Related work:

**Methodology:**

In order to analyze human emotion, a great deal of research has been done. As we already know that there are plenty of ways to recognize emotion, but as we are working with emotion recognition with facial expression, we will review the works related to that. But first we have to make a general model to describe the system of emotion recognition by facial expression.

Pre-process

Face

Detection

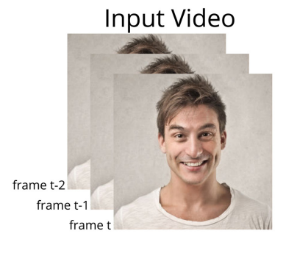
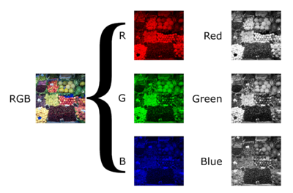
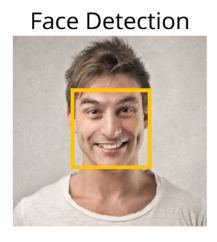
Input

Image/Video

Feature

Extraction

Classification



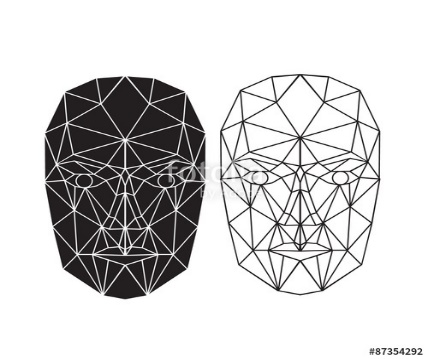
Feature

Extraction

Classification

Feature

Selection



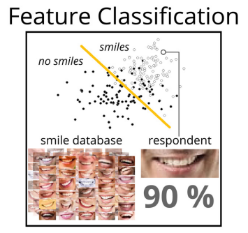


Fig: General mode of emotion recognition system based on facial expressions

As this is a model of a general emotion recognition system, it describes the flow of the processes. First a video sequence or still image a fed to the system. Then it does some pre-processing like extracting frames from the video or down sample the images. Now the processes images is used for face detection. There are a bunch of algorithms to find the human face in a picture, among them one or some combination of algorithms are used. After detecting the face, there comes the feature sets. A face contains different sets of features but most of the time only one type of feature set is used. After selecting or defining a feature set, some algorithm is used to extract the features from the face. Before calling the classification algorithm with the created feature vector, sometimes an optimization algorithm is ran to reduce the size of the feature set. Finally the classification is done based on the feature vector. This is the most basic work flow which can be found in many research papers [12, 20, 21, 17, 5]

**Dataset:**

The field of emotion recognition with facial expression is becoming popular and so a number of recognized datasets are available for research purposes.

One of the most popular database is Extended Cohn-Kanade Dataset (CK+) [22]. There are 593 sequences of image frame from neutral to the pick level of an emotion. It deals with the 8 basic emotions which are neutral, sadness, surprise, happiness, fear, anger, contempt and disgust. Another point to be noted, most of the images are gray scaled.

Another popular dataset is Japanese Female Facial Expressions (JAFFE) [23]. It has 213 static images which are gray scaled. It contains 7 basic emotions which are neutral, sadness, surprise, happiness, fear, anger, and disgust.

MMI Database [24] has both videos and still images. To be specific it has 1280 videos and more than 250 still images. Interestingly this database contains colored images and video.

The above stated datasets are highly used. But there are still many other datasets like DISFA [25], Multimedia Understanding Group (MUG) [26], Indian Spontaneous Expression Database (ISED) [27], AffectNet [28], FERG (Facial Expression Research Group Database) [29], Belfast Database [30] are used in different research related to emotion recognition system.

**Face Detection:**

**Feature Selection:**

First of all we should mention Facial Action Coding System (FACS) which was originally developed by Swedish anatomist named Carl-Herman Hjortsjö. [10] Then later developed by Ekman and Friesen in 1978. [11] Facial Action Coding System (FACS) is a system to taxonomies human facial movements from their appearance on the face.

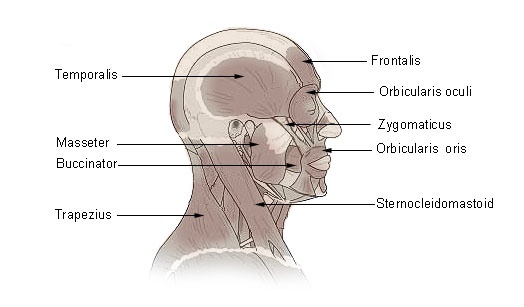
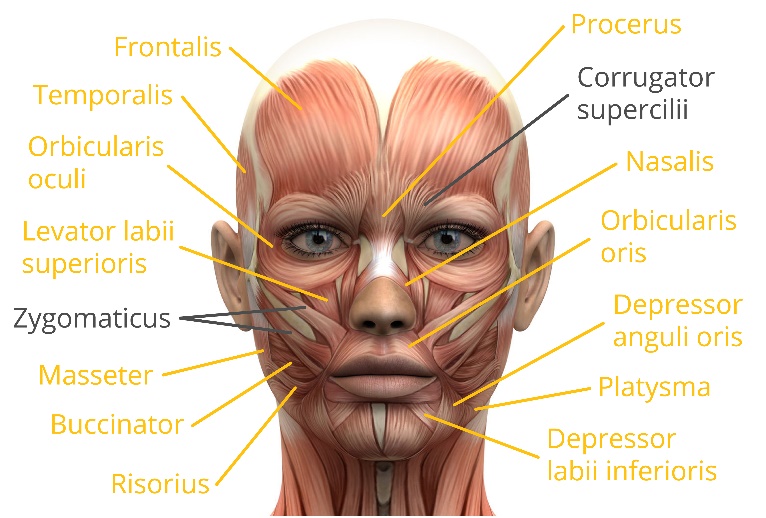


Fig: Facial muscles related to Action Units [17, 18]

FACS defines some Action Units (AUs), which actually refers to the contraction and relaxation of one or more facial muscles.

As an illustration, FACS can classify two types of smiles. [13] Insincere and voluntary Pan-Am smile which is contraction of zygomatic major alone. And another is sincere and involuntary Duchenne smile which is made by contraction of zygomatic major and inferior part of orbicularis oculi. So far this FACS system is being automated and giving promising results. That’s why recently FACS has been proposed for use in analysis of depression. [14]

EMFACS (Emotional Facial Action Coding System) [15] and FACSAID (Facial Action Coding System Affect Interpretation Dictionary) [16] has given a relation between basic human expression and Action Units (AUs).

| **Emotion** | **Action units** |
| --- | --- |
| Happiness | 6+12 |
| Sadness | 1+4+15 |
| Surprise | 1+2+5B+26 |
| Fear | 1+2+4+5+7+20+26 |
| Anger | 4+5+7+23 |
| Disgust | 9+15+16 |
| Contempt | R12A+R14A |

Fig: Action unit and emotion map

The action unit numbers are given in the table. With the number sometimes a letter is associated. Which are A for Trace, B for Slight, C for Marked, D for extreme and E for Maximum. “R” represents an action which occurred on the right side of the face and “L” indicates the left side.

| **AU number** | **FACS name** | **Muscular basis** |
| --- | --- | --- |
| 0 | Neutral face |  |
| 1 | Inner brow raiser | [frontalis](https://en.wikipedia.org/wiki/Frontalis_muscle) ([pars medialis](https://en.wikipedia.org/wiki/Pars_medialis)) |
| 2 | Outer brow raiser | [frontalis](https://en.wikipedia.org/wiki/Frontalis_muscle) ([pars lateralis](https://en.wikipedia.org/wiki/Pars_lateralis)) |
| 4 | Brow lowerer | [depressor glabellae](https://en.wikipedia.org/wiki/Depressor_glabellae), [depressor supercilii](https://en.wikipedia.org/wiki/Depressor_supercilii), [corrugator supercilii](https://en.wikipedia.org/wiki/Corrugator_supercilii) |
| 5 | Upper lid raiser | [levator palpebrae superioris](https://en.wikipedia.org/wiki/Levator_palpebrae_superioris), [superior tarsal muscle](https://en.wikipedia.org/wiki/Superior_tarsal_muscle) |
| 6 | Cheek raiser | [orbicularis oculi](https://en.wikipedia.org/wiki/Orbicularis_oculi) ([pars orbitalis](https://en.wikipedia.org/wiki/Orbital_part_of_frontal_bone)) |
| 7 | Lid tightener | [orbicularis oculi](https://en.wikipedia.org/wiki/Orbicularis_oculi) ([pars palpebralis](https://en.wikipedia.org/wiki/Pars_palpebralis)) |
| 8 | Lips toward each other | [orbicularis oris](https://en.wikipedia.org/wiki/Orbicularis_oris) |
| 9 | Nose wrinkler | [levator labii superioris alaeque nasi](https://en.wikipedia.org/wiki/Levator_labii_superioris_alaeque_nasi) |
| 10 | Upper lip raiser | [levator labii superioris](https://en.wikipedia.org/wiki/Levator_labii_superioris), [caput infraorbitalis](https://en.wikipedia.org/wiki/Levator_labii_superioris) |
| 11 | Nasolabial deepener | [zygomaticus minor](https://en.wikipedia.org/wiki/Zygomaticus_minor) |
| 12 | Lip corner puller | [zygomaticus major](https://en.wikipedia.org/wiki/Zygomaticus_major) |
| 13 | Sharp lip puller | [levator anguli oris](https://en.wikipedia.org/wiki/Levator_anguli_oris) (also known as [caninus](https://en.wikipedia.org/wiki/Caninus)) |
| 14 | Dimpler | [buccinator](https://en.wikipedia.org/wiki/Buccinator) |
| 15 | Lip corner depressor | [depressor anguli oris](https://en.wikipedia.org/wiki/Depressor_anguli_oris) (also known as [triangularis](https://en.wikipedia.org/wiki/Triangularis)) |
| 16 | Lower lip depressor | depressor labii inferioris |
| 17 | Chin raiser | [mentalis](https://en.wikipedia.org/wiki/Mentalis) |
| 18 | Lip pucker | [incisivii labii superioris](https://en.wikipedia.org/wiki/Incisivii_labii_superioris) and [incisivii labii inferioris](https://en.wikipedia.org/wiki/Incisivii_labii_inferioris) |
| 19 | Tongue show |  |
| 20 | Lip stretcher | [risorius](https://en.wikipedia.org/wiki/Risorius) w/ [platysma](https://en.wikipedia.org/wiki/Platysma) |
| 21 | Neck tightener | [platysma](https://en.wikipedia.org/wiki/Platysma) |
| 22 | Lip funneler | [orbicularis oris](https://en.wikipedia.org/wiki/Orbicularis_oris) |
| 23 | Lip tightener | [orbicularis oris](https://en.wikipedia.org/wiki/Orbicularis_oris) |
| 24 | Lip pressor | [orbicularis oris](https://en.wikipedia.org/wiki/Orbicularis_oris) |
| 25 | Lips part | [depressor labii inferioris](https://en.wikipedia.org/wiki/Depressor_labii_inferioris), or relaxation of [mentalis](https://en.wikipedia.org/wiki/Mentalis) or [orbicularis oris](https://en.wikipedia.org/wiki/Orbicularis_oris) |
| 26 | Jaw drop | [masseter](https://en.wikipedia.org/wiki/Masseter); relaxed [temporalis](https://en.wikipedia.org/wiki/Temporalis) and [internal pterygoid](https://en.wikipedia.org/wiki/Medial_pterygoid_muscle) |
| 27 | Mouth stretch | [pterygoids](https://en.wikipedia.org/wiki/Pterygoid_bone), [digastric](https://en.wikipedia.org/wiki/Digastric) |
| 28 | Lip suck | [orbicularis oris](https://en.wikipedia.org/wiki/Orbicularis_oris) |

Fig: List of Action units and corresponding facial muscle

If we look in the table we will see that Happiness consists of Action Unit 6 and 12. That means when cheek is raised and lip corner is pulled, the face will be classified as a happy face according to the FACS. Sometime 25 no. action unit is also associated with a smile which represents a happy face [18].

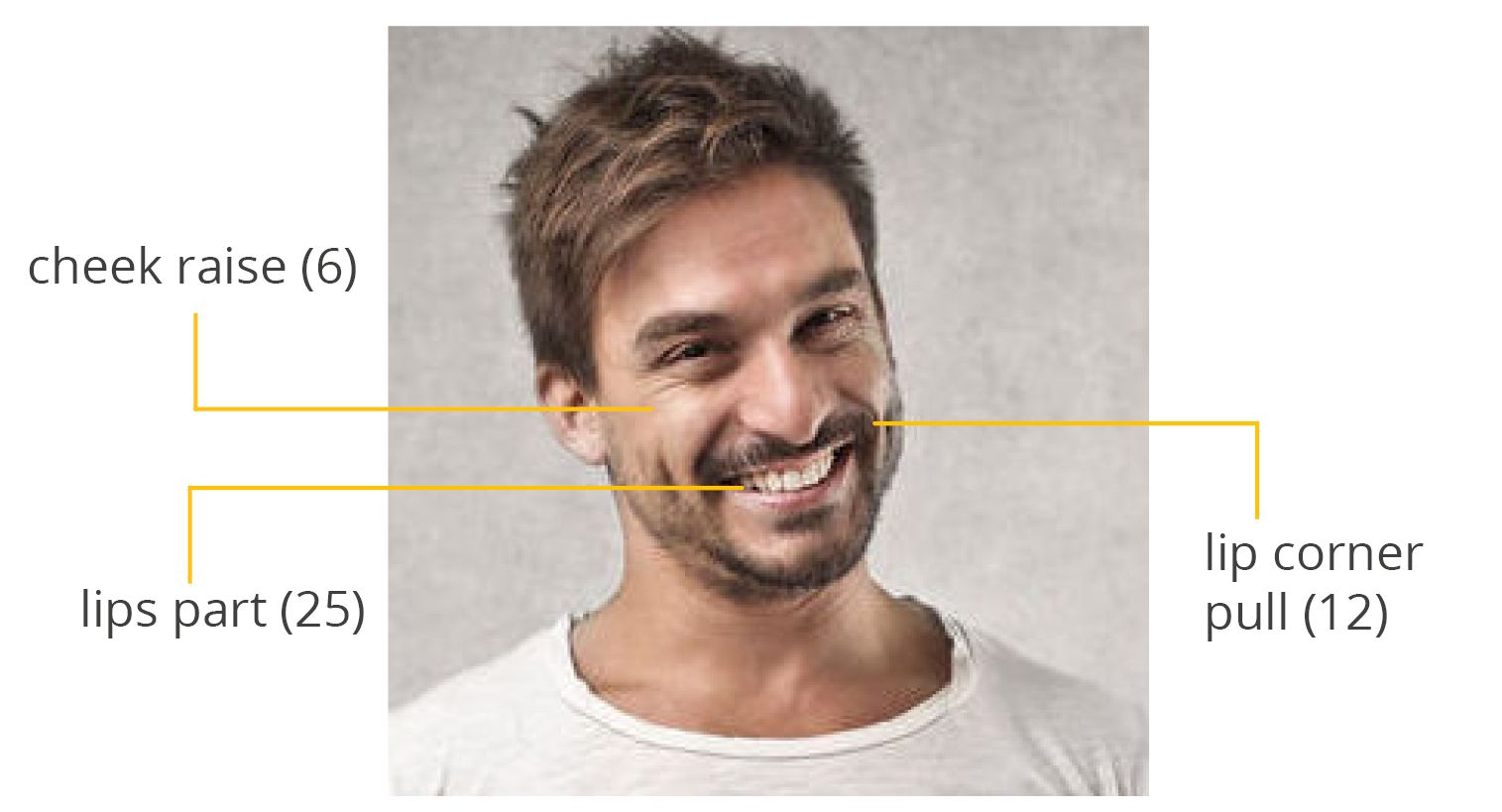


Fig: Pointing out the AUs of a happy face[18]

**Feature Extraction and Classification:**

One of the significant method is used in facial expression recognition is Gabor coding which mainly extract features from static images. This is done by using multi-oriented, multi-resolution set of Gabor filters. Gabor filters are topographically ordered and aligned approximately with face. [19] The combination of Gabor filter banks based facial expression coding which is used for feature extraction and multilayer perceptron (MLP) which is used for feature classification, reported to have better performance than geometric feature based facial expression recognition. Again there is a substitution for MLP. Learning vector quantization (LVQ) can also be used to classify the features. And there is a comparison between MLP and LVQ in [20]. In addition to this Principle component analysis (PCA) can be used to reduce the length of feature vector. PCA is a liner transformation which is commonly sued to simplify a data set by reducing multidimensional data set to lower dimensions. [20].