

# Facial Expression Recognition for HCI Applications

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## INTRODUCTION

**Facial expression** plays an important role in cognition of human emotions (Fasel, 2003 & Yeasin, 2006). The recognition of facial expressions in **image sequences** with significant head movement is a challenging problem. It is required by many applications such as human-computer interaction and computer graphics animation (Cañamero, 2005 & Picard, 2001). To classify expressions in still images many techniques have been proposed such as Neural Nets (Tian, 2001), Gabor wavelets (Bartlett, 2004), and active appearance models (Sung, 2006). Recently, more attention has been given to modeling facial deformation in dynamic scenarios. Still image classifiers use feature vectors related to a single frame to perform classification. **Temporal classifiers** try to capture the temporal pattern in the sequence of feature vectors related to each frame such as the Hidden Markov Model based methods (Cohen, 2003, Black, 1997 & Rabiner, 1989) and Dynamic Bayesian Networks (Zhang, 2005). The main contributions of the paper are as follows. First, we propose an efficient recognition scheme based on the detection of **keyframes** in videos where the recognition is performed using a temporal classifier. Second, we use the proposed method for extending the human-machine interaction functionality of a robot whose response is generated according to the user's recognized facial expression.

Our proposed approach has several advantages. First, unlike most expression recognition systems that require a frontal view of the face, our system is view- and texture-independent. Second, its learning phase is simple compared to other techniques (e.g., the Hidden Markov Models and Active Appearance Models), that is, we only need to fit second-order Auto-Regressive models to sequences of facial actions. As a result, even when the imaging conditions change the learned Auto-Regressive models need not to be recomputed.

The rest of the paper is organized as follows. Section 2 summarizes our developed appearance-based 3D **face tracker** that we use to track the 3D **head pose** as well as the **facial actions**. Section 3 describes the proposed facial expression recognition based on the detection of keyframes. Section 4 provides some experimental results. Section 5 describes the proposed human-machine interaction application that is based on the developed facial expression recognition scheme.

## SIMULTANEOUS HEAD AND FACIAL ACTION TRACKING

In our study, we use the *Candide 3D face model* (Ahlberg, 2001). This 3D deformable wireframe model is given by the 3D coordinates of  $n$  vertices. Thus, the 3D shape can be fully described by the  $3n$ -vector  $\mathbf{g}$  - the concatenation of the 3D coordinates of all vertices. The vector  $\mathbf{g}$  can be written as:

$$\mathbf{g} = \mathbf{g}_s + A\boldsymbol{\tau}_a \quad (1)$$

where  $\mathbf{g}_s$  is the static shape of the model,  $\boldsymbol{\tau}_a$  is the facial action vector, and the columns of  $A$  are the Animation Units. In this study, we use six modes for the facial Animation Units (AUs) matrix  $A$ , that is, the dimension of  $\boldsymbol{\tau}_a$  is 6. These modes are all included in the *Candide* model package. We have chosen the six following AUs: lower lip depressor, lip stretcher, lip corner depressor, upper lip raiser, eyebrow lowerer and outer eyebrow raiser. A cornerstone problem in **facial expression** recognition is the ability to track the local **facial actions**/deformations. In our work, we track the head and facial actions using our **face tracker** (Dornaika & Davoine, 2006). This appearance-based tracker simultaneously computes the 3D **head pose** and the **facial actions**  $\boldsymbol{\tau}_a$  by minimizing a distance between

the incoming warped frame and the current appearance of the face. Since the **facial actions**, encoded by the vector  $\tau_a$ , are highly correlated to the facial expressions, their time series representation can be utilized for inferring the facial expression in videos. This will be explained in the sequel.

## EFFICIENT FACIAL EXPRESSION DETECTION AND RECOGNITION

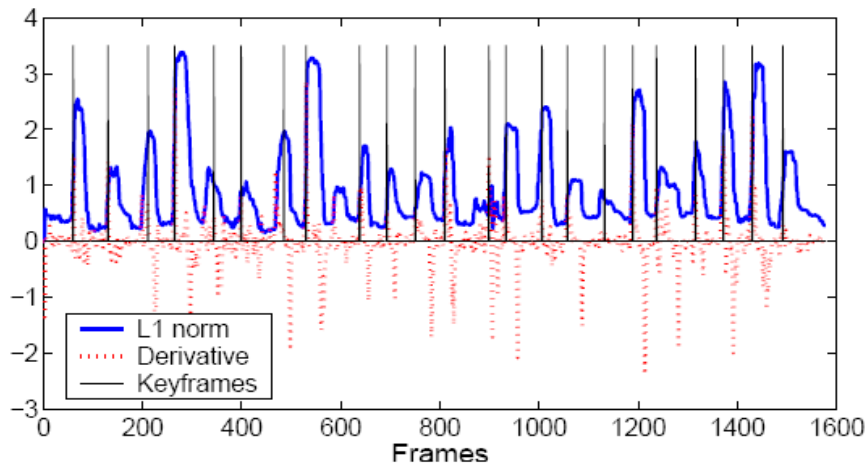
In (Dornaika & Raducanu, 2006), we have proposed a **facial expression** recognition method that is based on the time-series representation of the tracked facial actions  $\tau_a$ . An analysis-synthesis scheme based on learned auto-regressive models was proposed. In this paper, we introduce a process able to detect **keyframes**

in videos. Once a keyframe is detected, the temporal recognition scheme described in (Dornaika & Raducanu, 2006) will be invoked on the detected keyframe. The proposed scheme has two advantages. First, the CPU time corresponding to the recognition part will be considerably reduced since only few keyframes are considered. Second, since a **keyframe** and its neighbor frames are characterizing the expression, the discrimination performance of the recognition scheme will be boosted. In our case, the keyframes are defined by the frames where the **facial actions** change abruptly. Thus, a keyframe can be detected by looking for a local positive maximum in the temporal derivatives of the facial actions. To this end, two entities will be computed from the sequence of facial actions  $\tau_a$  that arrive in a sequential fashion: (i) the  $L_1$  norm  $\|\tau_a\|_1$ , and (ii) the temporal derivative given by:

Figure 1. Efficient facial expression detection and recognition based on keyframes



Figure 2. Keyframe detection and recognition applied on a 1600-frame sequence



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