Adapting Hausdorff Metrics to Face Detection Systems: A Scale-Normalized Hausdorff Distance Approach

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Abstract. Template matching face detection systems are used very often as a previous step in several biometric applications. These biometric applications, like face recognition or video surveillance systems, need the face detection step to be efficient and robust enough to achieve better results. One of many template matching face detection methods uses Hausdorff distance in order to search the part of the image more similar to a face. Although Hausdorff distance involves very accurate results and low error rates, overall robustness can be increased if we adapt it to our concrete application. In this paper we show how to adjust Hausdorff metrics to face detection systems, presenting a scale-normalized Hausdorff distance based face detection system. Experiments show that our approach can perform an accurate face detection even with complex background or varying light conditions.

1 Introduction

Several human machine interface systems and biometric applications need to be built over a reliable face detection system. Results of these applications will not be robust enough to be useful if a correct face localization is not performed; an automated system will not be able to fully recognize a facial expression, for instance, if this fundamental step is not correct and some essential information such as eyebrows position or upper face wrinkles are not properly recognized. However, although face detection significance, several complex systems avoid this step, due to the fact that their designers consider that is not so important, and manual techniques are used to know in a quite simple way where a face is in an image [11].

Recent research surveys [1] reveal the existence of several simplified facial detection systems that could be useful as a first step of more complex systems. These systems are based on *face localization* [2], that aims to determine the image position of a single face, with the assumption that the input image only includes one.

In the case of face localization, these surveys [1] indicate that the method based on template matching and Hausdorff distance is one of the most robust.

C. Bento, A. Cardoso, and G. Dias (Eds.): EPIA 2005, LNAI 3808, pp. 76–86, 2005.

In template matching approaches, a standard face pattern (usually frontal) is predefined, and the part of the image more similar to this pattern is searched in an image, by correlation. In [3], Jesorsky et al. describe a face localization system based on template matching, using Hausdorff distance to calculate correlation. Their method allows to find a face in an image at different scales, and gives better detection results that other face detction systems ysing differente distance metrics. However, results of this proposal and related ones are strongly affected if complex backgrounds are present. Other approaches are based on previous steps before using Hausdorff metrics, like skin color segmentation [8], but using color images is not always possible.

In this work, we present an improved face detection system based on a scale-normalized Hausdorff distance and template matching. We have chosen a face localization method because we will use it as a first step of a more complex facial expression recognition system. In section 2, we define Hausdorff distance metrics and how it can be used to find objects in an image. Then, in section 3, we explain how our face detection system works, remarking changes we have made to improve it. Finally, in section 4 we show some experimental results.

2 Hausdorff Distance for Template Matching

Hausdorff distance is a technique for comparing sets of points; for each point of a model set, it measures how near they lie from any point of another image set and vice versa. It is used in pattern recognition to determine the degree of resemblance between two objects ([4],[5]).

Hausdorff distance can be defined as the maximum distance from a point set to the nearest point in other point set. If $A = \{a_1, ..., a_m\}$ and $B = \{b_1, ..., b_n\}$ are two point sets, the Hausdorff distance between A and B is defined as

$$H(A, B) = \max(h(A, B), h(B, A)) \tag{1}$$

where

$$h(A, B) = \max_{a \epsilon A} \min_{b \epsilon B} \|a - b\| \tag{2}$$

is called the *directed Hausdorff distance* from set A to set B with some underlying norm $\| \cdot \|$ on the points of A and B, and

$$h(B, A) = \max_{b \epsilon B} \min_{a \epsilon A} \|b - a\| \tag{3}$$

is called the *reverse Hausdorff distance.* As we can see, Haussdorff distance is not symmetric. It gives an interesting measure of the mutual proximity of two set of points, by indicating the maximal distance between any point of one set to other set.

Two main problems exist when we use Hausdorff distance for image processing: scale (which will be discussed in section 3) and outlier points. The experiments in [7] have proven that outlier points effect can be reduced using an