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Associative Classification in Cardiovascular Disease Prediction: A Systematic Literature Review

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Abstract

Many disciplines have benefited from the increased use of high-performance computing in solving their challenges. This also applies to health care. An essential step in the information discovery process in databases is data mining (DM), which is the extraction of implicit, distinct, and perhaps valuable information from data. One of the interesting aspects of information mining which is used to create continuous itemsets, is association rules. DM tools are designed to help physicians make better diagnoses for therapeutic reasons by facilitating the efficient analysis of medical information. In order to improve the accuracy of diagnosis, data mining techniques are crucial in the detection of cardiac disorders.

Our effort aims to analyze different data mining methods and approaches in the healthcare area that can be used to forecast heart disease vis-à-vis cardio vascular disorders.

According to the study, DM is a potent technique that can be utilized to extract hidden, predictive, and useful information from a wide range of vast, diverse healthcare related databases in order to obtain fresh, in-depth insights. Advanced data mining tools have been viewed as an activist strategy to improve healthcare service quality and accuracy, particularly in the detection of cardiac problems, while reducing costs and time spent on diagnosis.

Keywords: Cardiovascular Diseases, Heart Diseases, Medical Data Mining, Association rule mining

Introduction

Cardiovascular disorders vis-à-vis heart diseases have a profound impact on both individual health and society as a whole. Efforts to reduce their prevalence and improve outcomes include prevention through healthier lifestyles, early detection, and ongoing research to develop more effective treatments. Deployment of advanced computing technologies is transforming the detection and prediction of cardiovascular diseases by harnessing the power of data analysis, artificial intelligence and machine learning. The techniques include data collection and integration, risk assessment, early detection, diagnostic support, predictive modelling, treatment planning, remote monitoring, research and drug discovery, patient education, health management etc. The methods improve patient outcomes and lessen the burden of CVDs on healthcare systems and society by supporting early diagnosis and risk assessment, as well as more individualized and efficient treatment and preventative initiatives. [1].

Finding and removing hidden patterns from various forms of data to aid in decision-making is the very essence of data mining [2]. Associative classification is a popular data mining classification technique that builds classification models using association rule prediction techniques.

In the context of data patterns and analysis, associative classifiers, such as association rule mining algorithms, can be used to indirectly predict cardiac disorders [3]. While they are not typically used as the primary method for predicting heart diseases, they can be valuable for discovering patterns, relationships, and risk factors within healthcare data that may contribute to improving predictive models or aiding in medical research. It is important to mention that while associative classifiers are valuable for pattern discovery and exploratory data analysis, they are not typically used as independent prediction models for the diagnosis of heart diseases. For direct prediction tasks, more sophisticated machine learning methods like logistic regression, support vector machines, or neural networks are typically utilized because of their ability to generate probabilistic predictions and handle the complexity of healthcare data.

Associative classifiers are used for data pattern discovery and analysis in the context of predicting heart diseases indirectly by uncovering associations, relationships, and risk factors within

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healthcare datasets. Their insights can inform feature engineering, hypothesis generation, and data exploration, ultimately enhancing the performance and interpretability of predictive models.

Association rules are employed to allocate a target value in an associative classifier which falls in the category of supervised learning model. New data are labeled using the model produced by the association classifier, which is made up of association rules that result in class labels.

Associative classification differs from some conventional rule-based classification techniques in two ways: (i) it produces an extensive amount of association classification rules, and (ii) it uses measure support and confidence to figure out the significance of the association classification rules.

The two-step procedure of data mining using association rules consists of mining the frequently occurring itemset and then creating the necessary rules. An item is defined as the pair of attribute concerned with the value. The first step is thus used for the searching of the attribute-value pair which are very frequent in their appearance in the data set and are repetitive in nature. Such pairs form the frequent pattern or frequent itemset. Certain requirements must be met by all association rules in terms of their correctness (or confidence) and the percentage of the data set that they truly represent (called support).

The fundamental idea of association rule mining, which explores single cardinality, is the use of *If* and *Else* statements to identify some relevance or relationship between two elements. The assertion is referred to as Consequent, while the element that is being examined is termed Antecedent. For example If *A Then B* is used in such rule based mining. It all comes down to establishing certain rules, and as the number of objects rises, so does cardinality. [4]. In order to assess the correlations among several thousand observations, various metrics are available, including:

- Support
- Confidence
- Lift

a) *Support :*

Support, or the frequency with which an item appears in the dataset, is defined as A's frequency. It is distinguished as the portion of transaction T that has the itemset X in it. The transaction T in a dataset X is often related as:

$$Supp(X) = Freq(X) / T$$

b) *Confidence:*

It shows how frequently the items X and Y occur together in the dataset when the occurrence of X is already known. In other words, it is a measure of the frequency of occurrence of truth. In essence, it's the ratio of the number of records containing X to the transaction that has X and Y.

$$Confidence = Freq(X,Y) / Freq(X)$$

c) *Lift:*

It is any rule's strength, which is best described as follows: In the event where X and Y are independent of one another, it is the ratio of the observed support measure to the expected support. It is expressed as:

$$Lift = Supp(X,Y) / Supp(X)*Supp(Y)$$

When Lift = 1, it means that the likelihood of the antecedent and subsequent events happening independently of one another, whereas Lift > 1 indicates that the two itemsets are somewhat reliant on one another. Conversely, Lift<1 indicates that one item is a stand-in for another and has a detrimental influence on the other.

Association rule learning can be mainly implemented employing three algorithms [5]:

a) *Apriori Algorithm:*

This technique uses common datasets to generate association rules. It is designed to function on databases that include transactions. This approach computes the itemset quickly by utilizing a hash tree and a breadth-first search. It is mostly used for market basket analysis and aids in understanding the products that can be purchased together. It can also be used in the medical field to determine a patient's pharmacological response.

b) *Eclat Algorithm:*

Equivalency Class Transformation is referred to as the Eclat algorithm. This algorithm uses a depth-first search approach to look for frequently occurring itemsets in a transaction database. It operates far faster than the Apriori algorithm.

c) *F-P Growth Algorithm:*

An improved version of the Apriori Algorithm is the Frequent Pattern, or F-P growth algorithm. The database is shown as having a structure like a tree, which is a typical pattern. This frequent tree can be

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used to extract the most common pattern.

Different Associative Classification techniques exist [6]. Below are a few of them:

a) CBA (Classification Based on Associations): It classifies data using association rule procedures, which work better than conventional classification methods. It needs to address the sensitivity of the minimum support criterion. If one chooses a lower minimum support criterion, a lot more rules are produced.

b) CMAR (Classification based on Multiple Association Rules): Classification Based on Associations takes more memory and space than this method since it employs an efficient FP-tree. The FP-tree might not always fit in the main memory when there are a lot of attributes.

c) CPAR (Classification based on Predictive Association Rules): The benefits of association classification and conventional rule-based classification are combined in classification based on predicted association rules. In classification based on projected association rules, a greedy algorithm generates rules straight from training data. Furthermore, in order to avoid overlooking important rules, predictive association rules-based classification generates and assesses a greater number of rules than traditional rule-based classifiers.

When working with high-dimensional datasets, associative classification has a number of advantages over other conventional classifiers like decision trees, neural networks, etc.:

a) Handles High-Dimensional Datasets **-** Because there are too many variables for reliable predictions, traditional classifiers suffer from the curse of dimensionality when working with high-dimensional datasets. However, because they only take into account pertinent features in common item sets, associative classifiers are effective with high-dimensional datasets.

b) Accurate Predictions **-** Associative classification can provide accurate predictions since it considers the relationships between attributes and their impact on the class label. By employing association rules to generate predictions, it also effectively manages missing values.

c) Interpretable Results **-** Associative classifiers produce interpretable results in terms of frequent item sets, which can help businesses understand customer behavior better. With the help of these insights, marketing tactics, product recommendations, etc. may be improved, resulting in higher sales and more satisfied customers.

d) Scalability **-** Associative classification algorithms like Apriori are scalable and efficient for large datasets with millions of transactions. In order to minimize the search space and expedite processing, these algorithms utilize pruning techniques.

Associative classification-based heart disease prediction finds patterns and relationships in medical data by combining data mining approaches with classification algorithms, ultimately providing valuable insights into an individual's risk of developing heart disease. In the prevention and treatment of cardiac disease, this strategy may help medical practitioners make better decisions and enhance patient outcomes.

In the present communication a detail review of the work carried out by previous researchers in the field of associative classification of the heart disease related data has been carried out.

Literature Survey

In general, associative classification is a versatile technique that can be applied in various domains where predictions or classifications are to be made based on patterns and associations discovered in the given dataset which is very large in size. It combines the strengths of both association rule mining and classification algorithms to provide valuable insights and predictions. It can be effectively applied in the medical field to assist in disease diagnosis. By analyzing patient data and historical medical records, one can predict the likelihood of a patient having a specific medical condition based on patterns in the data. In the present communication heart disease prediction has been considered as the subject matter of study.

Carlos Ordonez (2001) [7] investigated the use of association rules in the prediction of cardiac disease. The author concentrated on two prediction problems, such as anticipating the presence or absence of cardiac disease. Their method of mapping was straightforward. In this technique, the qualities could be numerical or classified. It was used to convert medical records into transaction formats. Restricted association rules are optimized using improved algorithms. The mapping table is prepared after mapping the attribute values to the items. Four constraints, namely, item filtering, attribute grouping, maximum item set size, and consequent rule filtering were utilized to reduce the number of rules.

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A Greedy approach was devised by *Ordonez et al. (2006) [8]* to find only the most significant rules and to accelerate up the process of searching. Three measures are used to evaluate the significance of association rules: lift, confidence, and support.

Predictive rules mining using decision trees and association rules were compared *by Carlos Ordonez (2006) [9].* Research demonstrated that decision trees are not as good at predicting arterial disease as association rules are. Simple rules were produced using decision trees, yet most of the rules only apply to limited amounts of patient data and are therefore unreliable. On the other hand, association rules worked well with user-binned attributes and offer more dependable rules. They also generated more straightforward predicting rules and relate to larger patient data sets.

Using a dataset intended for heart disease prediction, *Carlos Ordonez (2006) [10]* investigated association rule mining using the train and test approach. In the study, the greedy method was employed to find important association rules. Three measures were used to assess the relevance of association rules: lift, confidence, and support. On a real-time dataset, this association rules mining technique was evaluated.

Important trends for heart attack prediction were found in the heart disease database by *Shantakumar B. Patil et al. (2009) [11].* Regretfully, the enormous volumes of data that the healthcare industry gathers are not "mined" enough to reveal hidden information that can predict likely cardiac illnesses. The authors have proposed the MAFIA (Maximal Frequent Itemset) algorithm as a Java implementation for this. Following preprocessing, the data is split into two groups and the cluster important for heart attacks is retrieved using the k-means technique. The item set is then mined for recurring patterns, and the frequent data's significance weights are established. Based on these weights of the characteristics (e.g., age, blood pressure, cholesterol, and many others), patterns significant to heart attack are chosen.

Asha Rajkumar et al. (2010) [12] investigated the use of supervised machine learning-based categorization for the detection of cardiac disease. The data were classified using the Tanagra tool, evaluated using 10-fold cross validation, and the outcomes were compared. Tanagra is a free data mining software with scientific and pedagogical applications. Numerous data mining techniques from the fields of database management, statistical learning, machine learning, and explanatory data analysis are suggested. Eighty percent of the dataset is used for training, while the remaining twenty percent is used for testing. Of the three methods, Naïve Bayes has the lowest error ratio and requires the least amount of time.

The application of data mining techniques for the prediction of heart attacks was proposed by *K. Srinivas (2010) [13].* The authors examined a wide range of medical data using classification-based data mining techniques, including rule-based, decision trees, Naive Bayes, and artificial neural networks. The current study made use of machine learning, statistical learning techniques, and data analysis with the Tanagra data mining tool. They used a training data set with 3000 instances and 14 different attributes. The examples in the data set display the results of various test types that are used to precisely predict heart disease.

To extract association rules, *Deepika (2011*) [14*]* investigated the Pruning-Classification Association Rule (PCAR). Apriori algorithm analysis is the basis of PCAR. Through PCAR, irregular items are excluded from a group of items based on a set of minimal frequency entries. After that, it sorts the set of things based on how frequently they occur to find a collection of objects that it finds frequently.

A weighted class Association rule mining approach was presented by *S. P. Syed Ibrahim and K. R. Chandran (2011)* [15]. It uses weighted association rule mining for classification and builds a compact weighted associative classifier (CWAC). When creating weighted class Association rules, the data item's weight is taken into account. By generating fewer rules, the proposed method improved classification accuracy and used the Hyperlink-Induced Topic Search (HITS) model to calculate the weight.

An effective technique for mining association rules with numerous constraints was reported by *Li Guang-yuan et al. (2011)* [16]. There are three stages to the suggested approach. The suggested approach performs better than the updated Frequent Pattern growth algorithm, according to experimental results.

Three search constraints were used by *Himigiri et al. (2011)* [17] in their study on data mining approaches for heart disease prediction in order to increase performance. The goals are to: (i) produce only rules that are relevant for medicine; (ii) decrease the number of discovered rules; and (iii) optimize runtime. The decision tree may lead to a hybrid set of attributes, while the user may

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discard other attributes manually, according to the authors' conclusion. An additional suggestion is that a family of little decision trees could be utilized in place of several association rules.

Weighted Association rule-based Classifier (WAC) was used by *Jyoti Soni et al. (2011)* [18] to forecast cardiac disease and provide a GUI-based interface for entering patient records. In WAC, several attributes are given varying weights according to how well they can predict. The system was trained using benchmark data from the Machine Learning Repository (UCI) and was developed in Java. In terms of average accuracy, it is determined that the Weighted Associative Classifier (WAC) outperformed other Associative Classifiers that were previously in use, such as CBA, CMAR, and CPAR. The suggested work produced a maximum accuracy of 81.51% with a confidence level of 80% and a support value of 25%.

A study conducted by *Nidhi Bhatla et al. (2012)* [19] examined several data mining methods that have been developed recently to forecast heart disorders. The results showed that neural networks with fifteen attributes performed better than any other data mining method, and decision trees employing WEKA 3.6.6's feature subset selection and genetic algorithm also demonstrated good accuracy. In addition to the aforementioned common traits, this research effort also incorporated two additional characteristics: obesity and smoking, for an effective diagnosis. Utilizing the notion of natural evolution, a genetic algorithm was applied. It continues in this manner for several generations until, starting from null, it creates a population P whose rules all meet the fitness requirement. A decision tree with 15 attributes provided accuracy of 99.62%. Moreover, decision tree demonstrated 99.2% efficiency when combined with a genetic algorithm that had six features.

Naïve Bayes and Weighted Associative Classifier (WAC) are two data mining approaches applied by *Aditya Sundar et al. (2012)* [20]. The Data Mining Extension (DMX) query language has been utilized to content retrieval, prediction, training, and creating models. The CRISP-DM (CRoss Industry Standard Process for Data Mining) technique is used in the construction of the mining models in this system. This model has been verified against a test dataset after it extracts the hidden knowledge from a historical database on heart disease. Classification Matrix approaches are used to evaluate the models' effectiveness.

Using feature subset selection, *P. Chandra and M. Jabbar (2013)* [21] developed class association rules for the diagnosis of cardiac disease. Association rules determine the relationship between attribute values and classification to forecast classes in a patient data collection. Genetic searching and other functional selection strategies are used to identify the features that can predict the development of heart disease.

The effectiveness of several decision tree algorithms in disease classification and prediction was investigated by *K. Thenmozhi and P. Deepika (2014)* [22]. The attributes are chosen using a variety of attribute selection metrics, including distance measurements, Gini index, information gain, and gain ratio.

Using rule mining techniques (Apriori), *Said I. S. (2015)* [23] presented a rule extraction experiment on data related to heart disease. More rule-mining-based research was carried out by classifying the data based on gender, and significant risk factors for heart disease were found for both men and women. It's interesting to note that one of the components of a healthy cardiac condition is being "female," according to the set of healthy guidelines. This work has demonstrated how one can use rule mining to uncover fascinating information. This study has taken gender diversity into consideration in addition to concentrating on the use of computational intelligence, namely association rule mining-based classifiers, to pinpoint the primary causes of the illness. It is possible to improve and broaden the suggested work in order to automate the prediction of heart disease.

Using the Associative categorization technique, *Jagdeep Singh et al. (2016)* [24] created a framework for the early identification of heart disorders. Data from the UCI repository was used to test this work. Heart disease is predicted using a variety of factors, including blood pressure, blood sugar levels, gender, age, and type of chest pain. Heart disease prediction uses data mining methods including Apriori, FP-Growth, Naïve Bayes, ZeroR, OneR, J48, and KNearest Neighbor. This framework achieves a 99.19% prediction accuracy.

A. Dhanasekar and R. Mala (2016) [25] suggested a technique for determining how strongly qualities are associated. Probability measures are used to build valid Association rules. Real and artificial data sets have been used to test the suggested methodology. This study comes to the conclusion that men and those between the ages of 55 and 65 have a higher chance of developing coronary vascular disease (CVD).

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Various data mining techniques were suggested by *Ashwini Shetty A et al. (2016)* [26] to predict heart disease. Their research focuses at neural networks and genetic algorithms to predict heart problems. The main advantage of this method is that the initial weight of the neural network is established using the genetic algorithm. The neural network in this case has two output layers, ten hidden levels, and thirteen input layers. The inputs are the attribute layers; in this instance, 13 characteristics are employed, such as age, blood pressure, blood sugar, and resting heart rate, among others. The Levenberg-Marquardt back propagation algorithm was used for training and testing. Optimization Toolbox is used to implement this system. The weights of neural networks containing "configure" operations vary from -2 to 2. The fitness function used by the genetic method was the Mean Square Error (MSE). Weights are adjusted through a genetic algorithm. Based on MSE, the fitness function for each chromosome was ascertained. After selection, the genetic algorithm caused crossover and mutation to swap out less adapted chromosomes for more adapted ones. Fitter strings are generated by optimizing the solution corresponding to the neural network's threshold and linking weights. The resulting lower values, which are almost equal to zero, show the network's generalized format and indicate that it is prepared for the classification task. MATLAB is used by the system to calculate accuracy. With WEKA, preprocessing is carried out. The outcomes demonstrate that the hybrid system consisting of a neural network and genetic algorithm performs significantly better than a neural network on its own.

In order to build a framework for the early identification of heart-based disorders, *Singha J. et al. (2016)* [27] conducted research on a heart dataset using associative classification algorithms. Several data mining algorithms were tested using the Cleveland heart disorders dataset from the University of California, Irvine (UCI) machine learning repository. A number of characteristics, including gender, age, blood pressure, blood sugar, and the kind of chest discomfort, are linked to the development of cardiac diseases and can forecast the early signs of the condition. To forecast cardiovascular diseases, their study employed a range of data mining techniques, such as FP-Growth, Aprior, Naive Bayes, ZeroR, OneR, J48, and k-nearest neighbor. Based on the best results, the hybrid technique for Classification Associative Rules (CAR) was used to construct the heart disease prediction system, which produced a 99.19% prediction accuracy.

In order to get quick and accurate results at a minimal cost, *Harale S. et al. (2017)* [28] integrated the SIMPLE CART algorithm into a web application for the identification of cardiovascular illnesses. The program was constructed on the Visual Studio Platform and used SQL SERVER for database management. The MVC framework with Asp.Net was the technology employed.

An experimental evaluation of the effectiveness of models built with classification algorithms and pertinent characteristics chosen using a variety of feature selection techniques was carried out by *Dissanayake and Md Gapar Md Johar (2021)* [29]. The Cleveland heart disease dataset was subjected to ten feature selection techniques, including ANOVA, Chi-square, mutual information, ReliefF, forward feature selection, backward feature selection, exhaustive feature selection, recursive feature elimination, Lasso regression, and Ridge regression, as well as six classification approaches, including decision tree, random forest, support vector machine, K-nearest neighbor, logistic regression, and Gaussian naive Bayes. The purpose of the exploratory analysis was to ascertain the findings. With the decision tree classifier, the feature subset chosen by the backward feature selection technique had the highest classification accuracy (88.52%), precision (91.30%), sensitivity (80.76%), and f-measure (85.71%).

By compressing the stored transaction database using the clustering matrix method and introducing the prepruning and postpruning strategies based on adding constraint conditions, *Y R Liu et al. (2022)* [30] proposed a data mining algorithm of association rules combining clustering matrix and pruning strategy to improve the algorithm. The experimental results showed that the optimization algorithm has a distinct advantage in that it minimizes the number of database scans and candidate item sets generated, which in turn significantly reduces the algorithm's running time and I/O load and improves its efficiency.

Conclusions

The present communication provides an overview of some recent data mining research on cardiovascular illnesses. Medical datasets are typically extremely large, which makes accurate

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prediction challenging. Data mining methods have shown to be highly helpful in extracting pertinent and usable information from such large databases. These studies demonstrate that using a variety of mining approaches yields much better results than using only one technique when processing a data set. WEKA, Tanagra, MATLAB etc. have been normally used in understanding the medical data analytics. For heart disease prediction management, a judicious combination of various data mining tools (algorithms) can be applied for better detection process. The datasets that are being used have been classified into sets that are intended for testing and training. A comparison of the performances of various mining algorithms can be carried out to suitably classify to obtain the probability of the appearance of heart disease in a patient or not. Other researchers in this field have attempted to "mine" a dataset for the factors that contribute to heart disease. In the present communication, only association rule based mining technologies are considered for the review purpose.

Most of the literatures reviewed in this communication have focussed on the application part of the various mining algorithms for classification methods. However, data cleaning and pruning techniques provide betterment of the classification process are seen to be overlooked in the reports provided. It is obvious that cleaning and pruning of data set play a major role in effective mining process. By choosing appropriate methods for cleaning data and using appropriate classification algorithms, prediction systems with improved accuracy can be developed.

In addition to examining these widely used methods, other recent studies have looked into "hybrid models." A hybrid model aims to improve results by combining many well-established classification and selection methods into a single model. It can be finally concluded that a judicial combination of different algorithms will lead to a better result providing better efficiency and effectiveness of the detection system.

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