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Detection and Recognition of Objects on Images Based on MKV-Classifiers

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Обнаружение и распознавание объектов на изображениях на основе МКВ-классификатора

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Виявлення та розпізнавання об'єктів на зображеннях на основі МКВ-класифікатора

In article the algorithm of combination of the binary properties widely used in practice at system engineering of the automatic analysis of the visual information, in the form of the MKV-classifier is offered. Problems of training and using of MKV- classifiers for the decision of detection problems and recognition of objects are considered. The offered algorithms of training allow to generate more effective recognizing rules in comparison with known algorithm AdaBoost, in particular it is essential to reduce number of used properties at identical classifying ability, at the expense of more exact description of position of objects in feature space. Possibility of representation of the MKV- classifier in the form of a decisions tree allows increasing essentially of computing efficiency of classification process.
Key Words: image recognition, object detection, image analysis, image classification.

В статье предлагается алгоритм объединения бинарных свойств, широко используемых на практике при разработке систем автоматического анализа визуальной информации, в виде МКВ-классификатора. Рассматриваются вопросы обучения и использования МКВ-классификаторов для решения задач обнаружения и распознавания объектов. Предложенные алгоритмы обучения позволяют генерировать более эффективные решающие правила по сравнению с известным алгоритмом AdaBoost, в частности существенно сократить число используемых свойств при одинаковой классифицирующей способности, за счет более точного описания положения объектов в пространстве признаков. Возможность представления МКВ-классификатора в виде дерева решений позволяет существенно увеличить вычислительную эффективность процесса классификации.
Ключевые слова: распознавание изображений, обнаружение объектов, анализ изображений, классификация изображений.

У статті пропонується алгоритм об'єднання бінарних властивостей, широко використовуваних на практиці при розробці систем автоматичного аналізу візуальної інформації, у вигляді МКВ-класифікатора. Розглядаються питання навчання й використання МКВ-класифікаторів для вирішення завдань виявлення й розпізнавання об'єктів. Запропоновані алгоритми навчання дозволяють генерувати більш ефективні вирішуючи правила в порівнянні з відомим алгоритмом AdaBoost, зокрема істотно скоротити число використовуваних властивостей при однаковій якості класифікації за рахунок більш точного опису положення об'єктів у просторі ознак. Можливість представлення МКВ-класифікатора у вигляді дерева рішень дозволяє істотно збільшити обчислювальну ефективність процесу класифікації.
Ключові слова: розпізнавання зображень, виявлення об'єктів, аналіз зображень, класифікація зображень.

Detection and recognition of objects on images

The area of automation of processes of perception and the analysis of visions is the important direction in sphere of problems of an artificial intelligence. On the one hand within this direction the problems of modeling of human visual perception that is necessary for development modern robot systems as the visual channel of reception of the information about space around is one of the most powerful are considered. On the other hand, there is a necessity of the effective solutions of set of the applied problems connected with automation of processing of visual patterns, presented in the form of images.

The problem of the automatic analysis of the image in many practical appendices is divided into two consecutive stages: detection and recognition of objects. This division can be considered as model of visual perception of the human, consisting in attention focusing on certain objects of interest and the subsequent their more detailed analysis.

As a rule, interesting objects occupy not all image, but its separate subareas which are necessary for defining during a detection stage. After that, on an input of classifier the fragments of the initial image representing the images only of interesting objects arrive and the recognition stage is carried out.

It is possible to present the decision of problems of detection and recognition of objects on the images in the form of the classifier on which input the image or its fragment moves, and on an output a class number to which it belongs comes back. Difference consists only in number of classes (at their detection two – object and not object) and number of operations of classification which is necessary for executing at the analysis of the initial image. So at recognition their number is equal to number of the found objects, and at detection – to number of possible fragments of the image which can contain object. Considering that required objects can be located in any place of the image and can have various scales, the number of operations of classification at detection by multiscale scanning of the image can be big enough. Therefore for acceleration of process of search of objects except enlargement of spatial and scale steps of pass under the image use calculative more simple classifiers that is reached at the expense of use of quickly calculated features (for example, Haar-like properties) and using of the cascade of classifiers [1], [2]. Thus, the basic problem at the decision of problems of detection and recognition of objects on images is construction of effective classifiers of images.

In the present article the way of construction and training of the classifiers based on the analysis of vertexes of a multidimensional cube is offered, and also results of testing of the received classifiers on problems of detection of lips on the image of the face and recognition of symbols on car plates are resulted.

MKV-classifier construction

One of ways of the decision of recognition problems is construction of classifier on the basis of combination of simple, but insufficiently effective separately features, according to some algorithm of the training, which purpose to minimize a classification error. Algorithm AdaBoost concerns such algorithms is popular and often used for the decision of problems of recognition of visual patterns. Algorithm AdaBoost uses the approach to the classification training, based on combination of a set of ineffective elementary classifiers (EC) in one, better, on the basis of their linear combination. If such classifiers are binary (return two values, for example, 1 and 0) for their combination the classical approach offered by Schapire, etc. [3-5] is used.

In case of use of binary elementary classifiers position of objects in space of their representation in the form of values returned by classifiers is limited to vertexes of a cube, which has dimension equal to number of used classifiers. At such arrangement of objects, their linier classification is rough enough, especially if the number of classifiers is insignificant. For the better description of position of objects in space, it is expedient to use the data about an arrangement of training objects in vertexes of a multidimensional cube. We name such classifier – the MKV-classifier. At such approach, each from the limited set of vertexes is allocated with attribute of an accessory to a certain class. At classification the object gets according to the accepted values of a set of elementary classifiers to one of cube vertexes, and belongs to the class according to attribute of the given vertex. At the decision of two class problems of recognition where one class corresponds to some object, the second – to a background, sufficient is to mark the vertexes belonging to one of classes, and all the others will automatically concern objects of the second class. The last to the full concerns a problem of search of objects where classification of (object / all the rest) is necessary.

As the quantity of vertexes very quickly increases with growth of number of classifiers (2^n), at binary classification it is convenient to use representation of the classifier in the form of a decisions tree.

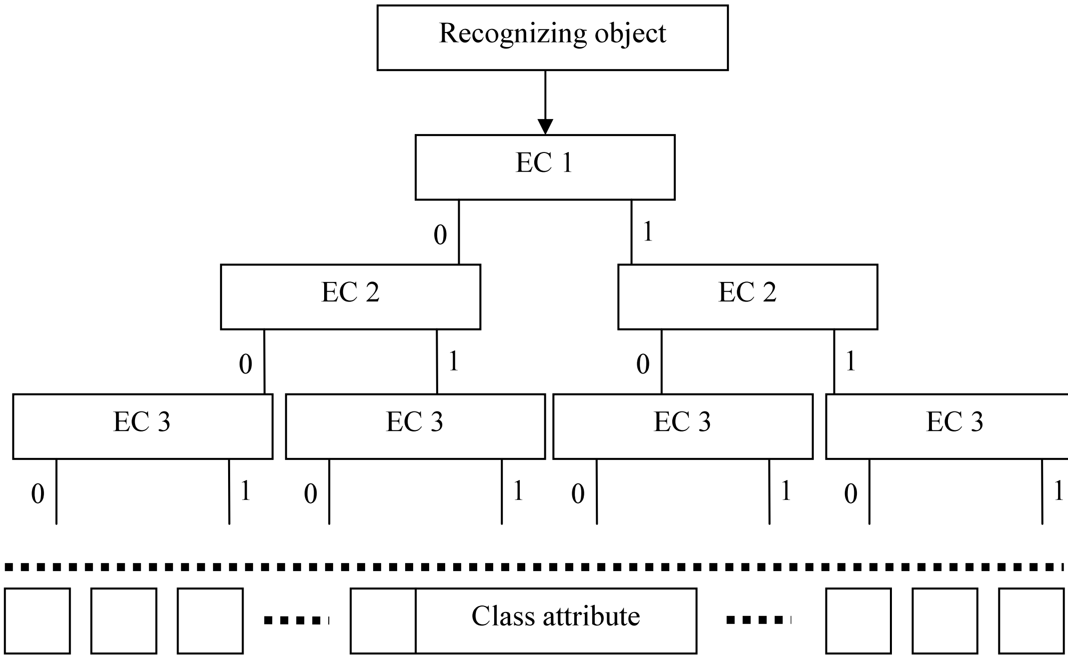

Fig. 1 – The scheme of representation of the MKV-classifier made on a set of elementary binary classifiers, in the form of a decisions tree

At considerable quantities of used elementary classifiers the number of vertexes of a multidimensional cube can be big enough, however owing to that the number of training objects, as a rule, is not so great the number of used vertexes is limited from above to volume of training sample.

MKV-classifier learning

MKV-classifier training assumes a combination of quantity of EC so that crossing of training objects of different classes in vertexes of a multidimensional cube was minimal. Any object submitted on an input of the MKV- classifier, according to accepted values of EC gets to one of vertex of a multidimensional cube. Thus, having a certain training set of objects and knowing their class association, it is possible to estimate frequencies of hit of objects of different classes in cube vertexes. Appointment of attribute of a class association of vertex is carried out by a choice of a class to which there corresponds the maximum probability of hit in the given vertex. If to designate the function of the MKV- classifier returning attribute of a class for any entrance object $\vec{x}$ as $h(\vec{x})$, and its true accessory (correct attribute) as y for a classification error we will have:

$$E = \frac{1}{N}\sum_{i=1}^{N} S_i \text{, where } S_i = \begin{cases} 1, h(\vec{x}_i) \neq y_i, \\ 0, \text{иначе.} \end{cases}$$

Here N – number of training objects. During training EC get out so that to minimize a classification error at each stage of new EC addition.

Process of a combination of elementary classifiers can have considerable computing complexity owing to necessity of the decision of a problem of full search, especially at great number of EC. At the same time, training process can be simplified considerably, having applied by analogy with AdaBoost consecutive selection of EC during MKV-classifier formation. The general scheme of process of training is resulted in figure lower.

1) Choosing the best first EC that gets an minimal classification error.
2) For the all learning stage (adding new EC) $t = 2,...,T$:
   2.1) The cycle of adding of new EC to the set of EC already added are organized;
   2.2) Estimated an error of classification after adding new EC into a MKV-classifier;
   2.3) Choosing EC, that minimized a classification error of MKV-classifier with adding of such EC.
3) Learning process terminated after achievement of the demanded error rate.

Fig. 2 – Algorithm of MKV-classifier learning

The most calculation difficult stage of the resulted algorithm is the estimation of an error of the MKV-classifier with addition of new EC. For acceleration of performance of calculations at this stage it is convenient to fill the table of the values accepted by elementary classifiers:

Table 1 – The values accepted by elementary classifiers

№EC	Object 1	Object 2	Object 3	Object 4	…	Object N
1	0	1	0	0	…	0
2	1	1	0	1	…	0
3	0	0	0	0	…	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮
T-1	1	1	0	1	…	0
T - new	0	0	1	0	…	1
Index of the first such vector in learning sequence	1	2	3	1	…	3

Last line of the table contains indexes of object which has smaller or equal index in the sequence of training objects and for which values of all EC coincide with corresponding values EC for current object. It allows to define quantity of vertexes of a cube to which all objects of a training set get, and to estimate frequencies of hit in each vertex of objects of each class. It allows appointing to vertexes of attributes of classes from a condition of minimization of classification errors.

Last line also allows to find quickly for the first time met vector in the table, equal to a current vector. Really, knowing values of last line without addition next EC and new EC value for the given object it is enough to add into the table above of two lines:

	Object 1	Object 2	Object 3	…	Object N
Index for the first such vector in training sequence without addition of the last EC	1	2	3	…	3
Index for the first such vector in training sequence if additional EC returns 0	1	2	10	…	28
Index for the first such vector in training sequence if additional EC returns 1	23	45	3	…	3

Calculating value of added EC for current object, and knowing the first object coinciding with it in the list of training objects without addition of the last EC, it is possible to receive index for the first same object, or to appoint current object as first found in sequence, as to bring in one of the added lines of the table. The described approach allows to calculate an error of classification after addition of the next classifier with the smaller computing expenses close to performance of similar operation in algorithm AdaBoost.

Testing of MKV-classifier on a problem of object detection

For testing of the offered MKV-classifier the problem of detection of lips area on the image of the face was used. As EC the rectangular logic properties offered in [6], similar to properties, used in [1], [2] were used. As search area the area of preliminary found face containing lips was considered. The database of lips images received at pronouncing of various phonemes which position has been marked manually was used. As a training set of images of lips the cut out images of areas of lips from database of images of faces and the images received by their horizontal mirror reflection – total 5616 images were used. All training images are scaled to working size of 16*16 pixels. As images of a class "Background" from database of face images and their horizontal mirror reflections 5348 images are in a random way taken. In total variants of images of a background containing in face image database, was nearby 461000000. Examples of images of a training set are resulted in figure below.

Fig. 3 – Training image samples:
а) «Lip»-class, б) «Background»-class

In the course of training on one training set of images dependences of an average error of classification of 1 and 2 types errors (false positives and false negatives) on number of used elementary classifiers for the MKV-classifier and the classifier in the form of the linear combination of EC, received by AdaBoost algorithm (fig. 4 see) are received.

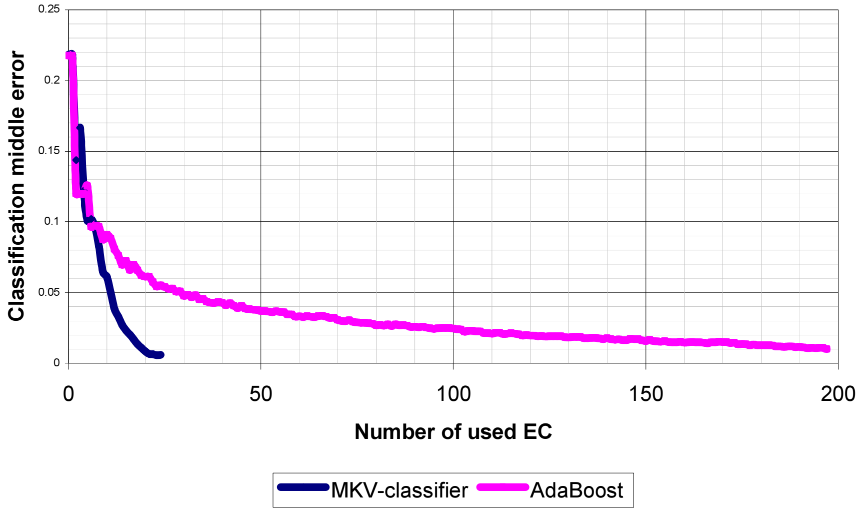

Fig. 4 – The comparative characteristic of quality
of classifiers MKV and AdaBoost by results of training

The analysis of the received dependences shows that MKV-classifier use in comparison with the classifier received as a result of work of AdaBoost algorithm, allows to reduce essentially number used EC at achievement of an identical average error of classification that gives the chance to accelerate process of performance of operation of classification considerably. For the MKV-classifier the reduction of a training error with increase a number of EC is greatly larger. According to the resulted dependences at use of 25 elementary classifiers the MKV-classifier error approximately in 10 times is less, than an error of training of algorithm AdaBoost. For achievement of such value of an error by algorithm AdaBoost it is necessary to use a combination more than 200 EC.

Testing of MKV-classifier on a problem of object recognition

Testing of the offered MKV-classifier for a recognition problem has been made for a problem of classification of symbols on car plates. As a initial data for training and testing was used a database of images of figures received by automatic segmentation of symbols on car plates (fig. 5 see). The total image database size equaled 4300 among which each of figures met approximately identical frequency. In a random way sets of images of each figure have been divided into the equal parts one of which was used for the training, the second – for testing of the trained MKV-classifier.

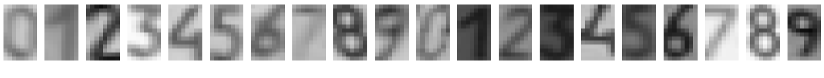

Fig. 5 – Examples of images was used to form training and test sets

During training the treelike MKV-classifier using EC in form of rectangular properties, similar used in the decision of the previous problem of detection has been constructed. The number of properties equaled 8. Properties were combined until the achievement of an average error on all classes less than 0.01. Dependence of an error on EC number, received during training, is resulted in Fig. 6.

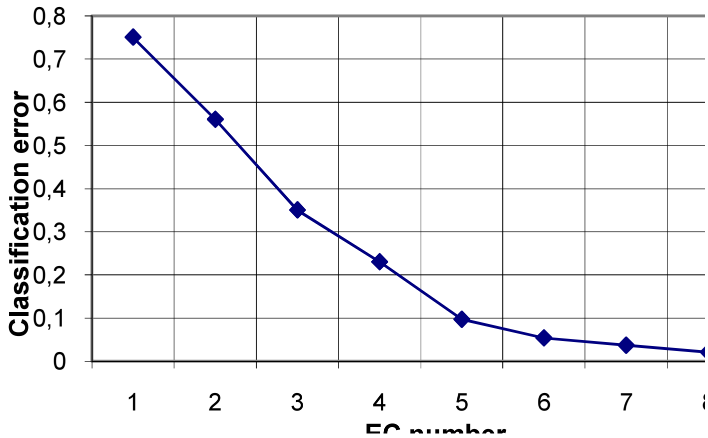

Fig. 6 – Dependence of classification error on number of used EC, achieved during classifier learning

After training the number of vertexes of a cube to which training objects got and which have received attribute of a class, was equal 136 (from 256). At classifier testing for a training set the following matrix of accepted decisions has been received:

Table 2 – The matrix of the decisions accepted by the classifier on a training set

Classes	0	1	2	3	4	5	6	7	8	9
0	**1**	0	0	0	0	0	0	0	0	0
1	0	**0.99**	0	0	0.005	0	0	0	0	0.005
2	0	0	**0.986**	0	0	0	0.005	0.009	0	0
3	0	0	0.005	**0.976**	0	0.005	0	0.015	0	0
4	0	0	0	0	**1**	0	0	0	0	0
5	0	0	0	0.005	0	**0.995**	0	0	0	0
6	0	0	0	0	0.006	0	**0.994**	0	0	0
7	0.004	0	0.004	0	0	0	0	**0.991**	0	0
8	0	0	0	0	0	0	0.009	0	**0.991**	0
9	0	0.005	0	0	0	0.01	0	0	0.01	**0.976**

In the table above relative frequencies of acceptance of corresponding decisions are resulted. The lines correspond to classes submitted on an input of the classifier, and columns – the made decisions. Diagonal elements correspond to relative frequencies of acceptance of correct classifying decisions.

The similar matrix has been received for the test set of images which are not crossed with the training set (tab. 3 see).

Table 3 – The matrix of the decisions accepted by the classifier on a test set

Classes	0	1	2	3	4	5	6	7	8	9
0	**0.988**	0.006	0.003	0	0	0	0	0	0.003	0
1	0.029	**0.951**	0	0.005	0.005	0.005	0	0	0	0.005
2	0.019	0	**0.92**	0.005	0	0	0.009	0.042	0.005	0
3	0.024	0.005	0.005	**0.941**	0	0.01	0	0.015	0	0
4	0.016	0.005	0	0	**0.974**	0	0	0	0.005	0
5	0.014	0	0	0.024	0.005	**0.948**	0	0	0.009	0
6	0.025	0	0	0	0.019	0	**0.944**	0	0.012	0
7	0.018	0.018	0.004	0.009	0	0	0	**0.952**	0	0
8	0.026	0	0	0.009	0	0.018	0.004	0	**0.939**	0.004
9	0	0.024	0	0	0	0.019	0	0	0.01	**0.947**

As can see from the resulted in tables 2 and 3 matrixes the trained classifier achieve of high efficiency and high enough characteristics of generalization of class features on training set. Use of eight properties has allowed to receive percent of correct recognition on the average on all classes – 0.95.

Conclusion

The approach considered in article to combination of simple properties in the MKV-classifier allows carrying out effective training to recognition of images. On speed of training the offered approach does not concede to algorithm of training AdaBoost, and by efficiency of received decisions allows to reduce considerably number of used properties at preservation of demanded quality of classification. Last characteristic of the MKV-classifier, and also possibility of its representation in the form of a decisions tree defines high calculation performance of the classifier, in comparison with a linear combination of EC, received at use of algorithm of training AdaBoost. Low computing complexity in a combination to a high overall performance of the classifier allows to use it for the decision of applied problems of detection and recognition of objects on images that results of the spent testing have confirmed.

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RESUME

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