Access Control Based on Visual Face Recognition using Depth Spatiograms of Local Quantized Patterns

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Abstract—**A novel and robust biometric face identification algorithm for access control applications is proposed. The key contribution is the design of a high discriminative feature descriptor for depth imagery, called Depth Spatiogram of Local Quantized Patterns, which is used as input of a bank of Support Vector Machine classifiers.**

I. Introduction

A new generation of robust access control systems has emerged thanks to the development of new and affordable range sensors, which are able to provide highly discriminative information about the human faces, and subsequently about the people identities. Range (or depth) imagery has two main advantages for the characterization of human faces compared to color imagery: richer structural information, and a natural robustness against the variations of the illumination conditions.

Most works that deal with depth imagery use the same feature extraction techniques (or with slight variations) as those in color imagery for human face characterization: Scale Invariant Feature Transform (SIFT) [1], Histograms of Oriented Gradients (HOG) [2], and Local Binary Pattern (LBP) [3]. There are also some proposals specific to depth imagery [4] that combine depth and normal facial information. However, all the previous approaches have in common that they do not exploit all characteristics of the depth imagery, potentially losing discriminative capability for the face recognition task.

In this paper, a robust access control system based on face recognition using depth imagery is proposed. The key contribution is the design of a novel feature descriptor, called Depth Spatial Local Quantized Pattern descriptor (DS-LQP), which fully exploits the characteristics of depth imagery. The DS-LQP is inspired in the LBP, but it introduces two novelties: the adaptive quantification of the depth data, and the explicit introduction of spatial information by means of a quantized spatial histogram (spatiogram). Both of them increase the capacity of distinguishing depth patterns. The proposed DS-LQP is used as input of a bank of Support Vector Machine (SVM) classifiers [5] that recognize people faces (identities), allowing or not the people access to a restricted area.

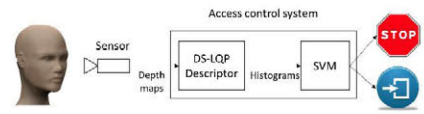

Fig. 1. Block diagram of the access control application.

The main contributions are: a quantification step adapted to depth information, and the inclusion of spatial information in the final computed feature vector.

II. System description

In Fig. 1, a block diagram of the access control system is presented. When someone is close to the camera, a sequence of his/her face is acquired by the depth sensor, and a DS-LQP descriptor is computed for each face image. Finally, a bank of SVM classifiers with a one-vs-all configuration have been used for the recognition purpose. A Hellinger kernel, more commonly known as Bhattacharyya distance, is applied to improve the SVM performance. Condition to the recognition result, the decision to allow or deny the access is taken.

III. DS-LQP descriptor

Inspired by the success of the LBP in recognizing human faces in color imagery, a novel descriptor called DS-LQP has been designed to boost the recognition performance in depth imagery. The computation of the DS-LQP can be divided into 3 stages (see Fig. 2): quantification of local depth differences, computation of histograms of quantized codes, and computation of spatiograms of bins of quantized codes. The first stage computes the differences between a pixel of

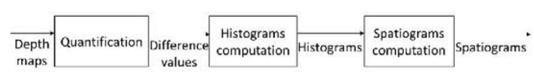

Fig. 2. Stages of the DS-LQP descriptor.

the depth map and 4 neighbor pixels (west, north, east, and south). The resulting differences have the advantage that are independent of the specific distance between the sensor and the human faces, favoring the robustness to depth changes. The differences are then quantified using a uniform scheme with 8 intervals that only considers a depth sub-range of $[-35, 35]$

mm. This sub-range is adapted to the sensor characteristics and to the face recognition task in order to retain the most discriminant information about the human faces. The values of the previous parameters are a compromise between the discriminant capacity of the final feature descriptor, and its resulting length, which has implications over the computational cost and memory requirements.

The second stage calculates a binary code by first representing every quantized difference by a binary number, and then stacking the binary numbers from all the neighbors of a pixel. The binary code is converted to a decimal code, called Local Quantized Pattern (LQP), which encodes the depth structure of a pixel neighborhood. Finally, a histogram of LQPs (H-LQP) is computed from all the pixels of the face depth image. The obtained histogram is a compact and efficient representation of a human face, but it discards the global spatial information among the different LQPs, retaining only the local spatial relationships (the own LQPs).

The last stage adds global spatial information to the previous computed histogram to make the final descriptor more discriminative. This task is carried out by computing a histogram of spatial coordinates for each bin of the H-LQP. The procedure is as follows. Given a bin of the H-LQP, a list of spatial coordinates from all the LQPs that contributed to that bin is generated. Then, a histogram is computed, called spatiogram of LQPs, using the previous list of coordinates. The number of bins of this histogram is quantized in 256 intervals using a bi-linear interpolation technique to constraint the length of the resulting final vector. Finally, the spatiograms of LQPs related to every bin of H-LQP are concatenated to form the final super descriptor DS-LQP.

The resulting DS-LQP descriptor has a high discriminative capability thanks to the fact that the proposed design interleaves local and global spatial relationships. For the proposed parameters, the total length of every DS-LQP descriptor is 2^{16}.

IV. Results

The proposed face recognition algorithm, has been tested and compared with other state-of-the-art algorithms using the HRRFaceD depth face database [6]. Each subject has 200 frames, which have been split into training ones, 160, and testing ones, 40 (80% and 20%, respectively).

The proposed algorithm using the DS-LQP descriptor has been compared with a variation of the DS-LQP descriptor, called H-LQP, which does not consider global spatial information, and also with the original LBP-based method [5], and a SIFT-based method [1]. The metrics adopted for the comparision is the accuracy measure:

$$\text{Accuracy} = 100 \times \frac{\text{Total number of correct faces}}{\text{Total number of faces}}. \quad (1)$$

In Table I, the quantitative results using the HRRFaceD database are shown. The subject numbers with an asterisk indicate that the subject can wear, or not, glasses, i.e., there are some images in which the subject is wearing glasses and others do not. The results obtained with the proposed algorithm based

Fig. 3. Different poses of one face.

TABLE I
ACCURACY RESULTS USING THE HRRFACED DATABASE.

Subject	Accuracy (%)			
	DS-LQP	H-LQP	LBP	SIFT
01	100,00	97,50	100,00	57,50
02	85,00	92,50	35,00	90,00
03	85,00	65,00	65,00	82,50
04*	88,75	65,00	96,25	78,75
05	96,25	81,25	96,25	78,75
06*	70,00	82,50	62,50	70,00
07	100,00	92,50	82,50	90,00
08	25,00	7,50	0,00	77,50
09*	100,00	92,50	97,50	90,00
10	80,00	85,00	7,50	82,50
11	32,50	60,00	47,50	60,00
12	82,50	57,50	50,00	27,50
13	85,00	82,50	77,50	82,50
14	77,50	82,50	80,00	87,50
15	82,50	45,00	60,00	42,50
16	100,00	82,50	50,00	85,00
17*	98,75	83,75	57,50	82,50
18	67,50	67,50	0,00	30,00
Mean	80,90	73,47	59,17	71,94

on the DS-LQP descriptor has the best score (around the 80%), outperforming the second best (the SIFT one) in around 9%. These scores are very promising, taken into account the great variability of the face poses (see Fig3), unlike other systems that only accept slight variations of the frontal face.

V. Conclusion

A robust access control system based on the face recognition in depth imagery has been presented in this paper. A novel face descriptor, called DS-LQP, has been designed for depth imagery to increase the recognition performance via a bank of SVM classifiers. Promising classification results have been obtained thanks to the capability of the DS-LQP descriptor to include information about the local and global spatial relationships. Specially remarkable is the fact that those results have been obtained using a database that has faces in different poses, not only frontal ones.

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