

PATTERN CLUSTERING USING ANTS COLONY, WARD METHOD AND KOHONEN MAPS

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Abstract: The goal of this paper is to propose improvements to the ACA (Ant-based Clustering Algorithm), and evaluate its performance relative to the Ward Method; to the One-dimensional Kohonen Maps and to the ACAM (Ant-based Clustering Algorithm Modified) algorithm. The algorithm containing the improvements will be referred here by "proposed" algorithm. Its the main changes were: the introduction of a comparison between the probability of dropping a pattern at the position chosen randomly and the probability of dropping this pattern at its current position; the introduction of an evaluation of the probability of a neighboring position when the decision to drop a pattern is positive and the cell in which the pattern should be dropped is occupied; and the replacement of the pattern carried by an ant, in case this pattern is not dropped within 100 consecutive iterations. To assess the performance of the proposed algorithm three real and public databases were used (Iris, Wine and Pima Indians Diabetes). The results showed superiority of the proposed algorithm when comparing with the ACAM algorithm in two of the three databases.

1 INTRODUCTION

Societies of social insects are distributed systems that exhibit a highly structured social organization, despite the simplicity of their individuals. As a result of this organization, ant colonies can accomplish complex tasks that in some cases exceed the individual capacity of a single ant. In research area of "ant algorithms" are studied models inspired by the observation of the behavior of real ants and these models are used as inspiration for the development of new algorithms to solve optimization and distributed control problems (Dorigo and Stützle, 2004).

Among the behaviors of social insects the most widely recognized is the ability of ants to work together in order to develop a task that could not be performed by a single agent. Also seen in human society, this ability of ants is a result of cooperative effects. These cooperative effects have recourse to the fact that the effect of two or more individuals or coordinated parts is higher than the total of their individual effects. Some researchers have achieved

promising results in data mining using a colony of artificial ants. The high number of individuals in ant colonies and the decentralized approach for coordinated tasks (performed simultaneously) mean that ant colonies show high levels of parallelism, self-organization and fault tolerance. These characteristics are desired in modern optimization techniques (Boriczka, 2009).

The Clustering algorithm based on Ants Colony was chosen for study, analysis and new proposals due to several factors. First, it is a relatively new metaheuristic and has received special attention, mainly because it still requires much investigation to improve its performance, stability and other "key" characteristics that would do such algorithm a mature tool for data mining (Boryczka, 2009). Moreover, this algorithm can automatically "find" the number of clusters within the patterns.

The purpose with this paper is to present changes and improvements to the Ant-based Clustering Algorithm (ACA) originally proposed by (Deneubourg et al., 1991), evaluating its performance when compared to the Ward Method,

to the One-dimensional Kohonen maps and to the Ant-based Clustering Algorithm (ACAM). The Multivariate Statistics area method (Ward Method) was used because it is one of the most classical methods in the literature (Johnson and Wichern, 1998). On their turn, the One-dimensional Kohonen Maps were used because, like the Ant-based Clustering, they perform simultaneously the clustering and topographic mapping tasks (Raug and Tucci, 2010); (Kohonen, 2001).

This paper is structured as follows: section 2 presents a literature review on Ant-based Clustering, describing the algorithm, the Clustering recovery and the measures for evaluating clusters; Section 3 presents the databases that was used for the comparison, the computational implementation details of the methods, as well as the major contributions (modifications and improvements) for the Ant-based Clustering algorithm; Section 4 presents the results and discussion and, finally, Section 5 presents the final considerations.

2 LITERATURE REVIEW

In the Ant-based Clustering proposed by (Deneubourg et al., 1991), ants were represented as simple agents that move randomly on a square grid. The patterns were scattered within this grid and the agents (ants) could pick, transport and drop them. These operations are based on the similarity and on the density of the patterns distributed within the local neighborhood of agents, isolated patterns - or surrounded by dissimilar ones - are more likely to be picked and then dropped in a neighborhood of similar ones.

The decisions to pick and drop patterns are made by the P_{pick} and P_{drop} probabilities given by equations (1) and (2), respectively.

$$P_{pick} = \left(\frac{k_p}{k_p + f(i)} \right)^2 \quad (1)$$

$$P_{drop} = \left(\frac{f(i)}{k_d + f(i)} \right)^2 \quad (2)$$

In these equations, $f(i)$ is an estimate of the fraction of patterns located in the neighborhood that are similar to the current ant's pattern and k_p and k_d are real constants. In the work of (Deneubourg et al., 1991), the authors used $k_p = 0.1$ and $k_d = 0.3$. The authors obtained the estimate f , through a short-term memory of each ant, where the content of the last cell in the analyzed grid is stored. This choice of the

neighborhood function $f(i)$ was primarily motivated due to its ease of implementation with simple robots.

Lumer and Faieta (1994, *apud* Handl et al., 2006) introduced a number of modifications to the model that allowed the manipulation of numeric data and improved the quality of solution and the algorithm's convergence time. The idea was to define a measure of similarity or dissimilarity between the patterns, since in the algorithm initially proposed the objects were similar if objects were identical and dissimilar if objects were not identical. In that work first appears the topographic mapping.

According to (Vizine et al., 2005), the general idea with this algorithm is to have similar data in the original n -dimensional space in neighboring regions of the grid, this is, data which are neighbors on the grid indicate similar patterns from the original space.

In the work of Lumer and Faieta (1994, *apud* Handl et al., 2006), the decision of picking up patterns is based on the P_{pick} probability given by equation (1) and the decision to drop patterns is based on the probability P_{drop} given by equation (3), where $f(i)$ is given by equation (4).

$$P_{drop} = \begin{cases} 2f, & \text{if } f(i) < k_d \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

$$f(i) = \max \left\{ 0, \frac{1}{\sigma^2} \sum_{j \in L} \left[1 - \frac{d(i,j)}{\alpha} \right] \right\} \quad (4)$$

In equation (4), $d(i, j)$ is a function of dissimilarity between patterns i and j belonging to interval $[0,1]$; α a scalar parameter that depends on the data (patterns) and belongs to the interval $[0,1]$; L is the local neighborhood of size σ^2 , where σ is the perception radius (or neighborhood). In their work the authors used $k_p = 0.1$, $k_d = 0.15$ and $\alpha = 0.5$.

Ant-based Clustering algorithms are mainly based on the versions proposed by Deneubourg *et al.* (1991) and Lumer and Faieta (1994, *apud* Handl et al., 2006). Several modifications were introduced to improve the quality of the cluster and, in particular, the spatial separation between the clusters on the grid (Boriczka, 2009).

Changes that improve the spatial separation of the clusters and allow a more robust algorithm were introduced by (Handl et al., 2006). One of them is the restriction on the $f(i)$ function given by equation (5), which serves to penalize high dissimilarities.

$$f^*(i) = \begin{cases} \frac{1}{\sigma^2} \sum_{j \in L} \left[1 - \frac{d(i,j)}{\alpha} \right], & \text{if } \forall j \left(1 - \frac{d(i,j)}{\alpha} \right) > 0 \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

According (Vizine et al., 2005), a difficulty in applying the Ants Clustering algorithm to complex

problems is that in most cases they generate a number of clusters that is much larger than the real one. Moreover, usually these algorithms do not stabilize in a cluster solution, this is, they constantly construct and deconstruct clusters during the process. To overcome these difficulties and improve the quality of results the authors proposed an Adaptive Ant Clustering Algorithm - A2CA. A modification included in the present approach is a cooling program for the parameter that controls the probability of ants picking up objects from the grid.

2.1 Parameters of the Neighborhood Function

The clusters' spatial separation on the grid is crucial so that individual clusters are well defined, allowing their automatic recovery. Spatial proximity, when it occurs, may indicate a premature formation of the cluster (Handl et al., 2006).

Defining the parameters for the neighborhood function is a key factor in the cluster quality. In the case of the σ perception radius it is more attractive to employ larger neighborhoods to improve the quality of clusters and their distribution on the grid. However, this procedure is computationally more expensive, once the number of cells to be considered for each action grows quadratically with the radius and it also inhibits the rapid formation of clusters during the initial distribution phase. A radius of perception that gradually increases in time accelerates the dissolution of preliminary small clusters (Handl et al., 2006). A progressive radius of perception was also used by (Vizine et al., 2005).

Moreover, after the initial clustering phase, (Handl et al., 2006) replaced the scalar parameter $\frac{1}{\sigma^2}$ by $\frac{1}{N_{occ}}$ in equation (5), where N_{occ} is the number of grid cells occupied, observed within the local neighborhood. Thus, only the similarity, not the density, was not taken into account. Boryczka (2009), in her algorithm ACAM, proposed to replace the scalar $\frac{1}{\sigma^2}$ in equation in (5) by the scalar $\frac{\sigma_0^2}{\sigma^2}$, in which σ_0 is the initial radius of perception.

According to (Handl et al., 2006), α determines the percentage patterns on the grid that rated as similar. The choice of a very small value for α prevents the formation of clusters on the grid. On the other hand, choosing a value too large for α results in the fusion of clusters.

Determining parameter of α is not simple and its choice is highly dependent on the structure of the data set. An inadequate value is reflected by an

excessive or extremely low activity in the grid. The amount of activity is reflected by the frequency of successful operations in the ant picking and dropping. Based on these analyses, (Handl et al., 2006) proposed an automatic adaptation of α . Boryczka (2009) proposed a new scheme for adjusting the value of α .

(Tan et al., 2007) examine the scalar parameter of dissimilarity in Ant Colonies approaches for data clustering. The authors show that there is no need to use an automatic adaptation of α . They propose a method to calculate a fixed α for each database. The value of α is calculated regardlessly of the clustering process.

To measure the similarity between patterns, different metrics are used. (Handl et al., 2006) use Euclidean distance for synthetic data and cosine for real data. Boryczka (2009) tested different dissimilarity measures: Euclidean, Cosine and Gower measures.

2.2 The Basic Algorithm Proposed by (Deneubourg et al., 1991)

At an initial phase, patterns are randomly scattered throughout the grid. Then, each ant randomly chooses a pattern to pick and is placed at a random position on the grid.

In the next phase, called the distribution phase, in a simple loop each ant is randomly selected. This ant travels the grid running steps of length L in a direction randomly determined. According to (Handl et al., 2006), using a large step size speeds up the clustering process. The ant then, probabilistically decides if it drops its pattern at this position.

If the decision to drop the pattern is negative, another ant is randomly chosen and the process starts over. If the decision is positive, the ant drops the pattern at its current position on the grid, if it is free. If this grid cell is occupied by another pattern it must be dropped at a free neighboring cell through a random search.

The ant then seeks for a new pattern to pick. Among the free patterns on the grid, this is, patterns that are not being carried by any ant, the ant randomly selects one, goes to its position on the grid, evaluates of the neighborhood function and probabilistically decide if it picks this pattern. This choosing process of a free pattern on the grid runs until the ant finds a pattern that should be picked.

Only then this phase is resumed, choosing another ant until a stop criterion is satisfied.

2.3 Cluster Recovery

The process begins with each pattern forming a cluster. After calculating the distances between all clusters, the two clusters with smaller distance should be connected. The most common types of connections are: Simple Connection, Connection Full, Medium Connection and the Ward Method (Johnson and Wichern, 1998). The distances between clusters are defined in terms of their distance on the grid. Each pattern is now composed of only two attributes that position them on the two-dimensional grid. The distance between any two patterns is then the Euclidean distance between two grid points. This process repeats until a stop criterion is satisfied.

When patterns around the edges of the clusters are isolated, (Handl et al., 2006) introduced a weight that encourages the fusion of these patterns with the clusters. The Ward Method used in this work connects two clusters based on "information loss".

2.4 Clustering Evaluation

In the evaluation of clusters, different aspects can be observed: determine clustering the trend of a set of data, compare results of an analysis of clusters with results externally known, assessment of how well the results of an analysis of clusters fit the data without reference to external information, compare the results of two different sets of cluster analysis to determine which one is better, or even determine the correct number of clusters (Tan et al., 2005).

According to these authors, the numerical measures applied to assess different aspects of cluster evaluation are classified into three types: external indexes are used to measure the extent to which cluster labels correspond to labels of classes provided externally; the internal indices are used to measure how good the clustering structure is unrelated to external information and the relative indices are used to compare two different clusters.

In her work, Boryczka (2009) used two internal indices (the Intra-Cluster Variance and Dunn's Index) and two external indices (Measure F and the Random Index). These measures are described below and are also used in this work.

Measure F uses the idea of accuracy and memory of information retrieval. Each class i is a set of n_i desired patterns; each cluster j (generated by the algorithm) is a set of n_j patterns; n_{ij} is the number of patterns in class i belonging to cluster j . For each class i and cluster j , precision p and memory r are

defined as $p(i, j) = \frac{n_{ij}}{n_j}$ and $r(i, j) = \frac{n_{ij}}{n_i}$, respectively.

The value of measure F is given by equation (6).

$$F = \sum_i \frac{n_i}{n} \max_j \{F(i, j)\} \quad (6)$$

where:

$$F(i, j) = \frac{(b^2 + 1) \cdot p(i, j) \cdot r(i, j)}{b^2 \cdot p(i, j) + r(i, j)}$$

Value b should be "1" to give equal weight to precision p and recall r . In equation (6), n is the size of the dataset. F is limited to the interval $[0, 1]$ and should be maximized.

Random Index (R) is given by equation (7), where a , b , c and d are calculated for all possible pairs of i e j patterns and their respective clusters U (correct classification - $c_U(i)$ and $c_U(j)$) and V (solution generated by the clustering algorithm - $c_V(i)$ and $c_V(j)$). R is limited to the interval $[0, 1]$ and should be maximized.

$$R = \frac{a + d}{a + b + c + d} \quad (7)$$

where:

$$\begin{aligned} a &= \left| \left\{ \{i, j\} \mid c_U(i) = c_U(i) \wedge c_V(i) = c_V(i) \right\} \right| \\ b &= \left| \left\{ \{i, j\} \mid c_U(i) = c_U(i) \wedge c_V(i) \neq c_V(i) \right\} \right| \\ c &= \left| \left\{ \{i, j\} \mid c_U(i) \neq c_U(i) \wedge c_V(i) = c_V(i) \right\} \right| \\ d &= \left| \left\{ \{i, j\} \mid c_U(i) \neq c_U(i) \wedge c_V(i) \neq c_V(i) \right\} \right| \end{aligned}$$

2.5 Other Clustering Methods used

In this work, as already mentioned, three methods were selected for comparison with the algorithm here proposed: Ward Method (classical statistical method); One-dimensional Kohonen Neural Networks (performs topographic mapping and clustering simultaneously) and the ACAM (analogous to the method proposed here). All three methods are briefly described below.

2.5.1 Ward Method

According to Johnson and Wichern (1998), the Ward Method used in this work connects two clusters based on "information loss". The sum of the square error (SSE) is considered the criterion for "information loss". For each cluster i , the cluster's mean (or centroid) is calculated, as well as the sum of the square error of cluster i (SSE_i), which is the sum of the square error of each pattern in the cluster in relation to the mean value. For k clusters there are $SSE_1, SSE_2, \dots, SSE_k$, where SSE is defined by equation (8).

$$SSE = SSE_1 + SSE_2 + \dots + SSE_k \quad (8)$$

For each pair of clusters m and n , the mean (or centroid) is first calculated for the cluster formed (cluster mn). Next, the sum of square error for cluster mn (SSE_{mn}) is calculated according to equation (9). The m and n clusters that show the smallest increase in the sum of square error (SSE) (smallest “loss of information”) will be merged.

$$SSE = SSE_1 + SSE_2 + \dots + SSE_k - SSE_m - SSE_n + SSE_{mn} \quad (9)$$

2.5.2 One-dimensional Kohonen Neural Networks

According to Fausett (1994), in 1982, Teuva Kohonen developed the method of self-organizing maps that makes use of a topological structure to cluster units (patterns). Self Organizing Maps (SOM), also known as Kohonen Neural Networks, form a class of neural networks in which learning is unsupervised.

According to Haykin (2001) the main purpose with the Kohonen Neural Networks is transform input patterns of arbitrary dimension into a discrete map. The neurons are placed at the nodes of a grid, which can have any number of dimensions. Usually two-dimensional grids are used (called 2D-SOMs). There are also the 1D-SOMs (used here) and 3D-SOMs, which use grids (or maps) of one and three dimensions, respectively.

The learning process of a Kohonen Neural Network is based on competitive learning in which the grid’s output neurons compete to be activated. The output neuron that wins the competition is called the winning neuron. All neurons on the grid should be exposed to a sufficient number of input patterns to ensure proper ripening of the self-organization process (Haykin, 2001).

According to Haykin (2001), besides the competition process to form the map, the cooperation and adaptation processes are also essential. In the cooperation process, the winning neuron locates the center of a topological neighborhood of cooperative neurons. For the self-organization process to occur the excited neurons have their synaptic weights set in the adaptation process. The adjustment made is such that the winning neuron's response to the application of a similar input pattern is enhanced.

According to Siqueira (2005), several error measures can be used to determine the quality of a map. In his work, the author uses the quantization error, which represents the average error that corresponds to the difference between the patterns

and the weights of the winning neurons, the topological error, which represents the percentage of winning neurons that lack the second winner in a neighborhood of unitary radius centered on the winning neuron and the square mean error.

There are several approaches to variants of Kohonen Neural Networks. The algorithms, inspired by the original, modify some aspects as, for instance, neighborhood criterion, how to choose the winning neuron, the use of hierarchical maps and accelerated learning, among others (Kohonen, 1995).

2.5.3 ACAM Method

Boryczka (2009) presented a modification of the clustering algorithm proposed by Lumer and Faieta. To increase the robustness of the clustering based on ants, the author has incorporated two major changes compared to the classical approach: 1. an adaptive perception scheme occurred in the density function and 2. a cooling scheme of α -adaptation, this is, a cooling scheme for the adaptation of parameter α , modifications already mentioned in section 2.1.

3 RESEARCH MATERIALS AND METHODS

The databases used in this study were: Iris, Wine and Pima Indians Diabetes, available at <http://mllearn.ics.uci.edu/databases>. Table 1 shows the number of patterns, the number of attributes and the number of clusters for each one of these databases. The data were standardized before the clustering methods were applied. The standardization was done by dimension.

Table 1: Databases used for algorithm evaluation.

Database	Patterns	Attributes	Clusters
Iris	150	4	3
Wine	178	13	3
Pima Indians Diabetes	768	8	2

The Ward Method was applied to the three databases with the aid of computer software MatLab2008. In these databases the correct number of clusters is known, which were provided so the clusters could be assessed. The dissimilarity measurement used was the Euclidean distance because it is the best known of the dissimilarity measures and because it has been employed in previous works for all methods used here.

Clustering by SOM, applied to the databases, was implemented in computer software MatLab2008

and ran 10 times for each database (Villwock, 2009).

The proposed algorithm, based on the basic algorithm developed by (Deneubourg et al., 1991) and presented in section 2.1, was implemented with computer software MatLab2008.

In this algorithm, several proposals for implementation are presented in Villwock (2009) in order to clarify it and improve its performance. Some procedures, although they are the same, are equally emphasized. There are three main changes, which are detailed in section 3.1.

For the cluster recovery, the Ward Method was used and a maximum number of clusters was defined. It is noteworthy that in Villwock and Steiner (2008) other methods have been tested, and the Ward Method showed better results.

As for the evaluation of results, two external indices were used (Measure F and Random Index) and percentage of misclassification.

3.1 Proposed Changes to the Ant-based Clustering

During the study of the Ant-based Clustering, it was observed that many of the changes in position of patterns occur unnecessarily. It is considered an unnecessary change when a pattern is among similar ones on the grid and, in this case, there is no need to change this pattern to another position. Aiming to avoid these unnecessary changes, it was introduced a comparison of the probability of dropping a pattern in the position chosen randomly with the probability of dropping this pattern at its current position. The pattern is only dropped at the position chosen randomly if this probability is greater than the probability of dropping this pattern at its current position.

The occurrence of fusion of close clusters on the grid was also observed. When a decision to drop a pattern is positive and the cell where that pattern should be dropped is occupied, a free random position close to this one is searched for. However, this new position may also be close to another pattern cluster on the grid. This may be one reason for the merger of close clusters. As an alternative to prevent the merger of close clusters on the grid, in this paper was proposed an assessment of the probability for the new position. The pattern is only dropped at the position chosen randomly if this probability is greater than the probability of dropping this pattern at its current position. All free neighboring positions are evaluated. If at no free neighboring position, the probability of dropping the pattern is higher than the probability of dropping the

pattern at its current location, the pattern is not dropped and the process starts again by choosing another ant.

Another issue observed in the Ant-based Clustering is that an ant can carry a pattern that is among similar ones on the grid. An ant only carries a pattern when it is not among similar ones on the grid. However, since the ant carries a pattern until it is drawn to attempt to drop the pattern, changes occur in this neighborhood and then can it leave it among the similar ones. Therefore, this ant is inactive because the operation of dropping the pattern is not performed. In this case, it was proposed to replace the pattern picked by an ant, if this pattern is not dropped in 100 consecutive iterations. The new pattern was chosen by lot, but it was only picked by the ant if the probability of carrying this pattern is greater than 0.13397. This value was defined by making the pick probability (P_{pick}) equal to the drop probability (P_{drop}). If there is no pattern with a picking probability higher than 0.13397, the ant picks the last pattern drawn. This could also be a stopping criterion.

3.2 Pseudo-code

I - Initial phase

- a) Patterns are randomly scattered on the grid.
- b) Each ant randomly chooses a pattern to pick and is placed at a random position on the grid.

II - Distribution phase

- a) Each ant is selected randomly. This ant moves randomly on the grid.
- b) The ant probabilistically decides if it drops its pattern at this position. The pattern is only dropped at the position chosen randomly if this probability is greater than the probability of dropping this pattern at its current position.
- b1) If the decision is negative, another ant is selected at random and the distribution phase starts over again.
- b1.1) The pattern carried out by the ant will be replaced if this pattern is not dropped after 100 consecutive iterations. Another pattern is randomly chosen, but the ant only picks it if the probability of picking this pattern is higher than 0.13397, a figure previously discussed in section 3.1. If there is no pattern with a picking probability higher than 0.13397, the ant picks the last pattern drawn.

b2) If the decision is positive, the ant drops the pattern at its current position on the grid, if it is free.

b2.1) If this grid cell is occupied, the pattern must be dropped at a free neighboring cell through a random search.

b2.2) The evaluation of probability of dropping the pattern at the new position is made and the pattern is only dropped at that neighboring cell if the probability of dropping the pattern at this position is still higher than the probability of dropping this pattern at its current position. If at no free neighboring position the probability of dropping the pattern is higher than the probability of dropping the pattern at its current location, the pattern is not dropped and the process starts again by choosing another ant.

c) If the ant drops the pattern, so the ant randomly searches for a new pattern to pick (among the free patterns), goes to its position on the grid, evaluates the neighborhood function and decides probabilistically whether it picks this pattern or not.

c1) This choosing process of a free pattern on the grid runs until the ant finds a pattern that should be picked.

III - Cluster recovery phase

a) The process begins with each pattern forming a cluster.

b) After calculating the distances between all clusters the two clusters with the shortest distance (these distances between clusters are defined in terms of their distance on the grid) should be merged (connected).

4 DATA ANALYSIS AND RESULTS

The proposed Clustering algorithm was applied to three real and public databases listed in Table 1. Because it is a metaheuristic, this method was applied to each database 10 times.

To evaluate the results it was used the evaluating measurements Random Index (*R*), Measure *F* and misclassification percentage. Preliminary results for the Iris and Wine databases have been published in (Villwock and Steiner, 2009a, 2009b).

4.1 Results of the Application of the Proposed Algorithm to the Databases

Table 2 presents the mean (μ) and the standard deviation (σ) of the evaluation measurements for the databases, in addition to measurements to evaluate the Clustering for the best result.

As can be seen, the results were quite satisfactory for databases IRIS and WINE (11.9% and 12.7%, on average, of wrong ratings). As for the PIMA database, the results were not as good; below it is shown that the other methods also showed no satisfactory results for this database.

Table 2: Results of proposed algorithm, averages of running it 10 times, for real datasets (Iris, Wine and Pima).

Results	<i>R</i>	<i>F</i>	Wrong class. (%)	
Iris	μ	0,871	0,877	11,9
	σ	0,039	0,050	4,6
	best	0,927	0,940	6,0
Wine	μ	0,843	0,871	12,7
	σ	0,019	0,021	1,9
	best	0,871	0,899	10,1
Pima	μ	0,510	0,583	43,6
	σ	0,010	0,022	4,0
	best	0,531	0,623	37,5

Figures 1 and 2 show the grid for the best result (whose evaluation measurements are presented in Table 2) for databases Iris and Wine, respectively.

In these figures, the patterns in red belong to cluster 1, patterns in black belong to cluster 2 and patterns in blue belong to cluster 3. It is worthy to point out that cluster 1 contains all the patterns assigned to it.

Table 3 (confusion matrix) shows the cluster distribution for the Iris database, where one can observe the patterns correctly assigned to clusters and patterns erroneously assigned to clusters. In this database there are only nine patterns in wrong clusters from a total of 150 patterns. Cluster 1 contains all the patterns assigned to it. Similarly, Table 4 shows the pattern distribution for the Wine database. In this database there are only 18 patterns in wrong clusters from a total of 178 patterns.

Table 3: Confusion matrix showing the Pattern distribution for the IRIS database – best result.

Iris	Generated Solution		
Correct Clustering	Cluster 1	Cluster 2	Cluster 3
Class 1	50	0	0
Class 2	0	48	2
Class 3	0	7	43

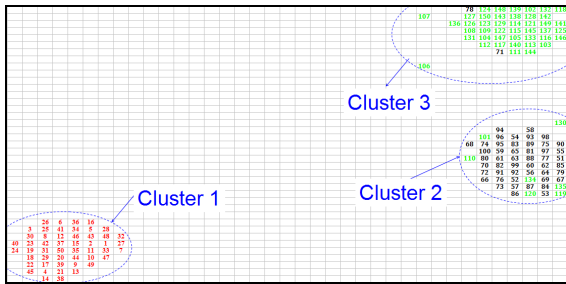


Figure 1: Result of the proposed algorithm for the Iris database – best result.

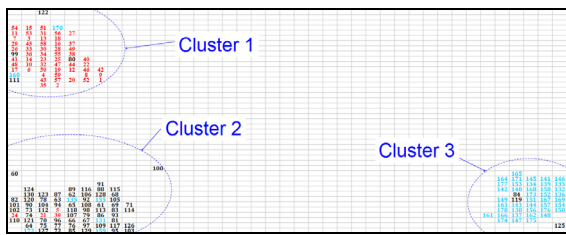


Figure 2: Result of the proposed algorithm for the Iris database – best result.

4.2 Comparison of the Proposed Algorithm with the other Methods

Table 5 shows the comparisons of average measurements of assessment for the three methods (proposed algorithm, Ward and Kohonen) for the Iris, Wine and Pima databases. The best results are in bold.

Table 4: Confusion matrix showing the Pattern distribution for the IRIS database – best result.

Wine	Generated Solution		
	Cluster 1	Cluster 2	Cluster 3
Correct Clustering			
Class 1	55	4	0
Class 2	4	64	3
Class 3	2	5	41

As can be seen, the results show no superiority of one method. In the Iris database, the Ward Method was better (about 3% of errors). In the Wine database, the proposed algorithm was better (about 12% errors) and in the Pima database, the One-dimensional Kohonen Networks technique was better (about 34% errors).

(Handl et al., 2006) also claim that no algorithm dominates the others forever. According to Ho and Pepune (2002), according to the “No-Free-Lunch” theorem, if there is no prior assumption about the optimization problem one is trying to solve, it is expected that no strategy has better performance

than others when tested on a large set of databases with different characteristics.

Table 5: Comparison of average results from the application of the Ward, SOM and Proposed Algorithm clustering methods for the Iris, Wine and Pima databases.

Database		Ward	SOM	Ants
Iris	R	0,957	0,863	0,871
	F	0,967	0,865	0,877
	Wrong Class.	3,333	12,8	11,9
Wine	R	0,819	0,764	0,843
	F	0,845	0,761	0,871
	Wrong Class.	15,169	22,416	12,7
Pima	R	0,531	0,549	0,510
	F	0,624	0,655	0,583
	Wrong Class.	37,370	34,570	43,6

Table 6 shows the comparison between the statistical measures for clustering evaluation for the proposed algorithm and the ACAM algorithm proposed by Boryczka (2009). The best results are in bold and show that the proposed algorithm is better than the ACAM for two of the three databases.

Table 6: Comparison of average results for the implementation of the proposed algorithm with results available in Boryczka (2009) for real databases.

Bases	Assessment Measurements	ACAM	Proposed Algorithm
Iris	R	0,819	0,871
	F	0,810	0,877
	Wrong class.	18,7	11,9
Wine	R	0,849	0,843
	F	0,868	0,871
	Wrong class.	13,9	12,7
Pima	R	0,522	0,510
	F	0,574	0,583
	Wrong class.	33,7	43,6

When comparing the mean evaluation measurements (Table 5), in applying these three Clustering methods the results showed no superiority of any of them. (Handl et al., 2006) also claim that no algorithm dominates the others forever.

In the comparison of the mean clustering evaluation measurements (Table 6) through the proposed algorithm and the ACAM algorithm, the results show that the first one showed a better performance for two of the three databases.

For future works it is suggested to use additional databases for testing, as well as the use of additional indices for Clustering evaluation.

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