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A Survey of Association Rule Classification Algorithms in Data Mining

Ramesh R, Saravanan V

Abstract –Data mining plays a vital role in discovering hidden patterns and unknown knowledge from different types of data bases. Association rule mining is not finding specific classes instead it identifies the frequent items but in classification, classifiers are used to determine specific classes. Integrating these two techniques gives more efficient approach called Associative Classification. It is a new era in data mining approaches which is integrating Association rule and Classification to build accurate classifier than traditional methods. Most of the researchers proved that AC produces accurate results and also time efficient with different datasets. There are several algorithms proposed in recent times for associative classification (AC) such as Classification based on Association (CBA), Classification based on Multiple Association Rules (CMAR) and Classification based Predictive Association Rule (CPAR). This study compares and analyses the various important AC algorithms in terms of method, contributions, experimental results, accuracy and execution time irrespective of data sets.

I. INTRODUCTION

In Knowledge Discovery from Databases (KDD), Data mining process is an important part to discover hidden and useful knowledge from data bases. It consists of various techniques such as Association, Classification, Clustering, machine learning etc. Data mining discovers useful patterns in many areas like business decisions, health care systems, and weather prediction etc., Classification rule mining aims to discover a small set of rules in the database to form an accurate classifier. Association rule mining finds all rules that satisfy some *MinSup* and *MinConf* constraints [1].In practical applications both association and classification are essential.

In 1998 Liu et al.,[1] proposed a hybrid approach by integrating both association rule and classification is called Associative Classification (AC). The integration is done by focusing on special subset of association rules called *Class Association Rules* (CAR) [1]. AC helps to extract a set of high quality association rules from the training data set which satisfy certain user-specified frequency and confidence threshold [2].

The popular algorithms such as Apriori and FPgrowth are used in order to get all the association rules. The rules that have a top quality are alone combined to form a small set and taken for consideration to participate in prediction. The experimental results proves to be of more accurate than many of the approaches such as C4.5[3]

This paper analyses the various algorithms proposed in recent times such as CBA [1], CMAR [2], CPAR [3], MMAC [4], ECR-CARM [5], LAC & CMAR [6], CARC [7],CAR-MINER [8], ACC-FFP [9], CARIM [10]. This paper discusses the main concept of the associative classification and various AC algorithms are presented with their different methodologies in rule pruning, ranking, pruning and prediction procedures, and experiments results.

II. ASSOCIATIVE CLASSIFICATION

In Association Rule mining, items which passes *MinSupp and MinConf* is known as a frequent item. Association Rules are generated based on the threshold value *MinConf*. The tasks are not predefined in Association. For example identifying frequently purchased items together in business transactions. But in classification the classes are predefined. It is in the form of single or multiple classes. Classification is one of the data mining functionality which is classifies an items into targeted classes. For example a classification model may used to identify whether to approve or not approve a loan application based on the credit limit, account history, income, age etc., In Associative classification mining, and the training phase is about searching for the hidden knowledge primarily using association rule algorithms and then classification model is (classifier) constructed after sorting the knowledge in regards to certain criteria and pruning useless and redundant knowledge [19]. The Association rule mining has three stages in general. The first stage looks out for the correlations that are not seen between the values of the attribute and that of the class in any input and considers them as class association rules. The second stage deals with the ranking and pruning procedures based on a definite threshold values framed from the support and confidence. In the final stage, the classifiers that are derived are tested on new data taking the complete CARs. The efficiency is also measured in terms of forecasting the class that went unseen. The major advantages of AC algorithm are the simplicity and easily understood with minimum error rate.

A. Associative Classification Problem Statement

Given a labeled training data set, the problem is to derive a set of class association rules (CARs) from the training data set which satisfy certain user-constraints, i.e support and confidence thresholds. X → Y, where Y is restricted to the class attribute values. X denotes a small set rule as a classifier. The general lifecycle of AC algorithms denoted in Figure 1.

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***** Correspondence Author
Ramesh R*, Computer Science , Sri Krishna College of Arts and Science Tamil Nadu, India.
Saravanan V , Computer Applications, Sri Venkateswara College of Computer Applications and Management . Tamil Nadu, India.

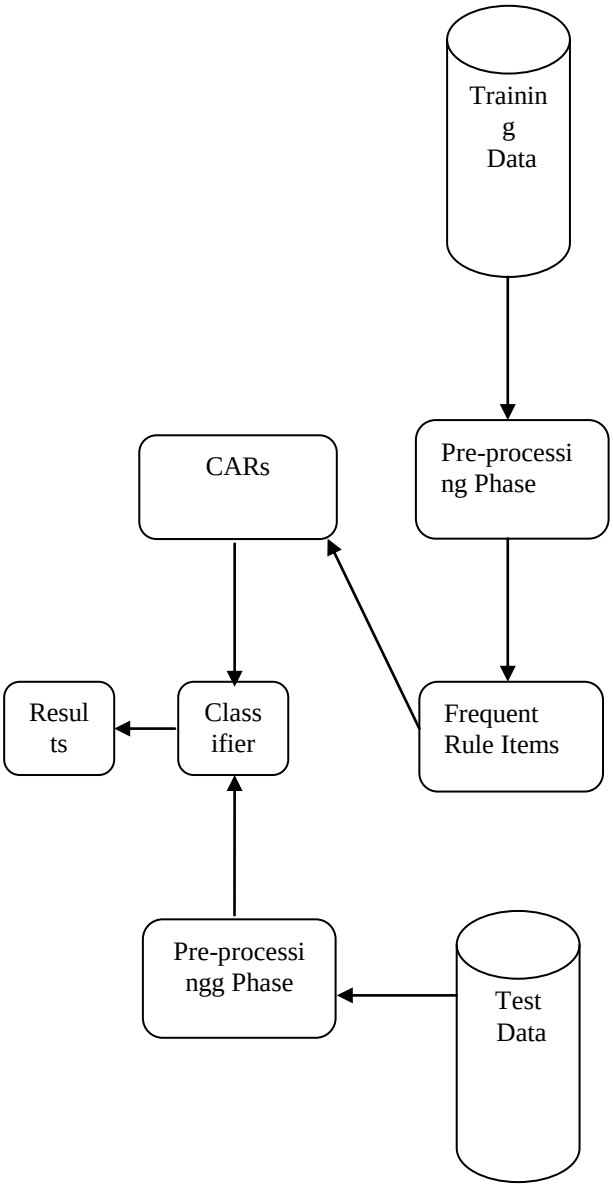

Fig 1: General process of AC algorithms

Most of the Associative Classification are depended upon threshold values called Minimum support and Minimum confidence. All the pairs of attribute-class are related based on the criteria of passing the threshold values. The minimum confidence is defined as the frequency of the value of an attribute and the class to which it is related in the training data.

III. TECHNIQUES AND DISCUSSIONS

A. *Classification Based on Association (CBA)*

Bing Liu, Wynne Hsu, Yiming ma, in 1998 with an idea to integrate association rule and classification, they proposed CBA (Classification Based on Associations). Class association rules improve the accuracy than C4.5. In existing association rule mining [Agarwal] is used to mine the entire CAR based on support and confidence threshold values. The CBA makes new way to build accurate classifier, using association techniques for classification tasks, it solves a number of important problems with existing classification techniques [1]. CBA consists of two phases, Rule generator (CBA-RG) based on Apriori algorithm and Classifier builder (CBA-CB). In phase one, CBA uses Apriori to find frequent item sets by multiple passes over training dataset based on *minSupport* threshold criteria. These frequent item sets are then converted as classifier rules based on *minConf* threshold criteria. In phase two, the CBA-CB algorithm is deployed for building a classifier using CARs. To identify best rule out of all generated rules would involve evaluating all the possible subsets of it on the training data and selecting the subset with right rule sequence that gives the least number of errors but it is relatively inefficient. But this algorithm uses heuristic method to identify best classifier. The experimental results of CBA based on the 26 datasets produces accurate results than C4.5 rules. The error rate decreases from 16.7% to 15.6 -15.8%. Even though CBA suffers from huge set of mined rules and requires multiple passes over large database.

B. *Classification based on Multiple Class-Association Rules (CMAR)*

In 2001, Wenmin Li, Jiawei Han and Jian Pei proposed a new associative classification technique is called Classification based on Multiple Association Rules (CMAR). The previous system still suffers from the huge set of mined rules and sometimes biased classification or over fitting since the classification is based on only single high-confidence rule. Extensive performance studies show that association based classification may have better accuracy in general. This technique extends an efficient frequent pattern mining method, FP-growth, constructs a class distribution associated FP-tree, and mines large database efficiently. The basic idea of CMAR is, instead of applying a single rule for classifier this method assumes a case to predict classifier and to develop efficient methods for storing and retrieving rules [2]. CMAR consists of two phases, rule generation and classification. The CMAR prunes some rules and only selects a subset of high quality rules for classification. CMAR extracts a subset of rules matching the object and predicts the class label of the object by analyzing this subset of rules. CMAR adopts a variant of FP-growth method and selects a subset of high quality rules based on database coverage. CMAR uses coverage threshold to select database coverage. The results concluded that CMAR is more consistent, scalable, and highly effective at classification and has better average classification accuracy in comparison with C4.5 and CBA.

C. *Classification based on Predictive Association Rules (CPAR)*

Classification based on predictive association rules (CPAR) is discussed by Xiaoxin Yin, Jiawei Han in 2003. One of the drawback of the existing methods is that it tends to generate large number of rules and also the measures of evaluation leading to the problem of over fitting [3]. This is addressed by CPAR by not generating a huge number of candidate rules but uses a technique that generated rules directly from training data. The problem of over fitting is addressed by keeping a value for the expected level of accuracy and all the rule that do not meet the level are eliminated and there by decreasing the number of rules generated and of high quality. The basic idea of CPAR is from FOIL.The First Order Inductive Learner was proposed by Ross Quinlan in 1993.

This aims to generate rules that distinguishes between the positive and negative examples. FOIL concentrates and discovers the rule that is best on the current time and automatically removes all the examples that are positive till all such items are covered[3]. Predictive Rule Mining (PRM) is a modified version of FOIL which address the issue of accuracy and to decrease the number of rules that are generated by FOIL thereby producing more accuracy. The literals are built one by one similar to PRM. During rule building process, CPAR keeps all literals close to the best. By doing so, it can select more than one literal and build several rules simultaneously. A study has been conducted to evaluate the accuracy and efficiency of CPAR and compare it with C4.5, RIPPER, CBA and CMAR. The result of the study, CPAR achieves high accuracy and efficiency.

D. *MMAC : Multi-label Associative Classification*

This approach aims to generate rules with multiple labels. A novel pproach called MMAC is introduced. The concept of one class-one rule is eliminated and it focus on generating rules not only for the most obvious class but for all instances that pass through a certain threshold. The iteration hence goes upto level M. This method comprises of three phases namely the, Recursive learning and Classification. The first phase is the Rule generation where scanning of the training data is carried out to identify and generate all the CAR. The second phase is the Recursive learning in which the iteration is carried out until the threshold limit of Minimum support and confidence is not met. The final stage is the classification where all the derived rules on each iteration is put under a global classifier [4]. The experimental results proves that the proposed method out performs the famous classifications such as PART, RIPPER and CBA in terms of accuracy. The results also indicate that this method produces lesser number of rules overcoming the run time issue.

E. *A Novel Classification Algorithm based on Association Rules Mining (ECR-CARM)*

This work aims to reduce the noise and focuses on the improvisation in terms of accuracy. A new algorithm ECR-CARM is proposed to reduce the noise. The method uses a tree called ECR to obtain all the CARs. The speed at which the rules are pruned are also increased. The classifications help in finding the set of rules in a DB to develop a classifier. Two approaches have been used the one with the classification based on Apriority and the other is the classification based on the FP – Tree. The former method results in generation of large number of candidates and performs scanning of the DB more number of times. The ECR tree recommends Classification Association rules and also reduces the rules that are repeated . The ECR – CARM calculates the intersections in the data set that are Obid and acquires faster support.

F. *A Novel Associative Classification Algorithm: A Combination of LAC AND CMAR with New Measure of Weighted Effect of Each Rule Group*

Pei-yi hao, Yu-de chen, proposed this study (2011). The proposed work was based on the CMAR which mainly concentrates on small disjunction mining. The problem of weight bias is addressed by a new method which helped in increasing the accuracy of CMAR. The rule that has the maximum weight is picked and the rules are classified as instances. Finally the LAC is applied to resolve the small disjunction problem. This is followed by pruning of rules which is done in couple of methods. I) The rules that are reserved and having high confidence are considered. 2) Selection of rules based on the data coverage. Experimental results have been conducted and compared with existing methods such as CBA , CMAR , LAC and LCUBE and found to be more efficient. The LAC is used to obtain small disjunction rules. The results prove that CMAR along with LAC produces better and accurate results.

G. *Mining Condensed Rules for Associative Classification*

Chih-Hung Wu, Jing-Yi Wang, Chien-Jung Chen introduced a method that uses a new metric termes “condenses” in order to find whether the rules that are infrequent and got filtered out by minimum support can also form good ARs for classification. CARC (Condensed Association Rules for Classification) is introduced. The strength of the relation among different items in a particular itemset is identified using a metric termed as “Condenses. This method took into consideration of three major factors such as rule generation, rule based generation and conflict resolution.

This uses traditional algorithms to generate ARs. This is more simple in terms of analysis and implementation. A new paradigm called conflict resolution is introduced when more ARS are assigned to a test data of different labels. A new approach to handle the test data is identified which was not possible with ARs. Experiments were carried out and the results were compared with that of CBA. The results proved that CARC is better particularly when the minimum support is even high. The issue of conflicts in classification rules is hence addressed in a better weay in CARC.

H. *CAR MINER – An efficient algorithm for mining class-association rules*

Loan T.T. Nguyen, Bay Vo, Tzung-Pei Hong, Hoang Chi Thanh introduced a method for mining class- association rule. Firstly, they design a tree structure for the storage frequent itemsets of datasets. Some theorems for pruning nodes and computing information in the tree are developed and then based on the theorem, they propose algorithm for mining CARs. Most of the decision support systems are based on classification techniques. The commonly used technique is CBA to mine ARs as it provides more and complete set of rules. The tree structure presented in the ECR is enhanced to MECR – Tree. The idea is to bring all the attributes that are same into a single group and to put those inside a single node. This seemed to be more time consuming and hence theoretical enhancements were brought in to reduce the time complexity of CARs. The Enumerate CAR initially produces a rule from a single node. The confidence is initially calculated and the rule if and only if satisfies the confidence are allowed to enter into the set of CARs.

This had better performance when compared to all the other existing algorithms.

I. *A Novel Efficient Fuzzy Associative Classification Approach Based on A Fuzzy Frequent Pattern Mining Algorithm (ACC-FFP)*

Michela Antonelli, Pietro Ducange, Francesco Marcelloni, Armando Segatori brought in a novel approach based on a fuzzy frequent pattern mining algorithm. It uses the fuzzy method of the FP-Growth algorithm to mine the fuzzy CARs. This produced better results when compared to the other fuzzy based FP-Growth methods. This is the first ever attempt to make use of the Fuzzy logic in CARs. This is based on the frequent pattern mining of Fuzzy CARs. This is segmented into three phases namely the Discretization , Fussy CAR mining and Pruning. Experiments have been carried out with seventeen datasets of various classifications and the results provd that it was better than that of CMAR , FARC-HD and D-MOFARC. It is proven that in almost all cases the AC-FFP produces more accurate rules than CMAR as it only selects the rules that are not redundant in nature and also performs classifications of patterns that are not labeled.

J. *CARIM: Approach with Interesting measures in Class- Association rule mining.*

Loan Nguyen, Bay Vo and Tzung-Pei Hong (2015) introduced the methodology in order to maintain the relations between the item sets. This increases the speed in generation of rules. The major advantage of this is that the possibility to extend to other measures of ranking. Interestingness measure is normally used to weigh the strength of a rule. The existing methods have used values up to kth highest value for prediction and this work aims to include the interestingness measures to Rank the rules. The CARIM is proposed to perform efficient mining of the CARs. This creates a child node by considering each node with other and uses the tree data structure to represent nodes. This aims to measure the ranking. The results depicts that the time taken for mining increases when the minimum is support is decreased. Experiments prove that there is only a negotiable deviation if at all all the measures of interestingness are added from the normal standard method. The application shows that the minimum execution time for the Breast data set is 15.1516 seconds and when on applying all the interesting features it was 15.4398 seconds which is not that much of deviation but the major advantage shows it works on the ranking.

K. *An Improved Algorithm for Mining Class Association n Rules Using the Difference of Obidsets.*

Loan T.T. Nguyen and Ngoc Thanh Nguyen (2014) introduce the CAR-Miner (Class Association Rule Miner) . The memory consumption of this was very high as it stores all the Obisets . The run time was also very high for the computation of intersection between two Obisets specifically when large data sets are considered. This is enhanced and a new CAR-miner was introduced which computes and uses the difference in two Obisets. This resulted in reduce of memory usage as it stores only the intersection and not he complete Obisets. The results proved that it is more efficient in terms of memory usage than the CAR-Miner . Better results were obtained in data sets that are dense such as Chess, Connect and Iono that normally occupies lot of memory space. The major disadvantage of using this method is that the question of efficiency to handle the data sparsity.

L. *Efficient strategies for parallel mining class association rules*

Dang Nguyen, Bay Vo and Bac Le (2014) proposes three different paradigms that work on parallel computing to effectively mine the CAR as the traditional method such as sequential rule mining do not produce quality results when applied to large data sets.

The available methods that work on parallel computing suffers from high cost issue due to the need of synchronization among the nodes. The three paradigms are Independent branch, Shared branch and Obidset. Theoretically this proves to produce better results in terms of speed when compared to existing parallel methods. The method uses the sequential CAR mining with the proposed paradigms and found to be efficient in handling the time complexity. Theoretically, the speed reaches up to v x m. The same experiment is conducted with both real and synthetic data and the results were found to be better when compared with the sequential CAR mining. This mainly serves the purpose of removing the synchronization issue that implies a large cost. The data redundancy is also reduced.

M. *A novel method for constrained class association rule mining*

Dang Nguyen, Loan T.T. Nguyen, Bay Vo and Tzung-Pei Hong (2015) came up with a new approach of using a tree structure for CARs mining. NCER tree was proposed in which each node of the tree has values of the attributes and the information. The problem of pruning the nodes in less time was addressed by proposing new theorems based on which the class constrains is created. The proposed method has the following steps:

- First, The support of the item set are computed using the Obidset.
- Second, The node's direct position is identified without the support values. With this as a base, The candidate rule is also determined based on this information.
- Third, The need of generating nodes that no longer can generate rules is eliminated based on the proposed paradigms and theorems.

As a result a new and more efficient algorithm named CCAR is introduced. The major advantages of this over CAR-Miner+ is that the speed and number of nodes that are pruned. This also has high advantage in terms of memory usage and run time.

Table 1

Research	Methods	Accuracy	Running time complexity
Classification Based on Association	CBA	82%	0.51 (sec)
	CBA-CB	84%	0.39 (sec)

Classification based on Multiple Class-Association Rules	C4.5	83.34	25 (sec)
	CMAR	85.22	19 (sec)
Classification based on Predictive Association Rules	CMAR	85.22	1.24 (sec)
	CPAR	85.17%	0.33 (sec)
Multi-label Associative Classification Approach	CBA	75.26%	33 (sec)
	MMAC	81.92%	30 (sec)
A Novel Classification Algorithm based on Association Rules Mining	CAR	81%	32 (sec)
	ECR-CARM	84%	27 (sec)
A Novel Associative Classification Algorithm: A Combination of LAC AND CMAR with New Measure of Weighted Effect of Each Rule Group	LAC	85.98%	28 (sec)
	LAC AND CMAR	87.1%	25 (sec)
Mining Condensed Rules for Associative Classification	CBA	75.26%	33 (sec)
	CARC	75.72%	20 (sec)
CAR MINER – An efficient algorithm for mining class-association rules	ECR-CARM	88%	0.069 (sec)
	CAR miner	92%	0.06 1 (sec)
A Novel Efficient Fuzzy Associative Classification Approach Based on A Fuzzy Frequent Pattern Mining Algorithm (ACC-FFP)	D-MOFARC	65.41%	10 (sec)
	ACC-FFP	87.69	7 (sec)
CARIM: An Efficient Algorithm for Mining Class – Association Rules with Interestingness Measures	CARIM	90.66%	0.15 (sec)

The Table 1 discussed about the performance metrics such as accuracy and running time complexity using existing methods.

IV. PERFORMANCE EVALUATION

A. Accuracy

The exact positive and the negatives total is described as the accuracy and it partitioned by the total number of classification attributes ($(T_p + T_n + F_p + F_n)$)

$$\text{Accuracy} = \frac{T_p + T_n}{T_p + T_n + F_p + F_n}$$

Where, T_p -True positive, T_n – Ture negative , F_p -False positive and F_n – False negative .

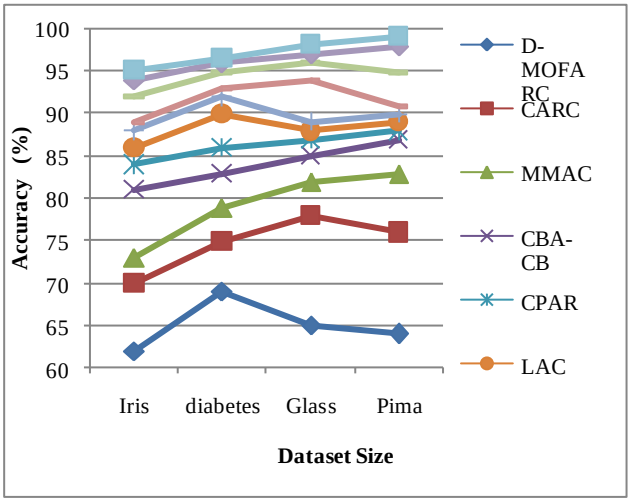

Fig 3 illustrates that the comparison of D-MOFARC, CARC, MMAC, CBA-CB, CPAR, LAC, ACC-FFP, ECR-CARM, CARIM , CAR miner and NCER in terms of accuracy. The number of datasets is taken as x axis and in y axis accuracy is taken. It concludes that the CAR miner method has shown the high accuracy results for all the datasets.

B. Precision

Precision is defined as the proportion of the true positives against both true positives and false positives results for intrusion and real features. It is defined as follows

$$\text{Precision} = \frac{T_p}{T_p + F_p}$$

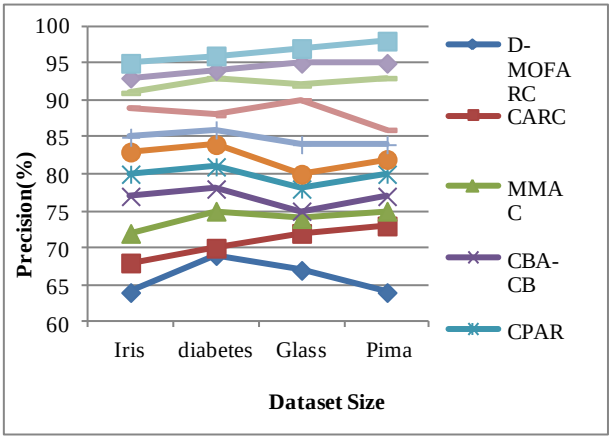

Fig 4 illustrates that the comparison of D-MOFARC, CARC, MMAC, CBA-CB, CPAR, LAC, ACC-FFP, ECR-CARM, CARIM CAR miner and NCER in terms of precision. The number of datasets is taken as x axis and in y axis precision is taken. It concludes that the CAR miner method has shown the high precision results for all the datasets.

C. Recall

It measures the proportion of positives that are correctly identified

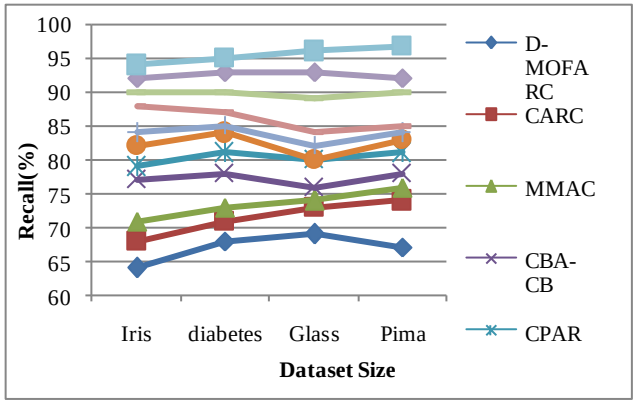

Figure 5. Recall Comparison

Fig 5 illustrates that the comparison of D-MOFARC, CARC, MMAC, CBA-CB, CPAR, LAC, ACC-FFP, ECR-CARM, CARIM , CAR miner and NCER miner in terms of recall. The number of datasets is taken as x axis and in y axis recall is taken. It concludes that the CAR miner method has shown the high recall results for all the datasets.

D. Time Complexity

The method is better when it takes lower execution time

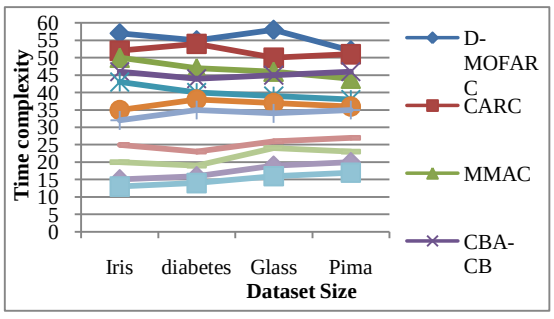

Fig 6: Time complexity comparison

Fig 6 illustrates that the comparison of D-MOFARC, CARC, MMAC, CBA-CB, CPAR, LAC, ACC-FFP, ECR-CARM, CARIM , CAR miner and NCER miner in terms of time complexity. The number of datasets is taken as x axis and in y axis time complexity is taken. It concludes that the CAR miner method has shown the lower time complexity results for all the datasets.

V. CONCLUSION

Several associative algorithms have been proposed for these years which give better results, accuracy than traditional classification algorithms. In this study many AC algorithms have been analyzed in terms of methodology, accuracy, execution time. All the algorithms troubled with analyzing and ranking the possible classification rules. The major issue of taking into consideration of all the nodes leading to large computational cost is solved by taking only the nodes that can satisfy the class constraints are framed. This paved the way for a new research dimension of confidence and non confidence based learning. This paper gives a brief insights about the research works carried out in Association rule mining, the methods proposed , their advantages and disadvantages and also the possibilities of new research area of confidence and non confidence based learning.

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AUTHORS PROFILE

Ramesh R, Is currently associated in the research area of Associative Classification and a research scholar in Bharathiyar University , Coimbatore. He is at present designated as an Assistant Professor in Sri Krishna Arts and Science College, Coimbatore

Dr. V Saravanan, has a PhD degree in the computer science and has over 15 years of academic experience .His research area includes Data Mining, Artificail Intelligence, data cleaning and Software Agents.