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].

Consequently it is more problematic to measure situations of mood. On the other hand, emotion is a quantifiable element because of its separate nature.

Primary attempts to measure and classify feeling through the perception of facial expressions has revealed that feelings are not the result of the retraction of only one muscle; nonetheless particular sets of muscles cause facial expressions to reveal these feelings. In 1872, Darwin postulated on his original work that facial expressions in people were the result of improvements and that: "The study of expression is difficult, owing to the movements (of facial muscles) being often extremely slight, and of a fleeting nature" [12]. Notwithstanding this test, early efforts to measure emotions on the basis of facial expressions in adults and infants were realized. Initial research on undesirable emotional states has proved that particular features of the eyelids and eyebrows, which Darwin called "the grief-muscles", agree in that "oblique position in persons suffering from deep dejection or anxiety" [12]. However, scientists during the 19th century were faced with challenges to separate emotional states, recognizing distinctions between perceptions and intentions. "A difference may be clearly perceived, and yet it may be impossible, at least I have found it so, to state in what the difference consists" [12]. Darwin considered general facial muscles, which were involved in each of the emotions' state (Table 1).

Table 1. Descriptions of facial muscles involved in the emotions Darwin considered universal [12].

Emotion	Darwin's Facial Description
Fear	Eyes open Mouth open Lips retracted Eyebrows raised
Anger	Eyes wide open Mouth compressed Nostrils raised
Disgust	Mouth open Lower lip down Upper lip raised
Contempt	Turn away eyes Upper lip raised Lip protrusion Nose wrinkle
Happiness	Eyes sparkle Mouth drawn back at corners Skin under eyes wrinkled
Surprise	Eyes open Mouth open Eyebrows raised Lips protruded
Sadness	Corner of mouth depressed Inner corner of eyebrows raised
Joy	Upper lip raised Nose labial fold formed Orbicularis Zygomatic

Significant improvements have been completed in the measurement of individual elements of emotion. Ekman's Facial Action Coding System (FACS) [13] relates the observation of particular muscle contractions of the face with emotions. Scherer et al. measured emotions using an assessment of defined components [14]; Davidson et al. published comprehensive studies on the relation between brain physiology and emotional expressions [15]; Stemmler's studies determined and revealed physiological reaction outlines [16]; Harrigan et al. carried out an appraisal and measured adequate behaviour [17];

and Fontaine et al. presented that in order to demonstrate the six components of feelings, at least four dimensions are needed [14]. These studies demonstrate that although emotions are various and multifaceted, and also often problematic to classify, they present themselves via designs that "in principle can be operationalized and measured empirically" [11]. The difficulty of classifying these patterns is what drives research in emotional computing. In the last 20 years, the majority of the study in this area has been into enabling processors and computers to declare and identify affect [9]. Progress made in emotional computing has not only assisted its own research field, but also benefits practical domains such as computer interaction. Emotional computing research develops computer interaction by generating computers to improve services the user desires. Meanwhile, it has also allowed humans to perceive computers as something more than merely data machines. Upgrading computer interaction over emotional computing studies has various benefits, from diminishing human users' frustration to assisting machines' familiarization with their human users by allowing the communication of user feeling [9]. Emotional computing enables machines to become allied operative systems as socially sagacious factors [18].

This helped in the early 1990s [7] to grow face-detection [19] and -tracking results in HCI and AC [9] evolution. The emotions of the user could be detected using advanced pattern recognition algorithms from extracted images (facial expression, gestures, etc.) or audio (speech) features. Recently, Cambridge University introduced the emotional computer [20] and the MIT (Massachusetts Institute of Technology) Mood Meter [21] From 2011, these have participated in several international emotion recognition challenges, such as AVEC (Audio/Visual Emotion Challenge) or MediaEval (Benchmarking Initiative for Multimedia Evaluation) [22,23].

In 2013, Cheng, J., et al. [10] proposed the GP-GPU (General Purpose - Graphics Processing Unit) acceleration service for continuous face- and emotion-detection systems. Promising results were achieved for the real-world scenario of continuous movie scene monitoring. The system was initially tested in MATLAB. It was proven that the GPU acceleration could speed up the processing 80-fold compared to the CPU (Central Processing Unit). This system can provide the detected emotional state every 1.5 s.

In 2015, the Microsoft Oxford API (Application Programming Interface) cloud service provided the recognition of emotions on the basis of facial expressions [24]. This API provides the confidence across a set of emotions for each face in the image, as well as bounding box for the face. The emotions detected are anger, contempt, disgust, fear, happiness, neutrality, sadness, and surprise. These emotions are understood to be cross-culturally and universally communicated with facial expressions. Recognition is experimental and is not always accurate [24]. Recently, fuzzy support vector machines (SVMs) and feed-forward neural networks together with a stationary wavelet entropy approach were investigated, producing results of around 96% accuracy on stationary images [25,26].

Several tools have been developed to record perceived emotions as specified by the four emotional dimensions. FeelTrace is a tool created on a two-dimensional space (activation and evaluation), which allows an observer to "track the emotional content of a stimulus as they perceive it over time" [27]. This tool offers the two emotional dimensions as a rounded area on a computer screen. Human users of FeelTrace observe a stimulus (e.g., watching a program on TV, listening to an affective melody or the display of strong emotions) and move a mouse cursor to a place within the circle of the emotional area to label how they realize the incentive as time continues. The measurement of time is demonstrated indirectly by tracing the position at which the mouse is in the circle with time measured in milliseconds. Arrangements using the FeelTrace classification were used to create the labels in the testing described in this paper. In Figure 1 is an example of a FeelTrace exhibition while following a session. The color-coding arrangement allows users to label the extensity of their emotion. Pure red represents the most negative assessment in the activation (very active) dimension; pure green represents when the user is feeling the most positive evaluation in the activation dimension (very passive). FeelTrace allows its users to produce annotations of how they observe specific stimuli at