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Optimization of Association Rules using Hybrid BPSO

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Abstract:

Data mining technology has emerged as a means of discovering hidden patterns and trends among large volumes of data and thus it can be considered as an important step in the knowledge discovery (KDD) process. In the area of data mining the task of Association rule (AR) mining is to discover interesting relations among various items in the database. One of the subfield of artificial intelligence is Swarm Optimization which is intended to study the cooperative performance of simple agents. The Particle Swarm Optimization (PSO) is one of the swarm optimization algorithms which can be used for mining improved quality rules. PSO is one of the population based heuristic search technique which is used for solving various NP-complete problems. But PSO has a basic limitation that it gets stuck in local optima. Hence, this research work focuses on; the Binary Particle Swarm Optimization (BPSO) algorithm with cross over operator of Genetic algorithm (GA) for generating better quality association rules among bulky datasets. Due to the better exploration property crossover operator is used with Binary Particle Swarm Optimization (BPSO) algorithm. This algorithm mines improved quality association rules in terms of fitness value without specifying minimum support and minimum confidence thresholds. To prove the practical significance of the approach, this algorithm is tested on three datasets viz. Book dataset, Chess dataset, Connect dataset, using MATLAB and the results obtained has been compared with standard BPSO and GA algorithm.

Keywords — Association rule (AR), knowledge discovery (KDD), Particle Swarm Optimization (PSO), Binary Particle Swarm Optimization (BPSO), Genetic algorithm (GA), Support and Confidence.

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I. INTRODUCTION

Data mining is the application of definite algorithms that has been extensively used for extracting patterns, finding relevant datasets in a database. Mining association rules in transactional or relational databases has attracted a lot attention in database communities. Association basically deals with exploring the association among data elements from massive amount of data**.** Association rule mining is employed to solve problems in marketing place viz., market basket analysis. This helps in understanding the buying behaviour of customers. **.** Association Rule Mining was first introduced by Agrawal in 1993. According to his statement "Let $I = \{i_1, i_2, \ldots\ldots i_n\}$ be a set having *n* binary attributes termed as *items*. Let $D = \{t_1, t_2, \ldots\ldots t_n\}$ be a set consisting of *n* transactions termed as *database*. Every transaction in *D* has a distinctive transaction ID and it contains a subset of items in *I*. An implication of the form $X \rightarrow Y$, where $X, Y \subset I$, and $X \cap Y = \emptyset$ represents a rule. The sets of items (*X* and *Y*) on left hand side of the rule are called *antecedent* and items on right hand side of the rule are called *consequent* ". There are two main terms associated with association rule mining:-

(a) Support for an association rule A→B is the percentage of transactions in the database that contains AUB. i,e it is the percentage of transactions in which the item occurs.
(b) Confidence for an association rule A→B is the ratio of the number of transactions that contain AUB to the number of transactions that contain A. It implies the strength of any rule. Association rule mining problem is generally decomposed into two sub-problems. The first one is used to find the item-sets whose occurrences surpass a predefined threshold in the database (known as support); those item-sets are termed as frequent or large item-sets. The second one is used to generate association rules from those large item-sets with the constraints of minimum confidence. Usually the association rule mining consists of the following steps:-

(a) The set of candidate *k* item-sets is generated by addition of one item at a time to large (*k-1*) item-sets generated in the preceding iteration.
(b) By scanning over the database support for the candidate *k* item-sets is generated.
(c) Now the item-sets not having the minimum support are discarded and the rest of the item-sets are called large *k* item-sets.

The above steps are repeated until no more large item-sets are found.

The pioneering work of Apriori algorithm was proposed by Agrawal in 1993. This algorithm consists of two phases. In the first phase the frequent item-sets generated. For discovering frequent item-sets from all-possible item-sets a measure termed as support count (SUP) is used and also a user-defined parameter known as minimum support. The support count of an item-set can be defined as the number of records in the database that consist of all the items of that set. In case the value of minimum support is too high, less number of frequent item sets will be generated, which in turn results in generation of a lesser number of rules. Also, if the value of minimum support is too small, then approximately all possible item sets will become frequent resulting in generation of enormous number of rules. Moreover selection of better rules among them is again a problem.

In this research work we devised a novel Binary Particle Swarm Optimization with crossover operator of Genetic algorithm for optimization of association rule mining. This algorithm is tested on three datasets viz. Book dataset, Chess dataset, Connect dataset, and its performance is compared with that of basic BPSO and GA algorithm.

II. LITERATURE REVIEW

Ashish Ghosh and Bhabesh Nath (2004), proposed a multi-objective association rule mining using Genetic Algorithm (GA), multi-objective in the sense that measures like support count, comprehensibility and interestingness which are used for evaluating the rule can be viewed as different objectives of association rule mining. To mine association rules a Pareto based Genetic Algorithm is used. Ansaf Salleb-Aouissi, Christel Vrain and Cyril Norlet (2007) proposed QUANTMINER, a mining quantitative (mining association rules both on numeric and categorical databases) association rule system. This system is based on genetic algorithm (GA) that vigorously discovers excellent intervals in association rules by optimizing together the support and the confidence. The algorithm is directly applied on the dataset without prior applying standard association rule mining algorithms. Mourad Ykhlef and Hebah Elgibreen (2009) proposed a hybrid evolutionary algorithm that is combination of Genetic algorithm and Particle Swarm Optimization for mining sequential pattern and the proposed algorithm is named as SP-GAPSO. Three genetic operators were used in the proposed algorithm viz. selection, crossover and mutation. The fitness function used is a combination of support and confidence. Veenu Mangat (2010) proposed a technique based on swarm intelligence for mining rules over a medical database. The author has proposed ACO/PSO with new quality measure PF and its results have been compared with ACO and ACO/PSO. Chunlai Chai and Biwei Li (2010) proposed a new association rule mining algorithm based on Genetic algorithm (GA) and Fuzzy Set strategy specifically for web content mining. The algorithm through the preamble of selection operators, crossover operators and mutation operators, enhances the global convergence speed, and can efficiently avoid prematurity. S.Vijayarani and M.Sathiya Prabha (2011) proposed Artificial Bee Colony Optimization (ABC) algorithm for hiding sensitive association rules. The author has used Equivalence Class Transformation (ECLAT) algorithm for finding frequent item-sets using minimum support and minimum confidence. After that from the received frequent item-sets sensitive data are selected and then Artificial Bee Colony Optimization (ABC) algorithm is used for modifying sensitive items. S.Deepa, M. Kalimuthu (2012) proposed a Weighed Quantum behaved Particle Swarm Optimization (WQPSO) algorithm for enhancing the performance of association rule mining algorithm. The algorithm establishes suitable threshold values involuntarily and it enhances the computational efficiency of Apriori algorithm. K.Indira and S.Kanmani (2012) proposed a swarm intelligence based algorithm for mining association rules which is named as chaotic Particle swarm optimization (cPSO). For updating the velocity function in PSO new chaotic parameters are derived by using chaotic maps. Indira.K and Kanmani.S (2012) proposed Self adaptive Particle Swarm Optimization based association rule miner. They proposed two adaptive mechanisms for adjusting the inertia weights that is self adaptive PSO1 (SAPSO1) and self adaptive PSO2 (SAPSO2) for mining association of rules. K.N.V.D. Sarath, Vadlamani Ravi (2013) proposed a binary particle swarm optimization based association rule miner. It generates association rules without specifying minimum support and minimum confidence. To measure the quality of the rule a fitness function is defined which is product of support and confidence. Poonam Sehrawat, Manju and Harish Rohil (2013) proposed an efficient firefly algorithm (ARMFA) to discover association rules. In this approach each firefly is considered as a rule and fitness value is calculated for each firefly with the aim of discovering high frequency association rules. Jitendra Agrawal, Shikha Agrawal, Ankita Singhai and Sanjeev Sharma (2014) proposed a SET-PSO based approach for mining association rules. SARIC applies the item-set range and correlation coefficient for avoiding specifying the minimum support and confidence, since it automatically determines them speedily and independently. Vineet Singh Bhadoria and Unmukh Dutta (2015) proposed Artificial Bee Colony Algorithm (ABC) with one additional operator called crossover for optimizing association rule. For better exploration capability the crossover operator is used as this will generate more number of candidate solutions.

III. PROBLEM IDENTIFICATION

The problem of association rule mining is frequently decomposed into two sub-problems:-
(a) To find out those item-sets whose occurrences surpass a predefined threshold in the database and those item-sets are termed as frequent or large item-sets.
(b) To generate association rules from those frequent item sets with the constraints of minimal confidence.

Discovery of association rule is considered as a NP-hard problem as it needs to search a search space of 2^n, where n denotes number of items. As the value of n increases in turn the search space increases. Due to the exponential growth of the search space and database dependent thresholds, many of the researchers have proposed the use of evolutionary algorithms. Using computational intelligence approaches like PSO or GA for mining automatically generates threshold values for association rule mining and discovers association rules but they are having certain limitations which should be overcome to generate even much better quality rules. Like PSO has a drawback of getting stuck into local optima and premature convergence, GA suffers from extensive computational cost.

IV. METHODOLOGY

For improving the performance of association rule mining we devised Binary Particle Swarm Optimization with crossover of an Evolutionary algorithm. This algorithm will overcome the shortcomings of basic Binary Particle Swarm Optimization that is the tending to stuck in local optima, as the crossover operator of genetic algorithm ensures better exploration so, more effective rules can be generated in case of association rule mining.

A. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO) was introduced by Keneddy and Eberhert in 1995 which is based on swarm behaviour observed in nature such as fish schooling or bird flocking. PSO explores the space of an objective function by adjusting the trajectories of individual agents which are termed as particles. The movement of the particles is influenced by two factors which use information from iteration-to-iteration as well as particle-to-particle. As an outcome of the iteration-to-iteration information, the particle accumulates in its memory the best solution it has visited so far, which is termed as pbest, and it experiences an attraction towards this solution as it traverses along the solution search space. As an outcome of the particle-to-particle information, the particle accumulates in its memory the best solution visited by any particle in the swarm and it experiences an attraction towards this solution and is termed as gbest. The first and second factors are called cognitive and social components, respectively. The pbest and gbest values are updated after every iteration, for each particle if an enhanced or even more dominating solution, is found in terms of fitness value. The same process continues iteratively until either the desired result is obtained or termination condition achieved. For a search space having n-dimension, the i-th particle of the swarm is represented by a *n-* dimensional vector, $X_i = (x_{i1}, x_{i2}, \ldots, x_{in})$. To represent the velocity of the particle another n-dimensional vector $V_i = (v_{i1}, v_{i2}, \ldots, v_{in})$ is used. The previously best visited position of the *i-th* particle is represented as $P_i = (p_{i1}, p_{i2}, \ldots, p_{in})$. The best particle index in the swarm is represented as *'g'*. For updating the velocity of the *i-th* particle the following velocity update equation is used:

$$v_{id} = w * v_{id} + c_1 r_1 (p_{id} - x_{id}) + c_2 r_2 (p_{gd} - x_{id})$$

and the position is updated using

$$x_{id} = x_{id} + v_{id}$$

where d(dimension) = 1, 2… n and i(particle index) = 1, 2,…, s. Here, s represents the size of the swarm and c1 and c2 are constants, termed as cognitive and social components respectively (generally, *c1= c2; r1, r2* are random numbers drawn from a uniform distribution). *w* is the inertia factor which controls the influence of previous velocity on the current velocity.

The algorithm for Particle Swarm Optimization :-

Step1. Initialize the population with locations and velocities.
Step2. Evaluate the fitness of the individual particle termed as "lBest".
Step3. Keep track of the individual highest fitness termed as "gBest".
Step4. Modify the velocities based on velocity update equation.
Step5. Update the particles position based on position update equation.
Step6. Terminate if the termination condition is met.
Step7. Go to Step 2

Kennedy and Eberhart in 1997 proposed the first binary version of PSO, called Binary PSO. While in classical PSO, the velocities serves as a basis for determining the next position of a particle. The binary PSO is an extended particle swarm optimization and is used to optimize the discrete binary space problem. In binary version each particle position is either 0 or 1. The velocity parameter $v_{id}(k)$ is calculated similarly as the classical PSO and it will function as a probability threshold to formulate one of the two decisions (0 or 1). This threshold needs to stay in the range of [0, 1]. The sigmoidal function shown in Equation below, maps the interval of $v_{id}(k)$ i to a range of [0, 1].

$$Sig(x) = \frac{1}{1 + \exp(-x)}$$

$$x_{id}(k+1) = \begin{cases} 0 & \text{if } rand() \le Sig(\mathrm{v_{id}}(k+1) \\ 1 & \text{otherwise} \end{cases}$$

For binary version of PSO the particle's position is updated using equation above, here *rand()* is a uniform random number between 0 and 1. The complete PSO algorithm of the binary version is approximately same as that of the basic continuous PSO except the position update equation.

B. GENETIC ALGORITHM

Genetic algorithm (GA) proposed by John Holland in 1970 belongs to a bigger class of evolutionary algorithms (EA), which produce solutions to optimization problems using techniques inspired by natural evolution such as selection, mutation and crossover. Genetic algorithm runs to generate solutions for succeeding generations. Basically Genetic algorithm is technique of "breeding" computer programs and solutions to optimization or search problems by process of simulated evolution. The algorithm of Genetic algorithm :-

Step1. Represent the problem variable domain as a chromosome and select the size of the chromosome population N.
Step2. Define a fitness function to determine the performance of an individual chromosome in the problem domain. The fitness function serves as a basis for selecting chromosomes that will be mated during reproduction process.
Step3. Randomly produce an initial population of size N.
Step4. Calculate the fitness value of each individual chromosome.
Step5. Select a pair of chromosomes for mating process from the currently available population. Parent chromosomes are selected with high fitness.
Step6. Create a pair of child chromosomes by applying the genetic operators.
Step7. Put the created offspring chromosomes in the new population.
Step8. Repeat Step 5 unless the size of the new population equals to that of initial population, N.
Step9. Replace the initial (parent) chromosome population with the new (offspring) population.
Step 10: Go to Step 4, and the process is repeated until the termination criteria is satisfied.

C. HYBRID BPSO FOR ASSOCIATION RULE MINING

The algorithm used in research work consists of two parts:-
Part 1: Pre processing
Part 2: Mining
The first part of the algorithm deals with the procedures related to calculate the fitness values of the particle swarm. Hence the transactional data are transformed and stored in binary format. The second part of the devised algorithm is used to mine association rules. The standard BPSO with one additional step of crossover operation is used for mining in the present research work, the algorithm continues the search procedure until the termination condition is reached, and here termination criteria used is maximum number of iterations. Afterwards it outputs the association rule for a given dataset.

1) Rule Representation:

The first and foremost task is to represents an association rule as particle position. To represent a rule two approaches are used. First is Pittsburgh approach, in which each of the chromosomes represents a set of rules. The second approach is Michigan approach in which each of the chromosomes represents a separate rule. In the proposed research work Michigan approach is being used.

Suppose there is 'N' number of items in the dataset. For each item there are two parts as well as two possible values for each part. The values may be either 0 or 1. In first part the value 1 means that the item is present in the rule and if the value in the first part is 0 it means that the item is not present in the rule. In the second part the value will determine whether the item is present in antecedent part or the consequent part of the rule. In the second part the value 1 means that the item is present in the antecedent of the rule and if its value is 0 the item is present in the consequent part of the rule. Hence, the dimension for each particle is 2N. Let if the value of an item *I* is 11 it indicates that the item is present in the transaction and it lies in the antecedent of the rule. If the value of an item *I* is 00 or 01 then the item is not at all included in the rule. If value of an item *I* is 10 it indicates that the item is present in the transaction and but it lies in the consequent of the rule.

2) Fitness function

To evaluate the importance of each particle the fitness value is used. The fitness value of each particle is determined by fitness function. The fitness function for an association rule A→B in the proposed research work is of the form:-

$$\text{Fitness} = \text{Support } (A \rightarrow B) * \text{Confidence } (A \rightarrow B)$$

Where,

$$\text{Support } (A) = \frac{\text{No. of transactions that contain A}}{\text{Total number of transactions}}$$

$$\text{Confidence } (A \rightarrow B) = \frac{\text{Support } (AUB)}{\text{Support } (A)}$$

This research work uses support and confidence as fitness function for association rule mining problem. The selection of fitness function has the following intuitive appeal. Because both support and confidence lies between 0 and 1, hence if their product is maximized in turn they will be individually maximized.

3) Hybrid BPSO algorithm for Association rule mining

The Hybrid BPSO algorithm for association rule mining in present research work is:-

Step1. Load the transactional dataset.
Step2. The Hybrid BPSO association rule mining algorithm is run M times to get M rules from the data set.
Step3. Set the termination condition for Hybrid BPSO association rule miner.
Step4. Initialize population with position and velocity.
Step5. Compute fitness value and store P_i (local best) and P_g (global best).
Step6. Update velocity and position using velocity update equation and position update equation respectively.
Step7. Compute fitness value of updated position and update historical information for P_i (local best) and P_g (global best).
Step8. Apply crossover operation, for it select two random particles as parent particle from the current swarm and generate offspring, if best offspring obtained than parent, then replace worst parent with that offspring.
Step9. If P_g (global best) satisfies desired criteria then terminate else goto step 5.
Step10. Pick up best rule and add to rule set. If desired number of rules not obtained then goto step 2.
Step11. Exit.

The transactional dataset for association rule mining is given as input on which the hybrid algorithm will run. Firstly Binary particle swarm optimization algorithm is run, for the given set of population the algorithm calculates fitness value for each particle, update local best and global best values, then two random solutions from the current swarm is selected for crossover. The crossover can aid the particles jump out of the local optimization by sharing the each other's information. If the solution obtained from crossover is having higher fitness value than the parent chromosome, then the worst parent chromosome is discarded and new solution obtained is added. The crossover probability in the proposed algorithm is 1 that is it is applied every time and one-point cross over is being used. The algorithm terminates after maximum number of iterations and displays one best rule obtained that is global best value.

When the algorithm finishes all M runs it outputs top M association rules obtained for the respective data set with respect to their support, confidence and fitness value. The idea of running the algorithm M times has an intuitive appeal. Generally, whenever an evolutionary algorithm is employed to generate rules, every time the user gets different rules because of the evolutionary nature of the algorithm that is the evolutionary algorithm works on the principle of random initialization. Hence different rules are generated each time. In each of the runs different rules are generated, the best rule of each run is picked and then collated to provide top best rules. In the present research work the algorithm is run five times that is value of M is equal to five, hence the algorithm outputs top best five rules obtained in each of the runs respectively for individual datasets.

4) Block diagram of Hybrid BPSO for association rule mining

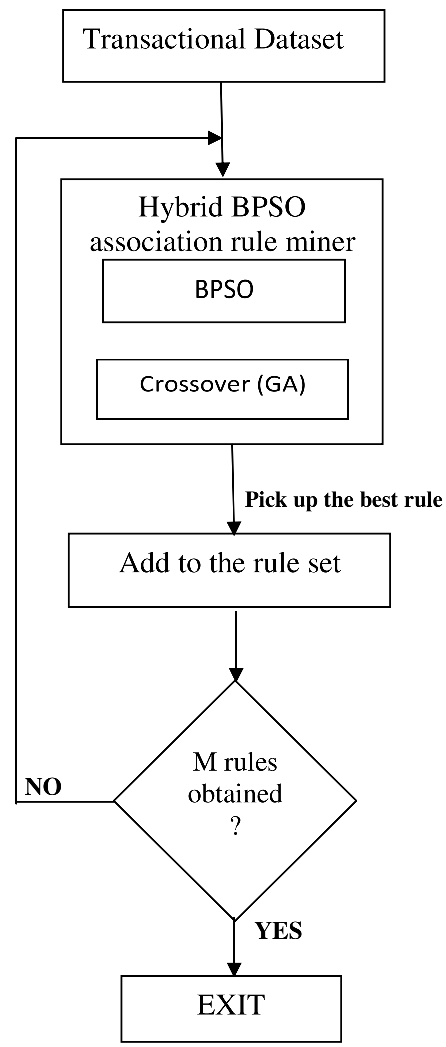

Fig1: Block diagram of Hybrid BPSO for association rule mining

V. EXPERIMENTAL RESULTS

To check the performance of devised algorithm, three datasets were used viz. Book dataset which contains 10 types of books and 2000 transactional records and another dataset is chess dataset which contains 60 items and 3000 transactions and the third one is connect dataset which contains 30 items and 2000 transactions. The results obtained for all the three datasets with the devised algorithm has been compared with standard GA and standard BPSO. The GA, BPSO and Hybrid BPSO for association rule mining are implemented in MATLAB. Since an evolutionary algorithm works on the principle of random initialization hence each time when the algorithm is run user gets different rules, so in practice it is run many times and then rules are collated by some mechanism. In the present research work each algorithm is run 5 times and in each run one best rule obtained is picked up and putted in the rule set. For each run the best rule obtained along with its support, confidence and fitness value is displayed. Finally top 5 rules obtained by each algorithm respectively.

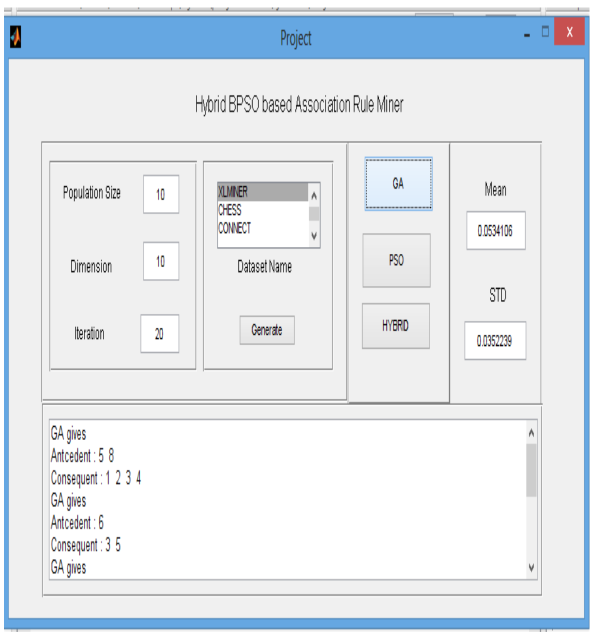

Fig2: A Demonstration of Implementation

The population size of all the three algorithms for book dataset is kept at 20 and number of iterations at 10. The top 5 rules generated by the GA, BPSO and Hybrid BPSO for Book dataset along with their fitness value is represented by graph. The graph shows the comparison of all the three algorithms for association rule mining with respect to the fitness value of the rules obtained.

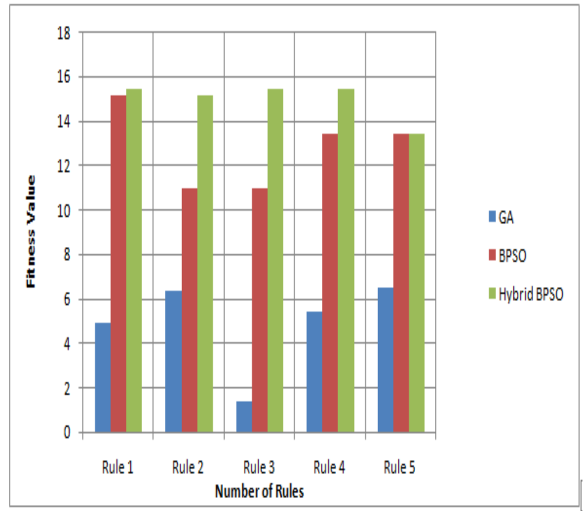

Fig3: Fitness value w.r.t Number of rules for Book dataset

The population size of all the three algorithms for chess dataset is kept at 10 and number of iterations at 10. The top 5 rules generated by the GA, BPSO and Hybrid BPSO for Book dataset along with their fitness value is represented by graph.

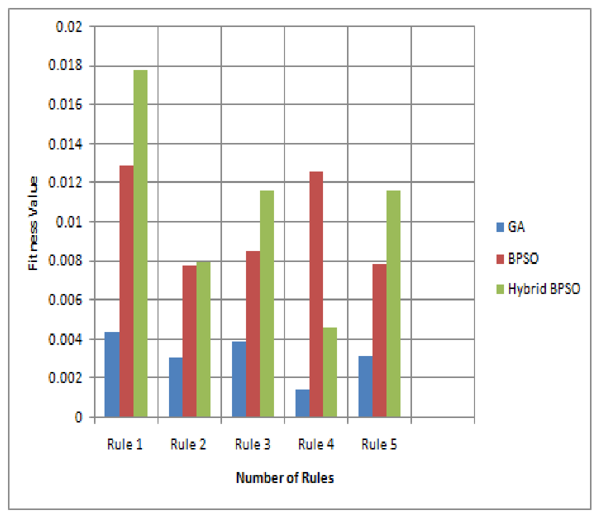

Fig4: Fitness value w.r.t Number of rules for Chess dataset

The population size of all the three algorithms for connect dataset is kept at 30 and number of iterations at 20. The top 5 rules generated by the GA, BPSO and Hybrid BPSO for Book dataset along with their fitness value is represented by graph.

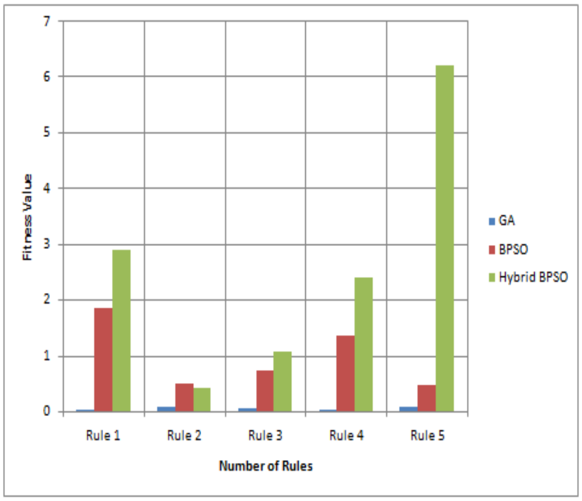

Fig5: Fitness value w.r.t Number of rules for Connect dataset

It can be observed from the graph that Hybrid BPSO generates better rules in terms of fitness value for all the three datasets in comparison with standard BPSO and GA. Hence it can be concluded that BPSO with crossover operator of GA generates better association rules in contrast with classical BPSO and GA.

VI. CONCLUSION

One of the most important techniques of data mining is the association rule finding. In the field of association rule mining, the minimum threshold values of support and confidence are given by the user. But this research work intends to determine the minimum support and minimum confidence values for mining association rules using BPSO with crossover operator of GA algorithm. This algorithm is mainly devised to overcome the performance of standard data mining algorithms of association rule mining. To perk up the performance of any swarm intelligence features or component of one algorithm is used or merged with another algorithm. To prove the effectiveness of algorithm it is run on three datasets they are book dataset, chess dataset and connect dataset. In this research work, Hybrid BPSO for association rule mining is compared with BPSO and GA. Experimental results show that Hybrid BPSO, for association rule mining gives better results than those of standard BPSO and GA.

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