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Facial Expressions can be Modelled Mathematically

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Summary: Facial expressions provide crucial information about an individual's internal mood state, but are difficult to quantify. We report the development of a mathematical method for measuring facial expressions, using photographs and a specially designed computer programme.

Facial expression is a particularly important indicator of a person's emotional state, and the existence of certain universally recognized expressions such as happiness, anger, sadness, fear, surprise and disgust (Ekman *et al*, 1969) suggests that they may be of fundamental biological significance. This possibility, as well as the obvious value to behavioural scientists of a method for quantifying facial emotions has led to a renewed interest in an area relatively neglected since Darwin's day (Ekman and Oster, 1979; Ekman, 1973; Gilman, 1979). The most recent approach is that developed by Ekman and Friesen (1976) known as the Facial Action Coding System, which uses units based on the visible actions of facial muscles assessed by trained raters.

We report a mathematical approach which makes possible the quantification of facial expressions (using photographs) and demonstrate its application to emotions along the happiness-sadness dimension. The essence of the method has been to develop a mathematical representation, or model, of the key facial muscle actions which subserve facial expression. Thus each group of muscles whose activity produces a particular action can for mathematical purposes be regarded as a single muscle. For example, the muscle group which elevates the corner of the mouth is the risorius plus the zygomaticus major. In order to simplify the task, we have begun by attempting to model expressions along the happiness-sadness dimension, using photographs (Ekman and Friesen, 1975) of an actor presenting relevant expressions, but we believe the approach can be applied to all other expressions, including those which do not have an obvious opposite.

To define the chosen axis, we have used the generally accepted facial configurations of extreme happiness and extreme sadness (Ekman and Friesen, 1975). Between these two extremes an expression is chosen as an arbitrary neutral expression, which then serves as a reference point.

A model of the expression-forming process has been developed which can generate different expressions from the reference neutral expression. The model is controlled by muscle groups so that the generated face is matched to a photograph of the expression to be scaled. The scale value on the particular expression axis is then obtained as a function of the activation of the muscle groups.

Methods

A photograph of an actor was used to provide a neutral expression as a starting point. Such a photograph contains far more information than is needed for the scaling procedure, and it is quite adequate to reduce the expression to a simple line drawing based on the location of about sixty key points on the face. An automatic computer graphic procedure was used to construct a line drawing by joining the key points with smooth curves. Once the locations of these points have been defined in terms of facial features it is a straightforward procedure to obtain the desired input data.

In terms of our model the muscle groups act on about 10 selected points in the line drawing. Each group has a fixed point of attachment and a variable point which moves toward the fixed point when the group is activated. For example, the group referred to earlier, whose function is to elevate the corner of the mouth, is regarded as a straight line which extends from the ear lobe to the angle of the mouth. When contracted it moves the angle of the mouth towards the ear.

The procedure as described, is adequate for modelling expressions close to the neutral expression. However, for more extreme expressions, the fact that points on the surface of the face are connected by skin needs to be taken into account. This is achieved in the model by introducing interactions between points via links, resulting in a good approximation to the effect of real skin. For example, the narrowing of the palpebral fissure with smiling has been simulated by this method (Fig 1).

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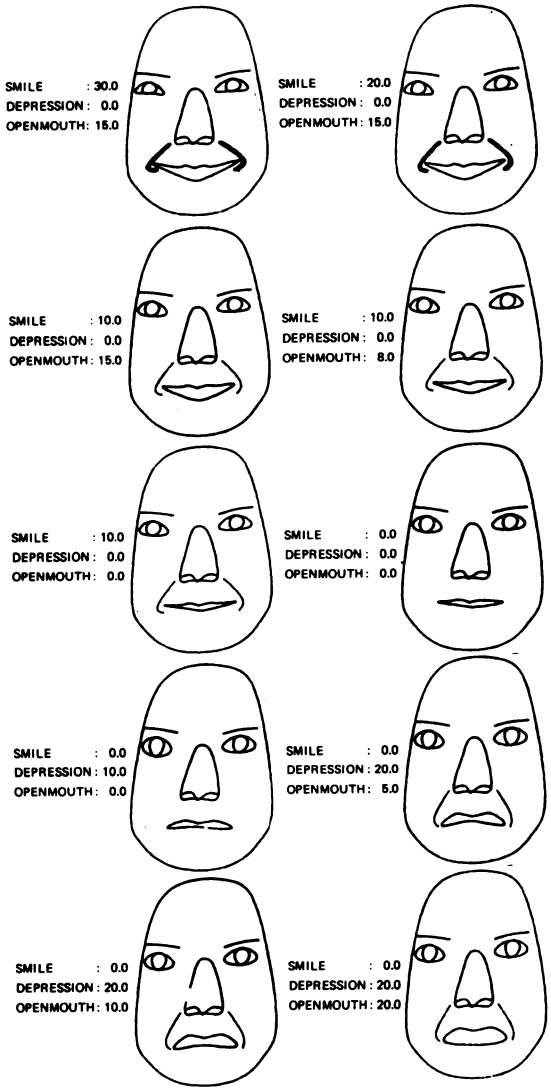


FIG 1.—Mathematically modelled facial expressions as presented on graphics display screen. (The expressions have been combined for convenience. They are normally displayed individually).

In this manner, the system can provide, from a given neutral face, expressions together with information on muscle group activity and scores indicating the location of the expression on one or more emotion axes. The line drawings show a sequence of expressions generated by the model from the neutral expression (Fig 1) together with their scale values.

While the model is sensitive to the exact locations of certain key positions, such as the corner of the mouth, these are the most easily located when a face is analysed, i.e. when a photograph is digitized. This property is a result of joining the points with smooth curves so that only points where the line is highly curved are critical.

The current model is two-dimensional, but by using information from fixed parts of the head it should be possible to transform the data derived from an angular view to the planar case. It would therefore be possible to utilize photographs of an individual's face from a variety of angles. However, the accuracy would obviously decrease at extreme angles.

The computer model has proved successful in generating a wide range of expressions from the neutral to the extremes, and associates with each expression an evaluation number on the happiness-sadness axis. Extension of the approach to other axes should now prove straightforward, so that the model will then provide, for given expressions, evaluation numbers on all desired axes. In addition, the model allows for the generation of any number of expressions which can be used as stimuli for investigations of facial emotion recognition. A series of such standard expressions could also be used as a reference for the crude scaling of expressions (Fig 1).

This methodology should prove useful in the estimation of mood from facial expression where it is possible to obtain a series of reasonable frontal photographs of the face. It will be appreciated that the programme is based on the principle that facial expressions can be matched to a standard configuration of muscle group activity corresponding to the muscle activity present when standard, pancultural expressions are emitted. This method attempts to quantify what is normally done with the naked eye.

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