The Heart of Artificial Intelligence: A Review of Machine Learning for Heart Disease Prediction

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***Abstract*—Heart disease is one of the main heart diseases that cause the death of people worldwide, affecting the engine of the human body: the heart. It has a greater incidence in underdeveloped countries such as Angola, Bangladesh, Ethiopia and Haiti, for this reason, obtaining accurate results based on risk factors manually is a complex task. Therefore, this systematic review allowed us to analyze and study 32 articles applying the PRISMA methodology, which allowed us to evaluate the suitability of the methods and, consequently, their reliability in the results. The results of the study showed that the algorithm with the greatest accuracy in predicting these heart diseases is Random Forest. The most commonly used metrics to evaluate machine learning algorithms are sensitivity, F1 score, precision, and accuracy, with sensitivity highlighted as the primary metric. The most predominant independent aspects for predicting heart disease in machine learning models are age, sex, cholesterol, diabetes, and chest pain. Finally, the most used data distribution is 70% for training and 30% for testing, which achieves great accuracy in the algorithm prediction process. This study offers a promising path for the prevention and timely treatment of this disease through the use of machine learning algorithms. In the future, these advances could be applied in a system accessible to all people, thus improving access to healthcare and saving lives.**

Keywords*—*Machine learning; heart disease; prediction; systematic review; artificial intelligence; algorithms; literature; heart

I. Introduction

One of the main causes of death worldwide is heart disease, which includes conditions such as coronary arteries, angina, heart attacks and heart disease, resulting from problems that affect the engine of the human body: the heart [1]. In addition, the American College of Cardiology mentions that 26 million people die from heart disease worldwide, and 3.6 million people undergo tests to rule out these diseases, aware of the great impact they can have on their lives [2].

Heart disease has a greater presence in underdeveloped countries such as: Angola, Bangladesh, Ethiopia and Haiti, with risk factors associated with this disease such as: high blood pressure, high cholesterol, uncontrolled diabetes, smoking and cardiac deterioration [3]. Therefore, to obtain accurate results in the diagnosis of this condition, a decision support system for your specialists is needed, since relying on multiple risk factors manually is a complex task [2].

Along with the challenges these nations face, the need for innovative solutions such as machine learning is highlighted, in addition, the adoption and application of this branch of artificial intelligence in the prediction of heart disease offers a promising approach. Compared to a human expert, machine learning models stand out for their speed and the lower cost associated with the predictions of these pathologies [4].

Machine learning, being a method of developing algorithms that help diagnose diseases of various kinds, has been crucial in a constantly modernizing world, where technology plays a vital role in continuous development. Through its techniques, it has been possible to save the lives of thousands of people by quickly detecting or predicting diseases, thus offering high-quality service to patients. Likewise, by identifying the primary phases of the conditions mentioned above, treatments can be adopted and counteract the disease, controlling the mortality rate in a comprehensive manner [5], [6].

On the other hand, machine learning models are classified into three categories: supervised learning algorithms, which focus on providing the user with an input x along with its corresponding output y, with the purpose of predicting y for a previously unseen input x, through the development of a classifier algorithm; Unsupervised learning algorithms, which do not focus on providing specific output values, but rather on inferring an underlying structure from the inputs, and reinforcement learning algorithms, where an agent is trained to determine certain policies, to solve efficient problems [7], [8].

Therefore, this systematic review focuses on the study of the most effective machine learning algorithms; powerful tools to make medical diagnoses and effective health services, revolutionizing the health sector. In addition, health professionals will be trained to identify assistance solutions faster and with greater accuracy [9]. Therefore, these algorithms, with their characteristics, make it possible to predict heart disease in people, which allows us to obtain an advantage against the disease.

Likewise, to carry out this study, a systematic review of the literature was carried out using the PRISMA methodology. In this methodology, articles were selected to address four research questions: Which machine learning algorithm demonstrated the best prediction performance in the present studies? What are the independent aspects for the machine learning model in its prediction process? ?, What performance metrics were used to evaluate the machine learning model(s) in the present studies? and What is the proportion of data used to train and test the machine learning model? Furthermore, the review was structured into sections of introduction, methodology, analysis of results and conclusions.

II. Methodology

To develop the systematic review, we applied the PRISMA 2020 methodology, allowing us to evaluate the adequacy of the methods and, consequently, the reliability of the results [10]. Additionally, Zotero software was used to store the articles, these documents were subsequently evaluated to determine their eligibility, following established criteria. Fig. 1 shows study selection flowchart.

A. Research Questions

The objective of this study is to examine, compare and summarize articles on heart disease prediction using machine learning, published from 2021 to 2022. The four research questions developed are as follows:

- Q1: Which machine learning algorithm demonstrated the best prediction performance in the present studies?
- Q2: What are the independent aspects for the machine learning model in its prediction process?
- Q3: What performance metrics were used to evaluate the machine learning model(s) in the present studies?
- Q4: What is the proportion of data used to train and test the machine learning model?

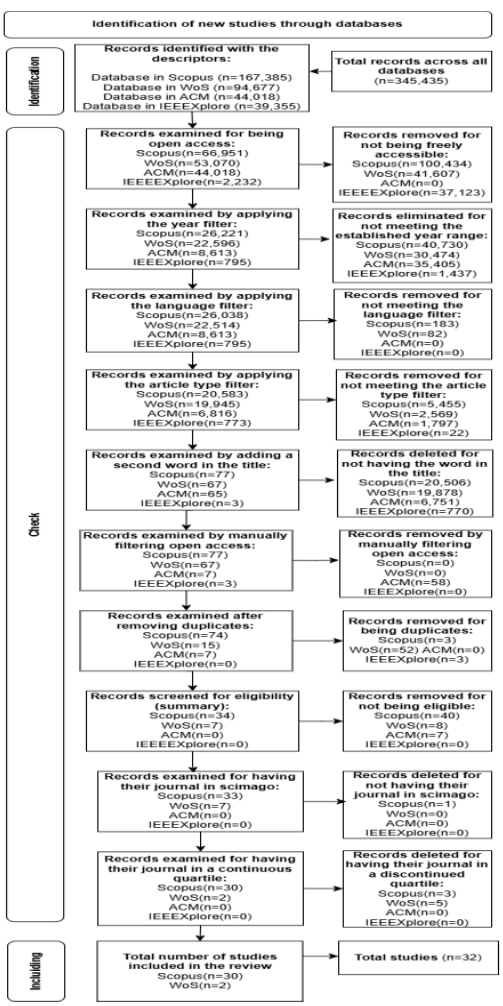

Fig. 1. Study selection flowchart.

B. Search Strategies

An exhaustive search of publications ranging from 2021 to 2022 has been carried out in four databases, these being: Scopus, Web of Science, ACM and IEEE Xplore. Likewise, to carry out this search strategy, the keywords were used: ("machine learning") and ("heart disease"), as shown in Fig. 2.

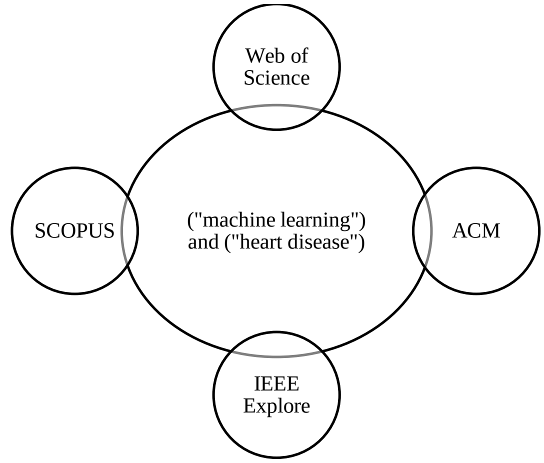

Fig. 2. Search criteria in databases.

C. Inclusion and Exclusion Criteria

For the selection of studies, studies were included that 1) the title of the articles must include the keywords, 2) they must be available as open access, 3) they must have been published between 2021 and 2022, 4) they must be written in English, 5) the type of document must be exclusively articles, 6) manual filter to access open access articles through Zotero, 7) they must have been non-duplicated articles, 8) they must have been eligible (summary), 9) must have had their journals indexed in scimago and 10) must have been from journals with non-discontinued quartiles. The exclusion criteria were: 1) the title of the articles does not include the keywords, 2) they are not available in open access, 3) they are not published between 2021 and 2022, 4) they are written in a language other than English. , 5) that the type of document does not correspond to an article, 6) they are not freely accessible through Zotero, 7) duplicate documents, 8) ineligible documents (abstract), 9) the journals of the documents are not indexed in scimago and 10) the magazines of the documents are of discontinued quartile. Fig. 2 presents the characteristics of the articles included in the systematic review, where the previously mentioned criteria are shown.

III. Results and Discussion

Of the 32 studies identified, they were compiled and summarized in a Microsoft Excel spreadsheet. The distribution of these studies according to their origin in the database is as follows: 94% of the studies come from Scopus, which is equivalent to a total of 30 articles. On the other hand, Web of Science (WOS) represents 6% of the studies, with two articles. Both ACM and IEEE Xplore do not have any studies that meet the inclusion criteria mentioned above. The details of the distribution of the selected articles according to their origin in the database are summarized in Table I.

TABLE I. SELECTED ARTICLES

N°	Database	Number of Articles	Percentage (%)
1	Scopus	30	94
2	WOS	2	6
3	ACM	0	0
4	IEEEXplore	0	0
	Total	32	100

a. Source: Own work

A. *Results of Machine Learning Algorithm with Higher Accuracy (Q1)*

Among the 32 studies analyzed, the presence of several machine learning algorithms for the prediction of diseases related to heart disease was observed. The most common algorithms include AdaBoost, CatBoost, Decision Tree, KNN, Linear Regression, Logistical Regression, Naive Bayes, Random Forest, Support Vector Machine, and XGBoost. Furthermore, models proposed by their authors were included in two studies, such as: HB + ET + SMOTE [11] y RECHOMMEND [12] highlighting a different approach that contributes to the field of machine learning.

TABLE II. ALGORITHM WITH BEST PERFORMANCE

N°	Algorithms	Papers	#	%
1	Random Forest	[13], [4], [2], [14], [1], [15], [16], [17], [18], [19], [20], [21], [3]	13	30.95
2	Support Vector Machine	[22], [23], [24], [25], [26], [9], [18]	7	16.67
3	XGBoost	[27], [28], [29], [19], [30]	5	11.90
4	Decision Tree	[5], [2], [31], [32]	4	9.52
5	Naive Bayes	[6], [33], [1], [18]	4	9.52
6	KNN	[34], [20]	2	4.76
7	Logistical Regression	[31], [18]	2	4.76
8	AdaBoost	[35]	1	2.38
9	CatBoost	[19]	1	2.38
10	HB + ET + SMOTE	[11]	1	2.38
11	Linear Regression	[21]	1	2.38
12	Rechommend	[12]	1	2.38

b. Source: Own work

Table II shows that the Random Forest algorithm is the most predominant in a total of 13 studies, which represents 30.95% of articles that use it. These findings are of utmost importance for future research that seeks to determine which machine learning algorithm provides the best performance in predicting diseases related to heart disease.

Thus, in the study by Maini et al. [15], the Random Forest (RF) algorithm achieved a diagnostic accuracy of 93.8%, evidencing a greater predictive capacity compared to other algorithms evaluated; concluding that the RF-based machine learning model not only offers an early diagnosis of heart diseases, but can also be easily accessible through the Internet, facilitating its implementation in clinical settings.

Likewise, an accurate ML model not only contributes to the early prediction of heart disease, but also allows identifying cases in which, although the patient appears to be healthy, the disease could be progressing imperceptibly. Therefore, the use of machine learning algorithms to prevent and treat heart disease in a timely manner is relevant.

B. *Result of Independent Aspects for the Prediction Process of the Machine Learning Model (Q2)*

Fig. 3 presents an analysis of the independent aspects or risk factors used in the prediction process of machine learning models.

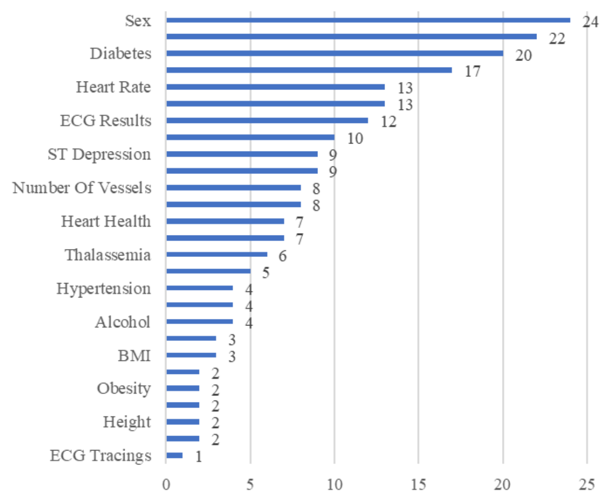

Fig. 3. Independent aspects.

Table III shows that age, sex, cholesterol levels, the presence of diabetes and chest pain are the predominant factors in the studies. These risk factors are considered highly effective in predicting heart disease-related diseases in patients, as stated and recommended by experts in the field [33].

TABLE III. PREDOMINANT INDEPENDENT ASPECTS

N°	Independent Aspect	Articles	#	%
1	Age	[1], [3], [4], [5], [9], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [24], [25], [26], [27], [28], [30], [31], [32], [33], [34], [35]	27	10.15
2	Sex	[2], [3], [5], [9], [12], [13], [14], [16], [20], [24], [28], [31], [32], [33], [34], [35], [15], [17], [18], [21], [26], [27], [14], [19]	24	9.02
3	Cholesterol	[1], [2], [4], [9], [13], [14], [16], [16], [17], [18], [20], [21], [22], [25], [26], [28], [30], [31], [32], [33], [34], [35]	22	8.27
4	Diabetes	[2], [3], [9], [14], [15], [16], [17], [19], [20], [21], [24], [27], [31], [32], [33], [34], [1], [4], [18], [26]	20	7.52
5	Chest pain	[1], [2], [3], [4], [5], [9], [13], [15], [18], [21], [22], [29], [31], [32], [35], [14], [24]	17	6.39

c. Source: Own work

Khdair and Dasari [25], in their study, highlighted that characteristics of medical records and associated risk factors such as: tobacco, LDL cholesterol levels, systolic blood pressure, adiposity and family history play a crucial role in preventing heart disease, as measured by medical records. They further noted that the success of predictions in the field of machine learning largely depends on the quality and diversity of the data used, as richness in data features and variables significantly improves the results in machine learning predictive models.

C. Result of Performance Metrics for Evaluation of Machine Learning Models (Q3)

Among the most commonly used performance metrics to evaluate machine learning algorithms, sensitivity, F1 score, precision, and accuracy stand out. As detailed in Fig. 4, sensitivity is the most valued metric in the studies, with 19.04%.

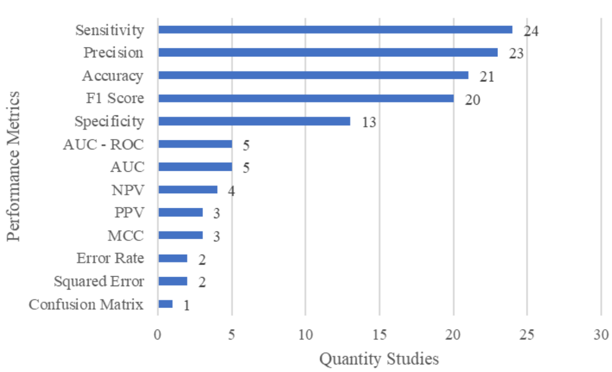

Fig. 4. Performance metrics.

In most studies that evaluate the performance of their machine learning algorithms, it exceeds 90%. As demonstrated by Maini et al. [15] where its RF prediction system achieved a sensitivity of 92.8% in the effective diagnosis of heart diseases. Another study reveals that an SVM-based model achieved 95% sensitivity [9].

Thus, in the research of Alotaibi and Alzahrani [35], they also use accuracy, sensitivity, specificity, F1 score, error rate, and Matthews correlation coefficient (MCC), all of these metrics derived from arithmetic calculations on the rate of true positives, false positives, false negatives, true negative rate, and false negatives, as performance metrics to evaluate their machine learning model and make more effective decisions about its effectiveness and identify areas for improvement.

D. Data Distribution Results for Training and Testing Machine Learning Models (Q4)

Regarding the distribution of data in the 32 articles, a proportion of data used for training (T) and testing (P) the machine learning models has been considered. Table IV shows the percentages of articles that do or do not provide information about the distribution of their data.

TABLE IV. DATA DISTRIBUTION

N°	Data Distribution	Articles	#	%
1	T: 70% - P: 30%	[22], [5], [35], [14], [28], [1], [15], [20]	8	25.00
2	T: 80% - P: 20%	[27], [17], [18], [21], [3], [20]	6	18.75
3	T: 75% - P: 25%	[11], [24], [9], [16]	4	12.5
4	T: 30% - P: 70%	[2]	1	3.12
5	T: 50% - P: 50%	[33]	1	3.12
6	T: 60% - P: 40%	[34]	1	3.12
7	T: 85% - P: 15%	[30]	1	3.12
8	Does not display information	[4], [6], [13], [19], [23], [25], [26], [29], [31], [32]	10	31.25

d. Source: Own work

After detailed analysis, it was observed that 25% of the studies used a data distribution in the proportion of 70% for training and 30% for testing. In the study by Absar et al. [20], two data distributions were used: one in a proportion of 80% for training (E) and 20% for testing (P), and another in a proportion of 70% for training (E) and 30% for testing (P). The 7:3 ratio allowed machine learning algorithms such as Random Forest, AdaBoost, and Decision Tree to demonstrate 99.025%, 96.103%, and 100% accuracy, respectively.

IV. LIMITATIONS

During the research, various limitations were presented. Firstly, the constant evolution of the literature implied that the information available at the time of the review may have changed, which represented a continuous challenge to keep the review updated with new developments in research.

Furthermore, the time available for the development of the systematic review was limited, which prevented the exploration of information in other databases that could have complemented the review.

Finally, there was a limitation in access to certain publications with relevant information, due to restrictions imposed by the authors, which prevented the inclusion of some significant studies in this research.

V. Conclusions

This systematic review, based on the analysis of 32 studies, has provided a comprehensive view of the impact that machine learning algorithms generate in the prediction of heart disease. Through the review, four key questions were addressed that framed the analysis, allowing us to identify common patterns and significant differences between the studies. Regarding the first question on Which machine learning algorithm demonstrated the best performance in the prediction of the present studies?, this study determined that Random Forest offers an early diagnosis of heart disease and can be easily accessible through the Internet, facilitating its implementation in clinical settings.

Regarding the second question on What are the independent aspects for the machine learning model in its prediction process?, it was determined that various independent aspects or risk factors were addressed, among which age, sex, cholesterol, diabetes and chest pain stand out, being the most predominant among the studies analyzed. Regarding the third question on What performance metrics were used to evaluate the machine learning model(s) in the present studies?, it was determined that various performance metrics are used, among the most used are: precision, sensitivity, accuracy and F1 score.

Finally, regarding the last question on What is the proportion of data used to train and test the machine learning model?, it was found that the distribution of data for training and validation are distributed in various proportions, such as: 70% - 30%, 80% - 20%, 75% - 25%, 30% - 70%, 50% - 50%, 60% - 40% and 85% - 15% for training and testing respectively, with the proportion of 70%-30% standing out as one of the most used. In this way, future research could integrate all the capabilities of machine learning into a system accessible to all people. This would allow for significant progress in the prevention of heart disease, making a decisive contribution to saving millions of lives.

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Conflict of Interest

The authors declare no conflict of interest.

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