Firefly-based Facial Expression Recognition (Extended Abstract)*

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ABSTRACT

Automatic facial expression recognition plays an important role in various application domains such as medical imaging, surveillance and human-robot interaction. This research presents a novel facial expression recognition system with modified Local Binary Patterns (LBP) for feature extraction and a modified firefly algorithm (FA) for feature optimization. First, in order to deal with illumination, scaling and rotation variations, we propose a horizontal, vertical and diagonal neighborhood LBP to extract initial discriminative facial features. Then a modified FA is proposed to reduce the dimensionality of the extracted facial features. This FA variant employs Cauchy and Levy distributions to further mutate the best solution identified by the FA to increase exploration in the search space and avoid premature convergence. The overall system is evaluated using two facial expression databases (i.e. CK+, and MMI). The proposed system outperforms other heuristic search algorithms such as Genetic Algorithm, Particle Swarm Optimization, and other existing state-of-the-art facial expression recognition research, significantly.

Author Keywords: Feature optimization; Facial expression recognition

1. INTRODUCTION

Automatic facial expression recognition has become a new hotspot of AI research and shows great potential in benefiting a wide variety of applications, e.g. personalized healthcare [1], interactive video games [2], human robot interaction [3, 4] and surveillance systems [5]. However, it is still a difficult task to select significant discriminating facial features that could represent the characteristics of each expression because of the subtlety and variation of facial expressions.

In order to deal with the above challenge, this research proposes a facial expression recognition system with a modified Local Binary Patterns (LBP) for discriminative feature extraction and a variant of firefly algorithm (FA) for feature optimization. In order to overcome illumination changes, rotation and scale variations, first of all, a horizontal, vertical and diagonal neighborhood LBP operator is proposed to generate an initial refined facial representation for an input image. Then the FA variant is proposed to reduce feature dimension and identify the most significant discriminative facial features. In order to mitigate premature convergence of the conventional FA, this FA variant employs the Cauchy and Levy distribution to further mutate the most promising solution identified by the FA to enable global exploration in the search space. Finally, multiple classifiers, such as Artificial neural networks (NN), Support Vector Machine (SVM), NN-based ensemble and SVM-based ensemble, are employed to recognize seven emotions including, anger, disgust, happiness, sadness, fear, surprise and neutral. Evaluated with the extended Cohn-Kanade (CK+) [6] and MMI [7] databases, the proposed system outperforms conventional optimization algorithms such as FA, Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and other state-of-the-art facial expression recognition research, significantly. The overall system architecture is shown in Figure 1.

The rest of the paper is organized as follows. Section 2 presents the proposed LBP operator for feature extraction. Section 3 introduces the proposed facial expression system including the FA variant for feature selection and emotion classifiers. Section 4 presents evaluation of the proposed system in comparison with other search methods. Section 5 draws conclusions and identifies future directions.

2. The Proposed Modified LBP Operator for Feature Extraction

In this research, we propose a new LBP operator, i.e. horizontal, vertical and diagonal neighborhood LBP (*hvdnLBP*), in order to improve the discriminative abilities of the original LBP. It is combined with the Gabor filter to produce discriminative facial representations.

In the original LBP [8], the comparison is conducted between center and the neighbouring pixels. Although it possesses great texture extraction capabilities, LBP is less efficient when dealing with images with low contrast ratios. Therefore, this research presents $hvdnLBP$ in order to retrieve the low contrast information among the neighbouring pixels effectively. Specifically, $hvdnLBP$ employs horizontal, vertical and diagonal neighbourhood pixels for comparison. That is, in vertical, horizontal or diagonal comparison, the intensity values of the vertical, horizontal or diagonal neighbouring pixels are compared with one another. $hvdnLBP$ assigns '1' to the pixel with the highest value and '0' to the remaining pixels.

In comparison to conventional LBP, the proposed $hvdnLBP$ operator captures more discriminative contrast information such as corners and edges in the neighborhood. However, both the original and proposed LGBP operators have the disadvantage of high dimensionality, which makes them less efficient in real-time

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applications [9, 10, 11]. In order to deal with such challenge, in this research, we propose a FA variant to conduct feature dimensionality reduction and identify the most discriminative feature subsets to inform subsequent facial expression recognition.

3. Feature Selection and Emotion Recognition

3.1 Feature Selection Using a FA Variant

In this section, we introduce the proposed FA variant for feature selection. FA is originally proposed by Yang [12], which is a swarm intelligence algorithm inspired by natural behaviours of fireflies. FA employs the attraction and attractiveness behaviours of the fireflies to explore the search space and identify optimal solutions. It has efficient local and global search strategies where brightness is linked with objective functions. The following three basic rules are followed by artificial fireflies to conduct search in the search space, i.e. (1) All fireflies are unisex and are attracted towards brighter ones regardless of their sex. (2) The attractiveness of firefly

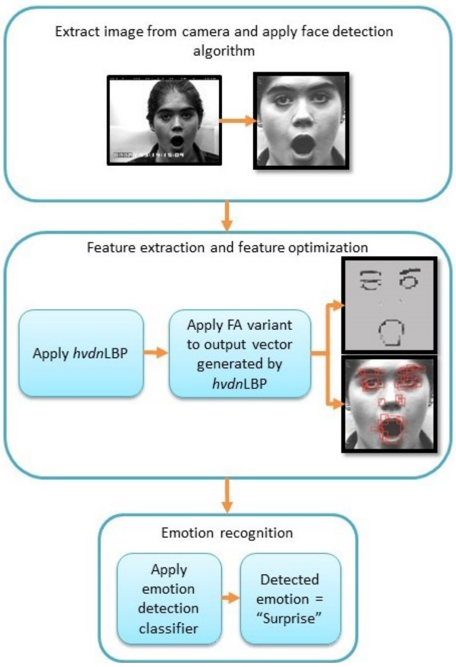

Figure 1. System Architecture

is directly proportional to the brightness of the firefly. Therefore, the less bright firefly will be attracted towards a brighter one. (3) The fitness function defines the brightness (light intensity) of a firefly.

The FA mechanism is very efficient in local search but shows limitations for global exploration [13]. Therefore, two mutation operators, i.e. Cauchy and Levy distributions, are applied in this research to balance between local exploitation and global exploration to mitigate premature convergence of the original FA. Specifically, these mutation techniques are applied to the global best solution identified by the FA to enable long jumps to avoid local optimum trap. The two mutation operators, Cauchy and Levy distributions, are employed since they are widely used random walk mechanisms [14].

The fitness function used to evaluate each firefly consists of two main criteria, i.e. the number of selected features and classification accuracy. It is defined in Equation 1 [15, 16].

$$F(x) = w_a * acc_x + w_f * (number\_feature_x)^{-1} \qquad (1)$$

Where w_a and w_f are two predefined constant weights for classification accuracy and the number of selected features, respectively, with $w_a = 1 - w_f$. In this research, w_a is higher than w_f since we consider classification accuracy is more important than the number of selected features. This FA variant is applied to each expression category to identify its discriminative features to inform emotion recognition.

3.2 Emotion Classification

In this work, diverse classifiers have been employed to detect the seven emotions (i.e. anger, happiness, sadness, surprise, disgust, fear, and neutral). NN, multi-class SVM, and the SVM-based and NN-based ensembles with SVM and NN as base classifiers respectively are employed to conduct emotion classification. The feature subsets retrieved by the FA-based feature selection are used as the inputs to the classifiers.

4. Evaluation

The proposed system has been evaluated using within and cross database evaluation with images extracted from CK+ and MMI databases. First, we compare the proposed *hvdnLBP* operator with the original LBP. Then the proposed FA-based feature selection algorithm is evaluated against the classical search algorithms such as FA, GA and PSO. Single and ensemble classifiers, such as, NN, SVM, and NN-based and SVM-based ensembles, are used for the classification of seven emotions. For all the experiments, a set of 250 images from CK+ is employed for training while a set of 175 images from each of the two databases (i.e. CK+ and MMI) is used for testing.

Since the proposed FA variant, FA, PSO and GA are evolutionary algorithms, due to their randomization characteristics, we perform 30 benchmark runs for each of these algorithms in order to conduct a fair comparison. The average accuracy of the 30 runs of each model is employed for performance comparison. The first experiment conducted uses 250 and 175 images from CK+ for training and testing, respectively. The evaluation results from first experiment show that *hvdn*LBP achieves the highest accuracy of 85.32% and outperforms the original LBP by 14.12%. The proposed FA variant algorithm achieves the best average accuracy of 100% over 30 runs when evaluated with the CK+ database. It also outperforms FA, GA and PSO by 13.05%, 15.95%, and 18.45% respectively. The system also shows promising performance for cross-database evaluation, achieves an average accuracy of 88.00% for the evaluation of MMI over 30 runs, and outperforms FA, GA and PSO by 3.76%, 9.94% and 10.49%, respectively.

5. Conclusion

In this research, we have proposed a facial expression recognition system, which employs *hvdnLBP* operator for feature extraction and a FA variant for feature optimization. Diverse classifiers are used to conduct the recognition of the seven facial expressions. Evaluated using diverse facial expression databases, it shows superior performances in comparison to other classical search methods. The proposed FA algorithm identifies the least number of features and outperforms other conventional search methods such as FA, GA and PSO, significantly. In future work, various hybrid or multi-objective FAs will also be explored for solving optimization problems with multiple criteria.

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