

## Giving crime the 'evo': catching criminals using EvoFIT facial composites

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### Abstract

*Facial composites are traditionally made by witnesses and victims describing and selecting parts of criminals' faces, but this method is hard to do and has been shown to be generally ineffective. We have been working on an alternative system called EvoFIT for the past 12 years. Much of the development for this system has been carried out in the laboratory but, more recently, police forces have been formally evaluating it in criminal investigations. The current paper describes three of these police audits. It was found that EvoFIT composites made from real eyewitnesses led to an overall arrest in 23.4% of cases, which is similar to a 24.5% correct naming level found by laboratory research. System performance therefore appears to be effective both using simulated testing procedures and in the hands of the intended user.*

### 0. Warning about content

This technical paper contains descriptions of criminal offences. Some of these offences were against young people and are very serious. While individual case studies are not described in detail here, some readers may still find them disturbing; these readers may prefer to skip over the case studies: they are clearly labelled.

### 1. Introduction

Witnesses and victims may be asked to construct a picture of a person they have seen commit a crime. This picture is known as a facial composite and can help the police to

detect the perpetrator. Various techniques are available to produce these images. Traditionally, eyewitnesses describe the face in detail and build the composite by selecting individual facial features: hair, eyes, nose, mouth, etc. However, we do not perceive faces in such a piecemeal fashion, but instead process it more as a complete entity [1]. For this reason, face construction using the 'feature' approach often results in poor quality images, especially when carried out several days after the face had been originally seen [2], the normal situation for eyewitnesses.

More recent so-called 'holistic' approaches [2-4] have attempted to overcome this problem using interfaces that require focus on the face as a whole. In essence, users repeatedly select complete faces from screens of alternatives, with cycles of 'breeding' in between, to allow a composite to be 'evolved'. The approach has the potential to allow construction when a witness has seen the face, but cannot describe it in detail. It is in this situation that the traditional methods cannot be used effectively, since they require a good description for locating subsets of features (for presentation to the witness). In contrast, the 'holistic' systems only require fairly general information: age, gender, race and hair.

The focus on the current paper is on one of these methods, EvoFIT. This system has been the focus of considerable research and development in the laboratory, and some of this work has been presented at previous BLISS conferences [5,6]. For three years now, EvoFIT has also been the subject of formal police field trials. These have explored the effectiveness of the system when

used with actual witnesses to and victims of crime. The results of three such evaluations are presented below.

### 1.1. Background to EvoFIT

The EvoFIT system has been comprehensively detailed in several research papers [2,5,7] and so for brevity, only a brief history will be given here.

EvoFIT was conceived in the 1990s by Peter Hancock [8]. He developed a computer program that presented arrays of whole faces. The faces were produced using a statistical technique called Principal Components Analysis (PCA) that captured variations in feature shape and greyscale colouring, and enabled further faces to be synthesized, initially with random characteristics. Users provided a goodness of fit rating for each face and a Genetic Algorithm (GA) combined preferences (using proportional fitness selection) to produce more items for selection. When repeated a few times, the set progressively resembled each other and the target face. The best likeness produced was saved as the composite.

Peter's prototype was developed into a full system as part of PhD work [2]. This involved a PCA model that generated white male faces in the range of 18 to 35 years. Users would choose a hairstyle and then select from screens of complete faces. They found this procedure difficult, however, as some items had appropriate feature shapes, while others were more accurate by feature colouring and skin tone. These two aspects of faces are sometimes referred to as facial *shape* and *texture* (respectively). The solution was to present screens of facial shape for selection followed by screens of texture. Users would then identify the most accurate likeness, a 'best' face, that is given twice the number of breeding opportunities in the GA and also is carried forward intact to the next generation as part of an *elitist* strategy (to avoid 'damage' occurring to the face by genetic recombination and mutation operators).

At this stage, EvoFIT was used in a police investigation in the Northants area. See Figure 1 and [9] for details. The person responsible was later identified using 'familial' (family) DNA matching, and convicted.

Early versions of EvoFIT did not reliably converge on an identifiable likeness [2]. This was in spite of adhering to UK working practices, including use of a cognitive interview (CI) to help witnesses recall details of the face before starting face construction. A breakthrough emerged when more care was taken when selecting the 'best' face: after users had selected shapes and textures, these were shown in combination to each other (each facial shape shown with each facial texture) to identify the best likeness. An evaluation of this version of software was carried out. Fifty laboratory-witnesses saw a photograph of a footballer, a target that was unfamiliar to them, and two days later described the face (using a CI)

and constructed a composite with EvoFIT or a traditional feature system. The resulting images were shown to football fans to name. For witnesses who attempted to remember the face in detail, EvoFITs were correctly named at 11% and feature composites at 4% [11].



Figure 1. The EvoFIT (left) and person (right) convicted in the 'Beast of Bozeat' case. Shortly after the crime, the perpetrator is believed to have changed his hairstyle in an attempt to conceal identity, as illustrated here.

Funding was sought from the UK Government to further improve the software. The first improvement was to limit age expressivity, since sometimes a face was evolved with the age somewhat inaccurate. The work resulted in four white male databases, each separated by age, to enable construction of offenders aged 17 years of age and older. Each of the databases was built using PCA as before, and in greyscale, as research suggests that face construction does not benefit from the use of colour images [15].

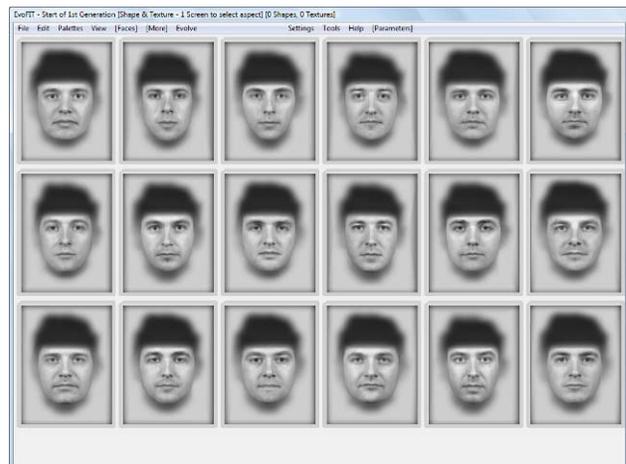


Figure 2. Witnesses select from screens such as this. The external parts of the face are blurred to help witnesses concentrate on the central facial region.

In spite of the age-limited databases, users sometimes still evolved a face inaccurately by age, although to a lesser extent now. The problem was overcome by providing a sliding scale to adjust the perceived age, and was extended to allow adjustment of other whole face properties. These so-called *holistic tools* included: face

weight, masculinity, threatening, attractiveness, honesty and extroversion. See Figure 3 for examples and [12] for a description of how the scales were designed.



Figure 3. An example of the ageing (top row) and pleasantness (bottom row) holistic scales. Manipulations increase in magnitude from left-to-right and are illustrated on an EvoFIT of TV celebrity, Simon Cowell.

Further scales were developed to add stubble, eye-bags and deep-set eyes, and to change the greyscale levels for brows, irises, mouth creases, etc. The holistic tools are used at the end of evolving after the external feature blurring has been turned off.

Example celebrity EvoFITs constructed from memory using this version of EvoFIT are illustrated in Figure 4.



Figure 4. EvoFITs made from memory. From left to right (top row), they are of footballer, David Beckham; actor, David Tennant; former US president, George W. Bush; singer, Noel Gallagher; and (bottom row) footballer, John Terry; singer, UK politician, Gordon Brown; Robbie Williams; and TV celebrity, Simon Cowell.

In an evaluation involving this version of EvoFIT, using a similar design to [11] including unfamiliar target faces and a two day delay, EvoFITs were correctly named at 24.5% while those from a feature system were named at 5% [7]. Both external feature blurring and holistic scales were shown to be effective.

## 1.2. Enhancing performance further

There have been other attempts to improve EvoFIT quality [5,6,14,15]. One of these involves changing the *mode* of presentation when publishing an image in the media. This is based on the idea that composites tend to appear quite similar to each other and that this lack of distinctiveness can make recognition difficult (for members of the public, etc.). Thus, exaggerating facial distinctiveness may help to overcome this problem. In a series of experiments, which are described in full in [14], considerable benefit was found when observing a composite as it was progressively caricatured, by exaggerating the shape information in the face, and then was de-emphasized, by rendering this information more average. An example of the animated procedure can be found online at [www.uclan.ac.uk/animatedcomposite](http://www.uclan.ac.uk/animatedcomposite)

Correct naming increased by over 40% overall using this technique. It was shown to be effective for sketch-based images, composites from feature systems and for EvoFIT. The animated caricature gave the greatest improvement for the worst named composites, but even recognizable images were improved to some extent. For the latest version of EvoFIT, correct naming levels should increase from 24.5%, as mentioned above, to 42% with caricature animation.

## 2. Field trials

Considerable time has therefore been spent developing EvoFIT in the laboratory, to ensure that it operates effectively using procedures of police work as far as possible. However, there are clearly aspects of system use that can be only tested in the field. The effect of stress on composite production, as experienced by victims of stranger rape for example, cannot be properly established in the laboratory.

Measuring system performance in the field has its own difficulties, which tend to be the very things that laboratory studies attempt to minimize. In the lab, users can see a target face for a fixed amount of time, under good lighting conditions and without distraction; these helpers can also be asked to construct a composite after a consistent interval of time. When a composite has been made, other people who are familiar with the target's identity can be asked to evaluate the quality of the face,

by attempting to name it. All of these variables (and others, e.g. [11]) can affect whether a composite is likely to be recognised.

In police work, when a composite is published in the media, it is normally accompanied by other information that can help to trigger the correct identity: a description of the person (e.g. age, build, height), the modus operandi (e.g. assault, murder, deception), crime location, etc. In the lab, this information is generally not provided. In contrast, the more people who see a given composite, or wanted poster, the higher is likely to be the level of identification; some composites in the real world may not enjoy recognition as their circulation (police officers, members of the public, newspapers, TV) is poor.

To complicate matters even further, there are different definitions of 'success'. In the laboratory, this can be taken as the number of times a composite is correctly named. For example, if 20 people are shown a composite and 6 of these observers correctly name it, this provides a correct naming level of 6/20, or 30%. Outside of the laboratory, a composite is valuable if it in some way assists in locating the perpetrator of the crime. This can be generally measured as: (1) a composite being named, (2) an arrest or (3) a successful conviction. In the UK, convictions are not based on eyewitness evidence alone. This is to limit wrongful conviction since eyewitness identification and testimony can be inaccurate (e.g. [10]). Evaluations based on composites that have triggered an arrest and then lead to a successful conviction would be an ideal measure. However, convictions can take considerable time to transpire, thus making field evaluations rather lengthy. A sensible compromise, and an approach supported by Senior Investigating Officers (SIOs), is to base evaluations on (1) or (2). These two measures make good sense as they are what a SIO requires: a suspect on which to focus his or her enquiries.

## 2.1. Lancashire police trial

The first formal evaluation of EvoFIT was carried out within the Lancashire force, UK, and ran from Autumn 2007 to Spring 2008. The project was funded by Crime Solutions, UCLan, UK. A version of EvoFIT was used that contained the white male database for face construction of offenders aged 17 years and older; a younger, teenage version was added during the trial. EvoFIT was used in conjunction with the PRO-fit composite system, to allow addition of hats, glasses and other accessories.

A suitable training course was developed and administered by the system designer (first author) and the force's existing composite officer (eighth author). The course involved training on the cognitive interview, for obtaining a facial description from a witness; EvoFIT

system training; exhibiting of evidence, for later use in court; training in a paint package, for the addition of shading, wrinkles, etc.; and considerable practice. A total of 21 police officers and staff were trained. Officers were supported during the evaluation by the existing composite officer and the system designer. Composites that were constructed were circulated among the force for identification, and some were published in the newspapers, on TV and on a wanted person's webpage. The webpage also used the animated composite format.

The system was reported to work well with witnesses and victims, and feedback was used to improve it ergonomically. One of the important changes was to improve the information EvoFIT provided to the police operators: e.g., improvements to the information shown in the title bar, and the display of messages if digression had occurred from the recommended procedure. Also, mid way through the evaluation, the construction procedure was improved to allow witnesses to set a facial aspect ratio – the face width and length – at the start. This facilitated face selection generally. In addition, to allow better adjustment of an evolved image, an extra holistic scale was added to manipulate face width.

During the trial, 30 EvoFITs were constructed, mainly for serious crimes such as indecent assault and distraction burglaries, but also for less serious offences such as minor theft. Six arrests were made, a success rate of 20.0%. The constabulary continues to use EvoFIT.

### 2.1.1. Case study

**Indecent assault:** The six month evaluation led to a number of notable successes. The first occurred in August 2007. The case involved an indecent assault in Stanley Park, Blackpool, on an 11 year old girl. The assailant was described to be white male, 16 to 20 years of age with a slim build and dark, short, stubby hair, lighter at the tips. He was also described as wearing a dark blue tracksuit, pale blue vest and black trainers. During the crime, he was reported to have stolen a mobile phone. The week following the crime, two people were arrested, but were later eliminated from the enquiry. Due to the absence of further leads, an EvoFIT was constructed seven days later, see Figure 5.

A public appeal was made. This involved police detectives and support officers attending the park at the same time as the crime had occurred the previous week. The appeal was based on physically showing the EvoFIT to members of the public and asking if they recognized him. Two people named the EvoFIT as a local person, Ross Gleave, placed him in the vicinity of the attack, and at the time of the attack. His name was also given following house-to-house enquiries. The police attended Gleave's home address and made an arrest. The description given by the victim was accurate and the

stolen property was recovered from his address. He was later identified by a number of other witnesses. These additional observers did not know him, but picked him out using VIPER, a system for conducting video line-ups (Video identification Parade Electronic Recording). Gleave was convicted for the attempted rape of a child under 13 years, jailed for seven years and placed on the Sex Offender Register for life.



Figure 5. The EvoFIT produced in the Stanley Park assault, left, and the person subsequently identified and convicted of the offence, right.

**Indecent assault:** EvoFIT was valuable in solving another indecent assault case, this time in an unexpected way. The offence took place in Morecombe Bay on a teenage male; the victim subsequently produced an EvoFIT using the 50 year old white male database. A DNA sample of the offender was available in this case and the police used this evidence to try to find a match. The DNA search produced a dozen partial matches, however, but a photograph from one of them bore a very strong resemblance to the EvoFIT. Consequently, the police attended this person’s home address first and were able to collect evidence that linked him to the scene of the crime (a train ticket). The EvoFIT provided valuable intelligence to guide the investigation; it also avoided wasting police time (which was likely otherwise).

## 2.2. Derbyshire police trial

For 12 months starting June 2008, Derbyshire police began a field trial of EvoFIT. This force has three composite officers, and these were trained in EvoFIT. The version of EvoFIT they used was similar to Lancashire’s, but with more databases. EvoFIT was found to work well and eyewitnesses reported being very satisfied with the likenesses produced.

The force constructed 57 composites over the year, which was about twice the number made in Lancashire (sensible perhaps as the Derbyshire trial ran for twice as long). Success was scored when an EvoFIT led to one of three outcomes: a name put forward, an arrest and a person charged. These data are summarized in Table 1. Note that the actions depicted in the table are not mutually exclusive; this means, for example, that 7% of

the figure for arrests (19.3%) also involve persons who were later charged. They appear to follow a sensible pattern, with roughly twice the number of names put forward (by police officers, members of the public) than arrests made. It also shows that about one-third of suspects have been charged to date. The arrest rate is very similar to that found in Lancashire (20.0%).

Table 1. Results of the Derbyshire police trial. Figures relate to successful actions arising from EvoFITs and are expressed as a percent of the total number of composites constructed (there were 57 in this evaluation).

Names put forward	Arrests	Charged
43.9	19.3	7.0

### 2.2.1. Case studies

**Indecent assault:** early on in the Derbyshire field trial, EvoFIT was used in an Indecent Exposure incident. This was a particularly nasty case as the lady victim had her newly born baby with her in a pram at the time of the offence; she was quite traumatized with worry that the offender might hurt her child.

The offender was described as a white male, approximately 30 to 35 years of age. The victim produced an EvoFIT of him two days after the offence using the 30 year (Western European) white male database. The victim was very happy with the likeness produced. The image was taken by the police operative to the local police station for circulation within the force, and he was immediately recognised by local officers. Within 4 days, the offender was arrested, charged and remanded in custody. He was sentenced to 16 months imprisonment at Crown Court and placed on the Sex Offenders Register.

**Connected thefts:** An EvoFIT image was produced by the victim of a 20 to 30 year old Eastern European male. The male had approached her in the street and stole a bank card from her purse. The victim felt particularly vulnerable, being on her disability motor scooter. She was delighted with the likeness produced and was most impressed with the system.

In a separate incident a week later, one with an almost identical modus operandi (method of operating), a second EvoFIT image was produced by a different victim of a 35 year old Eastern European male. As there was a chance that these crimes might have been committed by the same person, a different police operative interviewed the second victim (different interviewers are used in such cases to avoid the possibility of subsequent images being unknowingly contaminated by the same interviewer). The incident took place 10 miles from the first. The image produced was almost identical to the first and, for this reason, the crimes were linked, therefore providing valuable intelligence for the investigation.

### 2.3. Romanian police trial

Further work was carried out to allow EvoFIT be to used in Romania. This was made possible by collaboration of the first and twelfth author, and the Forensic Department of Iasi County Police Inspectorate, Romania. Funding was provided by Crime Solutions, UCLan. At the start of the collaboration, the available EvoFIT databases allowed construction of Western European white, Afro-Caribbean black and Asian offenders. It did not, however, accurately render Eastern European targets. While there are obvious similarities in skin pigmentation and facial features between Western and Eastern European faces, differences in anatomical physiognomies resulted in poor likeness when constructing Romanian faces using the existing Western European database.

In accordance with national Romanian legislation, an agreement was entered into that allowed an Eastern European male database to be created, and then the EvoFIT system evaluated and used in criminal investigations. This involved photography by the Romanian police of about 200 male faces, each taken in a front-face view under controlled lighting. During the trial period, enhancements were made to increase the number of hairstyles available within the system and to initiate development of a female Eastern European database. A mixed race database was also developed, to cater for mixed parentage offenders with Eastern European and Indian ethnicity. This so-called 'minority male' database was built with PCA using an equal number of faces from both of these racial types.

The effectiveness of the newly-designed Eastern European database was evaluated in the laboratory, as part of a research project by the sixth author. This involved asking people to construct Western and Eastern European male faces using the EvoFIT Western and Eastern male databases. It was found that better quality composites were produced when the race of the target matched the race of the database, as expected.

The first author traveled to Iasi in June 2009 to install the software and provide training for two experienced police officers. Over a five month period, EvoFIT was used 24 times, and this resulted in the location of nine suspects, an arrest rate of 37.5%.

#### 2.3.1 Case studies

**Mobile phone thefts:** Between May and August 2009, a series of connected crimes were committed against minors, especially to those aged 12 years and under. The offender in this investigation chose buildings with an elevator, to enable him to follow his victims into the

elevator. Between floors, he stopped the lift and, under threat of violence, stole the young person's mobile phone.

One of the victims, a 10 year old girl, was interviewed to construct a composite of the offender. She could not describe the robber's facial features, the same as for many victims, but was able to produce an EvoFIT. The 23 to 35 year Eastern European male database was used; the resulting image is shown in Figure 6.

The composite was released to local police forces. After a month, a policeman detained a person with notable similarities to the composite. He was later convicted and sentenced to 7 years in prison.



Figure 6. The left image is an EvoFIT produced by a 10 year old victim of robbery; the right image is a recent photograph of the person convicted in this case.

**Shimano bike thief:** EvoFIT also proved valuable for detecting a prolific bike thief. This involved four thefts of bicycles between May and August 2009, with the thief cutting safety locks. Two EvoFITs were constructed by eyewitnesses at the Iasi Police Headquarters (Figure 7).



Figure 7. The EvoFITs (left and centre) of a bicycle thief were constructed by separate witnesses over a two month period. On the right is a photograph of the person believed to be responsible for these crimes.

**Violent robbery:** EvoFIT was valuable for detecting another offender who committed two robberies one day earlier this year. He threatened victims with a knife and then punched them in the face. Two of his victims constructed an EvoFIT at the Iasi Police Headquarters. One victim used the 23-30 year Eastern European male database (Figure 8, left), and the other, the 'minority male' database (Figure 8, centre). The EvoFITs were produced between two and three days after the robberies.

The EvoFITs were released to the local police forces. Within a couple of hours, and based on these images, the suspect was named by young people who lived in a neighborhood near to where the robberies had been committed. The suspect is in custody awaiting trial.



Figure 8. The EvoFITs (left and centre) of a offender were constructed by separate victims. On the right is a photograph of the person believed to be responsible.

**Deception:** A further noteworthy case involved a person who reported being robbed of a large sum of money. An EvoFIT was constructed as normal. As the session was nearing the end of completion, however, he appeared to become rather agitated. It turned out that the ‘victim’ had both described and attempted to construct a composite of himself! He retracted the allegation of robbery.

### 3. Discussion

There are a range of techniques available to law enforcement for constructing facial composites. Most use a feature-by-feature approach, which is an unnatural task for eyewitnesses, but new methods are emerging based on the selection and breeding of complete faces. In the current work, one of these systems was considered, EvoFIT. This system presents arrays of whole faces for a witness to repeatedly select and a composite is ‘evolved’ over time. EvoFIT is the result of considerable research and development, and performance is now fairly good in the laboratory. System effectiveness was here carried out by three police forces.

The feedback aimed to improve both the system ergonomics (e.g. better reporting of session status) and the quality of the resulting composites (e.g. facial aspect setting and face width holistic tool). Situations were described where EvoFIT was notably effective at detecting offenders. The overall system effectiveness was also measured, and based mainly on arrests arising from composite identifications. Reports across the forces for these were 20.0%, 19.3% and 37.5% of the total number of composites constructed – these totals were 30, 57 and 24 respectively. Based on the total number of arrests made ( $6+11+9=26$ ) and the total number of composites constructed ( $30+57+24=111$ ), the mean arrest rate is 23.4%. In spite of the large number of uncontrolled

variables in field evaluations, this average appears comparable to the 24.5% correct naming level for EvoFIT measured in the laboratory [7]. Based on the two measures, EvoFIT performance is similar both in the laboratory and in the hands of the intended user.

Figures from the trials refer mainly to identifications arising from static images rather than from animated composites (caricaturing). While laboratory research has confirmed the effectiveness of this technique, and for a number of different construction methods including EvoFIT, a field evaluation now awaits it.

Further developments to EvoFIT look promising. One is a novel interviewing technique. This is based on witnesses and victims making whole-face judgments about the target face after having describing it but before starting composite construction. This technique has been shown to be very effective for feature-based systems [16], and is now in regular UK police service, but it appears to extend to the production of EvoFITs constructed after a long retention interval [Manuscript in preparation]. Other work is exploring different ‘modes’ of image presentation [6] and databases that are aligned more closely to an eyewitness’s verbal recall [5].

In summary, the current paper described the first formal end-user evaluations of EvoFIT. Overall system performance was found to average 23.4% across three forces, a figure which suggests the system is effective in the battle against crime. There are promising areas of development to further improve performance.

### 4. Acknowledgements

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### 5. A note about the paper’s title

The title is a play on words. The term ‘evo’ refers to the rhyming phrase ‘heave-ho’, or ‘yo-heave-ho’, which is a chant formerly uttered by sailors when they pulled ropes together, to coordinate effort. Here, it refers to EvoFIT working together with the police to catch criminals.

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