

DATABASES REDUCTION

Roberto Ruiz and José C. Riquelme and Jesús S. Aguilar-Ruiz

*Department of Computer Science. University of Seville
Avda. Reina Mercedes s/n. 41012-Sevilla. Spain.*

Keywords: Data mining, preprocessing technics, database reduction, feature selection, data set editing.

Abstract: Progress in digital data acquisition and storage technology has resulted in the growth of huge databases. Nevertheless, these techniques often have high computational cost. Then, it is advisable to apply a preprocessing phase to reduce the time complexity. These preprocessing techniques are fundamentally oriented to either of the next goals: horizontal reduction of the databases or feature selection; and vertical reduction or editing. In this paper we present a new proposal to reduce databases applying sequentially vertical and horizontal reduction technics. They are based in our original works, and they use a projection concept as a method to choose examples and representative features. Results are very satisfactory, because the reduced database offers the same intrinsic performance for the later application of classification techniques with low computational resources.

1 INTRODUCTION

The data mining researchers, especially those dedicated to the study of algorithms that produce knowledge in some of the usual representations (decision lists, decision trees, association rules, etc.), usually make their tests on standard and accessible databases (most of them with small size). The purpose is to independently verify and validate the results of their algorithms. Nevertheless, these algorithms are modified to solve specific problems, for example real databases that contain much more information (tens of attributes and tens of thousands of examples) than standard ones used in training. Therefore, applying these data mining techniques is a task that takes a lot of time and memory size, even with the capability of current computers, which make the adaption of the algorithm to solve the problem extremely difficult.

Therefore, it is important to apply preprocessing techniques to the databases. These preprocessing techniques are fundamentally oriented to one of the next goals: feature selection methods (eliminating non-relevant attributes) and editing algorithms (reduction of the number of examples). Existing methods solve one out of the two aforementioned problems.

In this paper we present a new approach to reduce databases in both directions. This is due to sequential application of vertical and horizontal reduction techniques. They both are based in our original works,

and they use a projection concept as a method to choose examples and representative features.

2 VERTICAL REDUCTION

2.1 Related work

Editing methods are related to the nearest neighbours (NN) techniques (Cover and Hart, 1967). Some of them are briefly cited in the following lines. Hart (Hart, 1968) proposed to include in the subset S , those examples of the training set T whose classification with respect to S are wrong using the nearest neighbour technique, so that every member of T is closer to a member of S of the same class than to a member of S of a different class; Aha et al. proposed a variant of Harts method; Wilson (Wilson, 1972) proposed to eliminate the examples with incorrect K -NN classification, so that each member of T is removed if it is incorrectly classified with the N nearest neighbours; (Tomek, 1976) extended the idea of Wilson eliminating the examples with incorrect classification from any $i=1$ to N , where N is the maximum number of neighbours to be analysed; the work of (Ritter et al., 1975) extended Harts method and every member of T must be closer to a member of S of the same class than to any member of T . Other variants are based on Voronoi diagrams (Klee,

1980), Gabriel neighbours (two examples are said to be Gabriel neighbours if their diametrical sphere does not contain any other examples) or relative neighbours (Toussaint, 1980) (two examples p and q are relative neighbours if for all other examples x in the set, is true the expression $\text{dist}(p,q) \leq \max(\text{dist}(p,x), \text{dist}(q,x))$). All of these techniques need to calculate distances between examples, which is rather time consuming. If N examples with M attributes are considered, the first methods take $O(MN^2)$ time, the Ritters algorithm is $O(MN^2+N^3)$; the Voronoi neighbours, Gabriel neighbours and relative neighbours are $O(MN^3)$.

The most important characteristics of our editing algorithm, called EOP (Aguilar et al., 2000) (Editing by Ordered Projection), are:

- Considerable reduction of the number of examples.
- Lower computational cost $O(MN \log N)$ than other algorithms.
- Absence of distance calculations.
- Conservation of the decision boundaries, especially interesting for applying classifiers based on axis-parallel decision rules (like C4.5).

2.2 Editing

If we choose a region where all examples inside have the same class, perhaps we could select some of them, which are not decisive, in order to establish the boundaries of the region. For example, in two dimensions we need a maximum of four examples to determine the boundaries of one region. In general, in d -dimensions we will need $2d$ examples, maximum. Therefore, if a region has more than $2d$ examples, we could reduce the number of them.

This is the main idea of our algorithm: to eliminate the examples that are not in the boundaries of the regions to which they belong. The aim is to calculate which set of examples could be covered by a pure region and then eliminate those inside that are not establishing the boundaries. A region is pure if all the examples inside have the same class.

Consider the situation depicted in Figure 1: the projection of the examples on the abscissa axis produces four ordered sequences $\{I; P; I; P\}$ corresponding to the examples $\{[9; 3; 5; 1; 11]; [8]; [7]; [4; 6; 2; 12]\}$. Identically, with the projection on the ordinate axis, we can obtain the sequences $\{P; I; P; I\}$ formed by the examples $\{[12; 10; 8; 6; 4]; [11]; [2]; [9; 7; 5; 3; 1]\}$. Each sequence represents a rectangular region as a possible solution of a classier (a rule) and the initial and final examples of the sequence (if it has only one, it is simultaneously the initial and the final one) represent the lower and upper values for each coordinate of this rectangle. For example, there is a rectangle formed by the examples $\{1; 3; 5; 7; 9\}$.

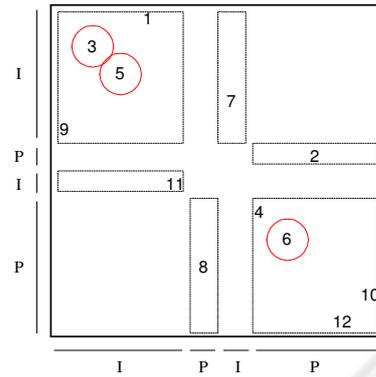


Figure 1: Results of applying EOP

This region needs the examples $\{9; 7\}$ to establish the boundaries of a dimension and the examples $\{1; 9\}$ for another one. Therefore, the remaining examples will be candidates to be eliminated because they are never boundaries. The idea is best understood by analyzing the non-empty regions obtained by means of projections on every axis and deleting the examples that are not relevant so as to establish the boundaries of a rule.

In regards to the analysis of this editing method, we have dealt with eighteen databases from the UCI repository (Blake and Merz, 1998). To show the performance of our method we have used C4.5 (Quinlan, 1993) and k -NN (Hart, 1968) before and after applying EOP. The obtained results (Riquelme et al., 2003) prove the validity of the method.

Table 1: EOP algorithm

```

Input: E training (N ex., M att.)
Output: E reduced (L ex., M att.)
for each example  $e \in E$ 
    weakness( $e$ ) = 0
for each attribute  $a$ 
    sort E in increasing order
    for each example  $e \in E$ 
        if it is NOT border
            increase weakness( $e$ )
for each example  $e \in E$ 
    if weakness = M
        delete register  $e$ 
    
```

3 HORIZONTAL REDUCTION

3.1 Related work

Depending on the evaluation strategies, feature selection algorithms can generally be placed into one of

two broad categories: wrappers, Kohavi (Kohavi and John, 1997), which employ a statistical re-sampling technique (such as cross validation) using the actual target learning algorithm to estimate the accuracy of feature subsets. This approach has proved to be useful but is very slow to execute because the learning algorithm is called upon repeatedly. Another option called filter, operates independently of any learning algorithm. Undesirable features are filtered out of the data before induction begins. Filters use heuristics based on general characteristics of the data to evaluate the merit of feature subsets. As a consequence, filter methods are generally much faster than wrapper methods, and, as such, are more practical for use on data of high dimensionality. LVF (Liu and Setiono, 1996) use class consistency as an evaluation measure. One method called Chi2 (Liu and Setiono, 1995) realize selection by discretization. Relief (Kira and Rendell, 1992) works by randomly sampling an instance from the data, and then locating its nearest neighbour from the same and opposite class. Relief was originally defined for two-class problems and was later expanded as ReliefF (Kononenko, 1994) to handle noise and multi-class data sets, and RReliefF handles regression problems. Other authors suggest Neuronal Networks for attribute selector. In addition, learning procedures can be used to select attributes, like ID3 (Quinlan, 1986), FRINGE (Pagallo and Haussler, 1990) and C4.5 (Quinlan, 1993) as well as methods based on correlations like CFS (Hall, 1997).

The most important characteristics of our feature selection algorithm, called SOAP (Ruiz et al., 2002) (Selection of Attributes by Projection), are very similar to that of EOP.

3.2 Feature selection

In this paper, we propose a new feature selection criterion not based on measures calculated between attributes, or complex and costly distance calculations. This criterion is based on a unique value called NLC. It relates each attribute with the label used for classification. This value is calculated by projecting data set elements onto the respective axis of the attribute (ordering the examples by this attribute), then crossing the axis from the beginning to the greatest attribute value, and counting the Number of Label Changes (NLC) produced.

Consider the situation depicted in Figure 2: the projection of the examples on the abscissa axis produces three ordered sequences {O; E; O} corresponding to the examples {[1,3,5],[8,4,10,2,6],[7,9]}. Identically, with the projection on the ordinate axis, we can obtain the sequences {O; E; O; E; O; E} formed by the examples {[8],[7,5],[10,6],[9,3],[4,2],[1]}. Then, we calculate the Number of Label Changes, NLC. Two for the first attribute and five for the second.

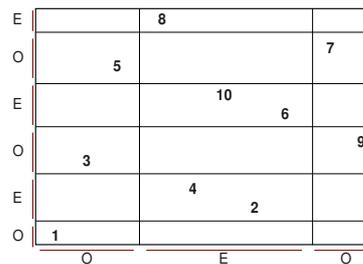


Figure 2: Results of applying SOAP

We conclude that it will be easier to classify by attributes with the smallest number of label changes. If the attributes are in ascending order according to the NLC, we obtain a ranking list with the better attributes from the point of view of the classification.

We have dealt with eighteen databases from the UCI repository [3]. To show the performance of our method we have used k-NN and C4.5 before and after applying EOP. Results obtained (Ruiz et al., 2002) prove the validity of the method.

Table 2: SOAP algorithm

```

Input: E training (N ex., M att.)
Output: E reduced (N ex., K att.)
for each attribute a
    sort E in increasing order
    count label changes
    ranking attributes by NLC
choose the k first attributes
    
```

4 INTEGRATION OF REDUCTION TECHNIQUES

The size of a data set can be measured in two dimensions, number of features and number of instances. Both can be very large. This enormity may cause serious problems to many data mining systems.

Our approach is to reduce the database in the two directions, vertically and horizontally, applying the aforementioned algorithms sequentially.

The algorithm is very simple and efficient. The computational cost of EOP and SOAP is $O(m \times n \times \log n)$, being the lowest of its category. Therefore, the new algorithm is efficient too.

Figure 3 shows the process to reduce a database with two thousand examples and forty one attributes, the last feature being the class. There are three possible labels A,B,C. At the beginning, vertical reduction is applied with the algorithm EOP. The number of examples decreases to three hundred and fifty. Then,

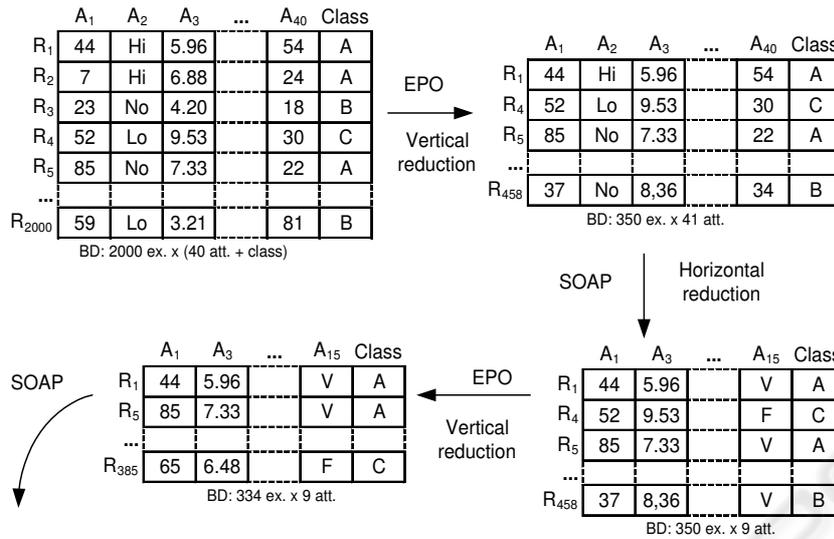


Figure 3: Database reduction process

```

Table 3: Main algorithm
Input: E training (N ex., M att.)
Output: E reduced (L ex., K att.)
E' = EPO(E)
while ( E' <> E )
    E = SOAP(E')
    E' = EPO(E)
endwhile
E' = SOAP(E)
    
```

the most relevant attributes are chosen by mean of the SOAP algorithm. The number of features decreases to nine attributes. The one and the other algorithm are applied using EOP as a stopping criterion, until a new execution does not reduce the data set.

5 EXPERIMENTS

In this section, we want to analyze our algorithm with a large data set. We would like obtain a set with a considerable size (more than twenty thousand examples), and with low missing values, and where we do not know the attributes' relevancy. This is not easy to find and we decided to create one. We considered a large enough database would be with forty thousand examples and forty features, and it would present an adequate difficulty to prove our algorithm in the desired environment.

We generate examples randomly, and we label them according to the same given rules. At the end, we add a percentage of examples with noise. We try to

set the minimum number of parameters (Table 5), and the other parameters are solved randomly. Therefore, there are three important fixed parameters: Number of rules (thirty-five); Conditions used in each rule (four); And the set of possible labels (five). We label examples consecutively (rule 0: label A, rule 1: label B,..., rule 5: label A,...). Then, each label can be obtained for seven different rules (35 rules / 5 classes = seven).

Table 4: Parameters

Examples	40000
Attributes	40
Rules	35
Conditions x rule	4
Labels	5
35 rules x 4 =	140 conditions
35 rules / 5 labels =	7

There are four attributes in each rule (one for each condition Table 5) and they are constants. But intervals of each attribute are obtained randomly within some fixed limits. One rule is different than the rest at least in two attributes, then, we offer a wide range of regions.

$$Condition : (li < att < hi)$$

$$att : constant$$

$$li, hi : random$$

$$\forall X, Y \#(ruleX \cap ruleY) \leq 2atts.$$

Consider that one attribute is more relevant than another if we use it more times in the set of rules,

Table 5: Rules

rule 1	condition1	AND condition2	AND condition3	AND condition4	THEN label A
rule 2	condition5	AND condition6	AND condition7	AND condition8	THEN label B
rule 3	condition9	AND condition10	AND condition11	AND condition12	THEN label C
...	...	AND ...	AND ...	AND ...	THEN ...
rule 35	condition137	AND condition138	AND condition139	AND condition140	THEN label E
Ex.	[lo1<att1<hi1] AND [lo2<att2<hi2] AND [lo6<att6<hi6] AND [lo9<att9<hi9] THEN label A				

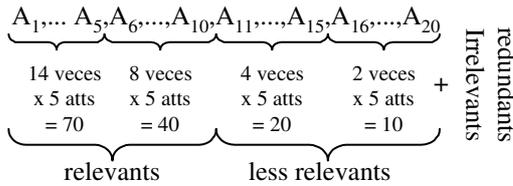


Figure 4: Relevance of the attributes

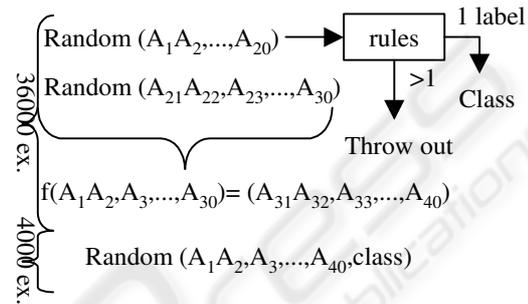


Figure 5: Process to generate de database

and we want to obtain four groups of well separated attributes. They are relevant, less relevant, redundant and dummy attributes with ten attributes in each group. The first and the second group (relevant and less relevant) are divided into two subgroups, with five attributes more relevant than the other five. Therefore, we have six different groups of attributes.

The importance of the attributes is related to the number of times that it appears in the set of rules. Rules are built by four of the twenty attributes, those who belong to the relevant and less relevant group. All in all, the distribution of the attributes in the set of rules is as follows: fourteen times five attributes belonging to the relevant group, and eight times the other attributes of the group. Four times five attributes belonging to the less relevant group, and two times the other attributes of this group.

The first step (Figure 5) in the process followed to generate the database is to obtain the value of twenty from forty attributes randomly (belonging to relevant and less relevant group). Then, we filter them through the set of rules and it is classified with a label. If an example validate more than one rule with a different label, then it is thrown out. In the contrary case, we set the value of the rest of the attributes; ten features obtained randomly, the irrelevant attributes, and another ten according to some part of the other thirty attributes (redundant group). This process is repeated until the database is full. At the end of the process, we add a number of register with noise (10%), i.e. the value of each attribute is obtained randomly (label included). The only thing remaining is to mix the attributes of the different groups.

We conclude that to obtain a learning model from the data set generated is very complex, i.e. if we try

to generate a set of decision rules or decision tree from the database, the model of accuracy rate from the training set will be low. Therefore, preprocessing techniques must be very robust and efficient, because of the size of the data.

Table 6: Results obtained

	Original	Reduced
Examples	40000	22451
Attributes	40	5
C4.5 %	53.33	58.45
C4.5 size	9897	8011

Table 5 shows, after the generation of the data set with 40000 examples and 40 attributes, we apply the classifier C4.5. and we obtain a tree with a size 9897, and 21334 well classified examples, this is 53.33% of the data. Now we apply our new algorithm, and we obtain a reduced data set with 22451 examples and 5 attributes. We reduce the number of examples to 56% of the original examples and 13% of the original attributes. In general, the size of the database (40000x40=1600000) is reduced to (22451x5=112255). Our method reduces the data by 93% of the original size, leaving us with 7% of the original data ().

Applying C4.5 to the reduced database, i.e. we use 7% of the original data. We obtain a smaller tree size, 8011 nodes. If we classify the 40000 examples, the accuracy is 58.45%, better than with the origi-

nal data. Therefore, this new method is robust. We conclude that a classifier like C4.5 generates a better result when an effective preprocessing technique is used.

6 CONCLUSIONS

In this paper we present an integration technique of database reduction algorithms. This integration is based on two techniques applied sequentially. The first is a reduction of examples method (editing or vertical reduction), and the second one is a reduction of attributes algorithm (feature selection or horizontal reduction). Both techniques are valid in previous papers, and they are efficient techniques, because their computational costs are the lowest of its respective categories.

Given the satisfactory results, using a specifically generated database with extreme complexity, we can state that the of integration approach of the two reduction techniques (horizontal and vertical) is very interesting from the data mining techniques application point of view.

Results show a very important data reduction, 93%. Nevertheless, the quality of the information is the same with only 7% of the original data. A model is generated based on a decision tree, and its accuracy is slightly better than the accuracy obtained with all the data.

Our work is going to be oriented to the integration of other reduction techniques and the application to real world data sets.

ACKNOWLEDGEMENTS

This work has been supported by the Spanish Research Agency CICYT under grant TIC2001-1143-C03-02.

REFERENCES

- Aguilar, J. S., Riquelme, J. C., and Toro, M. (2000). Data set editing by ordered projection. In *Proceedings of the 14th European Conference on Artificial Intelligence*, pages 251–255, Berlin, Germany.
- Blake, C. and Merz, E. K. (1998). Uci repository of machine learning databases.
- Cover, T. M. and Hart, P. E. (1967). Nearest neighbor pattern classification. *IEEE Transactions on Information Theory*, IT-13(1):21–27.
- Hall, M. (1997). *Correlation-based feature selection for machine learning*. PhD thesis, University of Waikato, Hamilton, New Zealand, Department of Computer Science.
- Hart, P. (1968). The condensed nearest neighbor rule. *IEEE Transactions on Information Theory*, 14(3):515–516.
- Kira, K. and Rendell, L. (1992). A practical approach to feature selection. In *International Conference on Machine Learning*, pages 368–377.
- Klee, V. (1980). On the complexity of d-dimensional voronoi diagrams. *Arch. Math.*, 34:75–80.
- Kohavi, R. and John, G. H. (1997). Wrappers for feature subset selection. *Artificial Intelligence*, 1-2:273–324.
- Kononenko, I. (1994). Estimating attributes: Analysis and extensions of relief. In *European Conference on Machine Learning*, pages 171–182.
- Liu, H. and Setiono, R. (1995). Chi2: Feature selection and discretization of numeric attributes. In *Proceedings of the Seventh IEEE International Conference on Tools with Artificial Intelligence*.
- Liu, H. and Setiono, R. (1996). Feature selection and classification: a probabilistic wrapper approach. In *Proceedings of the IEA-AIE*.
- Pagallo, G. and Haussler, D. (1990). Boolean feature discovery in empirical learning. *Machine Learning*, 5:71–99.
- Quinlan, J. (1986). Induction of decision trees. *Machine Learning*, 1:81–106.
- Quinlan, J. R. (1993). *C4.5: Programs for machine learning*. Morgan Kaufmann, San Mateo, California.
- Riquelme, J., Aguilar-Ruiz, J. S., and Toro, M. (2003). Finding representative patterns with ordered projections. *Pattern Recognition*, 36(4):1009–1018.
- Ritter, G., Woodruff, H., Lowry, S., and Isenhour, T. (1975). An algorithm for a selective nearest neighbor decision rule. *IEEE Transactions on Information Theory*, 21(6):665–669.
- Ruiz, R., Riquelme, J., and Aguilar-Ruiz, J. S. (2002). Projection-based measure for efficient feature selection. *Journal of Intelligent and Fuzzy System*, 12(3-4):175–183.
- Tomek, I. (1976). An experiment with the edited nearest-neighbor rule. *IEEE Transactions on Systems, Man and Cybernetics*, 6(6):448–452.
- Toussaint, G. T. (1980). The relative neighborhood graph of a finite planar set. *Pattern Recognition*, 12(4):261–268.
- Wilson, D. (1972). Asymtotic properties of nearest neighbor rules using edited data. *IEEE Transactions on Systems, Man and Cybernetics*, 2(3):408–421.