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HEALTHCARE MANAGEMENT USING AMAZON WEB SERVICES

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Abstract

Healthcare and life sciences represent a significant role in people's lives, these two aspects governing their well-being and functioning. Redefining patient care methods and treatment solutions, working on thorough genomics studies and balancing healthcare costs have become an upfront priority for any healthcare and life science organization. A cloud infrastructure composed of applications, servers, networks, and data storage represents an effective solution to both business and technical goals, but also a modernization tool. For this study, we created a web-based program called HealthCloud, which facilitates medical data interoperability, provides automation services, and uses machine learning for predictions and insights related to the possibility of developing a cardiovascular disease, based on patient input regarding food and nutrition. Our results include a user-friendly interface, easy access to patient and doctor data, and a high accuracy of disease risk prediction with a machine learning model built in Amazon SageMaker. The proposed prototype proved its potential through the attained outcomes and presents an appropriate approach of healthcare management, which merges with cloud technology for the enhancement of care delivery.

Key words: *Computer Applications, Digital Healthcare, Machine Learning, Supervised Learning, Unsupervised Learning.*

INTRODUCTION

The need for a digital transition in the healthcare management system has proved to be fast-forward and was mainly generated by the COVID outbreak (Hamilton, 2023). Now, the goal of health industry executives is to produce durable, cutting-edge medical systems, such that the challenges of today are surmounted with more resilience.

Not for a long time now, there have been some repeatedly occurring patterns that demonstrated the need for more creative solutions and tech related innovations (Pavaloiu et al., 2015).

Chronic Illnesses. According to the National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP), a chronic disease is commonly defined as a medical condition that lasts 1 year or more and needs constant medical care (Centers for Disease Control and Prevention, 2002).

Death, disability along with highly expensive healthcare costs per year are consequences produced by major chronic diseases, such as diabetes, cancer, and heart disease (Culberson et al., 2023). This represents a challenge for the healthcare management systems, which are burdened with the increase of chronic diseases among an aging population: four in ten adults suffer from 2 or more chronic illnesses (Hajat & Stein, 2018). Multiple Chronic Conditions (MCC) is when a person lives with several chronic conditions and requires a complex healthcare management system due to its posing difficulties on someone's life (Caldeira et al., 2021). Chronic illnesses can also include mental health related issues, such as chronic depression, anxiety, bipolar disorder, memory problems and so on (Manger, 2019).

Physical and emotional illnesses can have a significantly worse outcome on someone's quality of life, making them unable to manage day to day activities, such as exercising, doing house chores, or even working. Large amounts of medications are required to reduce the pain and symptoms of the illness and keep it under control (Nijs et al., 2021). However, side effects occur, and it becomes more exhausting to manage such a disease that cannot be cured. This leads to depression and a never-ending cycle, which burdens the patient and the healthcare providers with ineffective medications and, respectively, exponentially growing expenses.

Telemedicine and remote patient monitoring (RPM). This challenge emerged at its peak during COVID-19 and highlighted the importance of several technologies such as Internet of Things (IoT), machine learning (ML), virtual reality (VR), and Big Data (Brahmbhatt et al., 2022). The most affected area following the pandemic is the healthcare industry and was forced to quickly adopt the expanded use of digital technologies (Darbandi et al., 2022). Subsequently, the usage of tele-medicine brought upon the healthcare sector additional issues: in underdeveloped locations, healthcare providers and patients experience hardship since the limited resources restrict them from using these technologies to their fullest potential (Ftouni et al., 2022). The integration of telehealth and remote patient monitoring into healthcare-related workflows and operations may pose difficulties: clinical staff might need additional training, there would be a disruption in the existing workflows, and healthcare leaders must document these new technologies and have the knowledge to modify clinical procedures accordingly (Pugmire et al., 2023).

High-level digitalization depends also on the patient's willingness to engage and adapt, particularly in the case of elderly patients, being a prevalent preference for an in-person encounter with healthcare professionals. Their understanding of digital literacy is limited; hence, the start or continuation of their virtual care treatment would be impeded.

Machine Learning and AI. Artificial Intelligence brings with it numerous benefits in healthcare, such as disease prediction, consistent routine check-ups, managing appointments with virtual healthcare assistants, and drug discoveries (Haleem et al., 2022). However, developing and maintaining such practices may call for expensive investments, advanced technology infrastructure and skilled labor (Gangwar & Reddy, 2023). Financial investments for the application of the AI field in healthcare include the acquisition of additional specialized software and tools for production and deployment, high-performance computing, and other expensive resources. Additionally, obtaining AI solutions implies hiring data science and machine learning experts who can implement models and algorithms to solve several use cases.

The most fragile companies are the small businesses, which have less resources at their disposal, being prone to collapse while trying to acquire and maintain AI capabilities.

Another drawback lies in the lack of accuracy that could be generated due to the small amount of data regarding certain illnesses, demographics, or environmental variables (Coccia, 2023). This could result in the wrong interpretation of a diagnosis and the incorrect administration of prescription medicine. In this case, human surveillance is needed to confront the problem of misdiagnosis, which is especially prevalent in a particular demographic area (Mackenzie et al., 2022).

Cost-related obstacles. A constantly growing structure of the healthcare system requires a considerable number of resources and costs: infrastructure needs to be maintained and the healthcare systems become more complex with the user expectations and demands, as the populations grow and age (Waitzberg et al., 2022). Additionally, the regular monitoring of patients with diseases such as chronic illnesses implies that healthcare organizations get hold of more advanced technologies and interventions, which are of higher cost.

Greater expenses do not necessarily mean a great outcome: it has been confirmed that the U.S., as opposed to other countries, spends more on healthcare, with 30% of the expenditures being considered waste (Sullivan et al., 2023). Most of the waste emerges from high amounts of expenses and can be a result from the following difficulties: inability to provide proper treatment, poor care organization, overtreatment or care of low value, failure in pricing, fraud, abuse, and administrative complexities (Tushar et al., 2023).

A Cloud computing solution is an effective way to reduce waste and costs and to improve the patient's experience within a clinic: siloed data systems are no longer wanted by healthcare companies, since the cloud can offer the ideal balance between efficiency and costs (Barbandi et al., 2022).

Security and Integrity of Health Information Systems. One of the most delicate factors in healthcare is the data and its security, which is threatened with the expansion of modern technologies, making the healthcare sector the most targeted area by cyberattacks (Usmani et al., 2023).

There are several methods in which hackers could harm the healthcare system and its patients: firstly, the dark web is a gateway to anyone who has the intention of breaking into a system, even with limited abilities (Chauhan et al., 2022). Blackmail, stealing and selling information or the total compromise of the normal operation of a health information system are major threats in terms of healthcare hacking. Data must be safeguarded internally and externally, due to its frequent exchange between multiple healthcare establishments and providers, which increases its vulnerability to digital attacks.

Networks where medical data is shared in this manner attract more data thieves, who can access the patient records and steal information such as billing details. It is imperative that one pays more attention to the protection of electronic health records (EHRs), which are more challenging to secure. In the Materials and Methods section, is discussed the hosting with AWS Amplify and the advantages of cloud hosting. There are also explored the application of machine learning in healthcare and its role in predicting cardiovascular disease risk. Amazon SageMaker and its tools, such as Principal Component Analysis (PCA) and the XGBoost Classifier, are introduced as part of the current proposed software solution. There is highlighted the integration of machine learning into web applications and the need for more detailed accuracy assessment based on patient data. In the last section are mentioned the potential future improvements, including automated image analysis, virtual assistants, and a patient-focused mobile application.

MATERIALS AND METHODS

A. *Traditional Web Hosting versus Cloud Hosting*

Web hosting services offer the possibility of a business launching its product into the market, by establishing its visibility with online presence. There are two practical solutions for an application to be available on the internet and these are the traditional web hosting or hosting in the cloud (Zala et al., 2022). The classic hosting environment is divided into two categories: dedicated and shared. By using a dedicated hosting approach, the client receives a fixed number of resources over which he has full control, on one or more servers.

Shared hosting is more common among small and medium-sized businesses which will be given a set of resources shared with some other websites, on only one server. In the present moment, there are plenty of small and medium companies with limited budgets that are looking for a new and effective way of hosting their website according to their business requirements (Chidukwani et al., 2022). The innovative approach is Cloud hosting, which is also used in the current software solution, which is proposed, having several advantages over the traditional hosting (Ali et al., 2022), as shown in Table 1.

Table 1. Comparison between Traditional and Cloud Hosting

Metric	Cloud Hosting	Traditional Hosting
Scalability	“Pay as you go” for usage	Almost no scalability, hardware dependent
Elasticity	Elastic and resilient due to redundancy	Limited, no elasticity
Performance	Not affected by problems with one application	A single point of failure
Cost	Server operation and maintenance among several parties	Costly as one must buy necessary equipment
Deployment time	Less time, it does not rely on hardware	Extended time for setting up servers
Internet connection	It is needed as fast and reliable	Not needed

B. *AWS Amplify*

For the proposed project, AWS Amplify was chosen as a hosting environment (dedicated to multi front-end web and mobile apps), to deploy the web application in the cloud (Amazon, 2023). Additionally, as a version control system, GitHub was selected.

The steps which were respected were to navigate to the management console and choose the AWS Amplify service, followed by the connection of the source code from a GitHub repository, in this case the “master” branch is chosen. Afterwards, AWS Amplify was enabled to deploy all files of the project's root folder, automatically.

In Figure 1, the three steps of the previous mentioned process were completed successfully.

This type of deployment implied public Cloud as the category of Cloud for the current project idea since the application runs on the public infrastructure of AWS. Moreover, there are some benefits brought to this type of hosting, namely easy deployment, as the process is simplified by the automation of services configuration and the setup of continuous deployment pipelines.

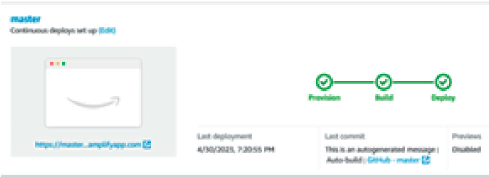

Figure 1. AWS Amplify Deployment
Source: own source

MACHINE LEARNING IN AWS

C. *Overview of ML in Healthcare*

The expansion of the healthcare industry depends recently on emerging technology approaches, such as artificial intelligence and machine learning, which allow the development of the field through fast diagnosis and a higher level of accuracy. It is worth mentioning that in the proposed software solution, both structured and unstructured data sets have been used to gain ML insights.

D. *Healthcare Dataset*

Before a diagnosis is made official, the doctor must make a thorough examination and analysis of the patient's mental or physical state. This assessment is done with the help of some medical data of the patient, which helps the healthcare provider to move in a particular path towards a certain diagnosis. To predict the presence or absence of risk for cardiovascular disease, a healthcare dataset from the National Institute of Aging (National Institute of Aging, 2023) has been used. This dataset encompasses an array of features crucial for gauging cardiovascular health.

The inclusion of objective features, subjective information, and examination results forms a multidimensional framework that aids in steering the diagnostic process in a targeted direction. It is important to note that this dataset does not operate in isolation; rather, it integrates various facets of the patient's health to provide a comprehensive overview.

From Table 2, one may observe that the input features are of three types, namely objective features represent factual data (age, height, weight, gender); subjective features which are provided by the patient (smoking, alcohol intake, physical activity); examination features which are discovered during the medical appointment (blood pressure, glucose, cholesterol).

Table 2. Features of used health dataset

Feature	Measurement
Age	int (days)
Height	int (cm)
Systolic blood pressure	int
Diastolic blood pressure	int
Weight	float (kg)
Gender	categorical code
Smoker	binary
Alcohol intake	binary
Physical activity	binary
Glucose	1: normal, 2: above normal, 3: well above normal
Cholesterol	1: normal, 2: above normal, 3: well above normal

Blood pressure (BP) is measured using two numbers: systolic and diastolic BP, where the first one must be less than 120 and the second one must be less than 80. Otherwise, in case of higher values, a cardiovascular disease might be present (Justin et al., 2022). Moreover, increased glucose and cholesterol levels also represent a risk factor in diabetes or a heart problem (Hariharan et al., 2022).

Besides the input features enumerated in the previous table, there is also the target variable, represented in binary, which marks the presence or absence of a cardiovascular disease. All the mentioned values were recorded during medical examinations.

The link between the input features and food and nutrition aspects of every person lies in the impact of dietary habits on objective and examination aspects associated with cardio-vascular health.

The systolic and diastolic BP are indicators of cardiovascular health that show the importance of maintaining a healthy blood pressure. Dietary factors such as high salt intake can contribute to elevated blood pressure (Robinson et al., 2019). Therefore, advising patients on a low-sodium diet can be crucial in managing blood pressure levels within the recommended range (O'Donnell et al., 2020).

Increased glucose and cholesterol levels are highlighted as risk factors for diabetes or heart problems (Eckel et al., 2021). Nutrition plays a significant role in managing these levels. A diet rich in fiber, low in saturated fats, and with controlled sugar intake can positively influence glucose and cholesterol levels (Samuel et al., 2023). Including foods like whole grains, fruits, vegetables, and lean proteins can contribute to

better overall cardiovascular health (Capurso, 2021).
Dietary needs vary based on age, gender, and body weight. Nutrition plays a vital role in supporting growth, maintaining a healthy weight, and addressing specific nutritional requirements based on gender (Wohlgemuth et al., 2021). Smoking and excessive alcohol intake are lifestyle factors that can negatively impact cardiovascular health (Kotseva et al., 2019). Proper nutrition, combined with lifestyle modifications such as regular physical activity, can contribute to reducing the risk of cardiovascular diseases (Lacombe et al., 2019).
Nutrition is a key factor in preventing and managing cardiovascular diseases. A diet rich in antioxidants, omega-3 fatty acids, and other heart-healthy nutrients can be recommended for individuals to reduce the risk of developing cardiovascular diseases (Szczepańska et al., 2022).

E. *Amazon SageMaker and ML Algorithms*

Amazon SageMaker is a cloud service belonging to AWS which makes simpler the process of building, training, and deploying ML models (Dubey & Dubey, 2022). It has the capability to process large amounts of structured and unstructured data and to significantly reduce the training time with a developed infrastructure.
The AWS ML Stack consists of AI, ML Services and ML Frameworks and Infrastructures. The ML Services include SageMaker Studio IDE, which enables the performance of all needed steps of the machine learning model (Ratan, 2022).
The disease prediction model of the current software solution was developed in a Jupyter notebook instance of SageMaker Studio.

F. *Principal Component Analysis Algorithm*

Principal Component Analysis (PCA) is an unsupervised machine learning algorithm that has as its goal to perform dimensionality reduction, where new features will be called components and will extract the most important information from the dataset (Ratra et al., 2022). This type of algorithm solves challenges in machine learning, such as overfitting, decreased accuracy, or increased computation time, since a high number of features in a dataset would result in an exponential growth in the data needed to obtain a meaningful result.
Regarding the proposed project, SageMaker PCA was used, which is an implementation of the traditional PCA, provided by AWS and has several additional features. Firstly, scalability, since the algorithm handles large datasets as well, as it functions in two modes: regular (for a smaller number of datasets and features) and randomized (for datasets with an increased number of features and observations).
Secondly, due to the interaction with other AWS Services, such as uploading training data to a S3 bucket. Lastly, hyperparameter optimization, by running many training jobs to determine the best model version. SageMaker PCA provides a list of hyperparameters for the training, such as *feature_dim*, which is the input dimension, *num_components* represents the number of principal components and *algorithm_mode* is the mode for calculating the components represented in Figure 2.

```
# reduce 11 features to 6 components
pca.set_hyperparameters(feature_dim=11,
                        num_components=6,
                        subtract_mean=False,
                        algorithm_mode='regular',
                        mini_batch_size=100)
```

Figure 2. PCA Hyperparameters
Source: own source

G. *eXtreme Gradient Boosting Classifier*

eXtreme Gradient Boosting (XGBoost) is a supervised machine learning algorithm that provides an ensemble of weaker and simpler models to predict a target variable more accurately (Khan et al., 2022).
By using gradient boosting, variance and overfitting are reduced and there is a significant increase in the model robustness. This ensemble algorithm is suitable for both regression and classification tasks.
Since a classification algorithm is more appropriate for disease prediction than a regression one, XGBoost Classifier was used in the SageMaker platform.
SageMaker XGBoost has several strong points over the standalone XGBoost library, as the ones of SageMaker PCA algorithm, namely scalability, as the regular model can handle large datasets; integration with AWS services,

such as uploading training data to a S3 bucket; model tuning for optimal values of hyperparameters.
In Figure 3, several hyperparameters are set, such as the maximum depth of a tree or the number of classes which are two, represented in binary and it establishes the presence or absence of a cardiovascular disease in a certain patient.

```
Xgboost_classifier.set_hyperparameters(max_depth=3,
                                       objective='multi:softmax',
                                       num_class=2,
                                       eta=0.5,
                                       num_round=150)
```

Figure 3. XGBoost Classifier Hyperparameters
Source: own source

H. ***Integration of ML Model with Web Application***
The connection between the model and the web application is made once it has been trained, tested and ready for use. The integration is done with Boto3, an AWS SDK for Python programming language, which invokes the SageMaker endpoint and returns predictions based on patient's input data, as provided in Figure 4.

```
# session

session = boto3.Session(
    aws_access_key_id='AKIASK6QF24XODPI3OEI',
    aws_secret_access_key='Ss411SiuevVF+hYs1nUJ+2xip1brdWyOxUNn+PI',
    region_name='us-east-1'
)

# get client instance
client = session.client('sagemaker-runtime',region_name='us-east-1')

print(type(client))

# invoke endpoint with input data
response = client.invoke_endpoint(
    EndpointName='sagemaker-xgboost-2023-04-28-09-26-22-062',
    Body=csv_data,
    ContentType='text/csv'
)

# convert the response from AWS service
# into Python object
predictions = json.loads(response['Body'].read().decode())
```

Figure 4. Endpoint Invocation and Prediction Retrieval
Source: own source

The doctor will receive a warning message on the screen that shows whether a patient belongs to a category of risk for cardiovascular disease or not. Furthermore, the incorporation of a machine learning model in the healthcare sector enhances the functionality of medical processes, helping the professionals to visualize data better and to make informed decisions based on real-time predictions.

RESULTS AND DISCUSSIONS

Considering the machine learning model, the results are based on the category of risk for whether a patient might suffer from a cardiovascular disease or not. The accuracy is based on each patient's medical data, such as age, height, weight, blood pressure. In this manner, the medical providers gain a granular understanding of the patient's health data, and it enables them to identify patterns and inconsistencies in the model. The accuracy of the model is computed using the following formula:

$$\frac{No.\ of\ correctly\ predicted\ labels}{No.\ of\ data\ points\ from\ dataset} \cdot 100 \qquad (1)$$

Another limitation is based on appointment scheduling, as the user is not shown on the screen the availability of a day and timeslot when a particular day and time from a certain department are chosen. This issue could be resolved with AJAX, which can update specific parts of a web page, without the need to reload the whole page.
Alongside the prediction of the category of risk for a cardiovascular disease, there have been several use cases implemented in this prototype:
 - Sign-Up (for both patients and doctors), where the user enters personal information such as first name, last name, email address, as illustrated in Figure 5.

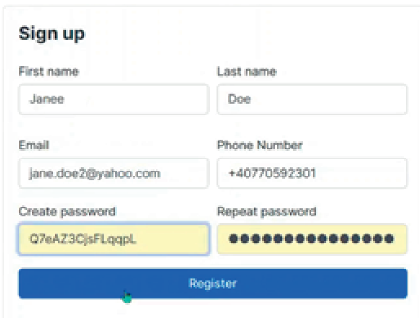

Figure 5. User Sign-up Interface
Source: own source

After the user presses the registration button, the information will be stored in the database and a success message will be displayed.
- Login (for both patients and doctors), allows the user to enter their credentials, which are the username and password.
After the user presses the login button, they will be redirected to their personal dashboard. Similarly, the Logout (for both patients and doctors) has been included in the application.
- Appointment Scheduling (patients only), as patients can book their appointment by completing the form from Figure 6.

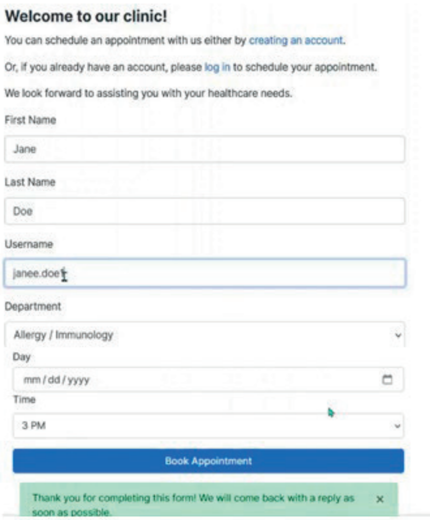

Figure 6. Appointment Scheduling Interface
Source:own source

- View personal details and appointments (patients and doctors), where the dashboard is as in Figure 7.

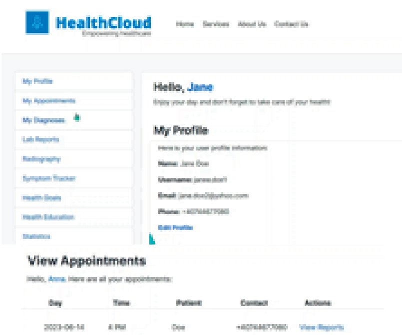

Figure 7. Personal Details and Appointments Interface
Source: own source

- View corresponding patients (doctors only), as doctors have an additional feature to view their patients' personal details, as in Figure 8.


My Patients

First Name	Last Name	Username	Email	Phone Number	Actions
Jane	Doe	janee.doe1	jane.doe2@yahoo.com	+40744677080	Get disease risk

Figure 8. Doctor's Interface for Patient Visualization
Source: own source

- Edit personal details (for both patients and doctors), where both patients and doctors can edit their personal details, that will be updated in the database, as in Figure 9.

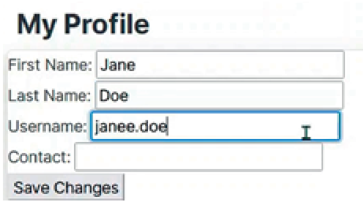

Figure 9. Edit Personal Details Interface
Source: own source

- Get disease risk feature, as after choosing the "Get disease risk" option from the patients view, a binary score will be shown on the screen which will establish the category of risk of the patient, as in Figure 10.

Figure 10. Get Disease Risk Feature Interface
Source: own source

CONCLUSIONS

The current paper highlighted the integration of Amazon Web Services (AWS) in healthcare management. Through conducting thorough research on various state-of-the-art models and comparing them with the proposed prototype, one can conclude that the project idea has proved its potential. The article has outlined the importance of digital transformation in healthcare, the challenges of chronic disease management, the potential of machine learning and AI, and the benefits of cloud hosting with AWS Amplify.

Improvements to the current work and future enhancements include first the fact that incorporating Amazon Rekognition for automated image analysis, such as chest X-rays, could greatly benefit early detection of pneumonia, leading to prompt intervention and better patient outcomes. This scalable AWS service supports telemedicine, allowing patients to easily upload radiographs for analysis, thus enhancing remote healthcare delivery. Secondly, the implementation of a Cloud bot using Amazon Lex presents an opportunity to create a virtual assistant in healthcare. This digital agent aims to simplify access to critical information, improve patient engagement, and provide 24/7 availability. Leveraging advanced natural language models, the bot can offer a conversational interface with speech and text capabilities, enhancing patient-provider interaction. Lastly, the extension of the current web application can include a Symptom Tracker mobile application. Tailored for patients with chronic conditions, this application can enable health data tracking and generate insights for self-management and remote monitoring. Utilizing Flutter as a cross-platform framework and Amazon Amplify for hosting, the Symptom Tracker application offers flexibility and scalability across different platforms.

In summary, while the current paper has laid the foundation for integrating AWS into healthcare management, there are opportunities for further enhancement and expansion. By leveraging emerging technologies and AWS services, the project can continue to evolve, addressing the ever-changing needs of the healthcare industry and ultimately improving patient care and outcomes.

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