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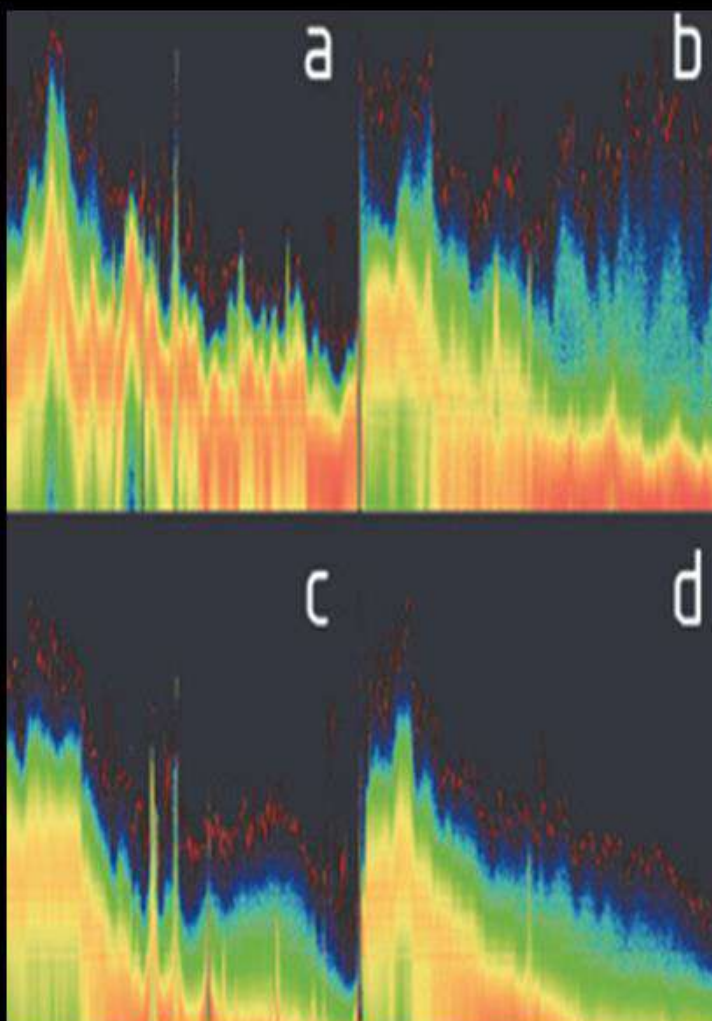
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Development of object detection algorithm in halftone images

Abstract. This paper researches the detection method in halftone images using AdaBoost algorithm for training a object detector. Modified Haar-like features are used as features in weak classifiers. The method has been tested on The Yale B Face Database where images are obtained under 65 different illumination conditions. Experimental research on face detection method was carried out using the Matlab environment.

Streszczenie. W artykule zbadano metodę detekcji w obrazach półtonowych z wykorzystaniem algorytmu AdaBoost do szkolenia detektora obiektów. Zmodyfikowane cechy podobne do Haara są używane jako cechy w słabych klasyfikatorach. Metoda została przetestowana w bazie danych Yale B Face Database, gdzie obrazy są uzyskiwane w 65 różnych warunkach oświetleniowych. Badania eksperymentalne metody detekcji twarzy przeprowadzono z wykorzystaniem środowiska Matlab. (Opracowanie algorytmu wykrywania obiektów w obrazach półtonowych)

Keywords: classification ability, light conditions, local binary patterns, simple classifier, clustering and verification.

Słowa kluczowe: umiejętność klasyfikacji, warunki oświetleniowe, lokalne układy binarne, prosty klasyfikator, grupowanie i weryfikacja

Introduction

The task of object detection is solved in many applications. It is the first step for further image processing, such as: face recognition, emotion recognition, gender classification, "human-computer interface", closed-circuit television, video conference, access control, contextual image search, counting visitors, etc. [1-5].

The best results of object detection are showing methods which consider the detection task as the classification of two classes (face /not face). Great attention is paid to boosting methods [2, 6-8], because they can process the image on a real-time basis and are effective according to the criteria for the detection probability and the number of false detections. These methods use training algorithms of classification from the family of boosting algorithms [3, 4, 9].

These algorithms solve the task of classification by combining poorly effective simple classifiers into one "strong" one, which is characterized by high classification ability. Adaboost (adaptive boosting) is used as a boosting algorithm in many boosting methods [3, 10, 11]. Haar-like features or their modifications are used as simple classifiers. The advantage of these features is the simplicity of evaluation, but they are sensitive to lighting conditions [5, 12].

In the early 90s experiments on combining classifiers by voting began [3, 13] with the study of how strong a classifier can be obtained by combining weak classifiers. The term boosting ("strengthening", "support") also appeared for strengthening weak classifiers. Their sequential training, taking into account the errors of previously, trained weak classifiers [2, 14].

Successful iterative AdaBoost algorithm was proposed in the mid-90s. AdaBoost algorithm trained weak classifiers gradually, taking into account the voting results of already trained weak classifiers [works [1, 2].

AdaBoost is adaptive. Each subsequent weak classifier is built on objects incorrectly classified by previous classifiers. AdaBoost is sensitive to data noise and outliers. However, it is less prone to overtraining than many other training algorithms [7, 15, 16].

AdaBoost evokes the weak classifier in a cycle. The distribution of weights corresponding to the importance of each object in the training set for classification is updated. The weight of each incorrectly classified object increases at each iteration (or similarly, the weight of each correctly

classified object decreases) [4, 17, 18]. Thus the new classifier "focuses its attention" on these objects.

For creating boosting method with high detection probability the set of features being robust to light conditions should be applied. Local binary patterns (LBP) can act as such features. Local binary patterns have recently been actively used in detection tasks [1, 7].

Purpose and tasks of research

The purpose of research is to explore the object (face) detection method in images for improving the existing detection methods images with low light conditions.

Materials and methods

The development of face detection method

It is reasonable to apply the approach proposed in [2, 4, 19, 20] for the method development. To speed up the image processing, AdaBoost algorithm selects a set of simple classifiers presented in the form of cascade of strong classifiers (CSC), using modified Haar-like features (MHF) as simple classifiers.

The development of face detection method consists of several stages:

1) training of cascade of strong classifiers on a set of examples;

2) image processing with cascade of strong classifiers;

3) verification of candidates - faces.

Modified haar-like features

Haar-like features [2, 4] are determined in halftone image. The feature value is defined as the difference of the sum of pixels' intensity of areas inside the rectangle (fig. 1).

The integral image is an algorithm for quickly and efficiently the sum calculating of the values sum inside the rectangle image. It was first proposed by Crowe in computer graphics for using in mipmaps. Viola and Jones applied the integral image for rapidly calculating of Haar-like features [6, 21, 22]. The integral image can be interpolated using the formulas:

$$(1) \quad ii(x, y) = \sum_{x' \leq x, y' \leq y} i(x', y')$$

where $ii(x,y)$ is the integral pixel image with coordinates (x,y) and $i(x,y)$ is the original image. Using the integral image, the sum of any rectangular region is calculated extremely efficiently, as shown in Fig. 1. The sum of pixels in the rectangle ABCD region can be computed as:

$$(2) \sum_{(x,y) \in ABCD} i(x,y) = ii(D) + ii(A) - ii(B) - ii(C)$$

using only 4 array references.

Local binary pattern (LBP) operator is represented by description of neighborhood of pixel image in the binary form. The meaning of local binary pattern (LBP) in applying to neighborhood of pixel image at (x,y) coordinates can be described as:

$$(3) CS-LBP(x,y) = \sum_{m=0}^{(N/2)-1} s(k_m - k_{m+N/2})2^m,$$

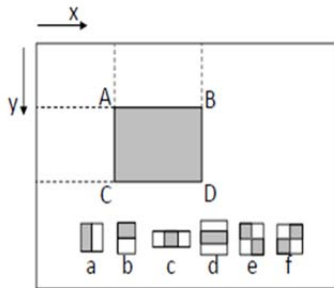


Fig. 1. Illustration of integral image and Haar-like rectangular features (a-f)

Where N is the number of pixel neighborhood; k is the meaning of pixel neighborhood intensities;

$$(4) s(k_m - k_{m+N/2}) = \begin{cases} 1, & \text{if } k_m - k_{m+N/2} > \lambda \\ 0, & \text{else} \end{cases}$$

where λ is the threshold.

According to the formula LBP operator, which is applied to pixel neighborhood of halftone image with coordinates (x, y), using eight pixels in the neighborhood ($k_0 - k_7$) composes of four-unit code (fig. 2).

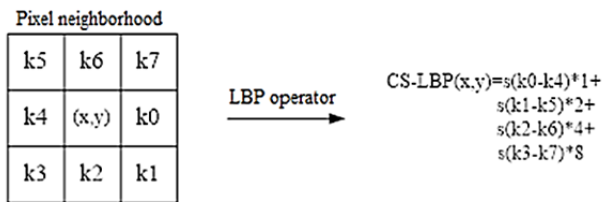


Fig. 2. Calculation of the value of LBP feature

Calculating values of LBP features of all the pixels of halftone image except interfacial it is possible to determine LBP array (fig. 3).

The new set of features that uses LBP features and Haar-like features are called the modified Haar-like features (MHF) [5, 22, 23]. To calculate MHF the halftone image is transformed into LBP array and then transformed into a set of integral LBP array (ILBP) according to the following expression:

$$(5) i_d(x,y) = i_d(x,y-1) + \delta_d(x,y),$$

$$(6) I_d(x,y) = I_d(x-1,y) + i_d(x,y)$$

where I is ILBP array; i is auxiliary array, $d = 1, \dots, 16$; $\delta_d(x,y) = 1$, if array cell out of the set I_{LBP}^P with coordinates (x, y) equals d, and $\delta_d(x,y) = 0$ in another case.

The MHF feature is determined by such set of parameters: type of Haar-like feature (fig.1), CS-LBP value, size and location in the image, which correspond to the size of minimal sliding window (for example, 24x24 or 48x48 pixel) [4, 25]. Sample of getting a set of ILBP arrays from LBP array is shown on fig.4.

According to MHF parameters, using the appropriate ILBP array I, number of CS-LBP features is calculated in light and dark rectangles of MHF. MHF value is calculated as follows:

$$(7) f(I) = S_W - S_B,$$

where S_W – number of CS-LBP features in light rectangles of MHF, S_B – number of CS-LBP features in dark rectangles of MHF, I – ILBP array.

The values S_W and S_B is calculated as follows:

$$(8) S = I(a_2, b_2) - I(a_3, b_3) - I(a_1, b_1) + I(a_4, b_4),$$

where (a_1, b_1) , (a_2, b_2) , (a_3, b_3) , (a_4, b_4) – are the coordinates of four pixels connected with the appropriate rectangle in MHF (neighboring on top with right upper pixel of rectangle, right lower pixel of triangle, neighboring on the left with left lower pixel of rectangle, neighboring on the diagonal on top with left upper pixel of rectangle).

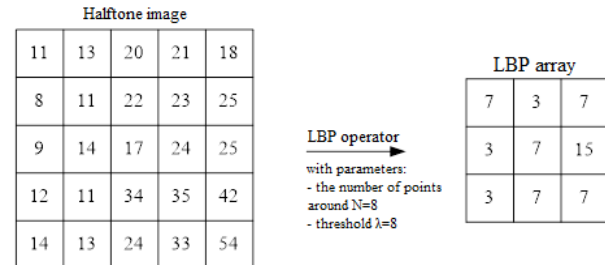


Fig. 3. Getting LBP array from halftone image

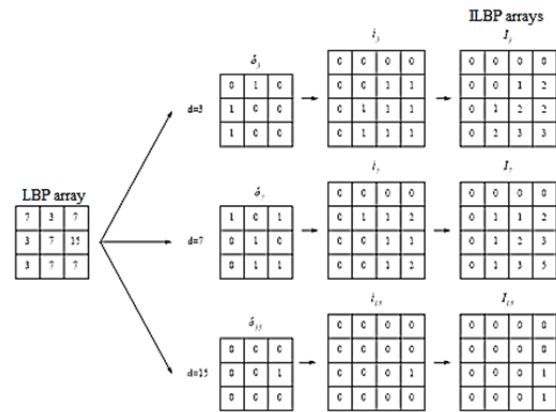


Fig. 4. Getting the set of ILBP array from LBP array

Research results

Training of cascade of strong classifiers

Implementation of the first stage requires sets of positive and negative examples. Therefore, the base of frontal faces images Bface using images from BioID [1, 7, 26], as well as the base of no faces images Bnonface using images selected on the Internet are created. The images from Bface are normalized so that the eyes in the images are in the same spatial coordinates and out of it training P and verification sets V_p of positive examples are created. Image regions are extracted from Bnonface and training P and verification sets V_p of negative examples are formed. Images in P, V_p , N, V_n sets are scaled to minimal sliding window.

In order to form a MHF set, it is advisable to limit the size of Haar-like features used in MHF. Small-sized Haar-like features at the application of MHF will not be discriminating enough. Let the minimal size of the rectangle in the Haar-like feature will be 4x4 pixels.

The probability value of false positive rate FP_C and probability of detection of TP_C , to which CSC has to achieve during the training, are established for CSC. Strong classifiers will be added to CSC for as long as the determined

FP_C and TP_C are achieved.

From the set of positive training examples at the application of LBP operator the set of LBP arrays of

positive examples IPLBP is obtained. In a similar manner, from the set of negative training examples we get the set of LBP arrays of negative examples I NLBP. Applying the formulas from the set I PLBP we get the set of ILBP arrays of positive examples I P, and from I NLBP set we get the set of ILBP arrays of negative examples IN .

Using IP and IN sets, the value of each MHF f_j is calculated. Its optimal threshold θ_j , and the direction of sign p_j are determined.

The probability value of false positive rate FP and probability of detection of TP, to which the strong classifier has to achieve during the training, are established for each strong classifier.

The training of each strong classifier with using Adaboost algorithm will be accomplished until achievement of the determined FP and TP. The training sample is formed by IPLBP set of positive examples and INLBP set of negative examples in a following form: $(x_1, y_1), \dots, (x_n, y_n)$, where x is LBP array, y – the target value that equals 0 – for the negative examples, 1 – for the positive examples. Initialization of weight w_1 , $i = 1/2m$, $1/2l$, for $y_i = 0$, 1 accordingly, where m – number of positive examples, l – number of negative examples, and currently value of false positive rate $fpRate$ (initially $fpRate=1$). A cycle is activated with a condition while $fpRate > FP$, where t - the current iteration, i – index of example, j – MHF index.

The weight examples of training sample are normalized:

$$(9) \quad w_{t,i} \leftarrow \frac{w_{t,i}}{\sum_{k=1}^n w_{t,k}}$$

The simple classifier h_j for each MHF using IP and IN is formed according to the following formula:

$$(10) \quad h_j(x) = \begin{cases} 1, & \text{if } p_j f_j(x) < p_j \theta_j \\ 0, & \text{else} \end{cases}$$

where f_j – MHF, x – LBP array, θ_j – threshold, p_j – direction of MHF sign.

The error of all simple classifier in training sample is calculated as [4, 27, 28]:

$$(11) \quad \varepsilon_j = \sum_i w_i |h_j(x_i) - y_i|$$

To the strong classifier, the simple classifier h_t is added with the smallest error ε_t . Weight examples are renewed according to the expression:

$$(12) \quad w_{t+1,i} = w_{t,i} \beta_t^{1-e_i}$$

where $e_i = 0$ if the example x_i is defined correctly, $e_i = 1$

otherwise, $\beta_t = \frac{\varepsilon_t}{1 - \varepsilon_t}$.

The strong classifier is defined as:

$$(13) \quad h(x) = \begin{cases} 1, & \sum_{t=1}^T \alpha_t h_t(x) \geq \psi \\ 0, & \text{else} \end{cases}$$

Where $\alpha_t = \log \frac{1}{\beta_t}$, $\psi = \frac{1}{2} \sum_{t=1}^T \alpha_t$.

Using verification set of positive examples V_p , threshold of SC is adjusted for reaching the defined probability value of detection TP. The probability value of false positive rate $fpRate$ of SC on verification

set of negative examples V_n is calculated. Transition into next iteration of the cycle is accomplished in case of implementation the condition $fpRate > FP$, otherwise, SC is added to CSC.

The transition to the next strong classifier is accomplished. To form the set of negative examples N of the next strong classifier is extracted from $B_{nonface}$ image region scaled to minimal sliding window and negative examples are formed out of them. Transformation of image

region into ILBP array is accomplished and placed to the CSC input. The examples, that CSC has taken as positive are added to set N.

Image processing with cascade of strong classifiers

Processing with CSC for face detection is accomplished in the following way. Using an optical device, such as a video camera, an image containing one or more human faces is entered into a computer. The image is transformed into LBP array and 16 ILBP arrays are produced. Sliding window, the size of which equals to minimal and then increases by coefficient M_s , at scale change, moves along image rows with step K_r pixels. The image region is extracted and corresponding to it parts of ILBP arrays are placed at CSC input. In case of strong classifier, using the obtained parts of ILBP arrays is calculated MHF value in simple classifiers. A decision is made on the transition to the next strong classifier in a cascade in the case $h(x) = 1$, or to the rejection of current image region in the case $h(x) = 0$ and the transition to processing of the next image region, extracted by sliding window. In the case when all strong classifiers of the cascade will make decision on $h(x) = 1$ image region is considered as a face.

Verification of faces – candidates

After passing the sliding window through the whole image in all scales, CSC marked out on the image several defined regions – faces – candidates. For verification of faces – candidates the rule of clustering is applied, in which all variety of faces – candidates are broken up for varieties, which are not intersected. At clustering two faces – candidates are related to one cluster, if they are intersected by more than percent ϕ . Cluster is a candidate for creating united region if the variety of faces – candidates is more than threshold η . United region is formed by finding arithmetic average of coordinates of faces – candidates, that are included into a cluster. Each of united regions is determined as face region.

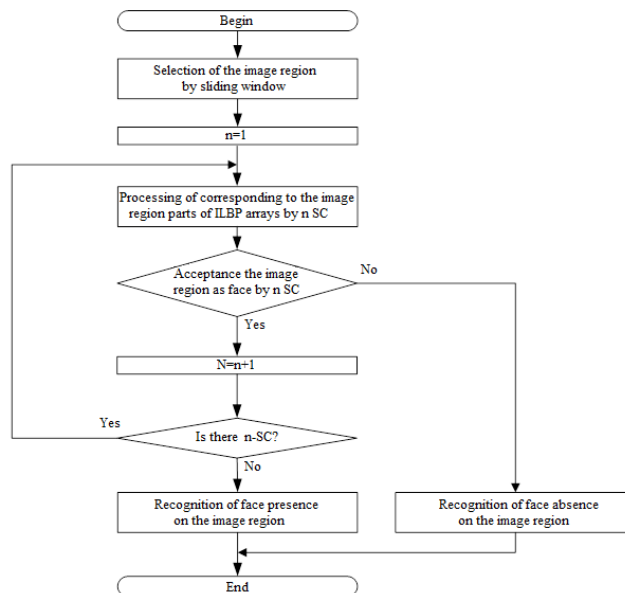


Fig. 5. Operation of the face detector. Scheme of the program

Conclusions

The paper proposes the face detector method which consists of a cascade of strong classifiers trained on a training sample using the Adaboost algorithm, stages of clustering and verification of candidate regions. The program scheme of the detector is shown in Fig. 5.

The author implemented the face detection method in the form of a programs set that allow to train the face

detector using a training set of "face" and "non-face" images, as well as to test the selected image choosing the parameters of the detector (selection of the intersection percentage of selected windows for clustering, selection of the number windows for clustering, shift of the sliding window).

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