).

## 

## 2.3 Conclusion

## In conclusion, there are various algorithms available for the prediction of medical expenditures, each tailored to specific data analysis needs. Machine learning algorithms can be broadly categorized into three types: classification, regression, and clustering. In our quest to address the challenge of detecting misinformation related to medical expenditure, the regression approach emerged as the most suitable choice. The rationale behind this selection lies in the variables we examined in our studies, which predominantly revolve around the analysis of costs over a temporal continuum. Given this context, time series regression emerged as the optimal method for predicting expenditure outcomes. Time series regression, in essence, is a powerful analytical tool that takes historical cost data and considers the time aspect, providing us with valuable insights into how medical expenses evolve. In simpler terms, utilizing time series regression to forecast medical expenses is akin to having a sophisticated calculator that not only considers past spending patterns but also projects future expenditures, thereby aiding in informed decision-making processes within the healthcare sector. This chapter undertook a comprehensive analysis aimed at identifying the top five forecasting algorithms employed for predicting medical sector expenditures over the recent five-year period (2017-2022). A total of 150 research papers were scrutinized, covering various aspects of forecasting within the medical field, including expenses, revenue, medical insurance premiums, risk factors, and more. This extensive pool was subsequently narrowed down to 35 papers that specifically addressed forecasting related to medical expenditures. Following a thorough literature review of these 35 papers, the five most popular and accurate algorithms in this domain were identified, these were: Support Vector Machines, Linear Regression, Bayesian Ridge Regression, Decision Tree Regression, and Random Forest Models. These algorithms found widespread application in research, consistently delivering commendable results. Additionally, the literature review revealed that the majority of datasets employed in various studies were sourced from reputable sources such as Kaggle, GitHub, Government agencies, and verified sources such as hospitals or insurance companies. Nevertheless, it's worth noting that a few studies opted to create their in-house datasets due to various constraints, such as language barriers, time limitations, and concerns regarding dataset reliability. Furthermore, it came to light during the literature review that certain papers explored more complex algorithms, such as Artificial Neural Networks [63] and Extreme Gradient Boosting [72], which demonstrated impressive accuracy. However, these were not considered in our top five selections due to their relatively lower popularity within the field.

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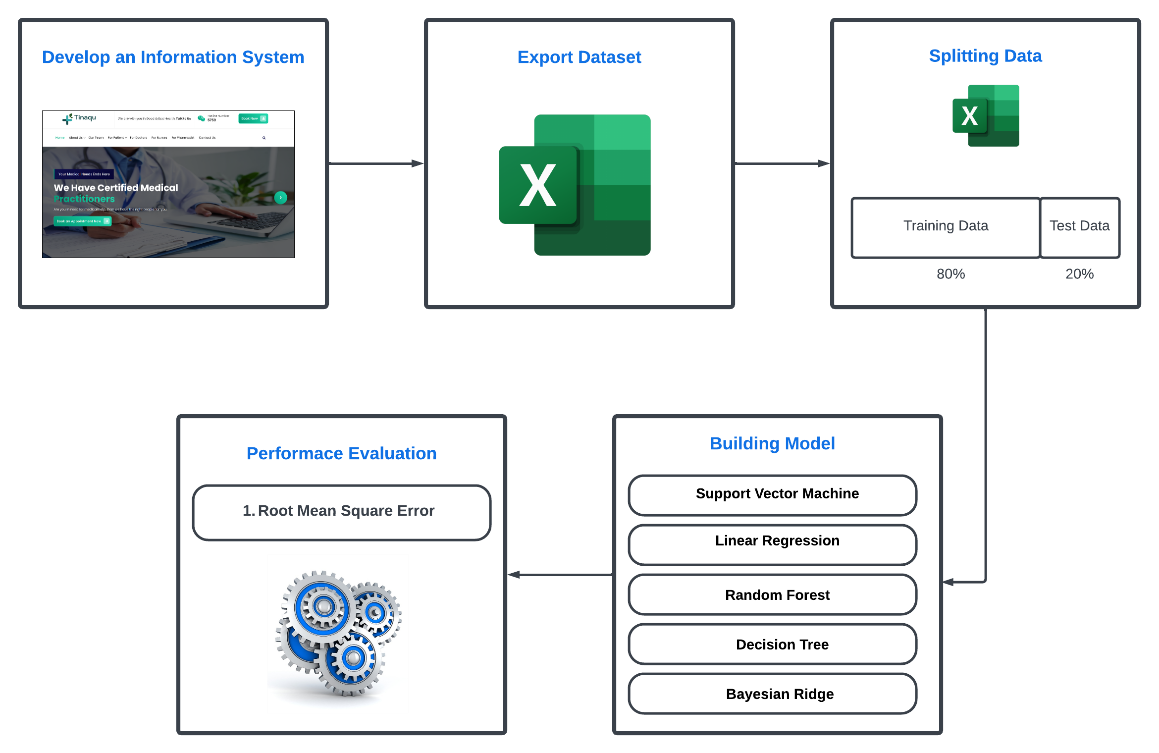
# CHAPTER 3: Experimental Study

## 3.1 INTRODUCTION

This chapter provides an extensive account of the research methods employed throughout this study, rendering it a pivotal component of our research endeavor. It serves as a comprehensive guide to the execution of the experiment and the attainment of our desired outcomes. The experimental study plays a fundamental role as it facilitates the examination of various machine learning models using sample data, thereby validating their performance against the documented findings derived from the initial qualitative study conducted in the first phase. Notably, the experimental study was carried out internally, within our research environment, culminating in the formulation of results expressed in the form of root mean square error.

## 3.2 Experimental Map

The experimental map shows detailed information on the different phases that were carried out during the experiment phase. The roadmap was thoroughly followed to accomplish the experimental phase of the search.



*Fig. 1: Experimental Map Representing each phase.*

## 3.3 Development of a Unified Information System

The initial and foremost critical undertaking for experimenting revolved around the development of an information system. The primary rationale behind creating this information system stemmed from its pivotal role: it served as the central repository from which data would be extracted to execute the desired experiments. The steps mentioned below were employed to develop a prototype of the core functionalities of the information system.

## 3.3.1 Requirement Gathering

The initial phase in the development of the desired information system involved the meticulous process of requirement gathering. This encompassed delineating how the information system should be structured, specifying its core functionalities, identifying fundamental modules within a medical information system, and exploring potential supplementary features for incorporation. To initiate this requirement-gathering endeavor, we embarked on an extensive search for existing information systems. Once identified, we pursued the acquisition of these systems, with some being readily available for free, allowing for straightforward downloading and setup for evaluation, particularly in the realm of open-source solutions. However, it is noteworthy that certain systems were exclusively available through paid versions. In such cases, we either requested a demonstration of the system's capabilities or scrutinized available demo videos. The roster of systems under scrutiny encompassed prominent names such as OpenMRS (Open Medical Record System), GNU Health, OpenEMR, FreeMED, Bahmni, RapidHealth, OpenClinica, and the Patient Information System (PATIS). Beyond this, we conducted informal yet insightful interviews with key stakeholders within the medical sector. This collaborative approach enabled us to pinpoint critical functionalities currently available in existing information systems that required enhancement or refinement. Subsequently, the culmination of these requirements, drawn from diverse sources, culminated in the development of an exhaustive requirement document. This document not only served as a robust foundational blueprint but also as the skeletal framework guiding the subsequent phases of information system development.

## 3.3.2 Designing of Medical Unified Information System

Leveraging the previously collected requirements, the development process initiated the creation of five essential core modules: the Doctor Module, Patient Module, Nurse Module, Billing Module (Insurance), and Prescription Module. Each of these modules serves distinct functions within the system, addressing specific healthcare needs. The subsequent section offers comprehensive insights into the roles and functionalities of each module. To give the information system a reference we gave it a name, the name that we proposed for the system was “Tinaqu”. Tinaqu is a Fiji’s indigenous language (native language in Fiji) for mother.

## 3.3.2.1 Doctor Module

The Doctor Module within Tinaqu serves as a comprehensive healthcare management tool that significantly enhances the efficiency and quality of patient care.

Firstly, it simplifies the task of patient record management by enabling doctors to create, access, and update electronic patient records, ensuring that vital personal information, medical history, and other details are readily available during consultations. This facilitates informed decision-making and personalized care.

A screenshot of a computer

Description automatically generated

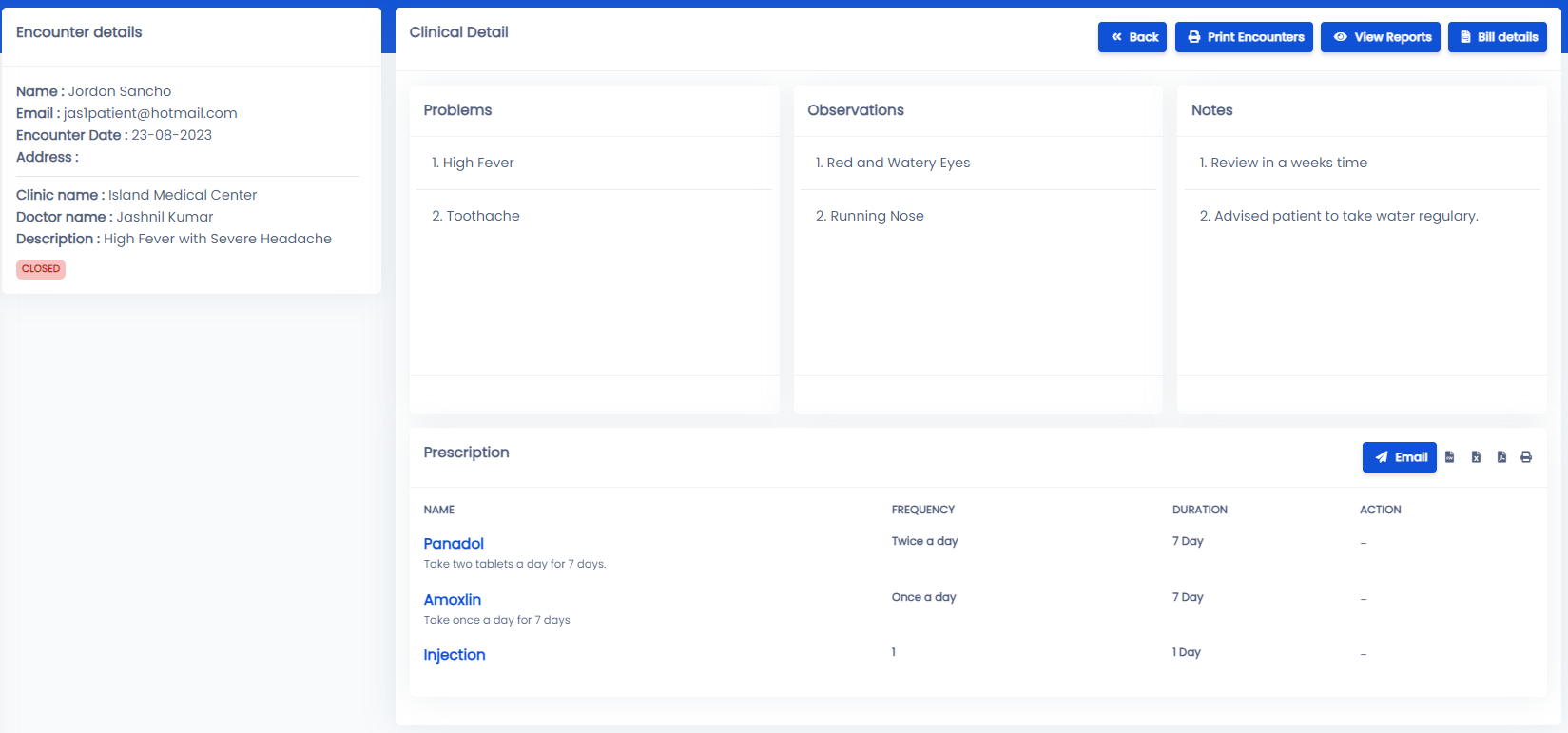
*Fig. 2: List of Patients’ List shown in Tinaqu*

A screenshot of a computer

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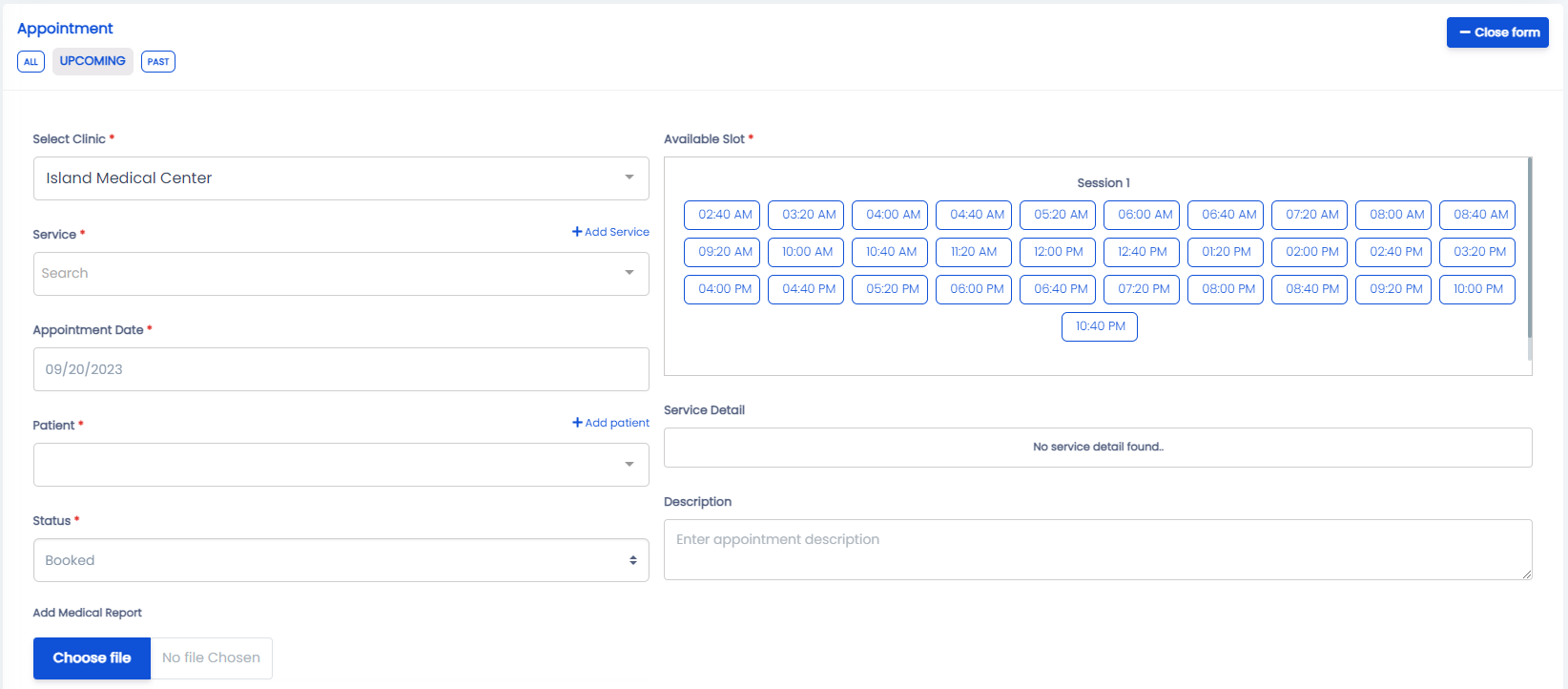
*Fig. 3: Editing of Patient Information in Tinaqu*

Moreover, the module provides access to patients' medical histories, test results, and prior diagnoses, aiding doctors in making precise diagnoses and tailoring treatment plans. It also supports seamless communication and collaboration among healthcare professionals, allowing doctors to share patient information and treatment plans with nurses, specialists, and other team members.



*Fig. 4: Part of Previous Encounter of a patient.*

Additionally, it includes appointment scheduling capabilities to help doctors manage their schedules efficiently, reducing patient wait times.



*Fig. 5: Part of Appointment Module in Doctors’ Portal*

The module assists in prescription management, offering electronic prescriptions that minimize errors in medication management.

![A close up of a white background

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*Fig. 6: Part of Prescription Module in Doctors’ Portal*

Furthermore, it facilitates accurate billing by documenting the services provided during patient visits, streamlining the billing process, and expediting insurance claims. Quick and secure access to patient health records is another key feature, enabling doctors to make well-informed decisions. In essence, Tinaqu's Doctor Module is a versatile and indispensable tool that simplifies a doctor's workflow, leading to more efficient and accurate patient care. The doctor module also includes other minor features that are not discussed above such as automatic sick sheet generation, and automatic emailing of a sick sheet to a patient or patient’s employer. The system can also be easily customizable, to add any other module required by stakeholders.

## 3.3.2.2 Patient Module

The Patient Module within Tinaqu plays a crucial role in elevating patient experiences and assisting healthcare providers in delivering top-notch care.

Firstly, patients have access to a centralized and updated record of their healthcare journey, which healthcare providers can reference during consultations for tailored care and informed decision-making.

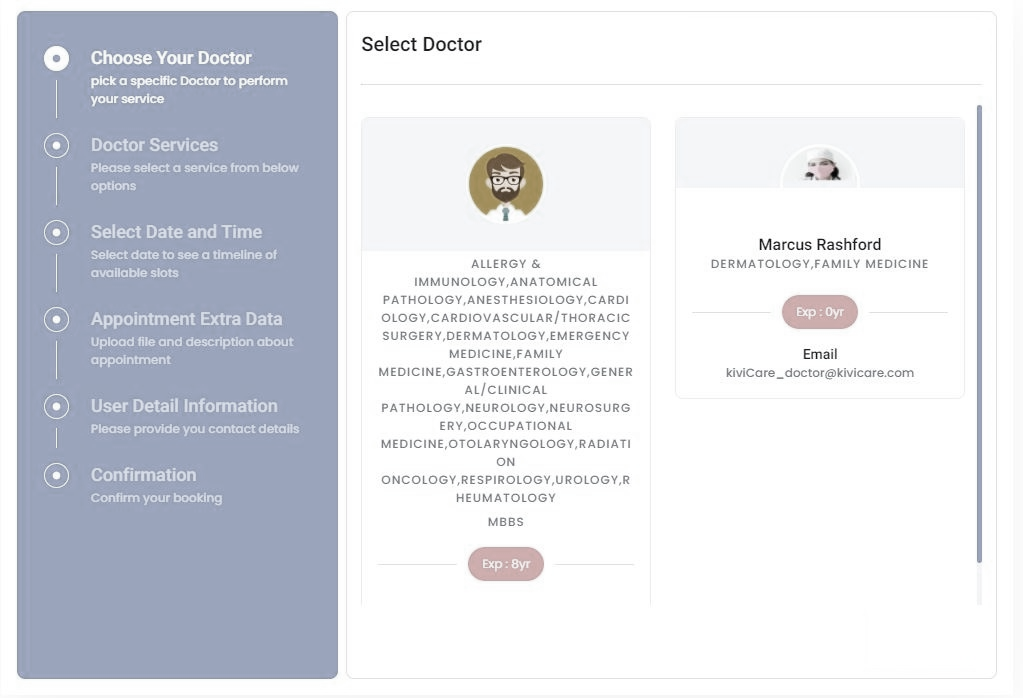
A screenshot of a computer

Description automatically generated

*Fig. 7: Patient Encounter Module in Patients’ Portal*

The module also includes features for appointment scheduling, allowing patients to conveniently request and manage their appointments. This reduces waiting times and enhances the overall patient experience.

Additionally, patients have secure access to their health records and test results, fostering transparency and empowering them to actively engage in managing their health.



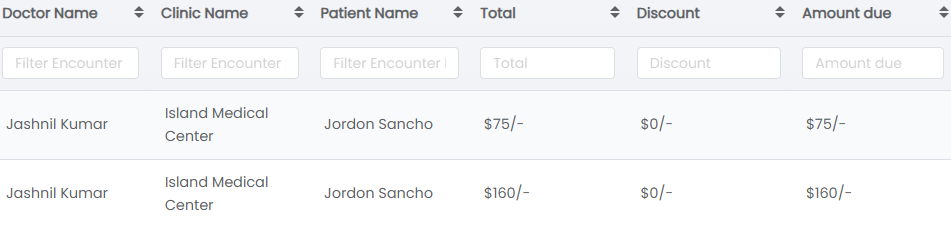
*Fig. 8: Booking appointment from website*

A white screen with blue text

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*Fig. 9: Booking appointment from the Patient Portal*

Beyond its patient-centric benefits, the Patient Module streamlines administrative tasks for healthcare providers. It simplifies billing and payment processing, making financial transactions and insurance claims more straightforward.



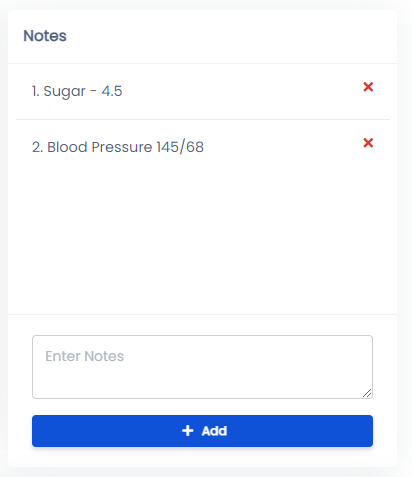
*Fig. 10: Billing Module in Patient Portal*

Furthermore, it facilitates communication between patients and healthcare providers through secure messaging, enabling patients to seek guidance and ask questions between appointments.

## 3.3.2.3 Nurse Module

The Nurse Module within Tinaqu is a pivotal component designed to streamline healthcare processes and enhance patient care delivery through the efficient coordination of nursing professionals. At its core, this module offers a range of functionalities that cater to the unique requirements of nurses in healthcare settings.

Firstly, the Nurse Module facilitates the comprehensive coordination of patient care. It includes features for recording and monitoring vital signs, which are critical for patient assessment and ongoing care. Additionally, nurses can utilize the module to administer medications, accurately document dosage administration, and track medication schedules, ensuring patient safety and compliance.



*Fig. 11: Vital Noting in Nurse Portal*

Documentation and patient progress tracking are also central to the Nurse Module's capabilities. Nurses can efficiently record patient observations, progress notes, and interventions, creating a digital trail of care that is easily accessible to other healthcare team members. This supports seamless communication and collaboration among the care team, ultimately benefiting patient outcomes.

Incorporating features for task management and prioritization, the module assists nurses in managing their daily workload. Nurses can efficiently organize and prioritize tasks, such as patient assessments, medication administration, and wound care, ensuring that critical patient needs are met promptly.

Furthermore, the Nurse Module enhances patient engagement by providing patients with access to their health information. Patients can view their vital signs, medication schedules, and nursing notes, fostering transparency, and empowering them to actively participate in their care.

## 3.3.2.4 Pharmacy Module

The Pharmacy Module within Tinaqu is a pivotal component designed to streamline pharmacy operations and enhance patient medication management within healthcare settings. This module offers a range of functionalities tailored to the unique requirements of pharmacists and pharmacy staff.

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*Fig. 12: Part of Medicine Listing in Pharmacy Portal*

First and foremost, the Pharmacy Module simplifies medication management by maintaining a comprehensive electronic repository of medication records. Pharmacists can efficiently manage drug inventory, track medication availability, and ensure that patients receive the right medications. This functionality promotes patient safety by reducing the risk of medication errors and ensuring that pharmacies are well-stocked with essential medications.

Medication dispensing is a critical aspect of pharmacy operations, and the module facilitates this process seamlessly. Pharmacists can accurately dispense medications, generate prescription labels, and provide patients with clear and concise instructions for medication use. Additionally, the module includes features for managing prescription refills and tracking medication adherence, ensuring that patients receive their medications as prescribed.

![A screenshot of a computer

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generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4REARXhpZgAATU0AKgAAAAgABQESAAMAAAABAAEAAAE7AAIAAAAOAAAIVodpAAQAAAABAAAIZJydAAEAAAAcAAAQ3OocAAcAAAgMAAAASgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEphc2huaWwgS3VtYXIAAAWQAwACAAAAFAAAELKQBAACAAAAFAAAEMaSkQACAAAAAzg0AACSkgACAAAAAzg0AADqHAAHAAAIDAAACKYAAAAAHOoAAAAIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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zJZQp3bTyCRxWL4Q/bC+GPj7x3ceF9F8ceG9Q8QW80ts1hHer53mxttdAD1KtwQMnrVcrDY9Koqut7udl2r8p456gYz27HjjPb14cL1SN3CrwAWbGSeMY7c4HrntU7ATUU1Jd7dOMkc98U6gAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAB1qNurVIOtRt1agDJ8S/8gO4+i/zrln++frXU+Jf+QHcfRf51y8nT8a2pmEtzU8Ff8htv+uX9a66uR8Ef8hpv+uR/nXXVnPcunsFeC/8FPpPL/YC+Kx+UY8PXDZZ9gGBnOfw/E8d696rjf2gvg1Y/tC/BnxF4J1K6urGx8S2UljNcWwQzQq4wWXerLn6g/1rqy6tCji6VWp8MZRb9E0ZYynOdCcIbtOx8T/Dr4h/HT4qfG8/D3wH448O+D9B8J+A9D1NZb/w8moTNLcW/wAsagshUNsO4sflB4BzmsGz/bK1T4l+I/2f/FXinQ/C8+uabrfinTNVlt7KOVWl06CVC9o8m54fMKjoeS2OnI+xPhH+x7oXwV+KuqeLtP1PVbm+1bQ9P0F4J2j8uOKzUrGy7VDF2HLbiQcdAK+YLv8AZhg+H37a/wAJ/BHhvR/GGsaP4f1XX/FGu6tf2DDT1XUopA0In2rG/wAz7Qg5Az17foVDNsqxWIn7iSjFPSKi37slK7STd21vc+VxGDxkKaTbvf8AyPJtB/4LDeN9S0PTPG//AAmHh3VJr69Xzfh1b+CNSjmSzMu07dUdRE1wkYLngR8EZJIr6A8OfGr46/taeKPiFrHwz1zwb4S8O+AdYn0TTNL1bRZLufxHcwIpk8+Yyp5CFiFVkViBycjNdRpX/BJfwlbfZ9FuPGnxAvPhrYaiup2ngea/i/siKVXEioSIxO8KvyIjJt9c8Y1PiT/wS/0Xxj4u8UXmhePvH3gbR/Hkwn8TaLod3DDa6o20KzLujLQs6gK5Q/MpI4JyJxmbcPSl/s0FGXRuClFRutHFRjeVrq7u/wC/1ToYHM2v30rrqr2u+/keK6do3xe8Uf8ABVK1kvPHln4blbwDZ6pf6PHpSahZrALkLPYxu0i/el3OLj7wyBt+U5539mj9p7xxceD/AAX8MvhzB4S8LeJPHHiXxNNcavNo6vb6ZZ2V06+YtvGUWW4fcpJdgODnnFfU13/wTn8N6V8TvBvijwn4i8UeBp/B+kx6Alpo88X2bUdPjkEi284lR2YBhnO7PPesWf8A4JXeEIvhtouj6d4o8ZaLrnhnWb7W9H8S2F4kOqWEt5KZJ03bCjxPnBRlII/MTLiDK6tNRqpWUYpLkSs4qVnJK6krtOzbdvnellmPjPmg7K8npJ31S2PCfj9+3V8af2ePCPxT8F6pq/hvVvHngu30nUdE8RWelC3gvre7u1t3W4tmMixsGyPlY5ByOmK9S+HPxi+MnwN/aq+H/gv4meJfCvjPR/iZY3slrPp2j/2ZLo9xbxpKU5lfzYmUkA4ByFPHQ7kX/BKHwje/DPxVo+teKfGHiLxB42urO61nxNqVzHNqVybWVZYolymxIVK4CKvAY8nNesePf2W9L+IHxm8A+N7jUtRt9S+Hq3a2cUQj8m6+0RCJvNyu47QMgKQM9ulefi82yp0/Y0acVzJ875Ery5VZwsrxXNfRW80dOHwOLUlOcpabJyurdn3PSoRu/hK8HAPapF5NNjt/L7+v69akAxXwevXufThRRRVAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUGig0ARzrviP8/SvFbjQb5v8AgoDY6l9kujp6+BpbdrnymEIl+3owj3Yxu2jOCScdMCvbcfzpi24WQtk/iScVUHypomSu0ORsj86dRjmipKCiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAqOfAUbhkZ6fpUlNkTzFx05B/I0AeI/Dnw9f2v7cvxN1KSzu47C60HRooLp4nWGZ1NzvVWwFYjK57182RS3XjP9n+++Gdj4J8Y3/j+48ZXt5Y3lz4duoLTQS2qvLHeyXksaoqrHhgY2YnOOVLV9+/ZcKArsvGM5zj8+P0pwtgrZB9gP4VH+f5VvCvy62M5U7vc/N/9oPwheXWjeMIdc0n4u6p8W5PE8a2F3YDWJ9Mn0v7Uhg2+WTZeQIXwytghwSc449R+D/g/wAST/tYt8KZpL6TwZ8NtVl8ZwXn2j/Xw3gb7JaPgjhJJLpiuOkacDNfZ4gIH3u5/wA/lXO+C/hJofgHxR4i1rTbVo9S8VXEdzqc7zSTPcvGnlx/fZtqqgwFXCjJOOa0lilKLTQKnZ3OkjXaP6DpTqRVx/WlrkNAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAB1qNurVIOtRt1agDJ8S/wDIDuPov865s/d/Gum8R/8AICuPov8AOuYf75+tbUzGehp+Cf8AkMN/1y/rXWVyngv/AJDTf9cv611dZz3Kp7BTXGadTXGR+NTuaDZIy57jnPFNW1Xd0APfAqUj5qUClruglZ6Mase0fQYwBxQow1ONNH3qFoA6iiimAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQB//Z)

*Fig. 13: Medicine dispensing in Pharmacy Portal*

## 3.3.2.5 Billing/Insurance Module

The Billing and Insurance Module within Tinaqu is a fundamental component designed to streamline financial transactions, manage insurance claims, and ensure the smooth operation of healthcare billing processes within healthcare organizations.

Firstly, the module simplifies the billing process for healthcare services. It allows healthcare providers to accurately document the services rendered during patient visits, including medical procedures, tests, consultations, and medications. This detailed documentation ensures that billing records are complete and compliant with regulatory requirements. Additionally, the module generates invoices and billing statements, which can be easily shared with patients for payment processing.

A screenshot of a medical center

Description automatically generated

*Fig. 14: Sample Invoice generated from in Billing Portal*

Insurance claims management is another essential function of the module. Healthcare providers can use it to process insurance claims efficiently. This includes verifying patient insurance eligibility, submitting claims electronically to insurance companies, and tracking the status of claims. The module helps reduce claim denials and accelerates reimbursement, improving the financial health of healthcare organizations.

A screenshot of a computer

Description automatically generated

*Fig. 15: Information displayed on Insurance Providers Dashboard*

Furthermore, the module can manage patient financial records, including outstanding balances, payment history, and financial assistance programs. This information is crucial for financial counselors and patient support teams to work with patients in managing their healthcare expenses effectively.

Insurance coordination is an integral part of the Billing and Insurance Module. Healthcare providers can verify patient insurance coverage, track insurance authorizations for medical procedures, and communicate with insurance companies to resolve any issues or discrepancies. This ensures that patients receive the maximum insurance benefits available to them.

Patient communication is also supported, as the module can generate and distribute patient statements and billing reminders. This helps improve patient billing transparency and encourages timely payment.

## 3.3.3 User Testing

Upon the successful development and integration of all five modules—namely, the Patient, Doctor, Nurse, Pharmacy, and Insurance Module—the project entered the critical testing phase. During this phase, dummy data was systematically employed to rigorously evaluate the functionality of each module, ensuring that they operated by their intended specifications and requirements. This meticulous testing process aimed to validate the seamless interaction and performance of these modules within the integrated healthcare system.

## 3.3.4 Entering Data into System

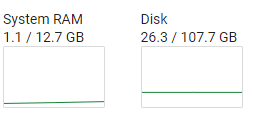
Following the successful completion of rigorous testing and comprehensive checks, the project transitioned into the dataset construction phase. Over two months, a carefully curated set of dummy data was methodically input into the system. This dataset played a pivotal role as it laid the groundwork for subsequent experiments, enabling us to extract essential information and conduct the planned experiments.

## 3.4 Getting Dataset

Following the input of data into the system, specifically Tinaqu, we proceeded to the second step which was exporting the dataset from the information system for experimental purposes. In this extraction process, we focused on specific data points, including the dates of patient visits, the prescribed medications, and the corresponding medication costs. These selected data elements were vital for our experiments and research objectives. After exporting the data into an Excel format, a thorough data verification process was conducted. This verification involved meticulous checks to ensure the cleanliness and readiness of the dataset for subsequent use. This step was essential to confirm the accuracy and reliability of the data, ensuring its suitability for analysis and experimentation.

## 3.5 Experimental Environment

The third phase of the experimental study entailed the careful selection of an appropriate experimental environment to facilitate our investigative efforts. After careful consideration, Google Colaboratory, commonly referred to as Google Colab, emerged as the optimal choice. This decision was driven by several key advantages. Google Colab provides a virtualized infrastructure, negating the necessity for additional physical hardware resources. Its accessibility via a standard web browser made it a convenient option. To execute our experiments, we employed the Python programming language, utilizing an online Jupyter notebook within the Google Colab framework. Integration with a Google account allowed for the seamless storage of all notebook files within Google Drive, obviating the need for additional configuration steps. During the initial setup, Google Colab allocated approximately 12 GB of RAM and 107 GB of hard disk resources, ensuring ample computational capacity for our experiments.



*Fig. 16: Google Compute Engine backend*

*Showing resources*

## 3.6 Importing Libraries

Throughout our study, a range of libraries were imported, each with its unique functionality and purpose. Google Colab boasted a rich ecosystem of pre-defined Python libraries, each readily accessible for importation as standalone modules or comprehensive packages. This feature greatly enriched the flexibility of our experimental setup. These libraries were instrumental in supporting and enhancing our research endeavors.

1. Pandas – an open-source library that is a popular data manipulation and analysis library in Python. It provides data structures and functions for efficiently working with structured data, such as tables or spreadsheets. These are particularly useful for tasks like data cleaning, data transformation, and data analysis.
2. Sklearn - Scikit-learn provides tools for various machine learning tasks, including classification, regression, clustering, and forecasting.
3. Datetime - built-in module in Python that provides classes for working with dates and times. It's a versatile module that allows you to manipulate dates and times, format them, and perform calculations.
4. Matplotlib - used to create and customize plots, set labels and titles, and adjust plot appearance. This module is particularly popular for creating static 2D plots like bar charts, scatter plots, line charts, and histograms.
5. Numpy - library in Python for numerical and array-based operations. It provides support for creating and manipulating arrays, mathematical functions for array operations, and tools for working with large datasets and matrices.
6. Keras - library written in Python, known for its user-friendly and modular interface, making it relatively easy for developers and researchers to build and experiment with neural networks.

## 3.7 Importing Dataset

In the earlier stages of our research, we acquired the dataset from the Tinaqu system. Once this dataset was ready for experimental use, we implemented a systematic process to facilitate our research endeavors. Firstly, the dataset was uploaded to a local machine designated for experimentation. Subsequently, we transferred the dataset from this local machine to a session storage system, which ensured convenient accessibility during our experiments. To initiate our research experiments, we utilized the "read" function to load the dataset into our experimental environment. The dataset, aptly named "Data," comprised three crucial columns: Dates, Prescribed Medicine, and Sum of Amount, encapsulating two months' worth of data. These meticulous steps were crucial in preparing and importing the dataset for our research, providing a solid foundation for in-depth analysis and experimentation.

A close-up of a computer screen

Description automatically generated

*Fig. 17: Loading and reading the dataset files to Google Colab*

## 3.8 Visualization of Dataset

To facilitate a more comprehensive understanding of the dataset, a rigorous analysis was undertaken. This analysis encompassed the assessment of several critical factors, notably the frequency of medication prescriptions within a 60-day window, the number of medical encounters occurring during the same timeframe, and the expenditure allocation concerning the country of origin or manufacturer of the medications. Data visualization was meticulously executed through the utilization of Microsoft Excel. It is noteworthy that this visualization exercise was conducted in parallel with, yet distinctly separate from, the core experiment with the primary objective of enhancing dataset comprehension.

*Fig. 18: Medicine Prescribed in 60 days.*

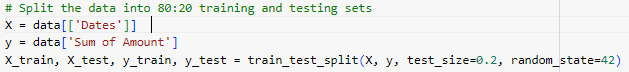
*Fig. 19: Medical Encounters in 60 days*

*Fig. 20: Expenditure per Country in 60 days*

## 3.9 Data Splitting

The dataset underwent a partitioning process where 80% of it was allocated for training the model, and the remaining 20% was earmarked for testing the model. Consequently, 48 days of data were designated for training purposes, while a distinct set of 12 days of data was reserved exclusively for model testing.

*Fig. 21: Graph depicting data splitting.*



*Fig.22: Data Splitting in Google Colab.*

## 3.10 Building the Model

Five forecasting models, including Support Vector Machines, Linear Regression, Bayesian Ridge Regression, Decision Tree Regression, and Random Forest Models, have been constructed with the assistance of the scikit-learn machine learning library. The subsequent sections will provide a professional and simplified account of the experimental methods and results for each of these forecasting models.

## 3.10.1 Support Vector Machine

## 3.10.1.1 Algorithm Description

Support Vector Machines (SVM) offer a robust framework for forecasting in various domains, particularly in time series forecasting. Starting with historical time-ordered data, SVMs can capture intricate patterns and relationships, even in cases with non-linear dependencies. After splitting the data into training and testing sets, SVMs are trained to understand underlying trends and patterns. Careful selection of hyperparameters, such as the kernel function and regularization parameter, can enhance forecasting accuracy. SVMs excel in scenarios where the data dimensionality is high or when facing limited training examples. SVMs find application in diverse fields, from financial forecasting, where they predict stock prices and market trends, to demand forecasting, weather prediction, and energy consumption forecasting, offering valuable insights for informed decision-making in these domains.

## 3.10.1.2 Mathematical Foundation

The mathematical foundation for support vector machine regression which can be utilized for predicting continuous values, can be expressed as:

Training data points (*X*1,*Y*1), (*X*2,*Y*2),…… (*X*n, *Y*n)

*X*1 -represents the dates.

*Y*1 - represents the target values, that is, the sum of amounts.

The SVM regression model aims to find a function that predicts *y* as closely as possible.

Where:

## 3.10.1.3 Algorithm Model

The Python code provided below was generated to create a SVR machine-learning model.



A close-up of a computer screen

Description automatically generated

A close up of words

Description automatically generated

*Fig.23: Support Vector Machine Regression model building.*

## 3.10.1.4 Results

After completing the experiment using the support vector machine model below results were obtained. The Root Mean Square Error which was obtained after the completion of the experiment was 44.37.





*Fig.24: Support Vector Machine Root Mean Square Error result.*

A graph with red and blue lines

Description automatically generated

*Fig.25: Support Vector Machine forecasted result.*

In the graph, the red data points denote the observed test data, while the blue line corresponds to the predictive values generated by the Support Vector Machine model. This visual analysis aids in gauging the model's ability to accurately capture the underlying data patterns.

## 3.10.2 Linear Regression

## 

## 3.10.2.1 Algorithm Description

Linear regression plays a vital role in predicting future values or trends based on historical data. It is often used when there is a belief that a linear relationship exists between the input variables (features) and the target variable (the quantity to be forecasted). For instance, linear regression can be applied to forecast stock prices, sales figures, or any time-series data by capturing the linear trends and patterns in the historical data. The algorithm estimates the parameters (slope and intercept) of a linear equation that best fits the data, allowing for future values to be predicted. While linear regression is a simple and interpretable method, it may not capture complex nonlinear relationships in some forecasting scenarios, where more advanced techniques like time series analysis or machine learning models such as ARIMA, LSTM, or Prophet may be more suitable. Nonetheless, linear regression remains a valuable tool in the machine learning forecasting toolbox, especially for tasks where linear relationships are apparent or when simplicity and interpretability are essential.

## 3.10.2.2 Mathematical Foundation

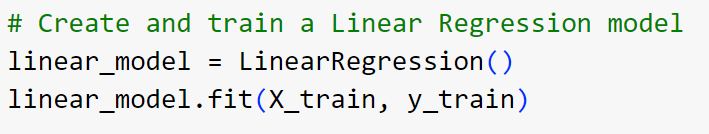
In linear regression, the goal is to model a relationship between a dependent variable (target) and one or more independent variables (features) using a linear equation. The mathematical equation for simple linear regression with one independent variable can be represented as:

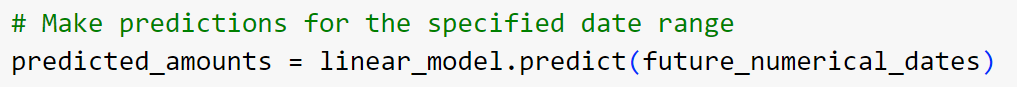
Where:

## 3.10.2.3 Algorithm Model

The Python code provided below was generated to create a linear regression machine-learning model.







*Fig.26 Linear Regression model building.*

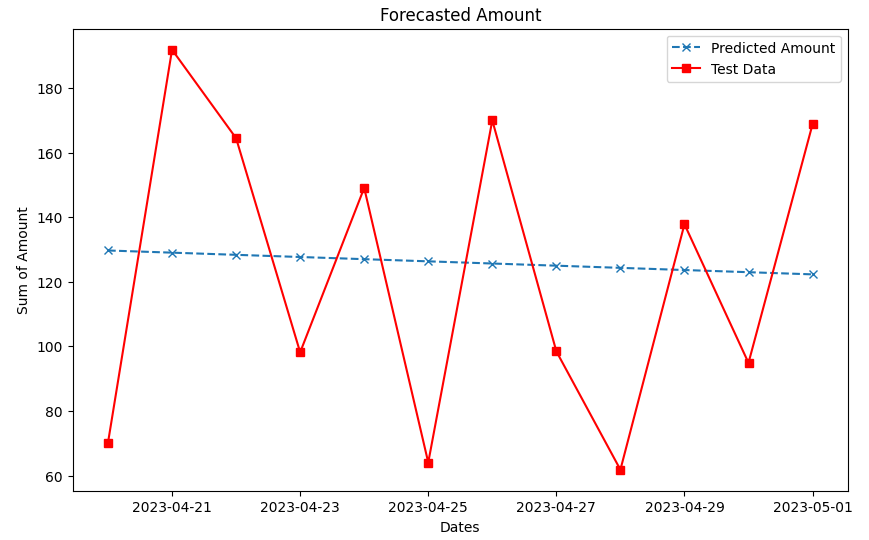
## 3.10.2.4 Results

After completing the experiment using the Linear Regression model below results were obtained. The Root Mean Square Error which was obtained after the completion of the experiment was 44.51.





*Fig.27: Linear Regression Root Mean Square Error result.*



*Fig.28: Linear Regression forecasted result.*

In the provided graph, the red data points represent the observed test data, which are the actual values from your dataset. On the other hand, the blue line represents the predictive values generated by the Linear Regression model. This visual analysis is crucial for assessing how well the model performs in capturing the underlying patterns in the data. This graphical evaluation provides a quick and intuitive way to gauge the model's predictive accuracy and its suitability for the given forecasting or regression task.

## 3.10.3 Bayesian Ridge Regression model

## 

## 3.10.3.1 Algorithm Description

Bayesian Ridge Regression is a powerful technique for forecasting that blends the principles of linear regression with Bayesian probabilistic modeling. This algorithm begins by preprocessing the historical data, ensuring its cleanliness and, if necessary, normalizing it. It initializes prior distributions for the model parameters, typically set to Gaussian distributions, and then leverages Bayesian inference to estimate these parameters. The result is a posterior distribution over the model parameters, which include the coefficients of the linear regression model and the precision of the noise term. For forecasting, the algorithm employs this posterior distribution to calculate predictive distributions for future values of the target variable, providing not only point forecasts but also estimates of the associated uncertainty. This approach is particularly valuable in situations where incorporating uncertainty into forecasts is critical, and when prior knowledge about the model parameters is available. Bayesian Ridge Regression provides a robust framework for accurate and probabilistic forecasting while allowing for control over model complexity through regularization.

## 3.10.3.2 Mathematical Foundation

In Bayesian Ridge Regression, the forecasting model can be expressed mathematically as follows:

Given a dataset consisting of observations of the dependent variable *Y* and one or more independent variables *X,* the Bayesian Ridge Regression model is defined as:

Where:

is the design matrix that includes the independent variables, including a column of ones for the intercept term if it's included in the model.

is a vector of regression coefficients that need to be estimated. In Bayesian Ridge Regression, these coefficients are treated as random variables with a Gaussian (normal) distribution.

is the error term, representing the random noise in the data. It follows a Gaussian distribution with mean 0 and precision (inverse of variance) *a.*

## 3.10.3.3 Algorithm Model

The below Python code was generated to create a Bayesian Ridge Regression machine-learning model.



A close up of text

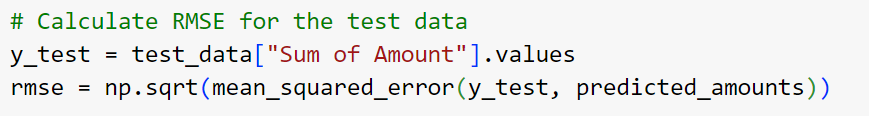
Description automatically generated



*Fig.29 Bayesian Ridge Regression model building.*

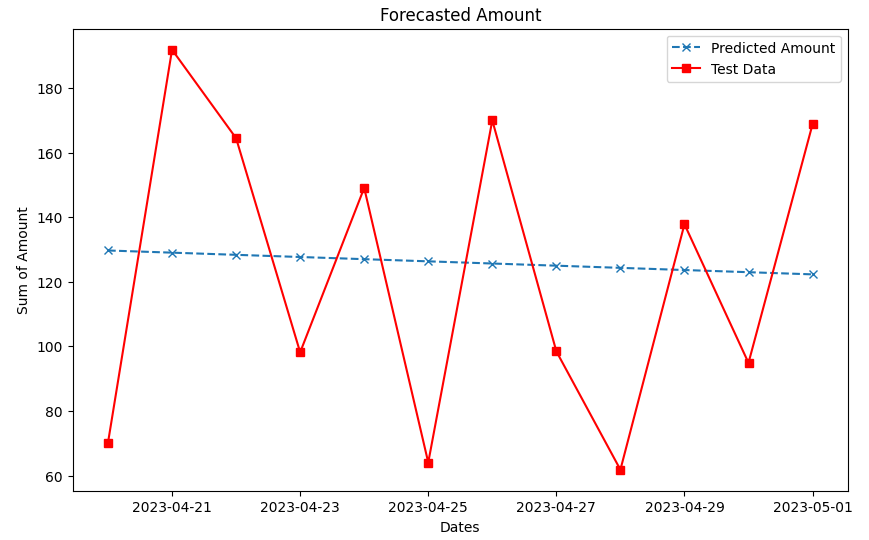
## 3.10.3.4 Results

After completing the experiment using the Bayesian Ridge Regression model below results were obtained. The Root Mean Square Error which was obtained after the completion of the experiment was 45.82.





*Fig.30: Bayesian Ridge Regression Root Mean Square Error result.*



*Fig.31: Bayesian Ridge Regression forecasted result.*

In the presented graph, the red data points serve as a representation of the observed test data, constituting the actual values derived from our dataset. Conversely, the blue line signifies the predictive values produced by the Bayesian Ridge Regression model. This visual depiction holds significant importance in evaluating the model's efficacy in capturing the inherent patterns within the dataset.

## 3.10.4 Decision Tree Regression model

## 

## 3.10.4.1 Algorithm Description

Decision Tree Regression is a machine learning algorithm used for forecasting or regression tasks. Unlike classification trees that predict discrete categories, decision tree regression predicts continuous values. Decision Tree Regression is a machine learning algorithm designed for forecasting tasks, specifically for predicting continuous values. It operates by recursively partitioning the dataset based on the most informative features, intending to minimize a chosen quality measure (e.g., Mean Squared Error) at each node. This results in a tree-like structure where leaf nodes represent predicted values. During prediction, new data is traversed through the tree, following the splits based on feature values, and forecasting is obtained from the corresponding leaf node. Decision Tree Regression is valuable for capturing complex, non-linear relationships in data, and its interpretability aids in understanding the factors influencing forecasts.

## 3.10.4.2 Mathematical Foundation

The mathematical equation for Decision Tree Regression is quite straightforward. Decision trees are a non-parametric supervised learning method used for regression tasks. The regression equation for a decision tree can be described as follows:

For a given input feature vector *X,* the predicted target value is determined based on the structure of the decision tree, which consists of a series of conditional rules applied to *X* to traverse the tree.

Mathematically, it can be represented as a piecewise constant function:

Where:

is the predicted target value for the input feature vector *X.*

*N* is the number of terminal nodes (leaves) in the decision tree.

represents the constant value associated with the *i*-th leaf node.

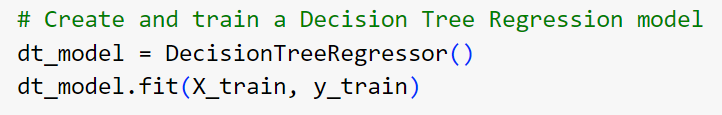
represents the region or subset of feature space defined by the *i*-th leaf node.

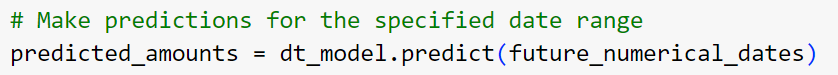
is an indicator function that equals 1 if *X* falls within the region and 0 otherwise.

## 3.10.4.3 Algorithm Model

The Python code provided below was generated to create a machine-learning model.







*Fig.32 Decision Tree Regression model building.*

## 3.10.4.4 Results

After completing the experiment using the Decision Tree Regression model the results obtained are shown below results. The Root Mean Square Error which was obtained after the completion of the experiment was 45.23.

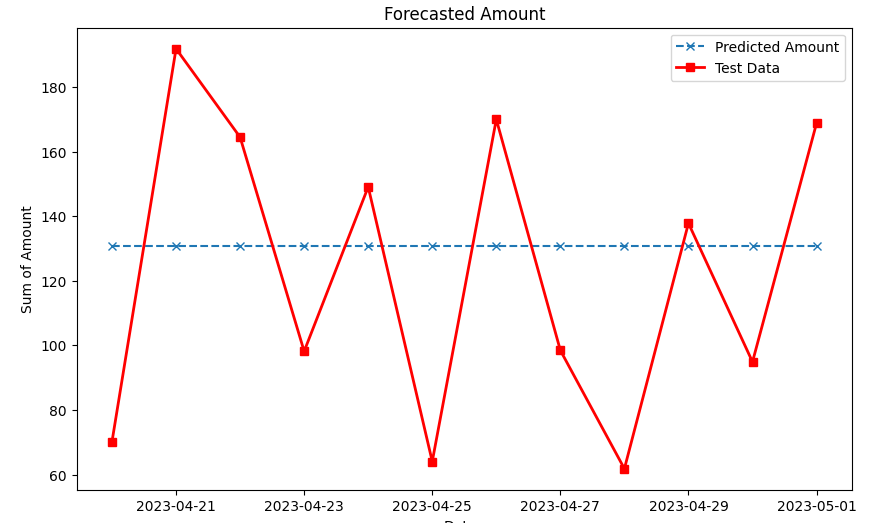
A computer code with text

Description automatically generated with medium confidence

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Description automatically generated

*Fig.33: Decision Tree Regression Root Mean Square Error result.*



*Fig.32: Decision Tree Regression forecasted result.*

In the depicted graph, the red data points represent the observed test data, reflecting the actual values extracted from our dataset. On the other hand, the blue line represents the predictive values generated by the Decision Tree Regression model. This visual representation plays a crucial role in assessing the model's ability to capture the underlying patterns within the dataset.

## 3.10.5 Random Forest Regression Model

## 

## 3.10.5.1 Algorithm Description

Random Forest Regression is a powerful machine learning algorithm employed extensively for forecasting tasks. It operates by creating an ensemble of decision trees, combining their predictions to yield accurate forecasts. In the input stage, historical data containing both independent features and the target variable is utilized. The number of decision trees in the forest (known as *n\_estimators*) is determined, along with parameters governing tree growth, such as maximum depth and minimum samples per leaf. Optionally, hyperparameters can be fine-tuned for further model optimization. The training process involves constructing each decision tree using bootstrapped subsets of the data and random subsets of features, fostering diversity among the trees. When making forecasts on new data, the Random Forest Regression model processes the input through each tree, obtaining individual predictions, and then averages these predictions to produce the final forecast. Model evaluation, typically done with metrics like MAE, MSE, or RMSE, ensures its performance on test/validation data. Random Forest Regression's robustness and capacity to capture complex relationships make it a valuable asset for various forecasting tasks, delivering reliable and accurate predictions.

## 3.10.5.2 Mathematical Foundation

A Random Forest regression model is an ensemble learning method used for regression tasks. It combines multiple decision tree regressors to make predictions. The prediction for a new input is typically the average (or sometimes the median) of the predictions from all the individual decision trees.

The mathematical equation for a Random Forest regression model can be represented as follows:

Where:

**​** i**s** the predicted value.

is the intercept (constant) term.

is the coefficient for the feature *X.*

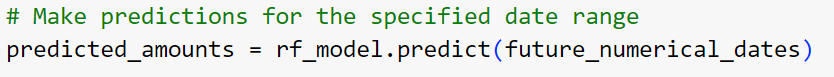
## 3.10.5.3 Algorithm Model

The Python code provided below was generated to create a Random Forest machine-learning model.



A close-up of a computer code

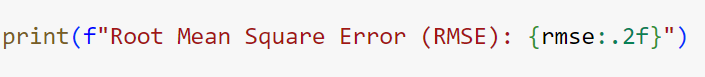
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*Fig.35 Random Forest Regression model building.*

## 3.10.5.4 Results

After completing the experiment using the Random Forest Regression model below results were obtained. The Root Mean Square Error which was obtained after the completion of the experiment was 45.55.



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Description automatically generated

*Fig.36:* *Random Forest Regression Root Mean Square Error result.*

A graph with red lines and blue lines

Description automatically generated

*Fig.37: Random Forest Regression forecasted result.*

The graph depicted in the visualization serves as a pivotal tool in evaluating the performance of the Random Forest Regression model and discerning the relationship between the actual observed test data and the predictive values generated by the model. In this graphical representation, the red data points, thoughtfully connected by a continuous red line, meticulously portray the observed test data. These data points are a direct reflection of the factual values sourced from our comprehensive dataset, covering the specific date range under consideration. In contrast, the striking blue line, distinctively marking the predictive values, embodies the model's ability to forecast future data points within the same date range. These predictive values are meticulously calculated through the model's comprehensive learning process, which primarily stems from the training data.

## 3.11 Conclusion

This chapter holds a central position within our research, as it serves as the cornerstone for substantiating our research findings. The initial step involved the development of the information system. Once that was completed, dummy data was fed into the system, and using the export function, the required dataset was obtained in Excel. Once we obtained the dataset, it was split into an 80:20 ratio, effectively segregating it into two critical components: the training data and the test data. This division is fundamental in machine learning as it allows us to train our models on one subset and assess their performance on another, unseen subset, thereby ensuring the validity of our results. In this experiment, we opted for regression algorithms as our modeling techniques, including Support Vector Machine (SVM), Random Forest, Decision Tree, Bayesian Ridge, and Linear Regression. To gauge the efficacy of these algorithms, we employed the Root Mean Square Error (RMSE) as our performance evaluation metric, a widely accepted measure in regression analysis. Notably, all the algorithms produced RMSE values in the 40s, which, as we hypothesize, may be attributed to the relatively limited size of our dataset, potentially constraining the models' ability to generalize effectively. Despite this, we identified three standout performers among the algorithms: Support Vector Machine, Linear Regression, and Decision Tree. These models exhibited superior performance compared to their counterparts in our experimental setup. Consequently, this chapter not only outlines our methodology but also hints at areas where further investigation and refinement may be needed to enhance the robustness of our findings.

# CHAPTER 4: Research Finding

## 4.1 Introduction

This chapter holds significant importance in our research as it presents the findings that address the initial research questions we established at the project's outset. These questions aimed to identify the three best algorithms for stakeholders in the medical field to use in predicting healthcare expenditure. This predictive ability is valuable for stakeholders in planning budgets, making investment decisions, and projecting returns. Unlike research projects that focus on a single topic, our study encompasses multiple research objectives. In this chapter, we explore three research questions that are closely tied to our research topic. These questions evolved and were refined throughout our research to broaden our study's scope. These three key research questions are as follows:

i. What are the five most used forecasting algorithms in the medical sector?

ii. What are the top three algorithms for forecasting healthcare data?

iii. Which algorithm is best suited for predicting pharmaceutical expenditure?

The thorough examination of these questions forms the core of this chapter, guiding our research toward well-supported conclusions and valuable insights.

## 4.2 Research Finding

**RQ1: What are the five most used forecasting algorithms in the medical sector?**

As per the comprehensive analysis conducted within the confines of our literature review, an extensive array of forecasting algorithms came to the fore. To distill this wealth of options into a succinct set of the top-performing five algorithms, a systematic approach was adopted. A matrix, thoughtfully constructed, played a pivotal role in this endeavor. Within this matrix, two primary criteria were employed to guide our selection process: the frequency of utilization and the algorithms exhibiting the most favorable Root Mean Square Error (RMSE) performance. These criteria not only ensured a thorough examination of the algorithms' prevalence in previous research but also emphasized their efficacy in achieving accurate predictions. Upon thorough analysis and evaluation, the five algorithms that stood out as the most prominent and robust choices were identified. These algorithms, namely Random Forest, Support Vector Machine (SVM), Decision Tree, Bayesian Ridge, and Linear Regression, enjoyed significant precedence in the literature. Their recurrent utilization in prior studies underscored their relevance and practical utility within the domain of forecasting. In essence, this discerning process, guided by both prevalence and performance, culminated in the selection of these five algorithms, laying the foundation for their rigorous evaluation in our research.

**RQ2: What are the top three algorithms for forecasting healthcare data?**

Upon finalizing the selection of the five algorithms to be employed in our experiment, we harnessed the previously developed information system to extract pertinent data. This dataset encompassed essential information such as the dates of patients' hospital visits, the corresponding medication expenditure, and the diagnoses. Prudently, we refrained from exporting sensitive patient-specific details, including their names, to uphold stringent data privacy standards. Subsequently, utilizing this curated dataset, we proceeded to subject each of the five identified algorithms to rigorous experimentation. Our evaluation entailed the calculation of the Root Mean Square Error (RMSE) for each algorithm, a crucial metric in assessing predictive accuracy. Furthermore, we visualized the results by plotting graphs for each algorithm, providing insights into their respective relationships with the data. Following the comprehensive experimentation phase, we conducted a meticulous comparative analysis based on the RMSE values obtained. The ensuing comparison matrix, depicted below, encapsulated the performance distinctions among the algorithms. Out of the five algorithms under scrutiny, three emerged as notable frontrunners: Support Vector Machine, Linear Regression, and Decision Tree. Their outstanding performance underscores their potential as pivotal tools in our quest to predict healthcare expenditure effectively.

*Fig.38: Comparison matrix of Algorithms.*

**RQ3: Which algorithm is best suited for predicting pharmaceutical expenditure?**

Having pinpointed the three most promising algorithms, the subsequent task of selecting the optimal one for integration into the information system became considerably streamlined. This pivotal decision bore the potential to enable real-time forecasting capabilities within the system, a prospect of paramount importance. Notably, the Support Vector Machine (SVM) algorithm emerged as the standout choice among the three contenders. Its superior performance in facilitating precise forecasting duties, whether in the realm of pharmaceuticals or any facet of medical sector expenditure prediction, underscored its remarkable efficacy. This determination was substantiated by referencing the Root Mean Square Error (RMSE) as the guiding metric—a trusted reference point that reaffirmed SVM's supremacy in our pursuit of accurate and dependable forecasting.

## 

## 4.3 Conclusion

This chapter serves as the culmination of our research efforts, unveiling the discoveries derived from a combination of prior scholarly work and our in-house experimental investigations. We embarked on this journey guided by three key research questions, which provided us with a clear roadmap and a defined focus for our ultimate objectives. The initial research question aimed at discerning the five most frequently employed algorithms within the medical sector for forecasting. Armed with this knowledge and a curated dataset, our subsequent inquiry centered on identifying the three most dependable algorithms with the lowest Root Mean Square Error (RMSE). The potential beneficiaries of these findings span a diverse spectrum, including insurance providers, government entities, and healthcare clinics, who stand to gain valuable insights for making informed, real-time decisions based on the data at their disposal. Our findings underscore the supremacy of supervised learning algorithms for medical expenditure forecasting. Notably, Random Forest, Support Vector Machine (SVM), Decision Tree, Bayesian Ridge, and Linear Regression emerged as the cream of the crop, demonstrating their consistent prowess over the past five years. It's worth highlighting that our dataset compilation was a meticulous process, drawing from a plethora of credible sources, while also necessitating the creation of in-house datasets due to limitations in the availability of suitable data. Leveraging our experimental study, we further narrowed down our selection to the top three algorithms: Support Vector Machine, Linear Regression, and Decision Tree, all of which exhibited the most promising performance with the least RMSE. These findings collectively represent a significant milestone in advancing our understanding of medical expenditure forecasting and its practical implications for diverse stakeholders within the healthcare landscape.

# CHAPTER 5: Conclusion

## 5.1 Discussion

Medical expenditure has been experiencing a notable annual increase, a trend that predates the COVID-19 pandemic and has been exacerbated by it. This upward trajectory is attributable to various factors, including shifting demographics with aging populations requiring more healthcare services, the continual emergence and adoption of costly medical technologies and treatments, administrative complexities within healthcare systems, and the rising prevalence of chronic diseases. However, the pandemic significantly amplified this expenditure surge. In response to the immediate crisis, countries allocated substantial funds to build temporary healthcare facilities, procure personal protective equipment, and enhance testing and contact tracing capabilities. Furthermore, the development and distribution of vaccines imposed additional financial burdens. Beyond the pandemic's emergency response, COVID-19 has led to increased healthcare needs, such as intensive care and long-term care for survivors, while also highlighting the growing demand for mental health services. This extraordinary demand for healthcare resources underscores the need for governments to invest more heavily in healthcare infrastructure and resources to protect public health and enhance healthcare system resilience. However, the challenge lies in balancing these investments within budgetary constraints, competing with other sectors for funding, and implementing strategies to control healthcare costs while maintaining quality and accessibility. The long-term implications of these trends are multifaceted, encompassing potential improvements in healthcare outcomes and infrastructure but also emphasizing the necessity for sustainable healthcare financing and delivery models. The thesis tackles the problem of forecasting medical expenditures over the past five years by evaluating various algorithms. It combines a systematic review with experimental studies to determine the most suitable algorithms for this task, offering valuable insights to stakeholders in the medical sector. The research begins with a comprehensive literature review, exploring the use of machine learning algorithms for medical expense forecasting. The review highlights five regression algorithms frequently employed between 2017 and 2022: Random Forest, Support Vector Machine (SVM), Decision Tree, Bayesian Ridge, and Linear Regression. The findings of the literature review emphasize the necessity for research in this domain, as the application of these algorithms could potentially address real-world complexities and serve as practical problem-solving tools. Subsequently, an experimental study is conducted to corroborate these findings, where the same algorithms are used to assess the root mean square error. Google Colab is employed as the experimental environment for these studies. The results of the experiments conclude that Support Vector Machine, Linear Regression, and Decision Tree are the top-performing algorithms due to their minimal root mean square error. In summary, the research demonstrates that the identified algorithms, while relatively simple, prove to be effective when compared to more complex alternatives. This work contributes to the field of medical expenditure forecasting, offering a clear path for stakeholders to make informed decisions based on reliable algorithmic predictions.

## 5.2 Novelty of Research

The novelty of the research lies in the development of a unified information system with the capability to extract real-time data. This system, coupled with the identified algorithms, offers a powerful solution with far-reaching implications for various stakeholders, including government entities, insurance providers, and investors. One of the key contributions of this research is the ability to provide these stakeholders with accurate and timely data-driven insights. For governments, this means improved budget planning, as they can better anticipate future healthcare expenditures based on historical trends and real-time data. This can lead to more efficient allocation of resources and improved fiscal responsibility. Insurance providers can benefit from this unified system by optimizing their premium structures. They can use the data and algorithms to calculate insurance premiums more accurately, considering changing healthcare costs and risk factors. This not only benefits the insurance companies by reducing the risk of underpricing or overpricing policies but also benefits consumers by potentially leading to more affordable and fair insurance premiums. Investors, too, can make more informed decisions based on the insights generated by the system. They can assess the potential returns on investments in the healthcare sector, factoring in the trends and predictions derived from the data and algorithms. This can lead to more strategic and profitable investment decisions. Overall, the research's novelty lies in its holistic approach to utilizing data and algorithms to create a unified information system that serves as a valuable tool for multiple stakeholders in the healthcare sector. It promotes data-driven decision-making, enhances financial planning, and ultimately contributes to more efficient and effective healthcare systems.

## 5.3 Limitations

While this research has made significant strides in creating a unified information system for medical expenditure forecasting and has demonstrated its potential benefits for various stakeholders, it's important to acknowledge and address any constraints or limitations that could impact the findings and conclusions of the project. One such minor constraint encountered in the research was:

## 5.3.1 Dataset

Due to constraints in time, limited resources, and considerations for data privacy, our research was constrained to utilizing a dataset spanning only two months. It's important to note that a more extensive dataset would have allowed for more accurate predictions, as it would have provided a richer training and testing environment. This constraint aligns with prior studies ([63], [73], [84]) that have emphasized the significance of larger datasets in achieving robust machine-learning outcomes. We recognize and respect the importance of data privacy, which played a role in limiting our ability to collect more extensive records. Our commitment to ethical data handling and privacy protection remains a priority throughout our research. It's essential to acknowledge that the limited dataset may have implications for the generalizability of our findings. A larger dataset could have offered deeper insights and improved prediction accuracy.

## 5.4 Future Works

In the context of this minor thesis, certain objectives and aspects have been identified as essential considerations for future research, which, due to constraints, were not attainable within the scope of this study. These prospective objectives may find their place in future research endeavors, potentially during my PhD studies. First and foremost, among these considerations is the expansion of the dataset. Recognizing the pivotal role of data volume in enhancing the accuracy of results, future research could involve acquiring a more extensive data set. This dataset could potentially be sourced from a local hospital or an insurance services provider. However, it is imperative to underscore that this endeavor would necessitate obtaining all requisite clearances and permissions to ensure ethical and legal data usage. Another significant aspect meriting exploration in future research pertains to the security of the information system. Given that medical information represents some of the most sensitive and confidential data, the development of robust security mechanisms is paramount. A promising avenue for achieving heightened security could involve the utilization of blockchain technology. Implementing a blockchain-based system would represent a substantial advancement, offering enhanced data integrity, transparency, and privacy protection within the healthcare domain.

## 5.5 Chapter Summary

## 5.5.1 Chapter 1: Introduction

This chapter provides a thorough examination of the essential role that data plays in today's society and economy. It highlights the importance of using data analysis tools to make better and more reliable decisions. The chapter also looks at how record-keeping has evolved, especially with the influence of technology. In addition, the chapter explores the significance of record-keeping in various aspects of life, from personal finances to government spending. It discusses the methods used to collect and store data, emphasizing how these methods have changed over the years. Furthermore, the chapter zooms in on the healthcare sector, explaining how data is stored and used for decision-making and other purposes. Finally, it outlines the research questions, objectives, and methodologies for the project.

## 5.5.2 Chapter 2: Literature Review

This chapter holds a significant place in this research because it reviews the work done in the past five years and the findings obtained. It demonstrates that researchers have applied various regression algorithms to predict outcomes in the medical sector. These predictions encompass areas like forecasting revenue, expenses, insurance premiums, insurance claims, and even predicting risk factors for diseases. The literature review confirms that supervised regression algorithms, while straightforward, have proven to be highly effective in delivering promising results. In this research, an extensive analysis was conducted, encompassing 150 research papers. From this pool, the top 35 papers were selected for inclusion in this study. The prior work highlights that, within the last five years, the most effective algorithms for predicting medical sector expenditures include Support Vector Machines, Linear Regression, Bayesian Ridge Regression, Decision Tree Regression, and Random Forest Models.

## 5.5.3 Chapter 3: Experimental Study

In this chapter, the researcher carries out an internal experimental investigation using Google Colab to validate the findings obtained from the previous research. The experimental study utilizes a dataset that was extracted from the information system established during the experiment phase. This dataset comprises two columns: one for dates and another for the sum of amounts. To ensure a robust analysis, the dataset is divided into two subsets – a training set (80%) and a testing set (20%). The researcher leverages machine learning models imported from the scikit-learn library to the experimental platform. To assess model performance, the root mean square error (RMSE) is employed as an evaluation metric. Furthermore, the chapter elucidates the mathematical equations underpinning each algorithm. The ultimate findings from this experimentation demonstrate that Support Vector Machine, Linear Regression, and Decision Tree emerge as the top-performing algorithms in predicting the desired outcomes.

## 5.5.4 Chapter 4: Research Findings

This chapter serves as a pivotal component of the research, as it offers conclusive responses to the research questions posed in Chapter 1. The findings yielded highly promising results, particularly in the realm of forecasting medical sector expenditure. However, it's important to note that this area presents substantial opportunities for further improvement, mainly due to limitations in the dataset and the inability to achieve near-perfect accuracy. The research findings underscore that when it comes to forecasting expenditures, regression algorithms stand out as both simple and highly effective, with dataset quality playing a pivotal role in their success. Out of the five algorithms initially considered, the top three performers were identified as Support Vector Machine, Linear Regression, and Decision Tree. These algorithms demonstrated the lowest root mean square error (RMSE) when compared to the others. Notably, the Support Vector Machine emerged as the best-performing algorithm among the three, boasting the lowest RMSE. The chapter also highlights the future works to be carried out.

## 5.5.5 Chapter 5: Conclusion

This concluding chapter provides a comprehensive summary of the entire research endeavor. It begins by delineating the core problem addressed, followed by a detailed account of the steps taken to analyze and resolve this problem. The chapter proceeds to present the ultimate outcomes of the research. Furthermore, it acknowledges the forthcoming research challenges and highlights the limitations encountered during this study. Notably, the chapter identifies potential avenues for future research, aiming to enhance the developed information system and reduce the root mean square error associated with the algorithms. One proposed method for improvement is to incorporate larger datasets, and the researcher recommends transitioning from synthetic datasets to real-world datasets, recognizing the scarcity of readily available public datasets as a current constraint.

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