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Aleksander Zgrzywa
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Multimedia and Internet Systems: Theory and Practice

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Preface

During the last 20 years we have witnessed a rapid development of Multimedia and Network Information Systems. What is even more important, the pace of change does not show any sign of slowing. When we look back we see how many research projects that have originated at universities or in research facilities now are part of our everyday life. This calls for a volume that addresses the capabilities, limitations, current trends and perspectives of Multimedia and Network Information Systems.

Our intention is to offer the readers of this monograph a very broad review of the recent scientific problems in that area. Solving them has became a principal task of numerous scientific teams all over the world. The volume is a selection of representative investigations, solutions and applications submitted by scientific teams working in many European countries.

Content of the book has been divided into four parts:

I Multimedia Information Technology
II Information System Specification
III Information System Applications
IV Web Systems and Network Technologies

Part I contains eight chapters that discusses new methods of visual data processing. The studies and resulting solutions described in the several chapters of this part follow the gaining momentum trend of exploiting artificial intelligence techniques, fuzzy logic, multi-agent approaches in the domain of multimedia information technology. The domain covers image alignment, video deinterlacing, cartographic representation, visual objects description, large scale 3D reconstruction, and hand gesture recognition. Two of the chapters focus on the content-based indexing and retrieval of visual data.

The second part of the book consists of seven chapters. Two of them address the specific problems of different applications of ontology's in information systems and the ontology alignment. This part also contains reports on the experiments on the evaluation of re-sampling combined with clustering and random oracle using genetic fuzzy systems and the study of parameter selection for the Dynamic Travelling Salesman Problem. One of the chapters deals with the modeling failures of distributed systems in stochastic process algebras. The important from a practical point of view problem of tracking changes in database schemas is also discussed in the last chapter of this part.

Part III presents a handful of applications. It consists of four chapters. One of them describes an adaptive e-learning application with a catchy name of Power Chalk. Innovative solutions to the problem of unified user identification for mobile environments and smart communications for remote users are also discussed. The last chapter presents a rule based expert system that covers semantic matching, spatiotemporal relation operators, and comparison of GIS data to eliminate VAT-carousel crimes.

Part IV refers to the trends and perspectives in Web Systems and Network Technologies. It contains 6 chapters. Two of them deal with e-commerce issues discussing the evaluation of the server performance and presenting an approach to use product reviews from e-commerce websites for the product feature opinion mining task. The usefulness of Web pages can considerably suffer from poor readability. Therefore a special chapter is devoted to a methodology of creating a computer aided system for measuring text readability. Finding relevant services from a service collection is yet another important aspect of the Web Technologies. Two of the chapters in this part are devoted to the problem.

The book should be of great interest to researchers involved in all aspects of multimedia and Internet applications. We hope that it will fulfill the expectations of its readers and we will be also very pleased if the book will attract more scholars to work on the area and to inspire the research community already working on the domain. If so, the goal that motivated authors, reviewers, and editors will be achieved. It will be also the greatest prize for our joint efforts.

Aleksander Zgrzywa
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Part I
Multimedia Information Technology

Chapter 1
Fuzzy Rule-Based Classifier for Content-Based Image Retrieval

Tatiana Jaworska

Abstract. At present a great deal of research is being done in different aspects of Content-Based Image Retrieval System (CBIR). Thus, it is necessary to develop appropriate information systems to efficiently manage datasets. Image classification is one of the most important services in image retrieval that must support these systems. The primary issue we have addressed is: how can the fuzzy set theory be used to handle crisp data for images. We propose how to introduce fuzzy rule-based classification for image objects. To achieve this goal we have constructed fuzzy rule-based classifiers, taking into account crisp data. In this chapter we present the results of the use of this fuzzy rule-based system in our CBIR.

1.1 Introduction

In recent years, the availability of image resources on the WWW and large image datasets has increased tremendously. This has created a demand for effective and flexible techniques for automatic image classification and retrieval. Although attempts to perform the Content-Based Image Retrieval (CBIR) in an efficient way have been made before, a major problem in this area has been computer perception, to which it is hard to introduce an additional semantic data model. In other words, there is a necessity to introduce fuzzy information models into image retrieval, based on high-level semantic concepts that perceive an image as a complex whole.

Images and graphical data are complex in terms of visual and semantic contents. Depending on the application, images are modelled and indexed using their

- visual properties (or a set of relevant visual features),
- semantic properties,
- spatial or temporal relationships of graphical objects.

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Over the last decade a number of concepts of the CBIR [1], [2], [3], [4], have been used. Proposals can be found for the relational [5], object-oriented [6], [7] databases. For about 10 years the fuzzy proposition has been applied in object-relation database models [8], [9]. Zadeh's fuzzy sets theory has allowed us to develop limited programming tools, concerned with graphical applications and dealing with imperfect pictorial data. Within the scope of semantic properties, as well as graphical object properties, the first successful attempt was made by Candan and Li [10], who constructed the Semantic and Cognition-based Image Retrieval (SEMCOG) query processor to search for images by predicting their semantic and spatial imperfection.

The feature vector is used for tentative object classification at the local level of a separated object. First, we have to classify objects in order to assign them to a particular class which is later used to describe spatial relationships characteristic of a particular image. In our system spatial object location in an image is used as the global feature; then it supports full identification of graphical elements based on rules of location. Next, classified objects are used to enable the user to compose their own image in the GUI. Finally, we apply classes in order to compare objects coming from different images [21].

We have chosen a fuzzy rule-based classification to support our pattern library which is constructed to enable the user to build their image query in as natural a way as possible. 'Natural' here means handling such objects as houses, trees, water instead of a red square, blue rectangle, etc.

In this chapter we present the fuzzy rule-based classifiers for object classification which takes into account object features, together with different spatial location of segmented objects in the image. In order to improve the comparison of two images, we need to label these objects in a semantic way.

In general, our system consists of four main blocks:

1. the image preprocessing block (responsible for image segmentation), applied in Matlab, cf. [11];
2. the Oracle Database, storing information about whole images, their segments (here referred to as graphical objects), segment attributes, object location, pattern types and object identification, cf. [12];
3. the search engine responsible for the searching procedure and retrieval process based on feature vectors for objects and spatial relationship of these objects in an image, applied in Matlab;
4. the graphical user's interface (GUI) allows users to compose their own image, consisting of separate graphical objects as a query. Classification helps in the transition from rough graphical objects to human semantic elements. We have had to create a user-friendly semantic system, also applied in Matlab.

There have been several attempts to design efficient, invariant, flexible and intelligent image archival and retrieval systems based on the perception of spatial relationships. Chang [13] proposed a symbolic indexing approach, called the nine directional lower triangular (9DLT) matrix to encode symbolic images. Using the concept of 9DLT matrix, Chang and Wu [14] proposed an exact match of the retrieval scheme, based upon principal component analysis (PCA). Unfortunately, it transpired that the first principal component vectors (PCVs) associated with the image and the same image rotated are not the same. Eventually, an invariant scheme for retrieval of symbolic images based upon the PCA was prepared by Guru and Punitha [15].

1.2 Fuzziness

1.2.1 Fuzzy Sets

Let $T = \{t_1,\ldots,t_n\}$ be a set of objects, where $t_i \neq t_j$, the attributes of t_i and t_j are different. Let $U = \{A_1, \ldots, A_m\}$ be the set of attributes over $t_1,\ldots,t_n$. Each attribute A_i has been associated with a domain, denoted by $U(A_i)$. The value of attribute A_i is either a crisp or fuzzy value. According to Zadeh [16], a fuzzy set F in $U \subseteq \mathbb{R}$ is uniquely specified by its membership function μ_i: $U \rightarrow [0,1]$. Thus, the fuzzy set is described as follows:

$$F = \{(u, \mu_F(u)) | u \in U\} \tag{1.1}$$

Two important concepts of *core* and *support* are related to a fuzzy set F:

$$core\ (F) = \{u \mid u \in U \wedge \mu_F(u) = 1\}$$

and

$$support\ (F) = \{u \mid u \in U \wedge \mu_F(u) > 0\}.$$

For our purpose, we use a trapezoidal membership function MF which is mathematically defined by four parameters $\{a,b,c,d\}$:

$$\mathrm{trapmf}(u; a,b,c,d) = \begin{cases} 0, & u < a \\ \frac{u-a}{b-a}, & a \le u \le b \\ 1, & b \le u \le c \\ \frac{d-u}{d-c}, & c \le u \le d \\ 0, & d < u \end{cases} \tag{1.2}$$

Let F and G be two fuzzy sets in the universe U, we say that $F \subseteq G \Leftrightarrow \mu_F(u) \le \mu_G(u)$, $\forall\ u \in U$. The complement of F, denoted by F^c, is defined by $\mu_{F^c}(u) = 1 - \mu_F(u)$. Furthermore, $F \cap G$ (respectively $F \cup G$) is defined the following way: $\mu_{F \cap G} = \min(\mu_F(u), \mu_G(u))$ (respectively $\mu_{F \cup G} = \max(\mu_F(u), \mu_G(u))$).

1.2.2 Fuzzy Rule-Based Classifiers

We assume that we have an M-class pattern classification problem in an n-dimensional normalized hyper-cube $[0, 1]^n$. For this problem, we use fuzzy rules of the following type:

$$\text{Rule } R_q : \text{If } x_1 \text{ is } A_{q1} \text{ and ... and } x_n \text{ is } A_{qn} \text{ then Class } C_q \text{ with } CF_q, \tag{1.3}$$

where R_q is the label of the q^{th} fuzzy rule, $\mathbf{x} = (x_1, ..., x_n)$ is an n-dimensional pattern/feature vector, A_{qi} is an antecedent fuzzy set ($i = 1,...,n$), C_q is a class label,

CF_q is a real number in the unit interval [0,1] which represents a rule weight. The rule weight can be specified by a heuristic manner or it can be adjusted by a learning algorithm [17], [18]. We use the n-dimensional fuzzy vector $\boldsymbol{A}_q = (A_{q1}, ..., A_{qn})$ to represent the antecedent part of the fuzzy rule R_q in (3) in a concise manner.

Let S be a set of fuzzy rules of the type in (3). That is, S is a fuzzy rule-based classifier. When an n-dimensional pattern/feature $\mathbf{x}_p = (x_{p1}, ..., x_{pn})$ is presented to S, first the compatibility grade of $\mathbf{x}_p$ with the antecedent part $\boldsymbol{A}_q$ of each fuzzy rule R_q in S is calculated by the product operator as

$$\mu_{\mathbf{A}q} (\mathbf{x}_p) = \mu_{\mathbf{A}q1} (\mathbf{x}_{p1}) \times ... \times \mu_{\mathbf{A}qn} (\mathbf{x}_{pn}) \text{ for } R_q \in S, \tag{1.4}$$

where $\mu_{\mathbf{A}qi}$ (.) shows the membership function of A_{qi}. Then a single winner rule $R_{w(\mathbf{x}^p)}$ is identified for $\mathbf{x}_p$ as follows:

$$CF_{w(\mathbf{x}^p)} \times \mu_{\mathbf{A}_{w(\mathbf{x}^p)}}(\mathbf{x}_p) = \max \{CF_q \times \mu_{\mathbf{A}q} (\mathbf{x}_p) \mid R_q \in S\}, \tag{1.5}$$

where $w(\mathbf{x}_p)$ denotes the rule index of the winner rule for $\mathbf{x}_p$.

The pattern $\mathbf{x}_p$ is classified by the single winner rule $R_{w(\mathbf{x}^p)}$ as its consequent class. If there is no fuzzy rule with a positive compatibility grade with $\mathbf{x}_p$ (i.e., if $\mathbf{x}_p$ is not covered by any fuzzy rules in S), the classification of $\mathbf{x}_p$ is rejected. The classification of $\mathbf{x}_p$ is also rejected if multiple fuzzy rules with different consequent classes have the same maximum value on the right-hand side of (5). In this case, $\mathbf{x}_p$ is exactly on the classification boundary between the different classes.

We use the single winner-based fuzzy reasoning method in (5) for pattern classification. This is because a responsible fuzzy rule can be always identified for the classification result of each input pattern when we use the single winner-based fuzzy reasoning method.

An ideal theoretical example of a simple three-class, two-dimensional pattern classification problem with 20 patterns from each class is considered in [19]. There three linguistic values (*small*, *medium* and *large*) were used as antecedent fuzzy sets for each of the two attributes and 3×3 fuzzy rules were generated. S_1 was the fuzzy rule-based classifier with the 9 fuzzy rules shown below:

S_1: fuzzy rule-based classifier with 9 fuzzy rules

R_1: If x_1 is *small* and x_2 is *small* then Class2 with 1.0,
R_2: If x_1 is *small* and x_2 is *medium* then Class2 with 1.0,
R_3: If x_1 is *small* and x_2 is *large* then Class1 with 1.0,
R_4: If x_1 is *medium* and x_2 is *small* then Class2 with 1.0,
R_5: If x_1 is *medium* and x_2 is *medium* then Class2 with 1.0,
R_6: If x_1 is *medium* and x_2 is *large* then Class1 with 1.0,
R_7: If x_1 is *large* and x_2 is *small* then Class3 with 1.0,
R_8: If x_1 is *large* and x_2 is *medium* then Class3 with 1.0,
R_9: If x_1 is *large* and x_2 is *large* then Class3 with 1.0,

R_3	R_6	R_9
R_2	R_5	R_8
R_1	R_4	R_7

Fig. 1.1 Classification boundaries for fuzzy rule-based classifier S1.

For simplicity, the rule weight is 1.0 in S_1. The location of each rule is shown in Fig. 1.1.

1.3 Graphical Data Representation

In our system, Internet images are downloaded. Firstly, the new image is segmented, creating a collection of objects. Each object, selected according to the algorithm presented in detail in [21], is described by some low-level features. The features describing each object include: average colour k_{av}, texture parameters T_p, area A, convex area A_c, filled area A_f, centroid $\{x_c, y_c\}$, eccentricity e, orientation α, moments of inertia m_{11}, bounding box $\{bb_1(x,y), ..., bb_s(x,y)\}$ (s – number of vertices), major axis length m_{long}, minor axis length m_{short}, solidity s and Euler number E and Zernike moments $Z_{00},\ldots,Z_{33}$. All features, as well as extracted images of graphical objects, are stored in the DB. Let Fo be a set of features where:

$$F_O = \{k_{av}, T_p, A, A_c, \ldots, E\} \tag{1.6}$$

For ease of notation we will use $F_O = \{f_1, f_2, \ldots, f_r\}$, where r – number of attributes. For an object, we construct a feature vector O containing the above-mentioned features:

$$O = \begin{bmatrix} O(k_{av}) \\ O(T_p) \\ O(A) \\ \vdots \\ O(Z_{33}) \end{bmatrix} = \begin{bmatrix} O(f_1) \\ O(f_2) \\ O(f_3) \\ \vdots \\ O(f_r) \end{bmatrix}. \tag{1.7}$$

The next complex feature attributed to objects is texture. Texture parameters are found in the wavelet domain (the Haar wavelets are used). The algorithm details are also given in [21]. The use of this algorithm results in obtaining two ranges for the horizontal object dimension h and two others for the vertical one v:

$$T_p = \begin{Bmatrix} h_{\min_{1,2}}; h_{\max_{1,2}} \\ v_{\min_{1,2}}; v_{\max_{1,2}} \end{Bmatrix}. \tag{1.8}$$

Additional features of the low level for objects are shape descriptors. They are also included in the above-mentioned feature vector. We apply the two most important shape descriptors such as moments of inertia:

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q f(x,y), \qquad p,q = 0,1,2 \tag{1.9}$$

and Zernike moments [20]. Zernike moments are a set of complex polynomials $\{V_{pq}(x,y)\}$ which form a complete orthogonal set over the unit disk of $x^2 + y^2 \le 1$. Hence, the definition of 2D Zernike moments with p^{th} order with repetition q for intensity function $f(x,y)$ of the image is described as:

$$Z_{pq} = \frac{p+1}{\pi} \iint_{x^2+y^2\le 1} V^*_{pq}(x,y) f(x,y)\,dxdy \tag{1.10}$$

where: $$V^{*}_{pq}(x,y) = V_{p,-q}(x,y)\,. \quad (1.11)$$

For our purpose, the first 10 Zernike moments are sufficient, which means we calculate moments from Z_{00} to Z_{33}.

1.4 Classification Results

The feature vector **O** (cf. (7)) is used here as a pattern/feature vector **x** for object classification. We collected $n = 32$ features for each graphical object. Based on the data collected in our CBIR system, we have analysed the most distinguished features to present our experimental results. We have chosen three classes from graphical objects in the training subset, namely: class1 - horizontal line, class2 - caret and class3 - vertical line, presented respectively in Fig. 1.2.

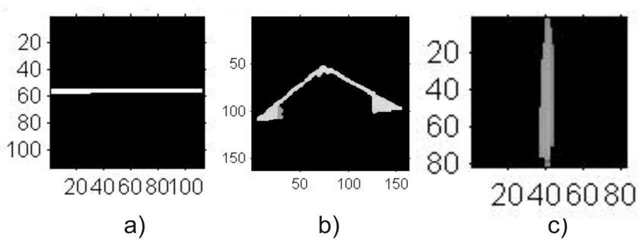

Fig. 1.2 Examples of graphical objects used as class1 - horizontal line a), class2 – caret b) and class3 - vertical line c) from the training subset.

For our fuzzy rule-based classifier we have chosen a trapezoidal MF (cf. (**1.2**)), as it better represents the character of our data. We have classified data from a training subset according to the fuzzy rule-based classifier S_1. As we mentioned earlier, in our experiment we used a three-class problem for two features: x_1 – area and x_2 – minor axis length (shown in Fig. 1.3).

Thanks to the use of the fuzzy rule-based classifier S_1, we can classify a new object (depicted as a magenta square in Fig. 1.4) from unknown class? to class2. After a comparison with the real image object, we can conclude that the classified object, in fact, belongs to class2. This confirms that we can use the single winner-based fuzzy reasoning method for our pattern classification (see Fig. 1.4).

In a multi-objective fuzzy rule-based classifier design, the accuracy of classifiers is not viewed as a factor related to interpretability. This is because accuracy is handled as a separate goal from interpretability in a multi-objective fuzzy rule-based classifier design. However, the accuracy of the winner rule seems to be an important factor, related to the explanation capacity for fuzzy rule-based classifiers [19].

Now, we show the use of a fuzzy rule-based classifier with three rules for our three-class problem, where:

S_2: fuzzy rule-based classifier with three fuzzy rules [19]
R_{123}: If x_1 is *small* then Class2 with 1.0,
R_{456}: If x_1 is *medium* then Class2 with 1.0,
R_{789}: If x_1 is *large* then Class3 with 1.0,

For this purpose we have chosen the fuzzy rule-based classifier S_2. As we have mentioned earlier, in our second experiment we used a three-class problem for two features: x_1 – minor axis length and x_2 – Zernike moment Z_{00}. We used a trapezoidal MF because the data are not normalised to the interval [0,1], according to the assumption from the fuzzy rules definition. We use the same classes (class1 - horizontal line, class2 - caret and class3 - vertical line). As it is shown in Fig. 1.5, the three rules are enough to separate the objects described by real data.

Through the use of the fuzzy rule-based classifier S_2, we can classify a new object (depicted as a magenta square in Fig. 1.6) from unknown class? to class2. After a comparison with the real image object, we can conclude that the classified object in fact belongs to class2. This confirms that we can use a single winner-based fuzzy reasoning method for our pattern classification (see Fig. 1.6).

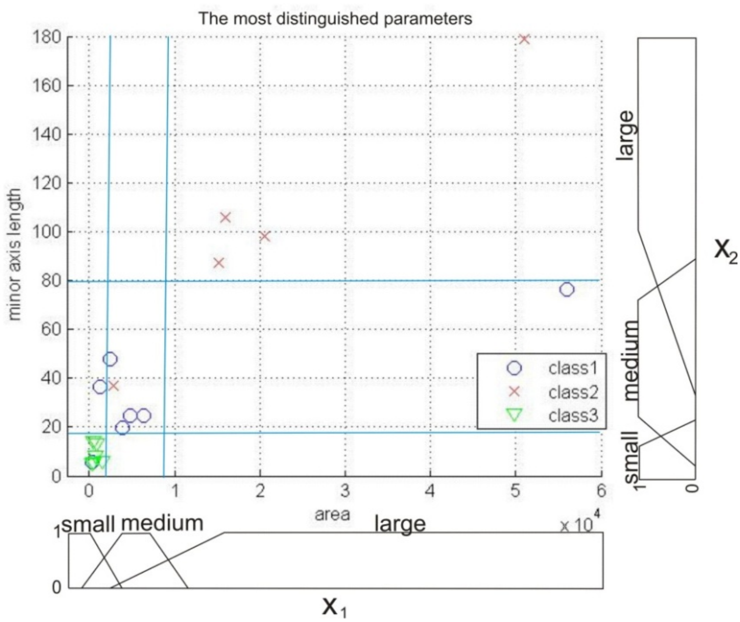

Fig. 1.3 Three-class problem for two features: x1 - minor axis length and x2 - area.

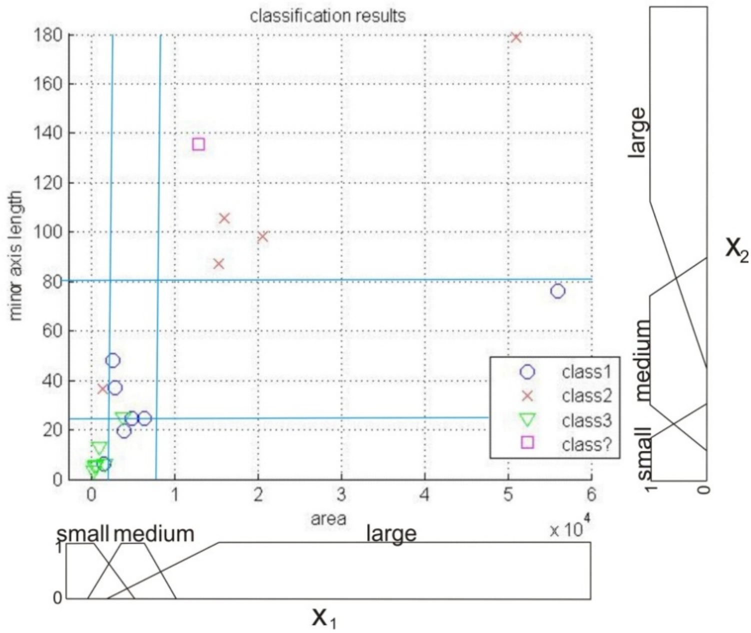

Fig. 1.4 The magenta square is a classified element for the fuzzy rule classifier S1 with 9 rules.

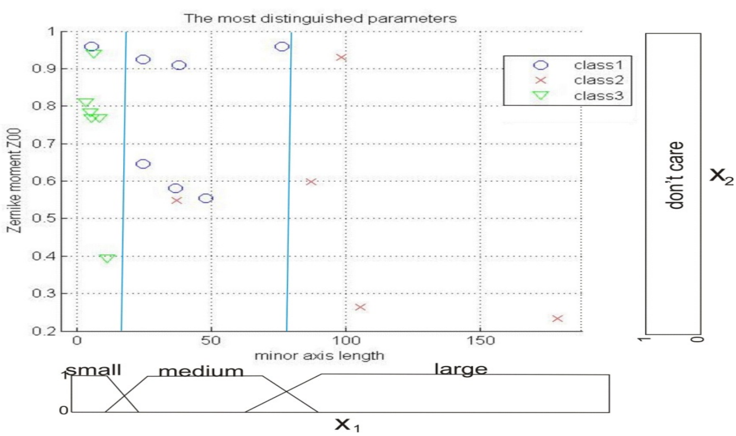

Fig. 1.5 Classification with three fuzzy rules S2

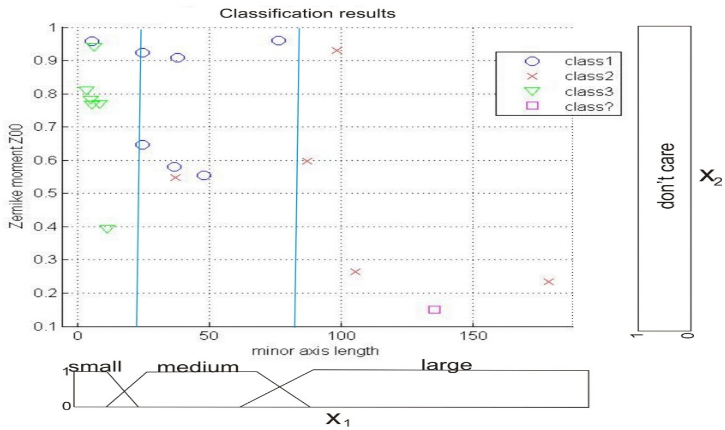

Fig. 1.6 Classification results for a classifier with three fuzzy rules S2

1.5 Further Use of Classified Objects in CBIR

Therefore, we have to classify objects in order to [21]:

1. use particular classes as patterns. We store these data in DB to use them in CBIR algorithms.
2. specify a spatial object location in our system. In our system spatial object location in an image is used as the global feature. The object's mutual spatial relationship is calculated based on the algorithm adopted from the concept of principal component analysis (PCA), proposed by Chang and Wu [14] and later modified by Guru and Punitha [15], to determine the first principal component vectors (PCVs).
3. to help the user ask a query in GUI. The user chooses for a query graphical objects semantically collected in groups.
4. compare image objects coming from the same class as a stage in the image retrieval process. Let a query be an image I_q, such as $I_q = \{o_{q1}, o_{q2},\ldots, o_{qn}\}$. An image in the database will be denoted as I_b, $I_b = \{o_{b1}, o_{b2},\ldots, o_{bm}\}$. In order to answer the query, represented by I_q, we compare it with each image I_b in DB. We determine the similarity between vectors of their signatures. Next, we find the spatial similarity between their PCVs. Later, we proceed to the final step, namely, we compare the similarity of the objects representing both images I_q and I_b, respectively between objects of the same class.

1.6 Conclusions

In this chapter, first we have determined the ability of fuzzy sets and fuzzy rule-based classifiers to classify graphical objects in our CBIR system. We have shown an example of classification based on nine and three fuzzy rules according to the