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ScienceDirect

Procedia Computer Science 2 (2010) 3–10

Procedia Computer Science

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ICEBT 2010

Varieties of biometric facial techniques for detecting offenders

Charlie D. Frowd

School of Psychology, University of Central Lancashire, Preston PR1 2HE, UK

Abstract

Many crimes are committed where the only record of the event is in the memory of a witness or victim. Recovering a recognisable image of the offender's face is then crucial for solving the crime. Traditionally, eyewitnesses describe the offender's face and select individual facial features – eyes, hair, nose, etc. – to build a 'composite'. This image is then published in the media so that someone can recognise it and phone the police with a name. Unfortunately, when tested using life-like procedures, this method rarely produces recognisable images. The current paper describes these systems for extracting such biometric information from witnesses. It also describes how useful they are and explores three such approaches for improving their effectiveness. Included are a new method to interview witnesses (a holistic-cognitive interview), a new method to present images to the public (animated composite) and a new system to construct the face (EvoFIT).

Keywords: facial composite; memory; techniques; witness; crime; offender

1. Introduction

Eyewitnesses are often asked to describe the events of a crime and those involved. In the absence of other evidence, these observers may also be asked to describe the criminal's appearance and to construct a picture of the face. The picture is known as a facial composite and is seen in the newspapers and on TV crime programmes, to allow members of the public to name the face to the police. There are various systems available to construct facial composites. The traditional method is for an eyewitness to select individual facial features from a kit of parts: eyes, nose, mouth, etc. There is good evidence, however, that this 'feature' approach does not produce recognizable images when deployed two days (or more) after a face has been seen, the norm for witnesses (in particular in the UK). New techniques are required if composites are to be an effective tool in the battle against crime.

This paper provides a brief overview of past and current composite systems of this type along with research to indicate their (in)effectiveness. In the sections thereafter, techniques to improve performance are described. These include a new method to interview witnesses, a new method to present composites to the media (for recognition) and a new method to construct the face (new system). All of these techniques are in current police practice.

2. Traditional composite systems

The earliest method to construct a face of an offender involved an artist working with a witness using pencils and crayons. In the 1960 and 1970s, new systems were developed that enabled composites to be produced by police practitioners with less artistic skill. These systems include the American Identikit and the British Photofit. The basic approach was for the witness to select facial features – eyes, hair, nose, and so forth – to produce a 'composition': hence the term, "facial composite". Provision was made to allow the addition of 'artistic' enhancement to the face if required, to add shading, wrinkles, spots, jewellery, etc.

Many problems were identified with these 'mechanical' systems [1]. One was limitation in the range of available facial features. Another was that witnesses would select features in isolation to a complete face – looking at pages of noses, for example, to select the best example – when there is good evidence to suggest that faces are seen as complete entities, not parts [2]. Selecting features in this way is likely to reduce the effectiveness of the features selected, and the resulting image.

Some of these problems were overcome with the computerisation of composite systems [3]. Individual features could be selected in the context of a complete face and a large database of facial features could be stored and indexed. Witnesses were

doi:10.1016/j.procs.2010.11.002

given an interview now to assist in the process of building the face: they were asked to describe the face in detail, to assist the police operative to locate suitable features. Computer graphics technology was engaged to allow individual features to be sized and positioned on the face as required, with additional adjustments possible to change feature brightness and contrast. As with the mechanical systems, software editing tools were could further enhance the likeness. There are now many such systems available worldwide, and examples include E-FIT, PRO-fit, Identikit 2000, Mac-A-Mug Pro, ComPhotofit and FACES. Most police forces use one of these modern software systems, or employ the services of a sketch artist, although there are still a few forces that use the older, mechanical systems [4]. Example images produced from some of these systems are shown in Fig. 1.

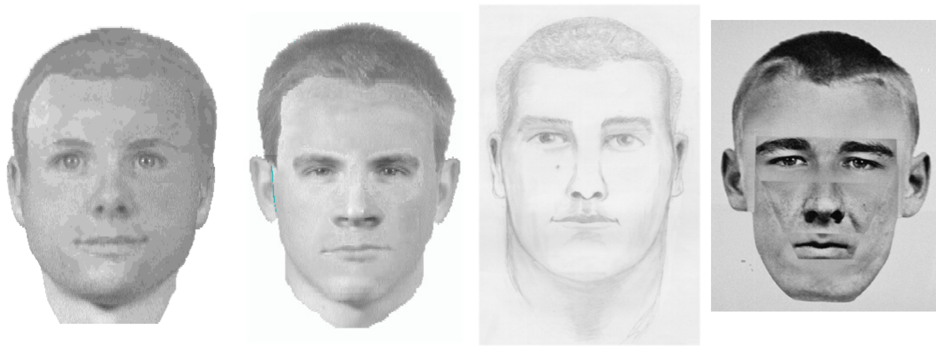

Fig. 1. Composites likeness produced from different systems. All are of the UK footballer, Michael Owen, and were constructed in Frowd et al. [3]. The systems shown here are (from left-to-right) E-FIT, PRO-fit, sketch and Photofit.

There have been several evaluations of these systems, past and present [3],[5]-[9]. Some of these evaluations have tried to mirror police procedures as far as possible using a careful and detailed laboratory procedure: a 'gold' standard [6]. To do this, laboratory-witnesses look at an unfamiliar target face and, after a set period of time, describe the face using a police-type (cognitive) interview and then construct a composite. The composites would be shown to other people who are familiar with the targets and asked to name them. The results of these studies have found that laboratory-witnesses produce images that are named with a mean of about 20% correct when construction takes place immediately or a few hours after seeing the face [3],[5],[10]. However, when the delay is much longer, a day or two, naming levels fall to just a few percent correct [7]-[9]. This latter finding is particular worrying as it is following retention intervals such as these, and sometimes ones even longer, that composites are constructed in police work. That said, composites are normally presented with some additional information – type of crime, location, offender's accent, clothing, and so forth – that can help to trigger an identification. However, the work demonstrates that composites are unlikely to be identified well from the image alone using current procedures.

So, why might composites be so poorly named when constructed after fairly long retention intervals? Frowd et al. [10] has shown that this is likely to be the result of inaccurate construction of the central parts of the face, the so-called 'internal facial features', the region including the eyes, brows, nose and mouth. Instead, witnesses tend to construct the exterior parts of the face much better, especially the hair. It is from the central region that other people, members of the public, will tend to process to recognise the face. The research implies that the effectiveness of composites can be increased by improving the quality of the internal features.

3. Enhancements

Three strands of research have successfully enhanced the effectiveness of composites by improving the identifiability of their internal features.

3.1. Interview

One strand of research has focussed on the interview that the police use with eyewitnesses for face construction using traditional 'feature' systems. The normal way to do this involves a cognitive interview (CI), which is administered prior to face construction, to recover the best description of an offender's face. The description is necessary to locate a set of matching features within the composite system (without which there would be too many examples). However, while the CI appropriately enhances face recall, it does not enhance face recognition ability, which itself is needed for the ensuing task: to select individual facial features to build the face (in actual fact, the CI seems to make recognition worse, see below). This research has therefore attempted to directly enhance face recognition ability, by asking users to make a series of whole face judgements about a target after the CI [11]. The resulting interview is known as the 'holistic' CI and was developed in collaboration with UK Association of Chief Police Officers (ACPO) Facial Identification Working Group. The novel 'holistic' part of the interview takes about 5 minutes to administer and is very effective at improving the identifiability of feature-based composites. To date, at least 35 police operatives from six constabularies in the UK have been trained in the use of this interview.

The work has also shown that the CI in itself has an unwanted side-effect: to reduce face recognition ability. The effect is known as the 'verbal overshadowing effect' (VOE) and is an established mechanism in the literature (although not all studies have successfully replicated it). Recent research has demonstrated that the VOE applies to the construction of facial composites, reducing their quality [12]. One way to overcome this is to use the global processing shift of the holistic interview, as described above. The other is to delay the start of face construction for about 30 minutes after the CI, as suggested by VOE research and verified in Frowd et al. [12]. An interesting theoretical contribution of this research has been to highlight the role played by recognition processes in face construction using feature systems (traditionally thought to be mainly one of face recall).

3.2. Caricature

A second strand of research has investigated individual differences in the construction and recognition of composites, with the aim improving the recognition of a finished composite. This is an important endeavour, to maximise the chance of composites being correctly named when circulated within a police force or published in the media. The work has identified a number of techniques that can successfully enhance recognition [13]-[15], but one that is the most useful is based on facial caricature [16]. Watching a composite as it is progressively caricatured, where distinctive feature shapes and their inter-relations are exaggerated, and then anti-caricatured, made to appear more average, substantially improves correct naming rates. An example composite caricatured in this way is shown in Fig. 2; in the animation, there are 21 frames rather than the five shown here.

Fig. 2. Positive and negative caricature of a composite of the former UK Prime Minister, Tony Blair. Exaggerations are at (L-to-R) -50, -25, 0 (veridical), +25 and +50% caricature.

The technique applies to a range of systems (feature, sketch, holistic). As illustrated in Fig. 3, it is effective for different quality composites, from poor to good, although the best improvement occurs for relatively poor-quality composites, which is the ideal.

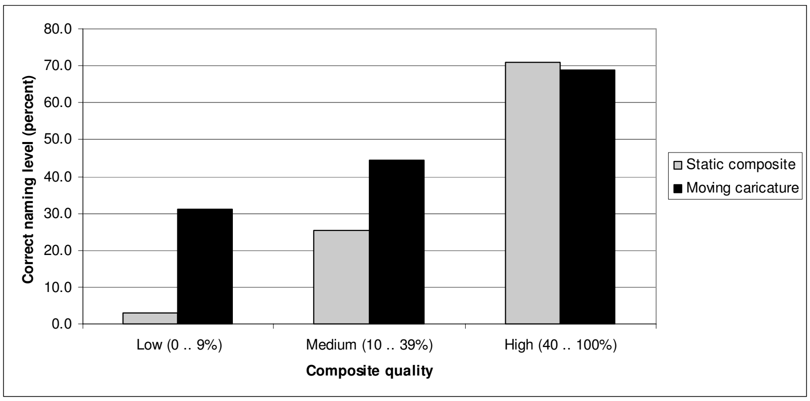

Fig. 3. The effect of caricature animation by composite quality. The data are from Frowd et al. [16]. Benefit has also been observed using a caricatured series of nine static images, like those shown in Fig. 2.

The research has implications for models of face recognition, and follow-up research [in prep] has provided greater insight into why the technique works as it does. Currently, three commercial computer programmes have applied this finding, and instruction has been provided to at least 20 UK police officers to use it in the PRO-fit 'feature' system and about 35 in the EvoFIT 'holistic' system (discussed below).

3.3. EvoFIT

For many investigations, eyewitnesses are unable to produce a sufficiently detailed description of an offender for a composite to be attempted: a description is necessary for police operatives to show witnesses a subset of facial features. In these cases, an alternative method is required to construct the face [19]-[21]. The author has been developing one, EvoFIT, as part of his PhD at Stirling [17] and thereafter [7],[9],[13]-[15],[18],[19]. The approach is generally referred to as a 'holistic' or 'recognition' system. With EvoFIT, witnesses repeatedly select complete faces from arrays of alternatives, with 'breeding' in between, to allow a composite to be 'evolved'. It is essentially a software program that has emerged from research. Twelve years have developed a system that produces much more identifiable composites than those from traditional feature systems [9]. EvoFIT is a working example of 'evolution by artificial selection', as described by Charles Darwin.

At the heart of EvoFIT is a model that can generate realistic-looking faces (see Frowd et al. [19] for more details). The initial focus during development was on adult white males, arguably one of the most useful in the UK for detecting serious criminals. The model was built from 72 faces using a statistical technique called Principal Components Analysis (PCA), and contains two types of information. The 'shape' part describes the shapes of the features and their inter-relations; the 'texture', the colour of the eyes, nose, mouth and overall skin tone. PCA is often used for image compression applications, but here allows novel (random) faces to be synthesised. The technique results in 71 coefficients (numbers) that uniquely describe the shape and texture properties of each face.

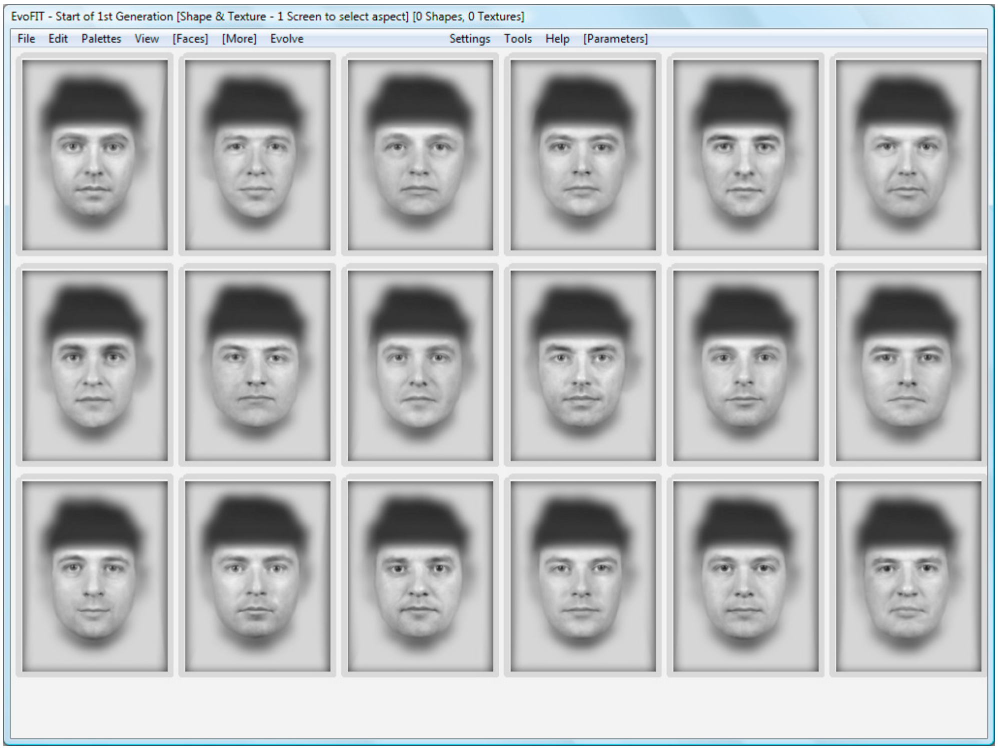

Fig. 4. A typical screen that a witness would see. The external parts of the face have been deliberately blurred, as described below, to help the witness focus on the important internal features. The blurring is removed when a composite has been evolved, so that the complete face can be seen clearly.

PCA does a poor job of generating realistic images of hair. So, along with the ears and neck, the hair is treated as an independent feature and selected at the start. Early on in development, EvoFIT presented screens of complete faces. Often, however, a face was generated with a good match to a target for shape but not for texture, and vice versa, making selection difficult. This was improved by presenting information separately: four screens of facial shape are now presented first, followed by four screens of facial texture; users select the two most similar examples per screen. Finally, the closest matching, item 'best face' is selected, a so-called 'best' face.

The selected items are then bred together: pairs of faces are chosen and their shape and texture coefficients mixed together randomly to produce an 'offspring' face. Each face is given same chance of being a 'parent', except the 'best' which, due to its preferential likeness, enjoys twice as many breeding opportunities. In addition, to ensure that the best face is not 'lost' through the breeding process, it is carried forward without change into the next generation. Finally, to help maintain variability within the population of faces, 5% of the coefficients are 'mutated', by changing them to random values. Thus, a new set of faces is produced that contain a mixture of characteristics based on witness selections, plus some mutation. See Fig. 4 for an example array of faces.

This version of EvoFIT was evaluated using a careful and detailed laboratory procedure: a 'gold' standard [3]. To do this, 30 laboratory-witnesses looked at an unfamiliar face, and then described and constructed it after three to four hours. Performance was disappointingly poor, with EvoFIT composites correctly named 2% of the time. The problem was that EvoFIT only produced an identifiable face on occasion; the system converged on a specific identity, but this was generally not close enough to promote recognition, in despite of considerable effort.

A breakthrough emerged when the selection of the 'best' face was improved: users now choose the closest match from all possible combinations of their selected shape and texture. Given the large impact the best face has on the breeding process, system convergence improved. In a further evaluation, EvoFITs were correctly named at 11%, while those from a traditional 'feature' system at 4% [7]. The study demonstrated the potential of the technique and UK government funding (EPSRC) was received to develop the prototype further.

One of the problems to be overcome was that EvoFIT faces tended look very similar to each other, making face selection difficult. This is a natural consequence of the faces seen with the same external parts (hair, ears, neck); the problem relates to biases in our perceptual system: since the faces are unfamiliar, observers will tend to focus more on the external parts, to the detriment of the central region (which is important for recognising the composite later) [10],[22]. The solution was to apply a Gaussian (blur) filter to the external features during evolving, to allow the internal features to appear more salient. In a small published study [14], blurring was shown to improve composite naming by 5%; it also substantially reduced the number of incorrect names that people gave, by 20%. Thus, while the distortion promoted a composite that looked a little more like the intended person, it looked considerably less like anyone else. An example of this filtering can be seen in Fig. 4.

A second problem was that faces would sometimes be evolved with the age noticeably incorrect [7]. This issue was rectified in two ways. Firstly, by building five models each of a different age range, to allow this aspect to be approximately correct from the start. This endeavour was generally successful, but some age inaccuracies remained. A software tool was then designed to allow manipulation of the perceived age and other 'holistic' properties of an evolved face – e.g. masculinity, health, attractiveness, extroversion and face weight. These so-called Holistic Tools were built by asking people (320 volunteers at the Glasgow Science Centre) to make holistic judgements on a 200 item face set [23]. The faces with the highest and lowest ratings were extracted and averaged, to provide mathematical vectors in which to manipulate a given face. This procedure tended to produce consistently recognisable images, as Fig. 5 illustrates.

A formal study was carried out to evaluate whether the effects of blurring and Holistic Tools would be additive [9]. A group of 32 people were shown a face of a person they did not know, in this case a UK snooker player, and two days later described the face (using a police cognitive interview) and then constructed a composite. They did this for EvoFIT, with or without external feature blurring, or for a 'feature' system (for comparison). The second group were snooker fans who named the composites. The blurring and holistic tools were most effective when used together, producing a correct naming rate of 25%, while the feature composites were named at 5%.

Much of the development for EvoFIT has therefore been carried out in the laboratory but, more recently, field trials of EvoFIT have been orchestrated with police forces [24] in Lancashire, Derbyshire and Romania. Police officers were trained on EvoFIT, and then used it with witnesses for a set period of time (typically six months). There were several notable successes. For example, EvoFIT was used in Lancashire with a young victim who was indecently assaulted the previous week. The EvoFIT image produced (Fig. 6, top row, far left) was later named by several people, providing a valuable lead. Along with other evidence, the suspect (second image from left) was convicted of the crime. Three other cases are illustrated in Figure 6. The field trials have confirmed system effectiveness: in 23% of cases, the EvoFIT resulted in an arrest.

Fig. 5. EvoFITs made from memory, to illustrate the system. From left to right, they are of footballer, David Beckham; actor, David Tennant; former US president, George W. Bush; musician, Noel Gallagher; footballer, John Terry; UK politician Gordon Brown; singer, Robbie Williams; and TV celebrity, Simon Cowell.

4. The future

The techniques described above have successfully improved the effectiveness of facial composite, unlike some others [7]. More recent research is exploring techniques to allow the caricaturing procedure to be used in the newspapers, using a small set of static frames similar to those shown in Fig. 2. Research is also exploring the use of interviewing techniques with EvoFIT. The evidence to date is that a type of holistic interview is likely to be valuable, since that improves witnesses' face recognition ability, and subsequently their ability to better discriminate between the presented face arrays. Research is also active in improving the context in which the internal features are presented, to further improve face recognition ability.

5. Summary

Composites are an important tool for assisting law enforcement to detect people who commit crime. The biometric often used to do this is the face, and is externalised from an eyewitness's memory. Traditional methods involve the selection of individual facial features, but these approaches on their own do not promote good composite naming rates. Three main techniques were described here for improving performance. The first is a new method of interviewing witnesses, primarily to improve their face recognition ability; the second is a caricaturing procedure that helps to trigger the correct name in an observer; the third is a system called EvoFIT, which produces higher naming rates than previous systems and can also be used when witnesses cannot recall details of the face. Techniques are underway to improve these methods even further, and to develop others, to ultimately produce an even more effective image.

Fig. 6. EvoFITs produced in criminal investigations. The EvoFIT is shown on the left in each pair, while the image on the right is a photograph of the person believed to be responsible for the crime. Images are printed with permission from the relevant police forces.

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