

In the 19th century, one of the significant works on facial expression analysis that has a straight association to the current state-of-the-art in automatic facial expression recognition was the effort made by Charles Darwin, who, in 1872, wrote a dissertation that recognized the general values of expression and the incomes of expressions in both humans and animals [6]. Darwin grouped several kinds of terms into similar groups. The classification is as follows:

- low spirits, anxiety, grief, dejection and despair;
- joy, high spirits, love, tender feelings and devotion;
- reflection, meditation, ill-temper and sulkiness;
- hatred and anger;
- disdain, contempt, disgust, guilt and pride;
- surprise, astonishment, fear and horror;
- self-attention, shame, shyness and modesty.

Darwin also classified the facial distortions that happen for each of the above-stated classes of expressions. For example, “the constriction of the muscles around the eyes when in sorrow”, “the stiff closure of the mouth when in contemplation”, and so forth [6]. Another considerable landmark in the researching of facial expressions and human emotions has been the work of Paul Ekman and his colleagues since the 1970s. Their work has had a massive effect on state-of-the-art automatic facial expression recognizer development.

The earliest study of facial expression automatic recognition was realized in 1978 by Suwa et al. [7], who generated a model for studying facial expressions from a sequence of pictures by employing 20 tracking arguments. Research was conducted until the end of the 1980s and early 1990s, when the economy’s computing power on-the-go became available. This helped to grow face-detection and face-tracking algorithms in the early 1990s. At the same time, human–computer interaction (HCI) and affective computing (AC) research began [4].

Paul Ekman and his colleagues classified the basic emotions, and their work has had a significant impact on the current emotion analysis development [8]. Emotional state analysis is most likely a psychology field. However, as a result of more and more computing methods being successfully used in this area, it has been merged into a computing topic with the new name of AC [9]. Signal and image processing and pattern recognition methods deliver a fundamental role for efficient computing. Firstly, the emotional state of a person can be detected from their facial expression, speech and body gestures by imaging systems. Secondly, the features can be extracted from these recordings on the basis of signal and image processing methods. Finally, advanced pattern recognition methods are applied to recognize the emotional states.

As far as is known, this is the first time that automatic emotional state detection has been successfully implemented on an embedded device (the field-programmable gate array—FPGA). The proposed system is 20 times faster than the Graphics Processing Unit (GPU) implementation [10] and can analyze 30 frames per second in real-time. In this paper, the technique’s implementation and the evaluation of both results are presented. The system is able to display the real-time and automatic emotional state detection model on the connected monitor.

## 2. Related Work

In contemporary psychology, affect is known as the experience of sensation or emotion as different from thought, belief, or action. Therefore, emotion is the sense that a person feels, while affect is in terms of state. Scherer defines emotion as the outcome of reaction synchronization whose output corresponds to an event that is “relevant to the major concerns of the organism” [11]. Emotion is different from mood in that the former has a strong and clear attention while the latter is unclear, can appear without reason, and can lack severity. Psychologists perceive moods as “diffuse affect states, characterized by a relative enduring predominance of certain types of subjective feelings that affect the experience and behaviour of a person” [11]. Moods may carry for hours or days; as a result of people’s characters and affect natures, some people practice some moods more often than others [11].

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