

An Evolutionary Multi Label Classification using Associative Rule Mining for Spatial Preferences

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ABSTRACT

Multi-label spatial classification based on association rules with Multi objective genetic algorithms (MOGA) is proposed to deal with multiple class labels problem which is hard to settle by existing methods. In this paper we adapt problem transformation for the Multi label classification. We use Hybrid evolutionary algorithm for the optimization in the generation of spatial association rules, which addresses single label. MOGA is used to combine the single labels into multi labels with the conflicting objectives predictive accuracy and Comprehensibility. Finally we built the classifier with a sorting mechanism.

The algorithm is executed and the results are compared with Decision trees and Neural network based classifiers, the proposed method out performs the existing.

General Terms

Datamining, Evolutionary Algorithms

Keywords

Multi label Classification, Associative Classification, MOGA, HEA

1. INTRODUCTION

The phenomenal growth of spatial data increases the importance of the spatial data mining, which is used to mine fascinating and constructive but inherent knowledge. Classification of spatial stuff is a primary task in spatial data mining. Spatial classification is defined as the task of learning models to predict class labels based on the features of entities as well as the spatial relationships to other entities and their features by Richard Frank et. al [1]. Koperski, K [2] said the goal of spatial classification is to learn the concept associated with each class on the basis of the interaction of two or more spatially-referenced objects or space-dependent attributes, according to a particular spacing or set of arrangements.

Subhija Ponjavic and Elvir Ferhatbegovic [3] said rapid urbanization process amplifies the need for space planning purposes with emphasis on user preferences on the construction of urban infrastructure for housing, work and a variety of supporting activities of the population. Because of the large number of specific objectives, which are needed to be considered in this planning, the application of spatial classification with multi objectives can have a significant impact on the quality, speed and cost of the planning. Classification is

the important task which can be employed for the space planning with multi objectives.

Classification is used to predict the class attributes and the association rule is used to discover correlations among the attributes. Association rule mining is used to find the rules for classification and it is called as Associative classification (AC). AC algorithms outperforms the traditional classification algorithms [4] – [7]. But there are few challenges in the associative classification to be addressed so that it can be widely used. Fadi Thabtah [8] said incremental learning, noise in test data sets and the extraction of multi label rules are the major limitations to be concentrated.

We propose a spatial associative classification algorithm optimized with the evolutionary algorithms for the classification for space planning to meet the user preferences. We consider classification problem as the multi objective one since if it is considered as the single objective, Sachidananda Dehuri and Sung-Bae Cho [9] said the main demerit associated is that, the generated rules are often more complex than necessary and not easy to comprehend. The reason behind is that the local, greedy search performed by traditional algorithms selects only one feature at a time and, therefore, the feature space is approximated by a set of hypercubes. In real-world applications, the feature space is often very complex and a large set of such hypercubes might be needed to approximate the class boundaries among different classes.

Multi-label classification based on association rules with multi objective genetic algorithms (MOGA) is proposed to deal with multiple class labels problem which is hard to settle by existing methods. This algorithm decomposes multi-label data to mine single-label rules optimized by the Hybrid Evolutionary Algorithm (HEA), then combines labels with the same attributes to generate multi-label rules with the help of MOGA. It extracts partial dataset features filtered by MOGA to build the initial classifier through assembling, and conducts classification prediction by assembling the classifiers. Thus, the computational complexity caused by the high dimensional attributes decreases while the performance and efficiency increases.

The paper is organized as follows: Section 2 deals with the background concepts of Multi objective view on spatial classification, SAR, MOGA and the ACO applied for the optimization of the rule generation. Section 3 deals with approach followed in this paper, Section 4 explains the

comparison metrics. Section 5 discusses the results obtained and Section 7 discusses the application of the paper under the area of consideration and Section 8 gives conclusion of the paper.

2. BACKGROUND STUDY

This section is divided into three parts. Section 2.1 discusses the need for considering spatial classifications as a multi objective problem, section 2.2 discusses the use of Associative classification and section 2.3 says about the need for the evolutionary algorithms for the Multi label Classification problem.

2.1 Multi objective view on spatial classification

Diansheng Guo and Jeremy Mennis [10] said classification is about grouping data items into classes (categories) according to their properties (attribute values). Ester et al [11], Koperski et al [12] said, spatial classification methods extend the general-purpose classification methods to consider not only attributes of the object to be classified but also the attributes of neighboring objects and their spatial relations. Ester et al. [10] discussed a neighborhood graph based extension of decision trees that considers both non-spatial attributes of the classified objects and relations with neighboring objects. However, the proposed method does not take into account hierarchical relations defined on spatial objects as well as non-spatial attributes. Malerba et al [13], investigates to exploit the expressive power of predicate logic to represent both spatial relations and background knowledge, such as spatial hierarchies. Nadia Ghamrawi and Andrew McCallum[14] said, single-label classification assigns an object to exactly one class, when there are two or more classes. Multi-label classification is the task of assigning an object simultaneously to one or multiple classes.

Benhui Chen et al [15] said Multi-label classification problem is an extension of traditional multi-class classification problem in which the classes are not mutually exclusive and each sample may belong to several classes simultaneously. G. Tsoumakas et al [16] said existing methods for multi-label classification fall into two main categories; namely problem transformation and algorithm adaptation. Problem transformation maps the multi-label learning problem into one or more single label problems. The most widely-used problem transformation method considers the prediction of each label as an independent binary classification task. Brinker, K., et al [17] transform the multi label classification task into one or more single-label classification, regression or label ranking tasks. Algorithm adaptation extends specific learning algorithms in order to handle multi-label data directly, it modify standard single-label learning algorithm for multi-label classification. Methods adopted by both Min-Ling Zhang and Zhi-Hua Zhou [18] Multi-Label k-Nearest Neighbor (MLKNN), Weiwei Cheng and Eyke Hllermeier [19] Instance Based Learning by Logistic Regression (IBLR) were considered algorithm adaptation state-of-the-art multi label classification algorithms that exploit instance-based learning. We introduce the problem of Multi label classification

as the multi objective classification with the help of genetic algorithms and the association rule mining.

2.2 Associative Classification

AC is a branch of a larger area of scientific study known as data mining. Fayyad et al.[20] defined data mining as one of the main phases in knowledge discovery from databases, which extracts useful patterns from data. AC integrates two known data mining tasks, association rule discovery and classification, to build a model (classifier) for the purpose of prediction. Classification and association rule discovery are similar tasks in data mining, with the exception that the main aim of classification is the prediction of class labels, while association rule discovery describes correlations between items in a transactional database. Thabtah F. et al [21] uses classification is a special case of association rule mining, in which the antecedent of the rule is the label attribute. W. Li, J. Han, and J. Pei [22] presented associative classification algorithm that selects and analyses the correlation between high confidence rules. Yin, X. and Han, J [23] presented a greedy associative classification algorithm called Classification based on Predictive Association Rules (CPAR).

2.3 Need for the Evolutionary Algorithms

Over the past decade, population-based evolutionary algorithms (EAs) have been found to be quite useful in solving multi-objective optimization problems, simply because of their ability to find multiple optimal solutions in a single simulation run. Multi-objective evolutionary algorithms (MOEAs) are a popular approach to confronting these types of problem. A lot many research contributions by Dehuri et al. exist in [24] and [25] as a problem solving tools of rule mining. The use of EAs as a tool of preference is due to such problems being typically complex, with both a large number of parameters to be adjusted, and several objectives to be optimized. EAs, which can maintain a population of solutions, are in addition able to explore several parts of the Pareto front simultaneously. The robustness and domain-independent capabilities of EAs attracts researchers to evolve a set of classification rules.

Genetic algorithm (GA) based classifier systems usually fall into two basic categories, the Michigan approach and the Pittsburgh approach. The main difference between these two stems from the chromosome encoding schemes in the population of individuals. In the Michigan approach, each individual with fixed length encodes a single prediction rule. In this approach there are at least two possibilities for discovering a set of rules. The first one is let each run of the GA discover a single rule (the best chromosome produced in all generations) and simply run the GA multiple times to discover a set of rules. Disadvantage of this strategy is that it is computationally expensive, requiring many GA runs. The second possibility is to design a more elaborate GA where a set of individuals-possibly the whole population-corresponds to a set of rules. Whereas in the Pittsburgh approach, each individual is represented by a variable-length string and encodes a complete set of rules. A. L. Corcoran and S. Sen in [26] said, the Pittsburgh approach is better suited for static domains and batch-mode learning, in which all training samples are available before the learning process starts, and the Michigan approach is more flexible to handle incremental-mode learning, in which training samples

arrive over time and dynamically changing domains. ACO is a paradigm for designing meta heuristic algorithms for combinatorial optimization problems. The ACO algorithm was first introduced by Coloni, Dorigo and Maniezzo [27]-[28] and the first Ant System (AS) was developed by Dorigo [29] in his Ph.D. thesis. The ACO is a meta-heuristic algorithm, which utilizes the inspiration from real ant colonies behaviours to find a shortest path from a food source to the nest without using visual cues by exploiting pheromone information [30]-[32].

3. PROPOSED METHODOLOGY

In this paper we propose a three stage multi label classifier based on the HEA, the MOGA and Association rule mining. The first stage generates the optimized spatial association rules by the use of the HEA. In the second stage the Multi label rules are generated by the MOGA. Final stage the Multi label classifier is built with a sorting mechanism applied to the rules generated.

3.1 Application of HEA for optimized Spatial Association rule mining

SAR uses apriori algorithm for the generation of the rules. Here the rules generated by apriori using the hybrid evolutionary algorithm. The MOGA is used to achieve the multi objective by with a Pareto based multiple-objective genetic algorithm. The possible rules are represented as chromosomes and a suitable encoding/decoding scheme has been defined, it also provides the diversity of associations among the rules generated by elitism. We follow the Michigan approach for the optimization. To increase the efficiency of the MOGA, we are using the ACO, which limits the algorithm from falling to the local optimal solution.

The procedures of HEA are as follows. First, MOGA searches the solution space and generates association lists to provide the initial population for ACO. Next, ACO is executed, when ACO terminates, the crossover and mutation operations of MOGA generate new population. ACO and GA search alternately and cooperatively in the solution space. Then the rules are clustered using the rule cover based on the consequent information.

3.1.1 String Representation

Chromosomes are encoded as real numbers the number of genes in each chromosome is equal to the number of item sets considered. Each gene will have 4 digits for vector index. A sample chromosome may look like as follows:

0001 0102 0204 0302 0401 0500 0601 0702 0802 0901 1002
1101 1201

Here, the first two numbers in each gene represents the attribute and the next two denotes the value, fourth gene has the value 0302 where 03 refers to the age group and 02 refers to the third age group ranges from 23 to 25. Like wise all the gene has been encoded, once the initial population is generated now we are ready to apply genetic operators.

3.1.2 Fitness

The fitness function is calculated as the arithmetic weighted average confidence, comprehensibility and J-Measure. The fitness function is given by

$$f(x) = \frac{[(w_1 * \text{Comprehensibility}) + (w_2 * \text{J-Measure}) + (w_3 * \text{Confidence})]}{[w_1 + w_2 + w_3]}$$

where w_1, w_2, w_3 are used defined weights.

3.1.3 Reproduction (Selection)

The selection process selects chromosomes from the mating pool directed by the survival of the fittest concept of natural genetic systems. In the proportional selection strategy adopted in this paper, a chromosome is assigned a number of copies, which is proportional to its fitness in the population, go into the mating pool for further genetic operations. Roulette wheel selection is used for the proportional selection strategy.

3.1.4 Crossover

Crossover is a probabilistic process that exchanges information between two parent chromosomes for generating two child chromosomes. In this paper, single point crossover with a fixed crossover probability of C is used. For chromosomes of length l , a random integer, called the crossover point, is generated in the range $[1, l-1]$. The portions of the chromosomes lying to the right of the crossover point are exchanged to produce two offspring.

3.1.5. Mutation

Each chromosome undergoes mutation with a fixed probability M . For binary representation of chromosomes, a bit position (or gene) is mutated by simply flipping its value. Since we are considering real numbers in this paper, a random position is chosen in the chromosome and replace by a random number between 0-9.

Pseudo code for optimization of rule generation

1. while ($t \leq \text{no_of_gen}$)
2. $M_Selection(\text{Population}(t))$
3. $ACO_MetaHeuristic$
while(not_termination)
generateSolutions()
pheromoneUpdate()
daemonActions()
end while
end $ACO_MetaHeuristic$
4. $M_Recombination_and_Mutation(\text{Population}(t))$
5. Evaluate $\text{Population}(t)$ in each objective.
6. $t = t+1$

7. end while
8. Decode the individuals obtained from the population with high fitness function.

3.2 Generation of multi-label rules by MOGA

For a given training dataset D , traditional associative classification algorithms produce only one single-label rules set, and form a default label for the remaining unclassified instances. Our proposed algorithm uses MOGA to generate the multi label rules from the rules obtained in the previous stage. The objectives we have under consideration is high predictive accuracy and high comprehensibility, which are conflicting objectives.

The rules are of the form $A_1 \wedge A_2 \dots A_n \rightarrow C$. The antecedent part of the rule is a conjunction of conditions say A (conjunction of $A_1, A_2 \dots A_n$). Predictive Accuracy is defined by Dehuri, S., Mall, R.[33] as

$$PA = (|A \& C| - \frac{1}{2}) / |A| \quad (1)$$

where $|A|$ is the number of examples satisfying all the conditions in the antecedent A and $|A \& C|$ is the number of examples that satisfy both the antecedent A and the consequent C . Intuitively, this metric measures Predictive Accuracy in terms of how many cases both antecedent and consequent hold out of all cases where the antecedent holds. The term $\frac{1}{2}$ is subtracted to penalize the rules covering few training examples.

Xian-Jun Shi and Hong Lei [34] discussed the standard way of measuring comprehensibility [17] is to count the number of condition in the rule. If a rule has at most L condition, the comprehensibility of the rule (or individual) p can be defined as

$$C_p = (L-n) / (L-1). \quad (2)$$

where n is the length of the rule (or individual) p . The fitness function is computed as the arithmetic weighted mean of comprehensibility and predictive accuracy. The fitness function is given by

$$\text{Fitness} = [(y_1 * PA + y_2 * C_p) / (y_1 + y_2)]$$

where y_1, y_2 are the weights defined by the user.

Repeated learning has been done using the different generations of the MOGA and until no more frequent item sets can be discovered. At this stage, any remaining unclassified instance form a default label. This process results in learning from several subsets of the original training data and generates few rules sets.

3.3 Multi label Classifier

When the learning process is finished and no further frequent item sets are found, a merging of the rules sets produced from each training data is performed to obtain a multi-label classifier. When merging the rules sets, the multilabel rules are prioritized based on the sorting procedure. The sorting procedure uses the support, confidence and J measure of the rules. We also take into account the fact that the highest priority rules are those that have been derived from the original dataset during the first iteration, then those generated in the second iteration, and so on. The sorting has been done by the weighted average of the above three measures. The weights of the measures are defined by the user. The sorting measure (SM) is defined as

$$SM = \frac{(z_1 * \text{Support}) + (z_2 * \text{J-Measure}) + (z_3 * \text{Confidence})}{(z_1 + z_2 + z_3)}$$

where z_1, z_2 and z_3 are used defined weights

4. COMPARISON METRICS

Multi-label evaluation metrics fall into two main categories: prediction-based and ranking-based. Prediction-based metrics evaluate how well the algorithm predicts the actual set of correct labels for each instance. Ranking-based metrics evaluate how well the algorithm ranks the labels relative to one another. Tsoumakas et al [16] use the following standard multi-label prediction-based evaluation metrics.

Hamming Loss is the percentage of correct labels not predicted and incorrect labels predicted. Accuracy is the percentage of true positives out of the total true positives, false positives, and false negatives. Precision is the percentage of predicted labels that were correct. Recall is the percentage of correct labels that were predicted.

5. RESULTS AND DISCUSSIONS

We have used the synthesized dataset, which has been collected in and around the city Madurai. This data has been collected based on the geographic, demographic, psychographic and behavioralistic of the customer characteristics for our research. The target group are students, professionals, working women, home makers and the senior citizens.

The general procedure of data mining is:

- Question raise
- Data preparation (including data selection, data pre treatment and data transformation)
- Data arrangement
- Model building/data mining
- Result evaluation and explanation.

We have followed the procedure adopted by by Xinqi Zheng and Lu Zhao [35], where we take advantage of import wizard in Matlab to accomplish the import of data file.

Table 1 : Environmental parameters for GA

Population size	100
Crossover rate (C)	0.8
Mutation rate (M)	0.1
Stopping criteria	100 generations

2. We compute our results using ten-fold cross-validation for each method over each data set. It is defined as break data into 10 sets of size n/10, train on 9 datasets and test on 1. Repeat 10 times and compute mean.

The results in the Table 2 indicates that MOGA based AC outperforms the other two methods. The hamming loss in our proposed approach is reduced around 34.89% and 10.48% compared to decision tree based associative classifier and Neural network based associative classifier respectively.

Percentage of correct labels not predicted and incorrect labels predicted has been reduced by the proposed approach. This is because of the associative classifier is optimized by the genetic algorithm with one of the objective as the predictive accuracy and the learning is followed by the sorting procedure.

The results in the Table 3 indicates that MOGA based AC outperforms the other two methods. The accuracy in the proposed approach is increased around 53.33% and 49.20% compared to decision tree based associative classifier and Neural network based associative classifier respectively.

Table 2: Comparison of the algorithms based on Hamming Loss

	Decision tree	Neural Network	MOGA based AC
Iteration 1	0.101	0.075	0.068
Iteration 2	0.104	0.075	0.069
Iteration 3	0.103	0.076	0.064
Iteration 4	0.103	0.072	0.066
Iteration 5	0.102	0.073	0.065
Iteration 6	0.101	0.074	0.066
Iteration 7	0.102	0.075	0.066
Iteration 8	0.101	0.074	0.067
Iteration 9	0.102	0.075	0.067
Iteration 10	0.104	0.075	0.068
Mean	0.1023	0.0744	0.0666

Table 3: Comparison of the algorithms based on Accuracy

	Decision tree	Neural Network	MOGA based AC
Iteration 1	0.326	0.355	0.698
Iteration 2	0.325	0.355	0.694
Iteration 3	0.323	0.354	0.694
Iteration 4	0.324	0.352	0.699
Iteration 5	0.323	0.352	0.692
Iteration 6	0.322	0.353	0.692
Iteration 7	0.322	0.353	0.694
Iteration 8	0.325	0.353	0.695
Iteration 9	0.324	0.354	0.695
Iteration 10	0.325	0.352	0.695
Mean	0.3239	0.3533	0.6948

Table 4: Comparison of the algorithms based on Precision

	Decision tree	Neural Network	MOGA based AC
Iteration 1	0.501	0.817	0.889
Iteration 2	0.499	0.814	0.885
Iteration 3	0.503	0.815	0.885
Iteration 4	0.504	0.816	0.886
Iteration 5	0.499	0.816	0.888
Iteration 6	0.498	0.815	0.885
Iteration 7	0.504	0.816	0.886
Iteration 8	0.503	0.817	0.885
Iteration 9	0.502	0.816	0.887
Iteration 10	0.502	0.815	0.887
Mean	0.5015	0.8157	0.8863

Table 5: Comparison of the algorithms based on recall

	Decision tree	Neural Network	MOGA based AC
Iteration 1	0.495	-0.199	0.684
Iteration 2	0.498	-0.201	0.685
Iteration 3	0.494	-0.199	0.683
Iteration 4	0.495	-0.204	0.683
Iteration 5	0.495	-0.201	0.683
Iteration 6	0.497	-0.202	0.686
Iteration 7	0.498	-0.202	0.686
Iteration 8	0.496	-0.203	0.683
Iteration 9	0.496	-0.201	0.689
Iteration 10	0.498	-0.201	0.689
Mean	0.4962	-0.2013	0.6851

The results in the Table 4 indicates that MOGA based AC outperforms the other two methods. The precision in the proposed approach is increased around 43.41% and 7.96% compared to decision tree based associative classifier and neural network based associative classifier respectively.

The results in the table 5 indicates that MOGA based AC outperforms the other two methods. The recall in the proposed approach is increased around 27.57% and 129.38% compared to decision tree based associative classifier and neural network based associative classifier respectively.

Percentage of correct labels that were predicted has been increased by the proposed approach. This is because of the associative classifier is optimized by the genetic algorithm with the objectives as the predictive accuracy and comprehensibility. The first phase of the association rule generation is also optimized so that the prediction percentage of the correct labels is increased.

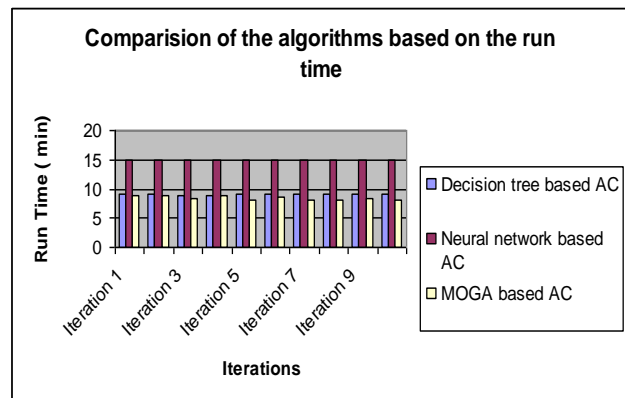


Fig 1: Comparison of the proposed approach with other benchmark algorithms based on the run time

Table 6: Comparison of the algorithms based on mean run time

	Decision tree	Neural Network	MOGA based AC
Time (min)	9.02	15	8.4

The result for the mean run time of the classifiers is given in Table 6. In comparing the times for the execution of the classifiers MOGA based AC outperforms the other two methods. This is due to the fact that the reduction in the number of rules in the first step.

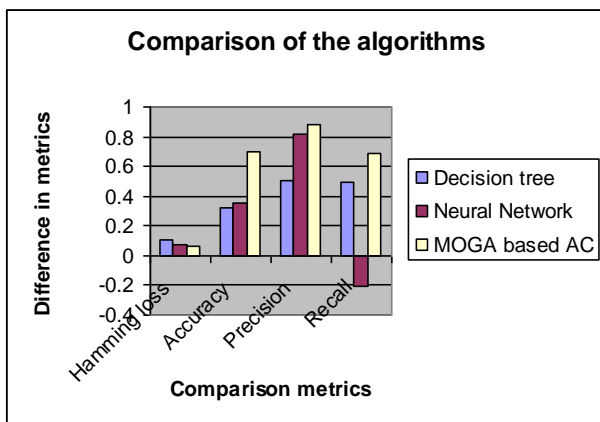


Fig 2: Comparison of the proposed approach with other benchmark algorithms based on the four measures

The consolidated report has been depicted in the Fig 2, it shows that the proposed approach shows remarkable improvement over the other two benchmark algorithms for multi label classification based on the four metrics considered.

The improved performance exhibited by the proposed approach is due to the fact that, we have used

- (1) Hybrid Evolutionary Algorithm for the optimization in the production of the association rules. This strategy helps us to minimize the number of rule generated.
 - a) We have used the multi objective genetic algorithm with the objectives confidence, comprehensibility and J-Measure
 - b) We have used ACO for the algorithm falling to avoid the local optimal solution

This approach helps us to produce the high quality and interested rules based on the basis given weigh by the user preference.

- (2) In the generation of the Multi label rules, we have introduced MOGA to do the repeated learning. It used the objectives predictive accuracy and high comprehensibility.

- (3) The merging of the rule set produced from each training set is followed by a sorting procedure. The prioritization of the rules is based on the support, confidence and J-Measure.

The collective combination of the HEA and MOGA in the various process of Multi label prediction is very effective. The effectiveness is demonstrated using the tables and graphs generated from the results obtained.

6 APPLICATIONS

The region for the study is Annanagar, Madurai which is the city taken for the case study. Moses santhakumar said [36] it is the second largest city in Tamilnadu state, having a very old history of about two thousand six hundred years and is often referred to as the Athens of East. Having different locations for residential, commercial, industrial, educational, public and semi-public habitats, we have chosen Annanagar as the place of study and collected data from various parts of it.

Aditi pai and Deepika Khatri [37] said women are now a critical consumer segment for marketers to tap, not only for household and conventional women’s products but also for services. Yet all women do not behave the same, their habits differ according to their status such as marital and working status. In our paper we have taken preferences of women in the area Annanagar in Madurai.



Fig 3: Preference based on women student



Fig 4: Preference based on just married women



Fig 5: Preference based on women with young child



Fig 8: Preference based on Multi label classification by all the categories of women



Fig 6: Preference based on working women



Fig 7: Preference based on home maker

Fig 3 through 7 gives the preferences of the women of five different categories and the Fig 8 gives the consolidated information based on the multi label classification of all the categories of women. This information gives the preference based optimal usage of the facilities such as Hospital, Provisions, educational institutions, Bus stop, Hotel and shopping malls, so that it can be maximally used by the user.

7. CONCLUSION

This paper proposed a methodology for the Multi label spatial classification optimized by the MOGA and the SAR using the Hybrid Evolutionary Algorithm. The results for the proposed method is promising and also lay a opening for the identification of Multi label which can be further extended to the real world multi label classification, which consider all available classes that pass certain user threshold for each item set. The work can be extended to the incremental learning of the training.

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