## Title: Shape analysis of local facial patches for 3D facial expression recognition


## Article preview

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# Shape analysis of local facial patches for 3D facial expression recognition
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## Abstract
In this paper we address the problem of 3D facial expression recognition. We propose a local geometric shape analysis of facial surfaces coupled with machine learning techniques for expression classification. A computation of the length of the geodesic path between corresponding patches, using a Riemannian framework, in a shape space provides a quantitative information about their similarities. These measures are then used as inputs to several classification methods. The experimental results demonstrate the effectiveness of the proposed approach. Using multiboosting and support vector machines (SVM) classifiers, we achieved 98.81% and 97.75% recognition average rates, respectively, for recognition of the six prototypical facial expressions on BU-3DFE database. A comparative study using the same experimental setting shows that the suggested approach outperforms previous work.
### Highlights
? We address the 3D facial expression recognition problem using Riemannian geometry. ? We propose local shape analysis of faces coupled with machine-learning techniques. ? A comparative study shows that the suggested approach outperforms previous work.
## Introduction
In recent years, 3D facial expression recognition has received growing attention. It has become an active research topic in computer vision and

pattern recognition community, impacting important applications in fields related to human?machine interaction (e.g., interactive computer games) and psychological research. Increasing attention has been given to 3D acquisition systems due to the natural fascination induced by 3D objects visualization and rendering. In addition 3D data have advantages over the 2D data, in that 3D facial data have high resolution and convey valuable information that overcomes the problem of pose/lighting variations and the detail concealment of low resolution acquisition.

In this paper we present a novel approach for 3D identity-independent facial expression recognition based on a local shape analysis. Unlike the identity recognition task that has been the subject of many papers, only few works have addressed 3D facial expression recognition. This could be explained through the challenge imposed by the demanding security and surveillance requirements. Besides, there has long been a shortage of publicly available 3D facial expression databases that serve the researchers exploring 3D information to understand human behaviors and emotions. The main task is to classify the facial expression of a given 3D model, into one of the six prototypical expressions, namely _Happiness_ , _Anger_ , _Fear_ , _Disgust_ , _Sadness_ and _Surprise_. It is stated that these expressions are universal among human ethnicity as described in [1], [2].

The remainder of this paper is organized as follows. First, a brief overview of related work is presented in Section 2. In Section 3 we describe the BU-3DFE database designed to explore 3D information and improve facial expression recognition. In Section 4, we summarize the shape analysis framework applied earlier for 3D curves matching by Joshi et al. [3], and discuss its use to perform 3D patches analysis. This framework is further expounded in Section 5, so as to define methods for shapes analysis and matching. In Section 6 a description of the feature vector and used classifiers is given. In Section 7, experiments and results of our approach are reported, and the average recognition rate over 97% is achieved using machine-learning algorithms for the recognition of facial expressions such as multiboosting and SVM. Finally, discussion and conclusion are given in Section 8.

## Section snippets

## Related work

Facial expression recognition has been extensively studied over the past decades especially in 2D domain (e.g., images and videos) resulting in a valuable enhancement. Existing approaches that address facial expression recognition can be divided into three categories: (1) _static_ versus _dynamic_ ; (2) _global_ versus _local_ ; (3) _2D_ versus _3D_. Most of the approaches are based on feature extraction/detection as a mean to represent and understand facial expressions. Pantic and Rothkrantz [4] and Samal

## Database description

BU-3DFE is one of the very few publicly available databases of annotated 3D facial expressions, collected by Yin et al. [12] at Binghamton University. It was designed for research on 3D human face and facial expression and to develop a general understanding of the human behavior. Thus the BU-3DFE database is beneficial for several fields and applications dealing with human computer interaction, security, communication, psychology, etc. There are a total of 100 subjects in the database, 56

## 3D facial patches-based representation

Most of the earlier work in 3D shape analysis use shape descriptors such as curvature, crest lines, shape index (e.g., ridge, saddle, rut, dome, etc.). These descriptors are defined based on the geometric and topological properties of the 3D object, and are used as features to simplify the representation and thus the comparison for 3D shape matching and recognition tasks. Despite their rigorous definition, such features are computed based on numerical approximation that involves second

## Framework for 3D shape analysis

Once the patches are extracted, we aim at studying their shape and design a similarity measure between corresponding ones on different scans under different expressions. This is motivated by the common belief that people smile, or convey any other expression, the same way, or more appropriately certain regions taking part in a specific expression undergo practically the same dynamical deformation process. We expect that certain corresponding patches associated with the same given expression

## Feature vector generation for classification

In order to classify expressions, we build a feature vector for each facial scan. Given a candidate facial scan of a person _j_ , facial patches are extracted around facial landmarks. For a facial patch _P_ _j_ _i_ , a set of level curves {c?}ji are extracted centered on the _i_ th landmark. Similarly, a patch _P_ _ref_ _i_ is extracted in correspondence to landmarks of a reference scans _ref_. The length of the geodesic path between each level curve and its corresponding curve on the reference scan is computed using a

## Recognition experiments

To investigate facial expression recognition, we have applied our proposed approach on a dataset that is appropriate for this task. In this section, we describe the experiments, obtained results and comparisons with related work.

## Conclusions

In this paper we presented a novel approach for identity-independent facial expression recognition from 3D facial shapes. Our idea was to describe the change in facial expression as a deformation in the vicinity of facial patches in 3D shape scan. An automatic extraction of local curve-based patches within the 3D facial surfaces was proposed. These patches were used as local shape descriptors for facial expression representation. A Riemannian framework was applied to compute the geodesic path

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## References (20)

* A. Samal _et al._

### Automatic recognition and analysis of human faces and facial expressions: a survey

### Pattern Recognition

(1992)

* P. Ekman, T.S. Huang, T.J. Sejnowski, J.C. Hager, Final report to nsf of the planning workshop on facial expression...
* P. Ekman, W.V. Friesen, Constants Across Cultures in the Face and Emotion,...
* S. Joshi, E. Klassen, A. Srivastava, I.H. Jermyn, A novel representation for Riemannian analysis of elastic curves in...
* M. Pantic _et al._

### Automatic analysis of facial expressions: the state of the art

### IEEE Transactions on Pattern Analysis and Machine Intelligence

(2000)

 * J. Whitehill _et al._
### Local versus global segmentation for facial expression recognition
 * P. Ekman, W. Friesen, Facial Action Coding System: A Technique for the Measurement of Facial Movement,...
 * J. Wang _et al._
### 3D facial expression recognition based on primitive surface feature distribution
 * H. Soyel _et al._
### Facial expression recognition using 3d facial feature distances
 * I. Mpiperis _et al._
### Bilinear models for 3d face and facial expression recognition
### IEEE Transactions on Information Forensics and Security
(2008)
There are more references available in the full text version of this article.
## Cited by (74)
 * ### Facial expression recognition with Convolutional Neural Networks: Coping with few data and the training sample order
2017, Pattern Recognition
Citation Excerpt :
However, in this work, just the 2D image of the subjects are used to recognize the expressions. There are other works in the literature that presents higher facial expression recognition accuracies, but using 3D information to infer the expressions [72?74]. A better evaluation of the proposed method in real environments is the cross-database experiments, i.e. train the method with one database and test with another (in this case the BU-3DFE).
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Facial expression recognition has been an active research area in the past 10 years, with growing application areas including avatar animation, neuromarketing and sociable robots. The recognition of facial expressions is not an easy problem for machine learning methods, since people can vary significantly in the way they show their expressions. Even images of the same person in the same facial expression can vary in brightness, background and pose, and these variations are emphasized if considering different subjects (because of variations in shape, ethnicity among others). Although facial expression recognition is very studied in the literature, few works perform fair evaluation avoiding mixing subjects while training and testing the proposed algorithms. Hence, facial expression recognition is still a challenging problem in computer vision. In this work, we propose a simple solution for facial expression recognition that uses a combination of Convolutional Neural Network and specific image pre-processing steps. Convolutional Neural Networks achieve better accuracy with big data. However, there are no publicly available datasets with sufficient data for facial expression recognition with deep architectures. Therefore, to tackle the problem, we apply some pre-processing techniques to extract only expression specific features from a face image and explore the presentation order of the samples during training. The experiments employed to evaluate our technique were carried out using three largely used public databases (CK+, JAFFE and BU-3DFE). A study of the impact of each image pre-processing operation in the accuracy rate is presented. The proposed method: achieves competitive results when compared with other facial expression recognition methods ? 96.76% of accuracy in the CK+ database ? it is fast to train, and it allows for real time facial expression recognition with standard computers.
 * ### Static and dynamic 3D facial expression recognition: A comprehensive survey
2012, Image and Vision Computing

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One of the main methods of classification that have been employed is Support Vector Machines (SVMs) [110,99,96,68,101,116,109,95,111], including multi-class SVMs [92,117]. Another technique that has been widely used is AdaBoost classification [106,99,101,109] with a selection of different weak classifiers such as linear regressors and LDA. A variation of this is GentleBoost classification, which was employed in [56,57].
Show abstract
Automatic facial expression recognition constitutes an active research field due to the latest advances in computing technology that make the user's experience a clear priority. The majority of work conducted in this area involves 2D imagery, despite the problems this presents due to inherent pose and illumination variations. In order to deal with these problems, 3D and 4D (dynamic 3D) recordings are increasingly used in expression analysis research. In this paper we survey the recent advances in 3D and 4D facial expression recognition. We discuss developments in 3D facial data acquisition and tracking, and present currently available 3D/4D face databases suitable for 3D/4D facial expressions analysis as well as the existing facial expression recognition systems that exploit either 3D or 4D data in detail. Finally, challenges that have to be addressed if 3D facial expression recognition systems are to become a part of future applications are extensively discussed.
 * ### A brief review of facial emotion recognition based on visual information
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2017, IEEE Transactions on Multimedia
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2016, IEEE Transactions on Pattern Analysis and Machine Intelligence
 * ### 3D facial expression recognition using SIFT descriptors of automatically detected keypoints
2011, Visual Computer
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