Automated Signature Detection from Hand Movement[1]

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Abstract: *The problem of analyzing hand movements of an individual placing a signature has been studied in order to identify him. A method for locating the signature zone and the duration of the process in series of camera recordings has been developed. Preliminary experiments have been carried out to describe the trajectory of the movement and to select identification features.*

Keywords: *Signature, Verification, Image Processing*

1. INTRODUCTION

The globalization of the information space and the increasing role of information systems in decision-making and social processes control impose the elaboration of measures for protection against illegal access to important objects and systems. The standard means based on codes, passwords and identification cards cannot provide sufficient reliability against intruders because of the existing danger of counterfeiting, cracking the code or sharing access among several persons. For these reasons attention is focused on access-permit tools based on the measurement of biometric parameters, of face, voice, iris and hand (geometry, fingerprints, palm prints, hand movement and signature). Some of these modalities (fingerprints, voice, face, signature) have been investigated for a long time [2, 3]. As a result sets of reliable features and robust classification rules for identification/verification have been suggested and real-time application systems have been developed. The opportunities for person's identification based on the evaluation of hand movements, the way of handling the writing tool, the speed of writing at different signature elements, the shape and the size of the hand, are less explored [4, 5]. Additional features as scars, skin color etc. can be used provided good space and color resolution is available.

The aim of this study is to investigate the possibilities of signature detection by automatic tracking of hand movements, which is based on reliable determination of the start and end moments (frames) of the signature and some preliminary personal identification parameters.

2. ACQUISITION AND PROCESSING OF THE INPUT DATA

Recording a sequence of images

Recording series of video images reflecting the process of signing is the first stage of the study. Images can be obtained using a TV or digital camera. In order to choose the appropriate registering equipment a Panasonic black-and-white CCD camera, Creative and Sony color web cameras and HP digital camera have been used. The cameras have been placed perpendicularly to the sheet of paper. The videos have been recorded in AVI or MPEG-1 file format and then divided in frames in BMP format. Experiments have been carried out at daylight laboratory conditions.

Evaluation of the background

Evaluation and elimination of the background are always necessary when the aim is to process images and to obtain quantitative parameters of the objects of interest. In this particular case the stationary conditions in the process of obtaining the input data allow the objects' extraction to be done in advance. This requires several frames to be recorded in the absence of object. For every two consecutive frames (*k, k+1*) the average absolute

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difference $\overline{E}^{k,k+1}$ of the grey levels or the three components of the digital color for the black-and-white and the color cameras respectively, is calculated:

$$\overline{E}^{k,k+1} = \frac{1}{MxN} \sum_{i=1}^{M} \sum_{j=1}^{N} \left| E^{k+1}(i, j) - E^{k}(i, j) \right|, \quad (1)$$

where *M* and *N* are image dimensions, $E^{k}(i, j)$ is the grey level vector with three color components at the pixel (*i*, *j*) in the *k*-th image (*k* = 1, 2, …, *K*-1) and *K* is the number of the frames in the series.

The maximal average difference

$$\overline{E} = \max_{k} \overline{E}^{k,k+1} \quad (2)$$

in the whole image sequence is used as a threshold for the detection of an object.

Determination of the signature zone

Two cases may be present when capturing the writing hand. In the first case the hand with the writing tool is in the field of view of the camera, capturing live images. The hand starts moving and after the signature is finished the hand remains moveless. This way the camera captures some frames before and after signing. The advantage here is in the easy determination of the starting and ending moments of signing and hence its duration and execution time. All these parameters are obtained by differencing the consecutive frames. A relative inconvenience is the coordination between the operator and the signing person concerning the beginning of the capturing process.

The other, more natural case, supposes that the camera is permanently working. The signing hand enters the field of view, accomplishes the writing movements and then goes out. The problem now is how to determine the moments of signature's beginning and end. However, the differentiation of consecutive frames can only provide information about the moments of entering and outdrawing of the hand from the field of view. The problem could be solved using the absolute differences between the frames and a reference frame, which does not contain the hand. A frame representing the average of several consecutive frames before the hand has entered could be used as such a reference. This could reduce the accidental noise in the reference frame and the light variability effect as well.

When the hand enters the view field of the camera the values of the average absolute differences between the current frame and the reference one would rise sharply, then oscillate about some constant value during the signing and would diminish with the hand's outdraw. The differences in the values of the slope of the obtained curve could provide the approximate determination of the beginning and the end of the plateau (± 1 frame), which means determination of the signature's zone.

3. QUANTITATIVE CHARACTERISTICS OF THE SIGNATURE

The verification of the signing person involves measurement of an informative set of features, which has to give precise description of the hand movement characteristics and its physical parameters as well. The construction of a curve representing the average differences between the signature frames and the reference frame, and the calculation of the slope between the consecutive points provide a way to determine features such as: signature duration in number of frames; number of zero-crossings; characteristics of the sections of the curve between two consecutive zero points; spectral characteristics. For the measurement of these features it is not necessary to separate quantitatively the hand from the background and to outline the contours, which makes them convenient for work. In contrast, the evaluation of the physical parameters and characteristics of the hand requires precise segmentation of its parts, which cannot always be done in a satisfactory way.

4. EXPERIMENTAL RESULTS

The image processing is accomplished on PC and Windows 2000 operation system. The series of images are captured at a speed of 15 frames per second. The resolution is 480x360 pixels for the black-and-white camera and 320x240 pixels for the color ones. The frames are recorded as bitmap images with 24 bits per pixel.

Threshold value determination

Series of up to 100 frames, which do not contain an object, are captured for the evaluation of $\overline{E}$. The average absolute differences in the grey levels are calculated according to formula (1).

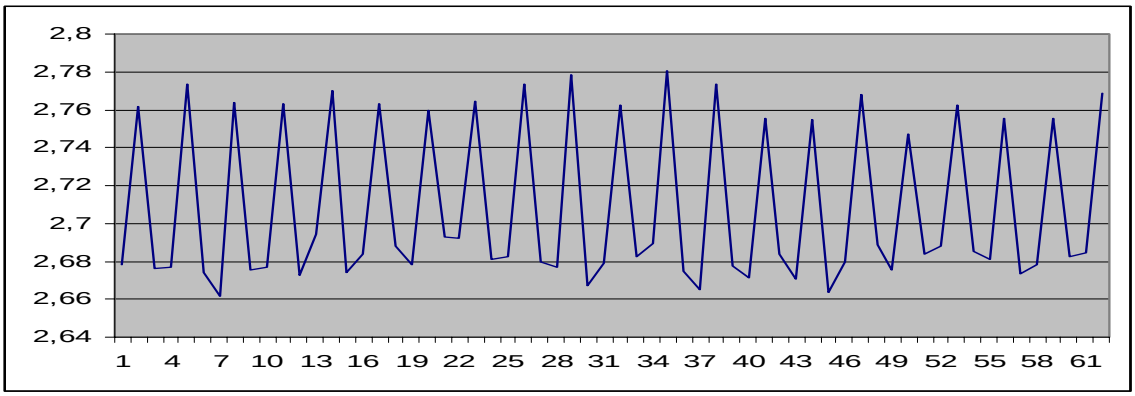

Fig.1. Average absolute differences for the black and white camera

The obtained maximal average difference is of the order of 2,78 for the black-and-white camera and 2,87 for the color cameras. The experiments with varying illumination showed that these values vary insignificantly and the results for the black-and-white camera were more stable (fig.1). In that case it seems reasonable to choose $\overline{E}$ =3.

Signature zone determination

Case 1. The hand is in the view field of the camera and after the movement is done, it stays there. Experiments with three persons have been made, resulting in three separate movies, respectively. The average absolute differences between each two consecutive frames look as shown in fig.2 (for the different cameras analogous results were obtained).

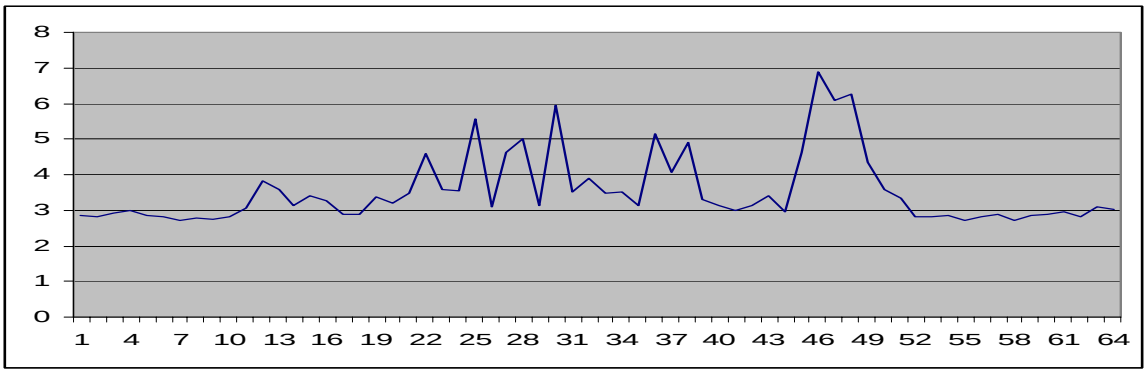

Fig.2. Variation of the average absolute differences between two consecutive frames when the hand initially is in the field of view of the camera

It can be seen from the figure that when the hand is in the field, a slight movement can reach or cross the preliminary selected threshold, which can lead to incorrect determination of the beginning or the end of the signing. To avoid this, a decision should be made only if the threshold is crossed at several consecutive frames.

Case 2: Initially, the hand is outside the field of view of the camera and after the signing is finished, it goes out.

The results obtained in this case are given in fig.3: the upper curve represents the average absolute differences per pixel between all the frames and a reference frame; the curve in the middle shows the average absolute differences per pixel between every two consecutive frames; the lower curve illustrates the slope (the absolute value of the gradient) of the upper one.

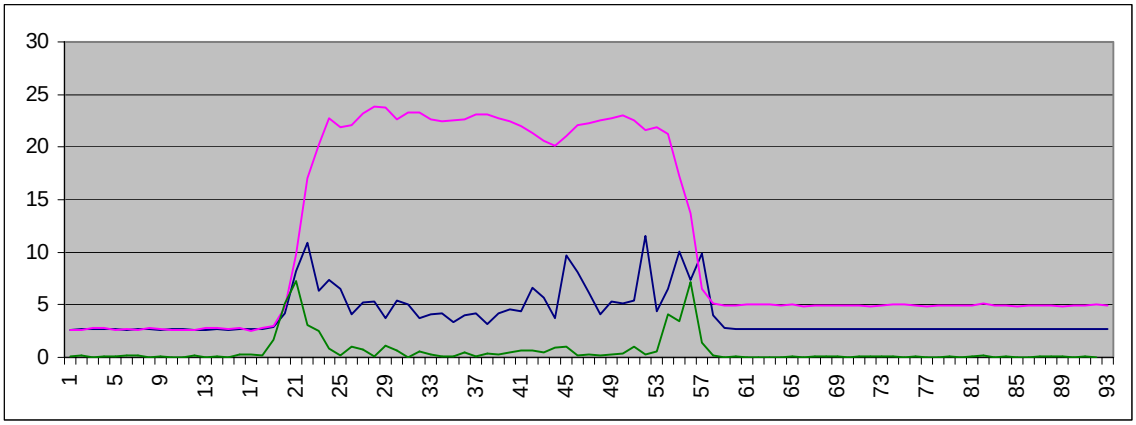

Fig.3. Graphs when the hand is initially outside the field of view of the camera

On the gradient curve, peaks can be seen in the moments of hand's entering and going out of the field of view, and the signing itself is situated between them. Three methods for solving the problem of finding the initial and the last frame of the signing have been tested.

The first and most reliable way to determine the start of the signing is based on calculating the average value of the gradient and finding the first value after the peak, which is smaller than the average value (fig.4).

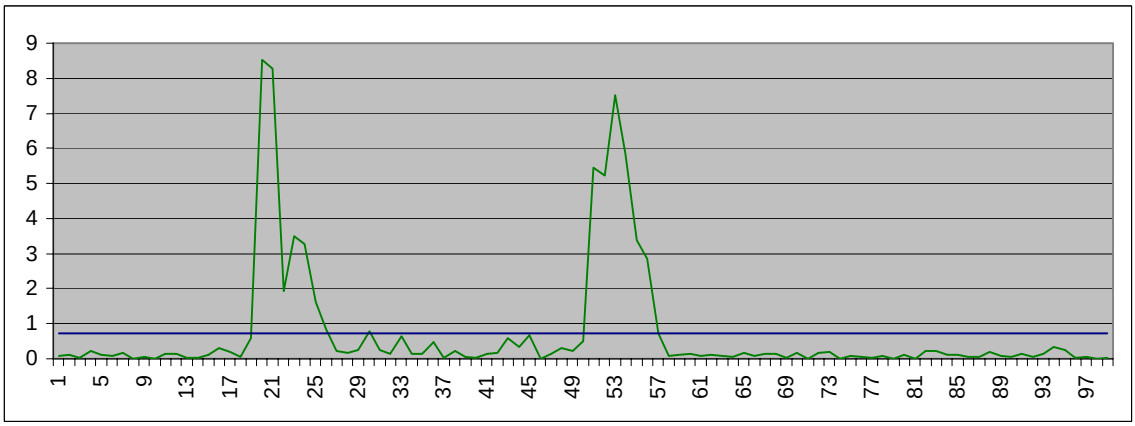

Fig.4. Gradient curve and its average value, represented by a thick horizontal line

To find the end point of the signing, the graph is processed analogously in the other direction, starting from the end.

The second method consists of evaluating the cosine of the angle between each three consecutive points of the gradient graph. Filtered values of the gradient were used. The first cosine after the peak, which is smaller than its neighbors, was chosen.

The third method represents a comparison of the radiuses of the circles passing through every three consecutive points of the same graph, after the peak. The first radius smaller than its neighboring radiuses is searched for. This method and the previous one do not determine precisely and reliably enough the beginning and the end of the signing.

Signature duration determination

For further processing, study of the frames where only the moving hand is present is necessary.

When the initial position of the hand is in the field of view of the camera, the beginning of the movement is in the frame, which maximal average absolute difference with the previous one exceeds the established threshold. The last frame of hand movement is determined in a similar way.

When the initial hand position is outside the field of view of the camera (fig.5), the beginning of the signature is determined by calculating the values of the gradient of the graph of the average absolute differences per pixel between the current frame and the reference one. The frame after the maximal gradient, where it comes down and goes under its average value, is considered as the first frame of the signing (fig.5e).

a b c d e

Fig.5. Signing with initial hand position outside the field of view of the camera. Entering of the hand (a-d) and beginning of the signature (e)

The starting and ending moments of the signatures of three persons have been found accurately, each of them making three signatures in the field of view and three with initial hand position outside the field.

5. CONCLUSION

The signature detection from hand movement analysis is one of the prospective methods for real-time person verification. Satisfying results may be expected regarding the accuracy of the conclusion, if movement characteristics and physical properties of the hand of different people are used.

The studies described above represent the first step in this direction. The signature zone determination problem in series of consecutive images has been solved. For this purpose a method is developed for the representation of the movement dynamics, which permits to determine reliably the beginning and the end of the signing. Two cases of capturing the human hand signature movement are examined.

Although the experiments were limited, they showed that some common quantitative features could be used for verification purpose. The combination of these features with most detailed movement trajectory description will improve considerably the accuracy of the final decision. A completely satisfactory solution can be obtained when physical parameters of the hand and the writing tool position during the signing process are included.

The future work will include extension of the experimental part, development of methods for obtaining a detailed information from the movement trajectory, evaluation of the information weight of different features, and development of reliable verification methods. An important element of the work will include methods for quantitatively describing the hand geometry and the position of the writing tool in the hand.

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